LOCAL PUBLIC SECTOR ALLOCATION OF SCARCE EMERGENCY ASSETS: AN EVALUATION OF THE FIRE SERVICE

by

Robert Carr Boyd Jr.

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Approved by:

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Dr. Gary Rassel

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Dr. Suzanne M. Leland

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Dr. Bill Graves

____
Dr. James Douglas

ABSTRACT

ROBERT CARR BOYD JR. Local public sector allocation of scarce emergency service assets: an evaluation of the fire service. (Under the direction of DR. GARY RASSEL)

The methodology utilized by public sector managers to allocate scarce resources determines the level, efficiency, and effectiveness of service delivery. These decisions are influenced by a myriad of factors, not the least of which is the ideal goal to distribute services in a fair and equitable manner. This ideal becomes problematic if service outcomes are important to public decision-makers, because the level of need for these resources is not spread equally across local jurisdictions. Therefore, when goods and services are located or distributed equally to all "customers," many do not receive enough assistance and others receive more than they prefer. This causes inefficient service delivery that fails to maximize potential positive outcomes with the available limited resources. This is particularly true with the geographic distribution of fire service resources across most communities in this country.

This research effort attempts to model the demographic characteristics that drive emergency service demand and workload across local jurisdictions. Specifically, data about demographic characteristics was collected at the Census block group level and compared to emergency response data collected by the Charlotte Fire Department. The findings from this effort are promising, as the bivariate correlation and multivariate regression analyses indicate that economic and structural factors common to all local communities can be used to confidently predict demand and workload on local public safety systems. Measuring these characteristics at the block group level permitted the opportunity to isolate homogenous groups within the population that have risk

characteristics associated with more or less demand for these services. These findings provide a solid base to support the development of an alternative model for locating these critical emergency resources according to demand and workload to better meet the needs of individual communities.

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CHAPTER 1: INTRODUCTION

Local public sector emergency services are critical to the quality of life experienced in every community across the country. Each community, no matter its size has some type of police and fire protection. As the size of the community increases, the distribution of these services becomes more complex. The ideals of the public sector are to deliver services equitably and fairly to constituents; however, scarcity creates a real paradox for public safety managers, who must contend with it while also providing effective services. The generally accepted methodology to locate fire service assets is based on response time benchmarks. Utilizing a response time benchmark to guide locational decisions spreads resources evenly across a defined jurisdiction, which meets the ideal criteria set forth above for the public sector to deliver goods fairly (Kuehnert, 1999). Unfortunately, treating all parts of a population the same disenfranchises those with more need, places people at greater risk, and increases inequality. To date, few if any emergency service organizations have explored the factors that drive demand for these resources to guide locational decisions that might improve service delivery. The following research effort will analyze demographic population characteristics and emergency service demand to build an alternative model to better inform decisions regarding allocation of these scarce emergency resources.

1.1 Background

The redistribution of resources in the form of public services is a primary function of local governments. Public goods and services contribute to the functionality and quality of life found within local communities by filling the service gaps left vacant by the private sector. All levels of government utilize tax authority to raise revenue and then distribute the funds in the form of goods and services. In general, the goods and services provided by government are those that the market fails to supply or under supplies. Delivering services associated with public safety is a primary responsibility of all levels of government, but it is the local level that has the most visible and direct impact in protecting citizens (Mikesell, 1999). Police, fire, and emergency medical services are most closely associated with local public safety. The location of public safety assets within a community is critical to the level of service effectiveness and efficiency that can be achieved. Local bureaucrats and elected officials charged with locating these scarce resources are challenged to maximize outputs and minimize community risk related to emergency events.

When citizens access the emergency 911 system in most communities, they are essentially playing an emergency resource lottery, where the odds of receiving a timely response may not be in their favor. Most local emergency systems in the United States do not prioritize responses based on incident severity or locate limited emergency resources based on demand. Instead, emergency resources respond based on a “first come, first serve” algorithm. These limited resources are often distributed evenly throughout communities to minimize response times (Barr & Caputo, 2003; Blackstone, Buck, & Hakim, 2005; Swersey & Ignall, 1991). In theory, this system for locating and responding to emergencies does not advantage or disadvantage any one person within a community. Unfortunately, the reality of these systems is much different, because this allocation strategy creates a lottery like system in which responders may or may not be available to respond in an expedient manner to an emergency situation. The goal of this project is to develop an alternative model to guide allocation decisions for locating limited emergency resources throughout the local community environment. This model will be based on locating resources in a manner that increases the probability that an emergency resource is available to respond in a timely fashion to citizens suffering life threatening events. This requires evaluating demographic and emergency response data to predict demand and incident severity for emergency services at the neighborhood level (Gyimah-Brempong, 1989).

Local government bureaucrats and elected officials are under constant pressure to provide more services with fewer resources. The public perceives government as operating inefficiently and often ineffectively (Citrin, 1974; Wood & Waterman, 1994). Whether this is true or not, the ways in which government redistributes limited resources to meet policy initiatives is often controversial. The private market has self-correcting mechanisms, “the invisible hand,” that encourages effective and efficient private sector operations (Walsh, 1998). Similar market forces do not exist in the public sector to reign in waste and ineffective methods. Government, by and large, provides services that the market will not provide on its own. Because of this, most government services are monopolies, which does not discourage or penalize the delivery of inefficient, and at times ineffective, services (Bergstrom, 1979; Savas, 2000). The public can hold elected officials accountable through the electoral process, but most local officials serve two or four year terms. This diminishes the opportunity for voters to gain instant gratification at the voting booth. Even when elected officials are voted out of office for presiding over and enabling inefficient services, the bureaucrats within the government structure more often than not remain static (Bergstrom, 1979; Wood, 1998). Therefore, more efficient and effective service delivery depends on the decision making processes and values of bureaucrats and elected officials. Whether or not these decision-making processes and values align with the social norms within a community is often a source of debate.

Public safety is a significant part of the service package delivered by local governments. Fire, police, and emergency medical services contribute to the public's perception of overall safety. Police agencies focus singularly on law enforcement activities, which separates them from organizations that provide fire protection. The modern fire service is no longer focused on the singular mission of extinguishing fires. The mission of most fire departments is multi-dimensional and includes responding to fires, emergency medical incidents, hazardous materials emergencies, and rescue situations. As more types of emergency services are delivered to local communities by the fire service, the efficient allocation of scarce resources becomes paramount to effective service delivery (Granito, 2003).

The fire service has long been a second tier industry among federal, state, and local government. It garners little political or public attention but is an integral part of every community in the United States. Most residents believe they will never need the fire department, making it easy to overlook this industry. Oversight and research into the fire service is minimal, which leaves the industry as a whole unaccountable for achieving its core missions (Donahue, 2004b; Swersey & Ignall, 1991). Politicians give little attention to the fire service because problems within fire departments rarely cost a politician political capital. Improvements in building construction and private fire suppression systems over the past three decades have contributed to reduced fire rates, but researchers have not found valid evidence to link these drops to changes in fire service operations. An evaluation of the fire service conducted by the Federal Emergency Management Agency (FEMA) in 1973 reported the depleted state of this industry in a document titled “America Burning,” but many of the problems mentioned in the report, such as insufficient emergency resources, still plague today’s fire service. The continued depletion of this industry is further supported by the National Institute of Standards and Technology (2008), which reported in 2005 that direct monetary fire losses exceeded $10 billion annually with indirect losses estimated at more than $40 billion. These numbers often exceed the total monetary losses attributed to all natural disasters combined each year, which contextualizes the impact of fire losses across the country in context.

Traditionally, public sector managers have claimed that to deliver effective emergency services, a large number of capital assets carefully located throughout a jurisdiction were required. In addition to having sufficient assets, delivering effective emergency services requires that the proper emergency resource, whether it be an ambulance, fire truck, or police officer, arrives at an incident fast enough to prevent the escalation of an emergency event (Granito, 2003; Rider, 1979). Community problems public safety services are expected to resolve can be time sensitive. A time sensitive situation is one that continues to worsen every minute that goes by without definitive action to mitigate the event. The location of emergency resources within a community, no matter the community size, impacts service delivery and incident outcomes (Watts, 2003). Small or rural communities usually operate public safety services from a central location. Often times the location is something that cannot be changed, but in larger urban and suburban communities emergency resource location decisions are more fluid (Hirsch, 1959).

The location of fire station facilities is often fixed; however, urban administrators are frequently forced by economic and/or structural factors to evaluate the need for new stations, the need to shut down existing stations, and/or the need to relocate emergency assets to other stations to maintain sufficient coverage. Unlike other local government services, the basic mission of a public safety organization is to protect life and property. Fire, police, and emergency medical agencies that do not maximize their limited resources will struggle to meet this critical mission (Rider, 1979).

When allocating fire, emergency medical, or police services it is necessary to permit some level of inefficiency to account for uncertainty (Smith, Greenblatt, & Mariani, 2008). Emergency situations that tax available public safety resources, such as disaster events, do not occur often enough to justify maintaining a large number of reserve resources at a constant state of readiness to manage these chance events. However, local jurisdictions still must find a balance between having enough resources to meet moments of exceptional demand, with respect to average demand for these services. On any given day, call volume for fire, police, and emergency medical services can spike, and without some reserve resources to manage such situations, a public safety system is quickly rendered ineffective (Felder & Brinkmann, 2002; Watts, 2003).

Many communities lack the resources to provide sufficient emergency services to meet even average call volume demand. This issue plagues the fire service, and raises the question of how these agencies can better locate resources to maximize service delivery. Simply distributing these scarce resources throughout a community without regard for risk factors associated with demand is detrimental to service delivery. Local emergency service agencies often struggle to determine the number of resources necessary to manage average demand or to even allocate available resources to their greatest good. It does not take a catastrophic event for emergency service requests to overwhelm the available public safety resources. Extreme weather conditions, civil unrest, holiday celebrations, and other large public gatherings can become a catalyst for increased demand on these systems. In addition, emergency systems often experience unexplained periods of increased requests for assistance over a short duration that stress the system's resources, jeopardizing timely responses to time-sensitive events. These situations are impossible to predict with certainty, making them difficult to plan for when allocating emergency resources (Coulter, 1979). However, emergency service managers who allocate these scarce resources more effectively ensure their agencies are better prepared to respond when demand does increase unexpectedly.

1.2 Problem Statement: Distribution of Scarce Resources

All local communities struggle to allocate scarce emergency assets in a manner that maintains an acceptable level of efficiency while also providing effective service delivery. Two extreme models exist for allocating emergency resources with the first maximizing efficiency and the second maximizing effectiveness. As most economists argue, it is rarely smart to maximize anything, which is evident when comparing these two allocation models (Heyne, 1997). The most efficient and least effective model to disburse these scarce assets utilizes one centrally located facility from which all emergency resources respond. This is extremely efficient because costs are kept low by maintaining only one facility. However, the effectiveness of this deployment strategy decreases steadily as the size of a community increases, because response times grow. In contrast, the least efficient but most effective strategy is to place a fire station on every street corner. Low response times would improve emergency incident outcomes, but the costs associated with such a strategy would be exorbitant. Because emergency resources are scarce, it is necessary to find middle ground between efficiency and effectiveness based on citizen preferences and budget constraints (McAllister, 1976).

Evaluating emergency service effectiveness is challenging because many different performance measures are used throughout this industry, including average response time, monetary losses, cost per response, and number of injuries and deaths. These measures can prove problematic to improving service delivery, as it is unclear how valid and reliable they are for assessing service delivery effectiveness (Ammons, 2001; Kopczynski & Lombardo, 1999; Rivenbark, Ammons, & Roenigk, 2007). In addition, such measures provide an incentive to public sector managers to maximize these indicators for service delivery to make the agency appear more effective, which is often detrimental to more important issues related to service outcomes (Lipsky, 1980). For example, decreasing response times throughout a community may add exorbitant cost with minimal benefits to protecting life and property. However, the reduced response time becomes the focus, so the principals (elected officials and public) believe the service is better, when that is likely not the case. Developing a valid strategy to ration emergency service assets is a real challenge because of the dynamic political and structural environments that influence these decision making processes (Heyne, 1997).

The expanded emergency services mission requires public safety agencies to prepare for and respond to many different types of emergency situations, which complicates the process of finding valid measures to assess service delivery efficiency and effectiveness. It is no longer acceptable to evaluate fire departments solely based on fire rates and fire losses occurring in a community, because a department's ability to lower fire rates and reduce damage is now impacted by the other services provided. Fire resources responding to medical emergencies or hazardous material leaks are not available to respond to simultaneous fire incidents. The number of fire events most departments respond to annually is on the decline, while the demand for emergency medical assistance, hazardous materials incidents, and rescue responses is increasing (Brudney & Duncombe, 1992). As a fire department expands its service delivery platform, its resources are more thinly spread throughout a community (Donahue, 2000b). This places more emphasis on the location of emergency service assets. Increasing demand for emergency services essentially reduces the number of available assets, which raises the chance of citizens being adversely affected by fire, medical, or other emergency situations. For example:

> *It is a Sunday evening on the eastside of a large city, where the population is predominately lower income. The fire stations in this general area, as in the rest of the city, are spaced geographically to minimize response times. Fire and emergency services in this particular part of the city experience increased service demand over other areas, which reduces*

emergency resource capacity to those living and working in this part of the community. On this night, three of the fire companies assigned to the eastside are on medical emergencies in their respective response zones. One of these units, ladder 223, has responded to a medical emergency in a nursing facility located on the outer edge of its response zone. Soon after clearing from this incident, the ladder is dispatched with four other fire apparatus to check a report of smoke in a neighborhood. This neighborhood is located in the primary response zone of one of the fire units that is currently tied up on a medical situation. Ladder 223 and the other responding fire apparatus have an extended response time to the incident. On arrival, Ladder 223 finds a two-story residential structure with the attached garage and one side of the house heavily involved in fire. Fortunately, the incident is mitigated with significant property loss, but no loss of life. However, while the fire and emergency medical resources in this part of the city were responding to numerous incidents, stations in other parts of the city that do not experience similar demand were sitting idle.

The decision-making process for locating emergency resources in most communities is guided by response time benchmarks. If followed, these benchmarks place an emergency unit or station within a certain distance of every part of a community. This equal distribution of resources is viewed as the most fair and effective method to protect a jurisdiction (Ammons, 2001). Other measures to evaluate performance either do not exist or are not widely used by the fire service. The industry has failed to develop reliable and valid measures that correlate with saving lives and property to guide service delivery models. For example, the *Commission on Fire Accreditation* developed a self-evaluation mechanism for fire departments to measure service delivery inputs and outputs. This is a popular mechanism used to evaluate the quality and effectiveness of fire department resources but, similar to fire standards published by the Insurance Services Organization (ISO) and National Fire Protection Administration (NFPA), it fails to contend with local budget constraints and the numerous service delivery platforms provided by these departments to mitigate a myriad of emergency events (Granito, 2003).

In accordance with the Insurance Services Organization (ISO) and National Fire Protection Administration (NFPA), fire service managers and local decision-makers allocate emergency resources based on geographical constraints to limit risk (Swersey & Ignall, 1991). The singular focus on response times often ignores risk factors present in a community that correlate to emergency service demand. In other words, where in a community, based on building characteristics and population characteristics, is demand for emergency services going to be greatest? Assuming community risk characteristics correlate with demand for emergency services, public leaders may be capable of locating their limited emergency resources more effectively to enhance service delivery. The Department of Homeland Security recognized the value of assessing risk and now allocates resources to local communities based on their risk of suffering a terrorism event. This has proven to be a more effective and efficient method to distribute grant money (Willis, Morral, Kelly, & Medby, 2005). Communities identified to be at greater risk for suffering a terrorist attack receive the bulk of resources. Although not a foolproof method to distribute resources, it does offer the federal government a tool to identify and rank communities according to need. Many decision-makers in communities deemed low risk have complained that the distribution of funds is not fair; however, it is more equitable as risk from terrorist events is effectively normalized across communities.

Allocating local emergency resources based on community risk characteristics has garnered little attention from decision-makers, who continue to subscribe to geographically driven methods based on response time criteria (Cubbin, LeClere, & Smith, 2000b). This method calls for distributing limited resources in a manner that reduces response times to every part of a defined geographical area to the extent possible. On the surface, this allocation strategy appears ideal because it does not, to the uninformed observer, favor any particular area within a community. However, locating emergency resources equally throughout a community based on response time benchmarks disenfranchises high demand areas while "over-protecting" low demand areas. In addition, once units begin responding to emergency incidents, gaps in service are created across a jurisdiction (Blackstone et al., 2005).

Therefore, guiding locational decisions by predicting demand based on demographic characteristics is likely to be a more productive allocation strategy, because more resources would be targeted to higher demand areas to improve service delivery outcomes (Gyimah-Brempong, 1989). Allocating emergency resources is challenging, especially when accounting for budget, political, and social constraints within a community. However, considering variables associated with increased or decreased risk in different areas of a community could provide decision-makers with valid information to help drive locational decisions to improve service delivery.

Evaluating community risk as it relates to the services provided by many fire departments is complicated by the high level of uncertainty synonymous with predicting demand for emergency services. No sure method exists to determine where the next fire, hazardous material leak, or medical emergency will occur or what its magnitude will be.

However, it is likely community demographic and structural variables are associated with an increased or decreased probability of such events occurring (Cubbin et al, 2000b). For example, a section of a city with a dense population of lower income persons living in wood framed apartment buildings is more likely to sustain a fire event than a business district consisting of concrete structures. Wood buildings are at greater risk for fire than concrete buildings and lower income persons tend to invest less in private fire protection system, such as smoke detectors or alarm systems. However, the likelihood of a fire event occurring and the timing of such an event remain highly uncertain. Still, it is possible to calculate risk with factors of uncertainty as a method to better guide emergency resource allocation (Gamache, 2003).

1.3 Purpose of Research

Emergency service resources are scarce, which makes it problematic to allocate these assets equally across a community and expect all citizens to receive sufficient service delivery. A strategy to allocate these resources that fails to recognize this reality will inevitably disenfranchise a greater part of the population (Heyne, 1997). In general, those who reside closer to fire stations and other emergency facilities are advantaged over those who live farther away. Similarly, locational decisions for parks and schools disadvantage some citizens based on the travel time required to the public facility (McAllister, 1976). Fire stations are spaced throughout most urban environments to minimize emergency apparatus response times, which is the time from when a call for assistance is received to the time when a unit arrives at the location of the emergency incident (Swersey & Ignall, 1991). Citizens do not bring their emergency situations to a public safety facility, emergency workers must respond to the incident location.

Distance to the emergency scene has long been the measure for making fire service locational decisions in an effort to minimize response times (Achabal, 1978; Kuehnert, 1999). These decisions are predicated on the notion that the faster emergency personnel and equipment arrive on scene, the greater the opportunity to protect life and property (Meislin, Conn, Conroy, & Tibbits, 1999; Watts, 2003). The fact that demand for fire and emergency services differs depending on the social and structural characteristics in the urban environment is often ignored (Lerner, Nichol, Spaite, Garrison, & Maio, 2007). It is arguably less equitable to spread emergency resources equally throughout a city in an effort to minimize response times to all areas within a jurisdiction because demand is not equally distributed. Predicting demand could afford decision makers the ability to locate resources closer to those who have more need and could benefit more often from reduced response times. However, the current model ignores population characteristics in favor of equal distribution.

The number of emergency resources in most communities is often insufficient to keep pace with demand, a problem that is exacerbated each time a service is added to a fire department's response platform (Granito, 2003). For example, fire departments that add emergency medical response to their service delivery platform will increase the workload demand on the existing resources. If more resources are not added to meet the new demand, the community is placed at increased risk. More responses per unit will subsequently reduce each unit's availability to respond to additional calls for service that may occur in its response area. Fire incidents are on the decline so public administrators are searching for ways to justify the cost of maintaining these resources. This has increased the pressure on the fire service to respond to other types of emergency situations, such as emergency medical incidents, hazardous material releases, rescue events, and a myriad of other incident types (Donahue, 2004a). This increases the measured outputs of fire departments, which helps to justify existing inputs.

These service delivery changes have not been accompanied by innovative methods to better allocate emergency assets. For example, most urban fire departments respond in the same manner to all calls for service without considering whether these specialized limited emergency resources will make a difference in the outcome of the incident. Many decision-makers and the public in general are under the impression that any time a call to the 911 system is made a true life-threatening emergency requiring a rapid response by emergency personnel exists. In fact, this is far from the truth. A study by Blackstone et al. (2005) found that in 2000, 96% of the fire alarms responded to by the Philadelphia Fire Department were false, meaning there was no fire or emergency found when emergency personnel arrived. This statistic represents a trend that, at the very least, should inspire change in how resources are allocated.

The costs of responding to false alarms or other non-emergent incidents are incalculable. Direct costs associated with an emergency response include personnel, fuel for the apparatus, equipment, training, maintenance, and wear and tear on equipment, which are essentially wasted when emergency resources respond to non-emergent events. The opportunity cost and economic cost associated with these responses can be detrimental to a community (Blackstone et al., 2005). This issue was highlighted in Pinellas County, Florida, a community where three fire and medical apparatus responded to all emergency medical calls regardless of severity. The county administrator for Pinellas estimated that millions of dollars could be saved each year by limiting the response to non-urgent medical incidents to one unit. The Director of the County's EMS and Fire administration described the emergency resource allocation strategy as "crazy." He also said, "It's risking people's lives. It's wasting people's money. It's not necessary" (Van Sant, April 28, 2008). A declining local economy and strained budget were catalysts for the Pinellas county decision-makers to identify this issue. Unfortunately, many local communities have failed to recognize such inefficiencies and continue to arbitrarily allocate their limited emergency resources without regard to risk.

Requests for emergency services vary widely in number and severity across local communities. In general, as the severity of an incident increases, it becomes more time-sensitive and more resources are required to mitigate the situation. As the Pinellas County example shows, most urban fire departments do not triage or alter response protocols based on incident severity. Instead, the worst is always assumed until definitively proven otherwise after emergency personnel arrive on scene. This methodology leads to ineffective and inefficient service delivery, because no local community has the resources to affect such a response strategy. For example, what happens when a fire apparatus that is located strategically to protect a specified geographic area is dispatched to a patient with a minor laceration to the hand? The truck, because the fire service treats all customers the same, speeds out the door with lights and sirens operating to meet response time criteria generated by outside organizations to this non-emergent event. This places more people at risk than can benefit from the rapid response and potentially disenfranchises others who have more urgent needs.

When units respond with urgency to incidents using emergency warning devices, the capital asset is at greater risk of being damaged, not to mention the human investments on the truck and the general public which are placed at increased risk by this unnecessary emergency response. Each year more than 25% of line of duty deaths among firefighters are attributed to motor vehicle collisions that occur while responding to or returning from emergency scenes. A study conducted by Solomon and King (1995) in 1990 found that the 11,325 motor vehicle collisions in the United States involving fire apparatus caused more than 1,300 firefighter injuries. 80% of these incidents occurred while the fire apparatus was responding emergency traffic to an incident. It is clear from accident data and research that emergency responders are most at risk while responding emergency traffic to incidents (Colwell, Pons, Blanchet, & Mangino 1999; Ho & Linquest 2001). What makes this situation a travesty is that only a small percentage of calls for assistance are truly emergent, where the outcome can be influenced by the minute or so saved by responding with lights and siren (Ho & Linquest 2001). The increased danger and potential costs associated with fire apparatus responding in emergency mode raises the issue of diminishing returns.

Few situations are positively impacted by a time sensitive emergency response. The outcome of the vast majority of requests for emergency assistance will not be altered by arriving a few minutes sooner (Felder & Brinkmann, 2002). At the same time, a minute can be the difference in the outcome of certain situations. Few emergency agencies recognize this distinction. Instead, they continue to deploy resources evenly throughout communities without regard for demand or incident severity. Consensus standards and insurance industry recommendations for response time benchmarks and emergency service locational priorities do not account for risk factors or utilize probability analysis to predict the likelihood of emergency events. Instead, public leaders attempt to provide these life-saving programs equally across geographical areas. The service delivery strategy is the same for the entire community population, yet within a population many different risk factors are present that affect emergency service demand (Southwick & Butler, 1985). The unwillingness to tailor deployment and response strategies to specific groups within the overall society generates inefficiency and can delay the arrival of resources to time-sensitive events.

Another cost factor often overlooked is the marginal cost associated with reducing an agency's average response time. Each second the response time is decreased in a fire service system that allocates resources equally throughout a geographic region inflicts a large cost on the taxpayer, because many additional emergency resources must be placed into service for this marginal benefit. It is beneficial to lower response times to certain types of emergency incidents (Coleman, 2007). However, a deployment model that does not prioritize responses based on call severity cannot improve response times to life-threatening incidents without also improving response times to non-emergent events, which is inefficient. This requires an enormous commitment of resources, where costs will dramatically exceed benefits. It is more efficient to respond to only the life-threatening emergencies with urgency, because it reduces marginal costs and improves the benefit-cost service delivery ratio.

Unfortunately, public sector decision-makers fail to grasp the inefficiency associated with directing programs to reduce risk and save lives toward large heterogeneous groups (Walsh, 1998). One size does not fit all, and failing to acknowledge this places emergency service decision-makers between the proverbial "rock and a hard place" when determining how to allocate limited resources.

Government officials want to treat every life the same, but each person's likelihood of requiring time-sensitive assistance from a local emergency services agency is different (Rhoads, 1999). Individual characteristics influence risk levels for being involved in a fire or car wreck, suffering a heart attack, or any of a myriad of emergent situations based on personal habits and lifestyles. At the same time, providing certain groups within a society more services than other groups creates an unpalatable situation for most politicians and public sector leaders who do not want the public to think they favor one group within the community over others (Feiock, 1986). Therefore, policy initiatives are developed to treat all members of a society the same, which is problematic at the service delivery level. This strategy fails to match demand with available resources (Hammitt & Treich, 2007).

This situation is exacerbated when public sector decision-makers fail to recognize the difference between a statistical life and an identified life, which impedes their willingness to customize resource allocation strategies based on the differing group characteristics that drive demand across local communities. Treating every life as an identified life leads to the belief that no amount of resources should be spared to save a life, ignoring the opportunity cost associated with programs that subscribe to this ideal. The resources are simply not available to treat every individual the same, because this disenfranchises others in the society. Local emergency service agencies will never have the resources to save everyone (Jenni & Leowenstein, 1997; Viscusi, 1993). Yet, most public sector leaders want to pretend that government programs can save every life. For example, during a congressional hearing, "Congressman David Obey (D-Wisc.) stated, 'Quite frankly, I believe that when you're dealing in questions related to human life, economic costs are irrelevant'" (Rhoads, 1999, 18). The unwillingness to evaluate opportunity cost, marginality, and distinguish between statistical and identifiable lives when developing policy is far more harmful than taking a more utilitarian approach.

The goal of any emergency service allocation model should be to save the most lives possible with the available resources. Allocating public goods and services to save every identifiable life disenfranchises society as a whole. Programs to save lives must be evaluated based on statistics, where the actual persons saved are not identifiable until after they have been rescued. This is a difficult concept for most, which explains why programs to reduce risk are, for the most part, inefficient and ineffective (Walsh, 1998). Public sector leaders also fear the possibility of the "false negative" when allocating scarce resources based on statistical trends, because there is an undisclosed error factor with these calculations. Even if an allocation strategy correctly predicts incident severity 95% of the time, it is the 5% error that will draw the public's ire. This issue goes back to Munger's (2000) assessment of the policy process, which rightly points out that "...good decisions can turn out bad and bad decisions can turn out good." Statistical analysis provides a means to make intelligent allocation decisions; however, the influence of politics on these decisions plays an important role that will be addressed by this research.

1.4 Overview of Research Study

It is theorized that demographic and structural characteristics found across local communities are associated with demand for emergency services. Therefore, this research study will analyze hypothesized relationships between numerous explanatory demographic variables at the block group level and dependent demand variables to better inform resource allocation decisions for these scarce emergency resources. Predicting emergency service demand is complicated and fraught with pitfalls that can threaten the validity of findings, because the emergency service environment is extremely dynamic and, in many ways, unpredictable. For example, it is one thing to associate demographic characteristics with overall demand, but isolating these relationships to only time-sensitive situations presents numerous challenges. The majority of emergency 911 requests are for situations that are not time sensitive, but predicting these and then filtering them out is problematic. However, the development of a model to predict, with a high level of certainty, the general location and severity of emergency incidents based on demographic characteristics could substantially improve service delivery. Based on these criteria, emergency units would no longer be blindly allocated to equalize distribution across a community but could target high demand/risk areas to maximize the likelihood of positive incident outcomes.

Such a model would facilitate better, more predictable service delivery across a community. To accomplish this, block group level demographic data will be collected and compared to emergency service demand measures found in the city of Charlotte, N.C. The block group characteristics that most strongly predict demand and incident severity can then be associated with unit availability. The goal is to produce an alternative resource allocation model guided by demand and incident severity, rather than response time benchmarks.

To perform this analysis, the city of Charlotte, North Carolina will serve as the research area. Response data collected for fire, EMS, hazardous materials, and rescue incidents by the Charlotte Fire Department during fiscal year 2006 is the data set. This emergency response data will be combined with Census block group information collected in 2006 through the *Charlotte Neighborhood Quality of Life Survey* and U.S. Census Bureau, which assembled demographic information about each of the 331 block groups within the city. The available data will be used to model the existing emergency services environment and allocation decisions based on demographic risk characteristics. As cities like Charlotte continue to grow both in land mass and population, there is more pressure placed on decision-makers to carefully evaluate where best to relocate existing resources or locate new emergency service facilities to maximize service outcomes. A detailed analysis of the emergency environment and its relationship to emergency resource allocation under budgetary constraints is critical to such decisions if they are going to be effective in meeting the mission of these public safety agencies.

Modeling emergency service demand based on demographic and structural risk characteristics could significantly alter how resources are located throughout urban and suburban environments. It is also possible that the analysis will provide scientifically driven findings to support the continued use of existing models for deploying limited emergency resources. Regardless, the information will be valuable to public sector decision-makers to either justify existing locational strategies or support a change in deployment methodology.

These potential changes include new methods to deploy limited emergency resources and improve public finance decisions. A more efficient method to deploy resources with the same or better outcomes could decrease budget line items, freeing up funds for other community needs. Again, the purpose of the emergency services is to first prevent loss of life and then to reduce property damage, so a deployment strategy that either reduces cost without negatively impacting loss of life and property or one that maintains existing funding levels but leads to fewer losses can be considered more efficient and effective. Budgetary constraints must be factored into any emergency resource allocation model, because each local community has a different funding capacity. A one size fits all model, as espoused by ISO and NFPA, is not realistic for most local communities (Granito, 2003). Therefore, a new deployment model based on risk characteristics and probability has the potential to enhance emergency service outputs based on existing structural and economic conditions.

Assessing the decision making processes used to allocate emergency resources and the exogenous factors that influence these issues will provide additional insight into the factors that enable or prevent public services from operating efficiently and effectively. A myriad of outcome measures have been established to determine the effectiveness of emergency services at the local level, but it is unclear whether these measures translate into the optimal provision of these services. The obvious trade-offs in efficient and effective service delivery must be balanced with the overall welfare of a community. The fire service provides an ideal opportunity to research how locational decisions impact service delivery for public safety organizations.

1.5 Summary

Providing effective and efficient public safety services is a priority for most local government decision-makers. A large percentage of the tax dollars collected at the local level are devoted to emergency services to limit risk of injury, death, and property loss associated with unexpected events (Coe, 1983). Budgetary constraints, societal priorities, exogenous institutions, and the political environment dictate the service level and location of these critical services within a community. No community can afford the resources necessary to be risk free, so the limited emergency resources that are available must be located and deployed methodically to maximize risk reduction. However, current allocation models ignore demographic and structural characteristics associated with demand, instead focusing locational decisions on response time benchmarks (Ammons, 2001).

The intent of this dissertation is to evaluate the allocation model supported by the NFPA and ISO to locate fire and emergency medical resources within urban communities and whether these decisions match characteristics associated with risk and demand for emergency services. Response time benchmarks and resource capacity espoused by NFPA and ISO do not consider the substantial differences in economic and social capacity found across local communities (Granito, 2003). Few, if any, communities have the resource capacity to fund and support the infrastructure required to meet NFPA and ISO standards for emergency service delivery. Instead, communities of all sizes must grapple with where to locate limited emergency resources to provide the most effective and efficient service outcomes possible. A model that accounts for emergency service demand and risk characteristics to guide the allocation of limited emergency resources could significantly improve service delivery outcomes, saving many lives and preventing unnecessary property losses.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

Decision-makers often struggle to determine where to locate public facilities because so many variables are at play that affect these decisions. Public facilities, such as libraries, parks, water and waste treatment plants, maintenance facilities, police and fire stations, landfills, and jails to name a few, are essential to a functioning community. The type of facility often determines whether or not citizens want it located near their homes. The "not in my back yard" problem is just one issue public decision-makers contend with when constructing new facilities. Citizens and neighborhood groups often lobby to receive parks or libraries, but few want the waste water treatment plant. The public facility locational literature is full of these examples, but also deals with how location decisions affect service delivery.

There are costs and benefits associated with where public facilities are located. For example, a fire station may reduce the risk of fire in an area but increase the noise pollution. Fire stations are best described as "site-preferred facilities," which are public facilities that provide greater benefits the closer one is located to the facility (Austin, 1974). Citizens must balance their preferences for public safety services with the potential cost when supporting or protesting such facilities. Emergency situations are often time-sensitive, so as one's distance from these facilities increase the potential benefits decrease. Citizens may not want a fire station in their neighborhood, but without such a facility citizens assume more risk for fire and other emergency situations (Felder & Brinkmann, 2002). However, there is more to consider when locating emergency service facilities than just response times, such as demand and ability to pay for these services. In the case of emergency services, demand and socioeconomic status tend to have an inverse relationship, meaning lower income areas have higher demand for these services (Gramache, 2003; Southwick & Butler, 1985). This challenges local decision-makers to balance locational decisions between those with the ability to pay and those who have more demand for the services. To further complicate these issues, most communities operate fire stations that were built many decades ago and cannot be moved to address current societal needs. Locating these facilities to ensure effective and efficient service delivery is extremely complex (Boyle & Jacobs, 1982). This is made more difficult by the organizational structure, traditions, and culture that pervade an industry that has been in existence since the colonial period (Granito, 2003; Middleton, 1992).

2.2 Fire Service History

The fire service is unique to other public safety organizations because the majority of fire departments are staffed by volunteers. In fact, 70% of the estimated 30,635 fire departments across the United States are volunteer organizations, where firefighters receive no monetary pay for their services. Volunteerism has been a significant part of the fire service's tradition since its inception. The insurance industry provided the primary initiative for the first organized fire departments to protect insured liabilities. The Colonial period marked a time when Britain was experiencing a significant increase in industrialization, which spurned intense demand for the goods produced in the colonies. The mercantile system ensured that British interests controlled the colonial economy. Insurance companies soon recognized the colonists contribution to the British economy, encouraging many of them to relocate to the colonies (Middleton, 1992). Although fire protection was limited to bucket brigades and the sheer will of volunteers to extinguish fires, it was better than nothing (Calderone, 1997; Klinoff, 1997; Jacobs, 1995). During these times, fire brigades often fought to prevent entire towns from burning (Golway, 2002).

Organizations often resist change, but the fire service has historically resisted change better than most. For example, the earliest fire brigades were adamantly against trading in their buckets for hand-drawn pumpers to transport water to fires. As fire pump technology improved, these same fire companies fought against using horse drawn fire pumpers and then combustion engine pumpers for firefighting in favor of the beloved hand drawn pumpers (Middleton, 1992). This culture continues to resist change, which has hampered progress toward developing a more effective and efficient emergency service delivery platform. The mission of the modern fire service is very different from that of just two decades ago, when fire suppression was the main priority for most departments and the only service provided by others. Now, fire departments must invest in fire prevention programs, respond to emergency medical and rescue situations, and manage hazardous material incidents in addition to extinguishing fires. Much of the changing mission stems from declining local budget funds and a need to maximize output from limited public resources to maintain service delivery standards (Donahue, 2004a).

A more proactive effort to prevent fire events is one significant change in mission many fire departments continue to resist (Granito, 2003). The need for fire prevention was demonstrated in the 1973 FEMA publication, “America Burning” as a means to reduce the number of fire events, injuries related to fire, and fire fatalities. The idea of fire prevention was a complete shift in philosophy for fire service managers. The fire service from its inception was tasked with extinguishing, not preventing, fires. Few industries would work to effectively put themselves out of business, which would essentially be the result of successful fire prevention efforts. In fact, fire prevention has become so successful that fire departments across the country have had to add other capabilities to their service delivery platforms to justify their budgets. These additional services include responding to emergency medical incidents, hazardous material releases, and technical rescue situations, which were not part of the fire service just a few decades ago.

2.3 Evolution of the Fire Service

The evolution of the fire service has been and continues to be slow. Although the culture of this industry is changing, the fire service still shuns technology and other advances in favor of antiquated service delivery methods. One reason for this is the local connection to the fire service. Fire departments are local entities and to this end reflect the local economic, geographic, and social environment (Duncombe, 1992). The authors of “America Burning” noted that the responsibility for fire protection and prevention should continue to rest in local jurisdictions and not the federal government. The report limits federal involvement in fire protection to providing monetary resources to local jurisdictions, collecting and researching fire data, and assisting state and local governing bodies with educational and training resources. Many of these requests have been fulfilled in recent decades, including the establishment of the United States Fire Administration and the National Fire Academy (Coe, 1983).

The "America Burning Report" established a goal during the 1970's to reduce the fire rate across the country by 5% annually. In hindsight, this was an aggressive goal that ignored the organizational attributes of the fire service, which were intrinsically resistant to change. In addition, some argue that more federal involvement, especially in the area of rating the level of fire protection in each community would improve fire service delivery techniques. This has been resisted by the insurance industry and other private organizations that have a financial stake in maintaining the existing practices for rating and delivering fire protection (Coe, 1983). This entropy found in the fire service and resistance from organizations that benefit from fire protection being a local collective good have prevented significant progress in reducing the destructive results of fire in the United States.

A second report titled "America Burning, Revisited" was published in 1987 to evaluate the progress made in reducing the national fire rate since the first report. It also promoted a new strategy to combat the fire problem. This report indicated the fire service had improved its efforts to combat the fire problem during the previous ten years. The number of fires, injuries caused by fire, and fire deaths had fallen. Although on the surface the data was encouraging, the exact cause of these declines remained unclear and no guidelines for how to continue the progress were provided. It is even more difficult to attribute the declines to the fire service, because of the many potential exogenous factors. For example, a myriad of fire codes and standards were passed during the ten year study period. Also, technological advancements in communications, building materials, and other factors far removed from the changes made by the fire service likely contributed to the decline. Despite all of the possible contributing factors, the one statistic that has remained constant for decades is the monetary losses attributed to fire (Ahrens, Frazier, & Heeschen, 2003).

Fire rates vary from place-to-place within the United States depending on climate, socioeconomic status of residents, and other demographics (Coulter, 1979). Annual fire losses in the United States often exceed losses suffered from hurricanes, tornadoes, earthquakes, and other natural disasters combined. Fire departments respond to more than two million fire incidents each year. Fire causes over ten billion dollars in property loss and thousands of deaths (FEMA, 2000). The authors of "America Burning, Revisited" (1987) recognized that the fire service was going through "revolutionary" change as the demand for emergency services shifted towards new frontiers, such as emergency medicine and hazardous materials response (p. 12). This change in organizational mission can be associated with the declining number of fire events. Fire service managers continue to search for ways to justify the exorbitant costs of manpower, equipment, and infrastructure. Although not mentioned in most government reports, the insurance industry remains a significant lobby and proponent for increased local fire protection resources (Coe, 1973).

The "American Burning, Revisited" report showed a small reduction in losses from fire across the United States. A renewed push for fire codes and regulations, fire prevention, and additional fire fighting resources followed this report. In general, the fire service is much different organizationally today than it was in the 1980's. Most fire departments, even those in rural America, provide suppression, prevention, and emergency medical services (Granito, 2003). However, monetary property losses from fire, even when controlling for inflation, remain comparable to losses in the 1970’s (Ahrens et al., 2003). Much of the reason monetary fire losses have been consistent for so long can be attributed to increasing population density and rising property values across the country. While responding to and combating these fire events, more than 100 firefighters die in the line of duty each year (Washburn, LeBlanc, & Fahy, 1991). This fatality rate has remained relatively constant for decades. Monetary property losses and firefighter deaths are just two examples of the fire service’s inability to find new and innovative methods to deliver emergency services.

Outside agencies, such as the National Fire Protection Association (NFPA) and the Occupational Safety and Health Administration (OSHA), have for decades published consensus fire protection standards and laws to improve community and firefighter safety. Standards published by the NFPA, for example, provide guidelines for minimum staffing on fire apparatus, response time benchmarks, equipment, and the resources required to meet an adequate level of fire protection for all types of communities. State and federal OSHA agencies provide additional laws and codes intended to improve the health and safety of firefighters and other rescue professionals while performing their duties. However, implementing many of these rules and regulations is extremely resource intensive, which has hampered their impact in the vast majority of communities across the country.

The fire service continues to push the same issues that it has for the past two decades with only minimal effect on fire losses. Aggressive efforts to educate the public and provide fire suppression services have proven inadequate to significantly lower fire losses. The organizational structure of the fire service may carry some of the blame because of its resistance to change. In addition, the opportunity cost of fire protection has proven to be a formidable barricade to improved fire protection. Citizens in most local communities continue to want the public sector to provide more services, which often requires funds to be diverted from emergency services to pay for these services (Citrin, 1974). Ignorance of the fire problem may be a cause, but the public is willing, in general, to spend for additional police protection and other forms of public safety. Even the smallest communities have paid law enforcement officers or rely on the local sheriff's department. This is not the situation for fire protection, as most small and rural communities depend on volunteers to provide these crucial services (Coleman, 2007).

Suburban and urban communities generally have the tax base to fund paid or combination staffed fire departments (Brudney & Duncombe, 1992). However, most fire protection agencies argue the resources allocated to the fire service are woefully inadequate to lower the losses associated with fire (Duncombe, 1992). These agencies attempt to lay firefighter deaths, property losses, and the countless civilian injuries and fatalities associated with fire at the feet of politicians not willing to fund the resources necessary to provide adequate fire protection to decrease these statistics. It is unclear at what point the marginal costs of fire protection resources begin to far outweigh any marginal benefits. Obviously, more emergency resources are desired by public safety officials, but the opportunity cost of adding more resources in most communities is usually too high to make the necessary additions. This places more emphasis on maximizing the existing limited emergency resources to improve public safety.

Fire departments tend to attract less attention from the public, because most citizens do not have regular contact with them or the need for their services. However, paid fire departments command the second largest budget, behind police protection, in most urban communities. Because these agencies are often overlooked, fire managers and administrators are able to act with impunity in developing organizational policies (Slack, 1989; Santoro, 1995). The fire service is a monopoly, which further empowers administrators in their policy positions. There are no alternatives if your house or business catches on fire, so the fire service has no competition (Caporaso & Levine, 1992; Romer & Rosenthal, 1979; Savas, 2000).

The fire service, similar to many government agencies, continues to blame inadequate funding for the inability to combat the fire problem. Much of the argument for increased funding has fallen on deaf ears at all levels of government. No matter how much "saber rattling" representatives of the fire service did throughout the end of the 20th century, funding levels in most areas only seemed to decrease and new funding streams were non-existent (Duncombe, 1992). Fire departments continue to resist change, as the overall number of fires decrease, while the demand for other emergency services increases. A byproduct of the increasing population density in most communities is increasing demand for the non-traditional services fire departments are either providing now or are being pressured to provide (Felder & Brinkmann, 2002). These services include responding to medical emergencies, providing technical rescue (i.e. vehicle extrication, confined space rescue, urban search and rescue, and rope rescue), and managing hazardous materials incidents. Urban administrators view most of these services as natural fits for fire personnel to provide, believing fire departments are set up well to provide these additional services because of their organizational structure and availability.

With the available manpower and locational advantages that fire protection services have over other public safety entities, it is easy to understand why public administrators continue to look to these agencies to take on additional emergency response tasks. The additional services do help justify the high costs of fire protection during a time when the number of fires is declining. However, as departments deliver more services they become less effective, because built in capacity for fire events does not account for the additional responses that come with providing more emergency services (Donahue, 2004b). Local officials who do not add fire and emergency resources or adjust allocation decision methods to meet the changing mission of the fire service place their respective communities at increased risk.

Fire departments provide a myriad of emergency services to most communities in the United States. These departments have become critical components of the emergency management and the public health systems, not to mention their contributions to the homeland security and environmental protection goals of this country. The fire service carries a large and diverse service delivery burden that is dependent on the decisions and resources provided at the local level. This is especially true in the urban environment, where demand for emergency services provided by local fire departments continues to rise. Despite the integral part the fire service plays in the local public safety arena, minimal attention has been devoted to developing ways to deliver these services more efficiently and effectively (Duncombe, 1992). Although many organizations continue to develop standards and make recommendations to improve this industry, few consider the local economic and political constraints that affect service delivery (Teitz, 1967).

2.4 Exogenous Influences: ISO and NFPA

The National Fire Protection Association (NFPA) and the insurance industry have strong influence over fire protection services in this country. The NFPA develops consensus standards for the fire service. Local fire departments are expected to comply with these standards, which do not carry the authority of a law but are admissible in a court of law if not complied with. This places fire administrators into a difficult position because even partial compliance with NFPA standards can be very costly. Yet, non-compliance creates liability that also has potential costs. It is not that the fire industry does not want to comply with these standards, but the resources are simply not available at the local level to be 100% compliant. Budget constraints and other practical limitations often determine a department’s level of compliance with NFPA standards.

NFPA standards are developed by persons associated with the industry, and often do not reflect what is prudent and reasonable for local communities based on financial capacity. In fact, no fire department is 100% compliant with NFPA standards, because local communities simply do not need or even desire the level of fire protection mandated by this organization. For example, NFPA 1710 mandates minimum staffing of four firefighters on each fire apparatus. Personnel costs account for well over half the budgeted dollars for most fire departments. It is debatable whether four firefighters is the optimal staffing level for fire apparatus, because the emergency environment is so dynamic (Granito, 2003). The standard also fails to account for the increased mission most fire departments are undertaking, as fire units are responding to more medical and rescue emergencies than fire events. Medical emergencies and most rescue situations are less manpower intensive than fire suppression operations. Improvements in fire prevention and building construction have further reduced the number and severity of fire events (Brudney & Buncombe, 1992). Therefore, locating fire and emergency resources based on ISO and NFPA benchmarks or complying with these staffing standards may lead to enormous service delivery inefficiencies for many local communities.

The insurance industry is the other major exogenous influence on fire protection resource allocation. The Insurance Services Organization (ISO) ranks local fire protection capabilities for the insurance industry. This organization is beholden to the insurance industry, which provides support and utilizes the rankings to determine the insurance rate each community is assessed. Local communities receive an ISO rating between 1 and 10, with 10 being the lowest and 1 indicating the highest level of fire protection. The exact methodology and guidelines used to rate communities is not available to the public, making it difficult to assess the validity of these rankings. In general, the ratings evaluate the water supply capabilities and the fire services provided by local communities. Rural communities that do not have fixed water supplies and rely on volunteer firefighters receive ISO ratings between 8 and 10. ISO ratings between 1 and 3 are usually only granted to urban jurisdictions that provide paid fire protection and have fire hydrants within 1000 feet of every structure. ISO provides an incentive for political leaders to fund fire protection to lower ratings, because a lower ISO rating correlates to lower insurance rates. However, it is often far more expensive to provide the additional fire protection resources necessary to lower ISO ratings than it is to just pay the higher insurance rates (Coe, 1983; Granito, 2003).

In addition, a number of fire incidents in recent history indicate that ISO ratings may not be associated with fire related losses or the level of fire protection provided by a local jurisdiction (Coe, 1983). This became evident during the summer of 2007 when nine city of Charleston, South Carolina firefighters were killed fighting a fire in a furniture store. The City of Charleston is one of only a few cities in the entire country that has an ISO rating of 1. The fact that nine firefighters perished in the fire is tragic but not the sole reason to question the validity of ISO ratings. It was the myriad of other factors contributing to the deaths that is at issue, which included inadequate water supply, outdated equipment, training deficiencies, poor tactics, and an inept command staff. These factors are all criteria ISO is assumed to evaluate when rating a community.

The changing mission of the fire service adds to the complexity of locating emergency resources. Urban fire departments must balance the availability of scarce emergency assets with the increasing demand for these resources generated by more emergency medical incidents, hazardous materials emergencies, rescue events, and fire emergencies. Statistically, calls for emergency medical events are the most common types of incidents departments manage (Brudney & Duncombe, 1992). However, the allocation of fire/emergency medical resources is more often than not based on ISO and NFPA criteria, which are focused on fire events. This leads to inefficient resource allocation decisions, because effectively mitigating a medical situation requires far fewer resources than managing a fire incident (Donahue, 2004b). Therefore, locational and response criteria that does not account for the different types of incidents fire departments respond to decreases the efficiency and effectiveness of these services.

2.5 Response Time Benchmarks

Fire stations are located in most communities to minimize response times to every part of an urban or suburban environment (Swersey & Ignall, 1991). However, equally spacing these stations to uniformly lower response times ignores demand. This leads to high demand stations and low demand stations because of the variability in social and structural characteristics found across response areas. For example, a city with forty fire stations will have some fire apparatus that respond to a few hundred calls per year while other apparatus respond to thousands of emergency incidents over the same time period. This disparity results from the equal dispersion of resources without regard for demand. Aside from the over use of some emergency resources and under utilization of others, the main issue with this strategy remains the potential for coverage problems as units respond to emergency events (Cubbin, LeClere, & Smith, 2000b).

This locational dilemma is addressed by McAllister (1976), who argues public facilities should be located based on demand, so that services consumed can be maximized to improve efficiency. Based on this concept, emergency resources should be located so that each unit responds to roughly the same number of incidents each year. Fire protection assets are not nonrivalrous, so when a resource is actively mitigating an emergency situation it is unavailable to respond to additional emergency requests for assistance. This means high demand jurisdictions are more vulnerable to units being unavailable when scarce emergency assets are dispersed evenly. After all, high demand areas within a community are more likely to experience simultaneous emergency calls, which can create large gaps in coverage (Blackstone et al., 2005). Response zones within urban environments where demand for emergency services is high are disadvantaged when emergency resources are spread evenly throughout an entire city. Each time a unit in a high demand area responds to an emergency coverage gaps occur, which lead to longer response times to any additional incidents that occur while the primary unit is occupied (Blackstone et al., 2005; Peters & Hall, 1999). NFPA standards and ISO evaluation criteria do not consider demand for emergency services under conditions of limited resources when determining optimal fire protection and emergency medical coverage.

Urban administrators conscious of potential legal and insurance issues try to disperse resources evenly, so theoretically each citizen can be reached within a maximum response time (Rider, 1979). According to ISO and NFPA response time criteria, the primary fire and/or emergency medical resource should arrive on scene within four minutes of the emergency call ninety percent of the time (Bryan & Pane, 2008; Kuehnert, 1999). This does not account for the specific type of incident or whether a four minute response versus a more extended time will make a difference in the final incident outcome. Many departments have implemented an alternative response time benchmark that is more reasonable. For example, the city of Charlotte Fire Department sets a lower response time benchmark to all incidents within the city. It strives to reach all emergency situations within 6 minutes of receiving a call for assistance 80% of the time. In fiscal year 2008 the department reported reaching 77.33% of incidents within 6 minutes, which demonstrates the difficulty in meeting NFPA response time criteria (Fully Involved, 2008, August). It is unclear whether a four or six minute response time benchmark significantly influences the measured outcomes of the fire service, such as monetary fire losses, fire fatalities, or injuries. The reality is that few local communities have the capability to fund enough resources to reach ninety-percent of all emergency incidents within four minutes, which explains why most communities rely on less stringent benchmarks to evaluate service delivery. This makes it difficult to compare the outcomes of different fire service communities (Rider, 1979).

Response time benchmarks drive the decision-making criteria for locating emergency resources in most local communities. However, evaluating emergency service effectiveness based on an average response time ignores two significant and often overlooked factors: the impact of outlier response times and the fact that majority of emergency requests for assistance are not time sensitive events, making a rapid response unnecessary (Meislin et al., 1999). It is well known by emergency responders, but often overlooked by decision-makers, that only a small percentage of emergency incidents are truly time-sensitive (Blackstone et al., 2005). For example, a five minute versus a ten minute response time will not change the medical outcome of a person suffering from the flu or a headache. Much inefficiency occurs when fire units do not alter their response to 911 calls for assistance based on severity, because non-emergent events receive too many resources and emergency events too few. Worst case scenario, units are tied up on non-emergent events and there are no units available to respond to emergent events. Emergency medical systems across the country are the only public safety organizations seriously addressing this problem. Many high performance emergency medical services now devote substantial resources to triaging requests for assistance. The severity and threat to life of each request for assistance determines which incidents receive an emergency response and which ones do not. Triaging emergency incidents based on severity facilitates more efficient emergency service delivery with scarce resources.

Emergency medical service agencies triage calls for service based on severity to guide ambulance allocation decisions, which improves service delivery effectiveness and efficiency. By prioritizing each incident, a unit responding to a lower priority medical call can be diverted to a higher priority call if that unit is the closest available unit. This strategy for assigning units to emergency medical calls permits EMS agencies to limit built-in resource capacity without sacrificing service outcomes. Few fire agencies have subscribed to allocating resources in this manner. One reason is that fire departments, with few exceptions, are public sector organizations. These agencies do not generate profits or have to fear going out of business for poor performance, which diminishes the incentive to expend human capital to improve efficiency (Morrill & Symons, 1977). This is not the case with most high performance EMS agencies, which rely on service fees and profits to provide the service. These agencies must prioritize calls to operate more efficiently within the guidelines specified by their local jurisdictions. Market forces enter into the process, which provides an incentive to find more efficient methods to deliver effective services.

Increasing fire and emergency resource “capacity” is the traditional solution to meeting increased demand (Granito, 2003). However, adding emergency resources is costly and difficult to justify (Teitz, 1967). Public goods are provided based on the public’s willingness to fund such services. Individuals allocate resources based on the utility they expect in return (Pratt & Zeckhauser, 1996). Most citizens believe they will never need the fire department, so why pay more for a service that they do not expect to use or benefit from? This makes it difficult to justify additional revenue for these emergency services. Rider (1979), in a study of fire department resources, determined that "capacity" must be ten or more times greater than necessary to meet average demand for emergency services. The study compared the number of fire apparatus that were committed to incidents and the number available to respond to additional emergency events during times of average demand across fire departments. Rider makes the point that it is unclear how much fire asset "capacity" a community requires, but an increase in available resources can equate to a decrease in response times depending on how these assets are distributed. Many local communities do not have the revenue to purchase and/or sustain this significant number of additional resources. Instead, public leaders are left to locate limited fire and emergency resources to meet the demand found in individual communities based on the funding constraints. This requires innovative methods that do not necessarily follow prescribed norms to gain efficiency and effectiveness in the public safety arena. ISO and NFPA benchmarks are idealistic and many times do not reflect the economic reality found in communities. Government officials do allocate resources for public safety, but they must balance these decisions with the provision of other services the public demands.

2.6 Public Sector and Local Government Environment

There is tension between the different levels of government over which are best suited to provide the different public goods and services demanded by the electorate. The characteristics of some public goods are more conducive to provision by one level of government over another, such as the federal level providing the military. However, based on the ideals of federalism public goods and services should be provided by the lowest feasible level of government (Tullock, Seldon, & Brady, 2002). Often times the level of government that should provide a particular service is not clear making it susceptible to the changing political environment. A polycentric system of government where each local jurisdiction provides a different market basket of public goods and services is supported by the public choice literature. This situation provides a pseudo-competitive market environment between jurisdictions, which gives people options when making locational decisions (Ostrom, Tiebout, & Warren, 1961). Local decision makers are much more likely to receive service delivery feedback from the people than those at the state and federal level (Niskanen, 1975).

The public sector is inherently handicapped in allocating resources efficiently, effectively, and equitably because information about citizen willingness-to-pay or service delivery preferences is not freely exchanged. Public decision makers are often left to gauge service delivery preferences of the electorate through the ballot box. Majoritarian voting rules provide incentive for elected officials to support policy initiatives that the median voter prefers (Sylves, 2004). Theoretically, it is the preferences of the median voter that influence how limited resources are allocated in the public sector. However, this overlooks the influence of the bureaucracy, which tends to have the expert knowledge and incentive to grow government.

Based on the Niskanen model, public bureaucrats gain prestige and power by maximizing budget allotments to increase salaries and resources (Rosen, 2002). Because of the principle-agent relationship between the political and bureaucratic decision-makers, the preferences of the median voter are often minimized. In fact, Niskanen (1975) found that public budgets often exceed the preferences of the median voter. These excesses are rarely acknowledged by legislators and local elected officials who resist their oversight obligations, because monitoring a bureaucracy or an executive branch is itself a public good. Monitoring the bureaucracy is not only costly for politicians, but the benefits are spread throughout the entire electorate and not just to the constituency of the politician conducting the oversight activities. Therefore, the rational politician attempts to free-ride on others who may be willing to provide some oversight of the bureaucracy. As with any public good, this situation encourages little to no oversight as those who are rational prefer to free-ride, which permits the bureaucracy to allocate resources based on their preferences. These preferences often do not parallel the desires of the electorate or median voter.

The incentive to grow government is a reason local leaders have failed to find new emergency resource deployment strategies to improve service delivery. Utilizing existing resources more efficiently is not the generally accepted solution to most public sector problems. Instead, emergency service decision-makers use service delivery issues caused by increased demand to plead or justify a need for additional resources, rather than finding new ways to use existing resources. For example, when local crime rates increase, often times the police chief utilizes a “knee jerk” reaction and argues for more police officers, instead of first attempting to redeploy existing resources in more innovative ways to combat the issue. However, as Niskanen explains, there is little incentive to find more efficient methods to deliver public services, which is a reason fire service leaders have shunned new deployment models in favor of simply arguing for more resources to meet new and increasing demand.

2.7 Economic and Information Issues in the Public Sector

Specifically, government must provide those goods and services that are inherently public, which means nonrivalrous and nonexclusive. The private market will either under provide or fail to provide public goods because of these characteristics (Munger, 2000). The concept of nonrivalry means that one person's enjoyment of a good does not detract from another person's simultaneous enjoyment of the same good. Nonexclusion describes the inability to prevent the consumption of a good or service. National defense is a pure public good, which necessitates its provision by the federal government. Every person who resides in this country and even many beyond the borders receive the benefits of the United States military regardless of status or position in society. There is no way to prevent the consumption of this good. In addition, the benefits are shared equally by all because consumption by one individual does not reduce or impact consumption by another (Williams, 1966).

Although few pure public goods exist, governments provide a myriad of goods and services that are collective in nature. These goods share many of the characteristics of public goods, but are not completely nonexcludable or nonrivalrous (Olson, 1982; Savas, 2000; Weimer & Vining, 2005; Williams, 1966). Emergency services are just one example of a good provided by government that has many characteristics of collective goods. The private sector is hesitant to provide these types of services for a myriad of reasons. Not only is exclusion costly, but these services generate many positive externalities that are difficult, if not impossible, for private firms to internalize. In effect, positive externalities can be equivocated to lost profits, which is not a situation that appeals to most private sector firms. Therefore, these services are best suited to be provided by lower levels of government because of the externality and collective good problem (Tullock et al., 2002). Each local community has its own emergency service needs, which could not be met if these services were provided by the state or federal level. At the local level, decision-makers can customize emergency services to match the dynamic needs and budget constraints found in their community. This permits the delivery of more effective and efficient services.

Another reason the private market will not provide collective goods is the inability to accurately ascertain consumer willingness-to-pay. Since exclusion is not possible, consumers have an incentive to overstate their preferences for collective goods (Buchanan & Tullock, 1965). Information about consumer preferences is asymmetric in the public market. Individual consumers may know how much of a service they prefer but are unlikely to accurately reveal those preferences. This brings us back to the problems of centralized government, which facilitates and even encourages free-riding. The country was founded on the concept of a strong national government, but the concepts of federalism ideally permit the provision of public goods and services by different levels of government. However, economic and social instability are often catalysts to centralizing power and service delivery at the national level (Smith et al., 2008).

Centralized decision-making processes tend to decrease the efficiency with which public goods and services are allocated (Tullock et al., 2002). Again, the mechanisms to transmit accurate and timely information between consumers and producers in the public sector become less effective as the level of government providing the services moves from local to state to federal. The decision processes move farther away from the individuals receiving the good as service delivery shifts from the local to the federal level. At the federal level services are paid for by and provided to a massive number of people who have a wide variance in preferences. Rational people will limit participation in collective actions involving large groups because participation is so costly for little to no benefit (Olson, 2001). Optimally, federal government decision-makers establish the amount of service to provide based on median voter preferences; however, service levels will always exceed or fall short of the majority's desires, which is inefficient. The inability to provide an efficient level of services has much to do with the heterogeneous national population. As service delivery is moved down to the state or local level, consumers of collective goods become less heterogeneous. Therefore, local level decision-makers, despite asymmetric information, can theoretically allocate resources more efficiently. Quite simply, if the median voter preferences are satisfied at the local level fewer persons with alternative preferences are dissatisfied (Olson, 1982; Tiebout, 1956).

Most people accept the inefficiency and ineffectiveness associated with public goods and services, which to an extent will always be the case when government provision is necessitated (Chilton, Jones-Lee, Kiraly, Metcalf, & Pang, 2006). The more centralized decision-making becomes, the less responsive and efficient the outcomes. Government decision-makers simply do not have the information or incentives to make efficient and effective resource allocation decisions, which Leeson (2007) clearly demonstrates in his analysis of the Federal Emergency Management Agency's (FEMA) response to the Hurricane Katrina disaster that afflicted the gulf coast states in 2005. FEMA knew a category five hurricane striking the New Orleans area would have catastrophic consequences. This threat was taken seriously enough by FEMA that a year before Hurricane Katrina struck the federal government held a mock exercise called "Hurricane Pam." This exercise simulated a category five hurricane striking the New

Orleans area (Cooper & Block, 2006). Based on this exercise and other preparations prior to the storm, FEMA claimed it was well prepared to respond to a disaster in the days leading up to the Katrina landfall (Sobel & Leeson, 2006). Unlike disasters that strike unexpectantly, hurricanes often provide emergency response agencies days and even weeks to prepare. Statistically driven weather models are also used to predict with a high degree of certainty the place a hurricane will make landfall many days in advance.

Despite the advanced notice, FEMA failed to follow their pre-deployment disaster plans developed during the Hurricane Pam exercise. Not long after the hurricane force winds subsided on the gulf coast news organizations began broadcasting photos of the devastation. These news agencies had pre-deployed ahead of the storm and utilized satellite feeds to broadcast information despite the massive power and communication outages. Meanwhile, FEMA was nowhere to be found. Why with all the preparation, was the primary federal agency for managing such an event not on the ground providing aid, while news organizations and other private sector services were already providing assistance? Leeson (2007) answers this question by comparing the FEMA response to this disaster to that of Wal-Mart. He explores the information and incentive problems that differentiate the private from the public sector.

Centralized decision making in the public sector does not permit the free exchange of information across the bureaucracy. Communicating resource needs and the urgency with which those resources are needed to decision-makers is almost impossible. The private sector, in this case Wal-Mart, is able to decentralize decision-making processes and utilize the voluntary exchange of information facilitated by the private market to guide allocation decisions that are more efficient and effective. In the days and weeks following the Katrina landfall Wal-Mart provided relief supplies to those in need, while FEMA continued to gather resources and evaluate where to send them. This situation is germane to the fire service, because the organizational structure of most fire departments is decentralized with fire stations placed in different parts of each community. This permits scarce emergency resources to be located in individual micro-communities where groups are more homogenous. Therefore, just as Wal-Mart stocks its stores with different products based on local consumer preferences, the fire service could, and at times does, allocate resources based on the demand experienced within each fire station's coverage area. When decision-making processes are pushed down to lower levels of government, information flows more freely and is often more timely than when gathered by a central entity. This was the crux of the problem FEMA dealt with when responding to gulf coast resident's needs following the Katrina landfall.

FEMA gathered information for days before deciding how to allocate its resources, which in many cases were plentiful but in the wrong locations. The agency failed to utilize resources to their highest level of output. For example, FEMA had 1000 trained rescuers sitting in an Atlanta, Georgia hotel ready for deployment while people remained stranded under collapsed homes and on roof tops in the disaster zone. Yet, these individuals were held for days to attend redundant training and then were deployed away from the most impacted areas to simply raise the FEMA flag in a vain effort to improve public relations. Although the information feedback mechanisms in the public sector are problematic, the news video alone should have provided FEMA the motivation to commit medical and rescue resources to the hardest hit areas, which the media exposed. The media outlets are private firms that enjoy a free exchange of information and must satisfy viewers to remain viable. Unlike FEMA, these news outlets had the incentive to pre-deploy their assets to the most impacted areas to ensure they gained market share (Burton, 2008; Cooper & Block, 2006).

Aside from the information problem, the public sector also has an incentive problem when allocating resources. The public bureaucrat does not have a profit motive to allocate limited public resources efficiently. This is not the case in the private sector where a firm that fails to adapt to market conditions, such as changes in consumer preferences, will be forced out of business. The government does not have to worry about going out of business if it fails to effectively or efficiently allocate resources. Government, in general, does not earn revenue to fund public goods and services, because it has monopolistic powers and the authority to take money out of the private sector via the tax system (Bergstrom, 1979: Savas, 2000). The example Leeson (2007) gives describes Wal-Mart's response to the disaster, which was quick and effective. He explains the profit motive in the private sector provides incentive to decentralize decision-making, which facilitates the exchange of information to ensure resources are allocated efficiently to maximize profits. In addition, private firms are concerned about their corporate image, because a positive image translates into profits. In Wal-Mart's case, it was able to pre-deploy the resources it predicted would be in highest demand to its stores located in and near the disaster zone. Generators and other equipment were moved to ensure stores could open and serve the populations. Whether Wal-Mart assisted in the disaster situation by giving away needed resources in some cases or selling them in others, the profits for the company as a whole increased because of the demand for goods and the goodwill engendered through the effort.

Leeson (2007) explains the differences between the FEMA and Wal-Mart response to this disaster as an issue of information and incentives. The private market provides for the free exchange of information so that decision-making can be decentralized. Profits provide the motivation to ensure that effective and efficient allocations are made. The public sector is hampered by a lack of information and incentives. In fact, the public market provides an incentive structure that rewards incrementalism and painfully slow response to citizen needs, especially under disaster circumstances. Monetary profits are the incentive for private market firms to be proactive in their efforts to meet consumer demand. This was evident during Wal-Mart's response, and the response of the media who were transmitting video from the disaster zone even while the storm raged. Private sector firms that are reactive will lose market share to proactive firms that are more organized and willing to take risks. This is not the case for the public sector.

The incentive structure in the public sector promotes a reactive strategy to manage citizen demand and preferences for services. Leeson (2007) attributes the reactive nature of political and bureaucratic leaders to fear of committing "type-one verse type-two policy errors" (16). He describes the type-one error as occurring when public leaders are not cautious enough when making policy decisions. Policy makers are susceptible to committing type-one errors when promoting proactive policy solutions to solve problems. When government acts proactively, actions are more observable to the public regardless of the outcome. A type-one error occurs when political leaders take proactive action that does not produce public benefits but instead appears to increase cost or lead to loss of life. In the hurricane scenario, proactive government officials might have mandated evacuations many days prior to landfall, organized mass transportation resources, and pre-deployed emergency personnel and equipment. However, these actions would have made the public officials susceptible to committing a type-one policy error had the hurricane taken a different track or diminished its intensity. The clear, early evacuation order, if later deemed unnecessary, would have generated far more criticism than the same order, proven effective, would generate praise. Therefore, the incentive structure in the public sector is paradoxical to the proactive policy initiatives found in the private sector (Sobel & Leeson, 2006).

Instead, government officials committed what turned out to be numerous type-two policy errors before and after Katrina made land fall. The most serious of these decisions was waiting to evacuate residents in the New Orleans area until landfall was certain, which did not leave enough time to empty the city. Public officials were too cautious in mandating evacuations because they feared moving people out of the city too early only to have the hurricane change course (Cooper & Block, 2006). This would have made the evacuations unnecessary, so they risked committing a type-two policy error. As hindsight would prove, the decision to hold off on the evacuations was a significant factor in the human catastrophe that occurred in New Orleans and along other parts of the gulf coast following the storm. However, the public sector incentive structure encouraged the reactive evacuation policies because the political cost of committing type-two errors is less than the cost associated with being proactive and committing a type-one policy error (Leeson, 2007; Sobel & Leeson, 2006).

The Katrina example demonstrates the distinct differences between public and private sector resource allocation mechanisms. Much of this is attributed to the centralized decision-making processes used by the public sector, which contrast the decentralized philosophy in the private sector. Wal-Mart shifted the appropriate resources to its stores located in the gulf region, while its other store locations across the country continued to receive normal supply shipments. In fact, high demand resources located in stores not near the disaster zone were relocated to stores in the impacted region. FEMA was unable to make similar resource deployment decisions, which led to an ineffective response to the disaster. In many ways, local fire departments are organized like Wal-Mart, in that most of these agencies provide services from numerous locations spread throughout a jurisdiction. Each one of these service delivery locations is located in a somewhat demographically homogenous area, meaning service delivery can be customized to meet demand. This is no different than how Wal-Mart shifted its resources to high demand stores to ensure effective and efficient operations. The logical method to resolve this issue is for all levels of government simply to decentralize operations; however, the structure of public markets makes this somewhat unrealistic because of information and incentive problems (Leeson, 2007; Sobel & Leeson, 2006).

As public finance economists recognize, government is a necessary component for any society to prosper. However, it collects most of its revenue to operate from the private sector through coercive mechanisms, such as taxes. There are inherent inefficiencies associated with public sector services because of transaction costs, equity considerations, political influence, and asymmetric information that are not as prevalent in the private sector. Therefore, it is preferred to have the private sector provide as many services as possible, so the public treasure is used to its greatest capacity. When private funds are taken to provide public resources, decision makers struggle to utilize the dollars efficiently to deliver effective services. The government simply does not have a reliable means to determine customer willingness-to-pay for goods and services, which hampers resource allocation decisions. Therefore, citizens often receive too many or too few services based on their preferences, which is not efficient. When private sector firms overproduce it drives the market price down or creates inefficiencies that detract from profits. In these situations, it is the company or shareholders who have voluntarily invested in the private firm who are harmed. A private sector firm that continues to overproduce will eventually lose shareholders or profits to the point of being forced out of business. This is not the situation in the public sector, where agencies can over produce without fear of retribution. In many ways, when local emergency services are allocated evenly rather than based on demand, unaccounted for inefficiencies are created that disenfranchise tax payers.

2.8 Local Government and the Fire Service

A centralized model of public service delivery has proven problematic in many ways; however, economic and social conditions tend to determine whether public services are delivered with a decentralized or centralized focus (Sobel & Leeson, 2006). The military is probably the purest of the public goods and provides services to the entire country and beyond making its provision by the federal level beyond debate. Fire protection, on the other hand, is the responsibility of local level jurisdictions (Dye & MacManus, 2007). Fire protection, in general, is a decentralized service because each local community has its own needs and risk factors. The provision of these services must be customized to efficiently and effectively protect a jurisdiction. The public safety needs of one jurisdiction are often very different from those found in other jurisdictions

(Coulter, 1979). Because these services are decentralized, a great deal of variance in service delivery exists between fire protection jurisdictions.

The private sector has proven unwilling to provide public safety services, especially fire, for public consumption. As a public sector service fire departments generate positive externalities. For example, a rapid response with adequate fire suppression resources to a house fire prevents fire from spreading to other structures. These positive externalities would be difficult for a private firm to capitalize on for profit, reducing the incentive to provide sufficient services to protect a community. Government has a role to play in the private market, one of which is to limit negative externalities. These occur when persons outside of a voluntary private sector exchange are impacted negatively by the transaction, such as residents living downstream of a paper plant that dumps hazardous materials into the water. The public sector's almost exclusive provision of fire protection and other emergency services in many ways limits potential negative externalities that may result from private sector firms supplying these services.

The provision of fire protection is an optimum service to analyze in exploring the challenges democratically organized governments experience when allocating scarce resources. It is the ultimate local collective service, because the state and federal levels have ignored the fire service for the most part. Recently, federal and state grants have been made available to help fund local emergency services, but on the whole it is the local government that provides these public safety services (Schneider, 1990). Unlike crime rates, deaths and injuries associated with fire garner little political attention. The fire service is, for the most part, viewed positively by the electorate which further diminishes its relevance in the political spectrum. Fire departments garner the second largest budget item in most local governments. Police protection is the only service that consistently supersedes fire protection in the budget (Coe, 1983). Providing public safety services is a significant funding challenge for most local jurisdictions, which places greater importance on how scarce emergency assets are distributed by decision-makers.

The FEMA response to Hurricane Katrina, compared to that of Wal-Mart, illustrates the issues associated with centralized decision-making for allocating limited resources. The fire service provides an opportunity to study the potential advantages of decentralization at the local level. The federal government has taken a myriad of responsibilities away from state and local governments or is, at the very least, imposing influence over them following the September 2001 terrorism events. The ever-present threat of terrorism, two active war fronts, and a declining economy have provided a favorable environment for the federal level to take a more dominant role in the policy arena. This effort has even trickled down to the fire service, which has traditionally been a purely local level service. For example, the Homeland Security Act of 2002 mandates that local and state governments train and equip fire personnel to respond to terrorist events (Dye & MacManus, 2007). The fire service is the primary entity that will manage a natural or manmade catastrophic event, and the federal government has taken relatively few actions to impede how local officials allocate their limited emergency resources. If anything, more federal dollars have been provided for public safety through a myriad of grants since 2001 (Posner, 2006). These grants have provided needed resources to many local communities to increase fire, rescue, and emergency medical assets above and beyond what the local tax capacity permits. This has afforded some localities greater flexibility in deploying emergency resources, because federal grants have provided many areas with more assets to use when responding to emergency incidents.

The decentralized nature of the fire service should permit local public decision-makers to capture the demand for fire, rescue, and emergency medical services that are particular to each individual community. This permits service delivery to be customized to the electorate and dictated by the community characteristics associated with fire and other emergency situations. Local officials are closer to their constituents and better able to gauge preferences for public services. In addition, citizens are more involved in government at the local level. Rational voters are more active at the local level because their voices have more influence and will receive more of the benefits than at the other levels of government (Olson, 1982). Decentralization also provides intergovernmental competition as each local jurisdiction works to provide a market basket of goods and services that attract residents and businesses to their community (Rosen, 2002; Tiebout, 1956). The other benefit of localization and decentralization of services is the ability of neighboring jurisdictions to evaluate and then copy or avoid service provision methods. In many ways each community acts as a “laboratory” (Rosen, 2002; Smith et al., 2008).

2.9 Locating Emergency Resources: Risk Aversion

The fire service industry is in many ways self regulated, which leads many to describe this industry as “200 years of tradition unimpeded by progress.” Allocating local emergency resources based on risk has garnered little attention from decision-makers, who continue to subscribe to geographically driven methods to minimize average response times by emergency responders to incident locations (Swersey & Ignall, 1991). It is unclear what the most effective and efficient method to allocate or locate these resources is, while accounting for budget and social constraints within a community to reduce risk. However, evaluating community risk with deference to the level of uncertainty that surrounds emergency incidents could provide decision-makers with valid information to help drive these locational decisions to improve efficiency and effectiveness.

Locational decisions determine where emergency resources are placed within a community and can mean the difference between life and death for a citizen. Seconds can matter when responding to certain types of emergency events. For example, a fire can double in size every minute it is left unattended (Shpilberg, 1977). In addition, for every minute a victim suffering cardiac arrest does not receive Cardiopulmonary Resuscitation (CPR) and other emergency care, the chance of survival decreases by 10%. In other words, someone suffering cardiac arrest has a 0% survival rate if care does not arrive in the first 10 minutes of the medical crisis (Nichol, Steill, Laupacis, Pham, DeMaio, & Wells, 1999). Although fire protection resources are spread throughout most urban communities, it is unclear whether the dispersion methodology used to locate these resources is the most effective and efficient method to save lives and property. Unlike pure public goods, the use of fire protection is not nonrivalrous at the individual level, because once firefighters and equipment are committed to an emergency event these resources are no longer available to other citizens who may have an emergency (Weimer & Vining, 2005). Because of this, spacing fire stations and emergency resources equally throughout a community is arguably an inefficient and ineffective means to maximize public safety. All emergency requests are not the same, so allocating resources equally is problematic and does not account for true demand of these services.

Most people are risk averse when making decisions. However, government is often more risk averse than its citizens, especially when formulating policies to decrease overall societal risk. It is impossible to create a risk-free environment, but most politicians campaign on issues that would lead many to believe government can eliminate all risks, especially the risk of death. Political decision-makers have incentive to overstate risks, because it provides the opportunity to gain support for programs and initiatives that appear to reduce risk. However, risk is often determined by individual actions and characteristics, which explains why government programs directed at large heterogeneous groups tend to be ineffective (Rhoads, 1999; Tullock et. al., 2002).

Public sector programs to reduce societal risk, such as emergency services, are inherently inefficient. These programs provide a service level that inevitably falls well short of some and exceeds the preferences of others in a demographically diverse community. Efficiency is only gained by separating large heterogeneous groups into smaller more homogenous groups, which is challenging for the federal and state governments. At the local level, persons tend to self-select into homogenous groups based on where they choose to reside. Because of this, communities become fragmented into neighborhoods that provide local decision-makers the opportunity to customize programs intended to reduce societal risk (Oakerson, 1999). In particular, the emergency services are set up well to take advantage of this fragmentation, because emergency response assets are often located at the neighborhood level. The more homogenous a target population is the more effective and efficient a risk reducing program can be (Walsh, 1998). Unfortunately, public sector leaders have, in most cases, failed to take full advantage of these relatively homogenous groups that naturally form in every community to improve the efficiency and effectiveness of local programs to reduce societal risk.

This is the situation with policies to allocate fire and other emergency resources throughout individual communities. Local government decision-makers attempt to spread these limited resources to minimize response times to every part of a community. This is a conservative strategy that prevents the commission of a “type-one policy error.” The victims of this policy are difficult if not impossible to identify, which is preferred by decision makers (Leeson, 2007). This subscribes to the maximin rule, which supports allocating resources evenly across a community so that even the individuals at minimal risk have equal opportunity to benefit from the services. This is an overly cautious strategy to deploy scarce emergency assets, because risk factors are not spread evenly across communities (Friedman, 2002; Rosen, 2002). With any public policy initiative there will be winners and losers. This strategy to deploy emergency assets is representative of distributive policies at the federal level that are most closely associated with “pork barrel” spending. The hallmark of a distributive policy is that the winners know who they are and losers have no idea who they are. Persons who are “saved” or who directly benefit from emergency services know who they are; however, it is difficult for the person who is disenfranchised by this system to recognize that they are “policy losers.” This situation provides further incentive to maintain the status quo for distributing scarce emergency assets, rather than searching for a more efficient method that may improve overall social welfare.

A more utilitarian approach to formulating risk reducing programs could be more effective and efficient, especially with regard to the allocation of emergency resources.

This approach would locate limited resources with the goal of doing the most good for the most people. For example, resources could be located according to neighborhood characteristics, which more closely capture individual risk factors (Rosen, 2002; Tullock et al., 2002; Walsh, 1998). This is an approach not popular with most public leaders, because it requires a more proactive policy, opening the possibility for committing a type-one policy error. Such a location strategy would require using demographic and emergency response data to predict demand for these services. Emergency resources could then be concentrated in the highest demand areas. This situation would make the winners and losers more evident, because scarce resources would be located disproportionately throughout a community based on risk levels.

The incentive to proactively allocate these resources is not pronounced, because chance emergency events occurring in areas with reduced resources would elicit strong criticism. This strategy is prone to type-one policy errors, as victims are more identifiable (Leeson, 2007). The potential benefits of the deployment strategy will be ignored, despite the likely increase in general welfare resulting from directing resources towards those most at risk. A more utilitarian deployment strategy for emergency resources focusing on characteristics associated with risk for fire and medical emergencies would also reduce opportunity cost, or the cost forgone by providing too many risk reduction services to those without the need (Walsh, 1998).

The reality of government provided emergency services is that basing locational decisions at the individual level is impractical and costly. The population becomes less heterogeneous as you move from the national to the state and then to the local level. It is easier to allocate resources more effectively and efficiently to homogenous populations.

Most local communities are considered highly heterogeneous, especially large urban environments. However, neighborhoods within urban locales tend to be highly homogeneous because people want to live near others who are like them. For example, persons with similar incomes tend to cluster together in neighborhoods. Evaluating risk at the neighborhood level could prove to be a powerful tool to allocate fire and emergency service resources (Cohen, Gorr, & Olligschlaeger, 2007).

Most urban and suburban communities provide paid fire protection and work to meet ISO and NFPA standards, which dictate that a fire station is located every so many square miles to minimize response times. These standards ignore the risk differences found between neighborhoods, and lead to some having too many resources and others not having enough for adequate protection. A more effective deployment strategy could be developed by evaluating neighborhood risk characteristics associated with fire and other emergency events to locate these resources. In many ways, this is simple risk discounting or making decisions based on probability analysis about neighborhood characteristics prior to an emergency event occurring (Munger, 2000).

A more efficient and effective deployment strategy is possible if resources are allocated based on neighborhood level risk factors. These factors could be used to determine which areas have the greatest need and avoid the issues of service inefficiency associated with allocating finite risk reducing resources to large heterogeneous groups. Walsh (1998) provides a good example that typifies the value of evaluating risk on an individual basis explaining that, “Statistics for automobile fatalities may yield a lifetime risk of 1 per 100 persons dying in a car accident – but this doesn’t mean that a particular person’s chances of dying in a car accident is 0.01” (134). A community fire fatality or injury rate is meaningless to the allocation of fire protection resources, unless you are following the maximin rule, because one neighborhood alone could generate all of the fire fatalities experienced by the jurisdiction. Allocating fixed resources based on neighborhood risk characteristics and then allocating response criteria based on individual risk characteristics is in many ways the Pareto optimal solution, because no one would be better off if resources could be moved to certain areas without harming others. Yes, groups or neighborhoods in a jurisdiction will not have a fire resource as close as other jurisdictions using this model. However, resources would be located where they will provide the greatest net social benefit, which will result in reduced property damage and loss of life from fire and other emergency events (Cubbin et al., 2000b; Rosen, 2002).

The insurance industry uses a similar strategy to price discriminate against high risk customers to ensure an efficient level of risk spreading resources. The industry monitors insurance claims and purchasing patterns and the characteristics of individual consumers. A description of the characteristics most associated with increased and decreased insurance claims is then developed to assess risk (Walsh, 1998). The insurance industry then charges persons with the characteristics associated with higher claim rates more than those with characteristics associated with minimal claims. This rewards those who are low risk and should not be saddled with paying for those who are at increased risk. This also reduces the moral hazard effect, because those with increased risk pay more. The idea put forth in this research for allocating emergency resources follows this same philosophy, which is to allocate scarce assets based on risk to avoid deadweight losses that result when trying to evaluate collective risk for large heterogeneous groups (Tullock et al., 2002).

2.10 Statistical versus Identifiable Lives

Information to allocate emergency resources more efficiently and reduce the number of statistical lives lost is not freely exchanged in the public sector. However, individual and structural characteristics are often associated with increased risk throughout local communities. Data on these characteristics could be collected and utilized to better allocate scarce emergency resources. Knowing that neighborhoods are relatively homogeneous based on demographic and economic characteristics, it is possible to better allocate fire and medical resources to areas with a higher potential for time-sensitive emergency events. For example, medical emergencies make up the vast majority of fire service responses. Persons suffering cardiac arrest or severe trauma have the most time-sensitive medical emergencies. A study performed in Chicago found that African-Americans are at significantly higher risk of suffering premature cardiac arrest. Personal traits such as age, initial cardiac rhythm, and potential for early initiation of CPR by a bystander are associated with survival rates. The study further found that response times to all races in the Chicago area for non-traumatic cardiac arrest were comparable and overall mortality rates exceeded 97% regardless of race (Becker, Han, Meyer, Wright, Rhodes, Smith, & Barrett, 1993). This information is valuable to more effectively distribute medical resources throughout a community. Mortality rates for cardiac arrest were almost 100% to begin with in Chicago (this is not the case in most communities), so any change in deployment strategy would likely result in more lives saved. Relocating resources to neighborhoods where individuals with increased risk factors reside improves overall social welfare (Southwick & Butler, 1985, Viscusi, 1993).

Unfortunately, it is not likely that public decision-makers will recognize or utilize economic and research mechanisms to allocate limited emergency resources to improve social welfare. This would require proactive policy initiatives, which most public decision makers attempt to avoid. Locating scarce emergency resources based on predictive research or probability analysis would expose public leaders to committing type-one policy errors, which they have proven unwilling to do (Leeson, 2007). The status quo emergency service deployment strategy ignores true risk characteristics and attempts to distribute resources equally throughout communities. This is a reactive solution to protecting society, which is preferred by policy entrepreneurs. However, this ignores an important concept that Munger (2000) develops for evaluating policy decisions, which points out that “good decisions can turn out bad and bad decisions can turn out good.” Equal distribution of emergency resources renders consumption on a first come, first service basis, which may be fair but is not efficient or effective (Blackstone et al., 2005). Those disenfranchised by this system are difficult if not impossible to identify, which explains the incentive to maintain the status quo. Utilizing predictive methods to better allocate resources based on characteristics associated with increased risk would make for better decisions. However, as Leeson (2007) pointed out, the cost of a mistake is greater for public decision-makers implementing proactive policy initiatives, which decreases the likelihood such policies will be implemented.

2.11 Summary

In the end, it does not matter which level of government provides the service, there is going to be inefficiency and ineffectiveness, because government is simply not organized to gather and distribute information and then respond appropriately to that information. Public finance economists recognize the influence political actors have on budgets and resource allocation decisions. Issues of equity and fairness must be considered in the public arena. It is the responsibility of the political leaders to gauge social preferences that go beyond economically efficient allocation of resources (Rosen, 2002). Neoclassical economists are more concerned with economic efficiency and have an eye toward Pareto optimal allocation. The concept of marginalism is also critical to evaluating allocation decisions in the public sector according to the neoclassical ideal. This is a powerful concept, but in some ways ignores the political influence that is part of every public decision (Levy, 1995; Sobel & Leeson, 2006). The public sector simply does not have the information and incentive mechanisms to permit the effective decentralization of services, which is present in the private sector. Public resource allocation is based on imperfect information, an incentive structure counter-productive to efficiency, issues of equity, and the influence of interest groups, making it irrational to even conceive of an economically efficient and effective public sector (Boettke, Chamblee-Wright, Gordon, Ikeda, Leeson, & Sobel, 2007). However, recognizing all of the limitations to resource allocation provides valuable insight into improving the overall social welfare of the public.

CHAPTER 3: DATA & METHODS

3.1 Introduction

The city of Charlotte serves as the research area for this analysis. Data collected by the Charlotte Fire Department, information from a neighborhood quality of life survey, and Census data at the block group level are used to test the stated hypotheses. Demographic and structural characteristics vary across the city of Charlotte, making it similar to other local communities. Much of this variation is captured in the individual block groups that divide the city into homogenous areas. These geographical units closely reflect the neighborhood divisions throughout the city, which is optimal for assessing societal risk characteristics that influence emergency service demand (Iwashyna, Christakis, & Becker, 1999; Ostrom, 2000). The plethora of data available for this study provides an opportunity to thoroughly investigate neighborhood social and economic characteristics that are related to demand for local emergency services.

Scientifically driven research into the fire service is limited. A quick scan of the literature reveals that few academic or other research bodies have recognized the overall importance of this industry from a public policy standpoint. Much of the national data and information about this industry is limited, making it difficult for academics and stakeholders to perform systematic research into the public policy issues pertinent to the fire service (Swersey & Ignall, 1991). Exogenous organizations, such as the NFPA and ISO, compile fire department emergency response statistics, but this data is not available to the general public. For a substantial fee, the NFPA will release some fire service data and reports; however, the flow of information needed to conduct scientific research and draw conclusions that can be inferred beyond a sample is not readily available. In 1974, Congress passed the Federal Fire Prevention and Control Act to help facilitate more research and evaluation of the fire service industry (Ahrens, 2008). The legislation gives authority to the United States Fire Administration to collect fire incident data from local fire departments across the nation through the National Fire Incident Management System (NFIRS).

NFIRS is the most comprehensive national database for information about the emergency services provided by fire departments across the country. However, participation is voluntary, which has proven an impediment to the submission of accurate and complete data. Recent Homeland Security initiatives have provided federal officials new ways to incentivize participation in NFIRS. For example, fire departments can no longer apply for federal fire grants without the submission of incident data to NFIRS. Fire departments not willing to participate in NFIRS are not eligible to compete for these federal grants. These provisions have significantly increased the number of fire departments that are consistently submitting information to NFIRS. Unfortunately, a two year lag in the public release of data is standard, because NFIRS relies on each state to submit its departments' incident data. State officials must collect and sort the data before submitting it to the national database, which slows the dissemination process (Ahrens, Stewart, & Cooke, 2003).

The most recent data available through NFIRS is from 2005 and includes information on more than eight million emergency incidents. This database continues to be plagued by incomplete and inaccurate information about emergency incidents. The lack of standardization and strict guidelines for collecting data mean individual fire departments often use their own measurement criteria for variables and fail to ensure that the information submitted is accurate (Swersey & Ignall, 1991). In addition, the completeness of information relevant to conducting research into the fire service is not collected through NFIRS, such as response time measures to the nearest second. In the case of response times, this is a problem because seconds can and do matter when evaluating emergency service issues and outcomes. Currently, NFIRS rounds all time to the nearest minute, which can significantly change the outcome of an analysis. Finally, fire departments are local entities, making it challenging to collect data that is comparable from one department to the next.

Local fire departments must collect information that is relevant to their stakeholders, and this data, at times, differs from that collected by NFIRS. Despite the numerous challenges to NFIRS data, it remains the most comprehensive national data set available to the public (Ahrens, 2008). Unfortunately, the data challenges associated with NFIRS render it inadequate as a reliable comprehensive source of information for this research effort. Because of this, data for this analysis was derived from information collected by the Charlotte Fire Department for emergency incidents and neighborhood level demographic data collected through the Charlotte Neighborhood Quality of Life Study 2006 and U.S. Census at the block group level.

3.2 Description of Research Area

The city of Charlotte, North Carolina serves as the study area. Charlotte is a growing city with a population that exceeds 650,000, making it the 20th largest city in the

United States. Incorporated in 1768, favorable annexation laws in North Carolina have facilitated land area growth that now spans more than 280 square miles. The city sits within Mecklenburg County, which is located in the piedmont region of the state and borders South Carolina. It is the second largest banking center in the country behind New York City, is served by an international airport, and is home to more than 250 Fortune 1000 companies, making it a hub for domestic and international business. Other unique features include two major interstate highways, a comprehensive regional mass transit system, numerous post-secondary academic institutions, professional sports complexes for football and basketball, and two nuclear power plants located just outside the city limits to its south and north. These characteristics and others make this a dynamic environment that presents many challenges to the local public sector emergency service departments.

The Charlotte Fire Department is the primary first responder agency for the city. It provides trained personnel, equipment, and other resources required to mitigate all emergency incidents (fire, rescue, EMS, hazardous materials) occurring within the city limits. The department responds to more than 80,000 emergency events annually from 37 different fire station locations that are dispersed throughout the city. Each station is staffed twenty-four hours a day every day of the year by trained firefighters. The department maintains more than 54 front line fire units, each staffed by four firefighters, to respond to emergency events. The front line units consist of 38 engine companies, 14 ladder companies, 5 airport crash units, and 2 rescue companies. The department also maintains 3 hazardous material units, 6 brush fire units, 5 water tankers, and 2 urban search and rescue trucks to respond to specialty type incidents. When needed, these specialty units are staffed by on-duty firefighters who are assigned to front-line units. Charlotte continues to grow through annexation and economic development efforts, which places substantial demands on these emergency service resources.

Throughout the history of the department, fire stations have been strategically located across the city based on geographic requirements. This allocation strategy locates fixed facilities and units primarily based on fire apparatus response time benchmarks. In modern times, the department has used a six minute response time as its benchmark measure. Therefore, the goal is that every part of the city can be reached by a fire apparatus within six minutes of receiving a request for assistance. This is an effective strategy for deploying resources as long as all emergency units are available in their respective fire stations when a call for service is received, because under this scenario response times are predictable with a high level of accuracy. Unfortunately, most emergency service systems receive multiple calls for service at a time, meaning units are more often not located in their respective fire stations to receive calls for service compromising the response time benchmark deployment strategy (Perrin, 1998). The fire department further exacerbates this situation by not using a priority dispatch system to triage calls for service. Units frequently respond to non-urgent situations which compromises availability for emergent situations. This is a common strategy used throughout the fire service industry for deploying and responding to emergency incidents to reduce overall societal risk; however, it ignores the fact that groups or neighborhoods within a community have different levels of risks and need for these services (Hammitt & Treich, 2007).

The emergency service environment in Charlotte is dynamic with structural and social characteristics varying throughout this community. Like most fire departments across the country, the Charlotte Fire Department responds to a wide variety of emergency incident situations that require many different specializations. Because emergency response and incident data is abundant and diverse, there is a great deal of opportunity for mistakes when collecting such information. This has proven particularly problematic with NFIRS and other national emergency service databases. Utilizing response and incident data from Charlotte makes for more valid findings, since there is more opportunity to research and correct data errors. This would not be the case if using data from NFIRS, because it would be impossible to contact each fire department associated with a discrepancy or missing value. Instead, the Charlotte data can be checked for accuracy and any problems found can be resolved by contacting the source of the information.

Fire service response data collected by the Charlotte Fire Department and data from a neighborhood quality of life study and the Census will be used to test the hypotheses, listed in chapter 4, to develop an alternate model for locating emergency resources. The goal of the new model is to account for the myriad of emergency services provided by urban and suburban fire departments and their impact on service delivery. To date, the Charlotte Fire Department allocates its emergency resources in a way that focuses on the individual, meaning it attempts to provide equal service delivery outputs to every person residing within the city. This method fails to separate individual from societal risks, which leads to service inefficiency and ineffectiveness (Cubbin et al., 2000b). The situation is exacerbated by the increasing demand on limited emergency service resources in Charlotte and other communities across the country. This means fewer resources are available to respond to more urgent requests for assistance, because units are more frequently committed to non-emergent incidents. Finding an alternate method to deploy these resources to maintain or reduce current societal risk levels based on the available limited emergency resources is necessary to manage demand (Barr & Caputo, 2003). Identifying factors that correlate with increased or decreased demand for emergency services provides an opportunity to more effectively guide where to locate these resources to better address demand.

3.3 Charlotte Neighborhood/Block Group Data Sources

In 1997, the Charlotte City Council commissioned a neighborhood study to measure quality of life, at which time seventy-three inner city neighborhood areas were identified. These areas were aligned with U.S. Census block groups to the extent possible. The study area was expanded in 2000 to include an additional 100 neighborhood statistical areas (NSA) that encompassed all of the incorporated areas and the city's sphere of influence areas. In 2002, 2004, and 2006, a more consistent methodology was implemented to perform the Neighborhood Quality of Life Studies to facilitate better comparisons between neighborhoods. These studies were completed by the Metropolitan Studies Group at the University of North Carolina at Charlotte.

The 2006 Neighborhood Quality of Life Study and Census block group information provides data on more than twenty demographic variables about the city. The variables measure population demographics, crime statistics, economic conditions, and structural appearance of the neighborhoods to assess quality of life. Many of these neighborhood characteristics have been linked to demand for emergency services in previous studies and government reports. However, reports and other research into the subject do not attempt to combine these characteristics with fire response data or to evaluate the impact on the entire service delivery platform that is provided by most urban departments.

A potential issue to overcome with the Neighborhood Quality of Life Study for this analysis is the focus on permanent residents. Data is sparse for areas of the city with few residents, such as the business district uptown. The uptown area is predominately high-rise office buildings and other non-residential structures; however, emergency service demand is high in this jurisdiction because of daily population density increases, the vagrant population, and other unique factors. Fortunately, the business district is small in land area. Two fire stations are located uptown, each with an engine and ladder company assigned, that have the business district within their primary response jurisdiction. Each of these two stations also have residential areas included in their primary response jurisdictions, which are included in the neighborhood study. The Charlotte Neighborhood Quality of Life Study does not include information about the business district, because in 2006 there were few if any residential structures in this finite area of the city. This situation does create a potential for bias because fire units do respond to a significant number of incidents in these areas. Without demographic data it is not possible to confidently assess relationships that might be associated with these responses. It is likely the sample will contain so few responses into the business district that any bias will be limited. However, to further limit the effect of the neighborhood deficiencies, individual census block groups were substituted for the NSA's. Instead of 173 NSA areas, the block groups effectively divide the city into 331 areas, providing for more precision and fewer information gaps. Because the NSA divisions were derived from the census block groups, the demographic information is similar and provides additional variables to include in the analysis.

Eleven variables from the Census Block Group data for the Charlotte area are used for this analysis to inform a new fire service resource allocation model. These variables were selected because of their hypothesized association to emergency service demand based on theory, experience, and previous literature (Gamache, 2003; Cubbin, LeClere, & Smith, 2000a). The following variables were selected: POPULATION, HOUSE UNITS, HOUSE INCOME, CODE, APPEARANCE, HOMEOWNER, FOOD STAMP, YOUTH, AGED, HS GRAD, and BUILD AGE. Below each variable is defined and the method for measuring each is explained.

POPULATION is often associated with demand for emergency services. Typically, population is positively associated with the number of emergency incidents, so block group areas with more people are expected to have more demand for emergency services than block groups with fewer people. The variable is defined as the total number of persons residing in a block group and is measured at the ratio level.

HOUSE UNITS is associated with the level of fire risk in each block group area. Roughly 80% of civilian deaths and injuries nationally result from fires occurring in residential structures each year. In 2006 direct dollar losses from residential fires approached $7 billion. More than 2,600 people died and 13,000 injuries resulted from these residential fires (U.S. Fire Academy, 2006). The volume of residential structures is likely associated with the chance of fire within a block group, which impacts demand for emergency services. The variable is defined as the number of residential structures located in each block group and is measured at the ratio level.

HOUSE INCOME is a measure of wealth. Poverty is associated with increased risk for fire according to national data trends (Gamache, 2003). The variable is defined as the median household income in dollars for each block group and is a ratio level measure.

CODE violations are expected to be associated with increased demand for emergency services, because dilapidated buildings are more prone to fire. Code inspectors circulate daily throughout the city surveying residential and commercial structures. These inspectors also respond to complaints and inspection requests. Structures not deemed structurally stable, with broken windows or other hazards, can be cited for code violations. Inspectors have the authority to condemn and demolish structures that are in extreme disrepair or pose a substantiated danger to the public. This variable also represents the economic conditions found in each block group. The variable is defined as the percent of residential units within a block group that have been cited for building code violations.

APPEARANCE violations represent how well the structures in each block group are maintained. Poorly maintained structures are more susceptible to fire. Block group areas with more appearance violations are likely to be associated with increased demand for emergency services. The variable is an indexed interval number describing the condition of properties found in each block group. This variable represents the percentage of appearance code violations for each block group. Higher scores are awarded to block groups with structures in better condition and lower scores represent block groups with residential areas in a more dilapidated physical condition. Appearance violations can include high grass, vehicles parked on lawns, and obvious structural issues.

HOMEOWNER is likely correlated with demand for emergency services, and also serves as a measure of economic status for the block group. The variable is defined as the percent of owner-occupied residences in each block group measured at the ratio level. This is a measure of an area's structural condition because owner-occupied dwellings tend to be in less disrepair than renter-occupied structures.

FOOD STAMP is a measure of economic status. As reported in the *Topical Fire Report Series 2008,* the poor are at greater risk of being impacted by fire than other economic groups. The variable is defined as the percentage of persons residing in a block group who are receiving food stamps. This is a ratio level measure associated with poverty.

YOUTH are almost twice as likely as the average person to sustain an injury or die from fire. The variable is defined as the percentage of persons 18 years and younger residing in each block group and is an interval level measure.

AGED is associated with increased risk for fire and medical emergencies, which influences demand. The variable is defined as the percentage of persons 65 and older residing in each block group and is an interval level measure. The measure indicates only a higher or lower percentage across neighborhoods.

HS GRAD is a measure of the percentage of persons 25 years and older residing in each block group that have either graduated high school or earned a graduate equivalent degree (GED).

BUILD AGE is a measure of the average age of the structures located within each block group. This variable is included because older structures are more prone to fire. Building codes have improved progressively with time, so older structures tend to have fewer fire protection systems such as sprinklers and monitored alarms. In addition, there is more opportunity to be in disrepair as the building ages. Although older buildings tend to have fewer fire protection systems, newer construction also has many problems that create fire hazards. For example, laminated wood beams and truss systems commonly used today in all types of construction permit rapid fire spread and collapse, which limits the opportunity to extinguish fires in these buildings.

Below is a table (Table 1) providing summary statistics for each of the eleven variables for the randomly selected sample of block groups and for the entire population of block groups for comparison.

Table 1: Independent Variable Univariate Statistics

Explanatory Variable Summary Statistics	Sample (n=118)		Population (n=331)	
Variable	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**
POPULATION	2506.95	2261.97	2260.67	1898.07
HOUSE UNITS	1073.09	909.15	971.92	785.65
HOUSE INCOME	52877.47	27500.58	56478.59	35367.96
CODE	0.0962	0.02	0.0114	0.0442
APPEARANCE	0.2	0.1972	0.1849	0.1842
HOMEOWNER	0.527	0.2492	0.5528	0.2466
FOOD STAMP	0.1099	0.1111	0.1086	0.109
YOUTH	0.2478	0.0704	0.2512	0.07
AGED	0.0963	0.0509	0.1031	0.594
HS GRAD	0.8188	0.1495	0.8228	0.1501
BUILD AGE	34.39	15.74	34.32	15.28

Charlotte is a diverse and dynamic city, ensuring variability across the 331 block group areas. The clearly defined boundaries of each area permit comparison with data acquired from the Charlotte Fire Department to facilitate this research effort. The eleven block group level independent variables were chosen based on their hypothesized relationship to emergency service demand. These relationships were derived from previous research, such as that performed by FEMA (2008, February) for its *Topical Fire Report Series*, which describes fire risk characteristics from 2004. FEMA used NFIRS data to compile demographic factors associated with increased risk for fire to produce this report. Many of the variables, such as AGED, YOUTH, MEDIAN INCOME, and FOOD STAMPS, were included for this analysis to test the stated hypotheses listed in Chapter 4.

3.4 Charlotte Fire Data

Emergency incident and response information collected during fiscal year 2006 by the Charlotte Fire Department is the other data source for this analysis. Charlotte Fire is the key city business unit charged with responding to and mitigating all fire, medical, hazardous materials, and rescue emergencies that occur within the city limits. Local tax dollars are the primary funding source for the department, which has an annual operating budget that exceeds $80 million. The department also receives money from the federal government through Homeland Security grants. These grants help to fund specialty units and services, such as a regional hazardous materials team and urban search and rescue units. Incident data from FY2006 matches the time period when data for the Neighborhood Quality of Life Study and census block group information was collected, which is important to ensure valid findings. The data set developed for this analysis contains information on 84,023 emergency incidents that occurred within the city limits between July 1, 2005 and June 30, 2006. The Charlotte Fire Department maintains information on each emergency incident to which it responds. This data includes the nature of the emergency, date and time, unit(s) that responded, time unit(s) were dispatched, time each unit responded, time each unit arrived at the incident, time each unit completed the assignment, location of the incident, and where units responded from to each incident. This information is stored by the department for legal and documentation purposes. The dependent variables to test the hypotheses are derived from this data set.

During FY2006 the department responded from 37 fire stations located throughout the city with 54 front-line fire apparatus. Front-line apparatus include engine, ladder, and rescue companies. These companies are staffed by firefighters twenty-four hours a day. Engine 37 began operation during this fiscal year, responding from a temporary station located in close proximity to the permanent site for the new station, which is located in the southern part of the city. Each of the 37 fire stations has at least one engine company and 17 of the stations also have a ladder company, rescue company, or airport crash unit assigned. In addition, the department operates two urban search and rescue trucks out of Station 11, two hazardous materials units out of Station 13, a regional hazardous materials unit out of Station 32, five brush trucks, and five tankers for specialty type emergency incidents.[1] For this analysis, front line units are the only units included, since they are the ones staffed full-time by firefighters and have the capability

[1] Description of specialty type apparatus: See Appendix A.

to initiate action to mitigate emergency incidents. These units are engine companies, ladder companies, and rescue companies.

- *Engine Company*: Apparatus that carries thousands of feet of hose, a pump, and water to extinguish fires. Each Charlotte engine company has a minimum 1500 gallon per minute (gpm) pump with the three companies assigned to the high-rise district having 2000 gpm capacity. These trucks carry a minimum of 500 gallons of water with companies assigned to out-lying stations having 750 gallon water tanks. A myriad of hose sizes are also carried that include 1 ¾ inch diameter attack lines with 180 gpm capacity, 2 ½ inch diameter attack lines capable of 300 gpm, and 5 inch supply lines used to connect the truck's pump to the fire hydrant for water. All engine companies in the city are staffed with four firefighters except Engine #9 which is staffed by five firefighters.
- *Ladder Company*: Apparatus that carries hose, a pump, water, a full complement of ground ladders, vehicle extrication equipment, and an aerial ladder. The fourteen ladder companies in Charlotte all carry 370 gallons of water, a 2000 gpm pump, a small complement of hose, three hydraulic powered vehicle extrication tools, multiple ground ladders of lengths 16', 28', & 40', and a 105' aerial ladder. Four firefighters staff these trucks, which are used for fire suppression and technical rescue.
- *Rescue Company*: Apparatus that carries technical rescue equipment for vehicle extrication, high angle, confined space, structural collapse, trench collapse, water emergencies, and dive rescue. The two rescue companies in Charlotte are each staffed with five firefighters.

The 37 stations are separated into seven battalions, which are administrative designations. A battalion chief is assigned to each battalion and supervises four to six fire stations. The Charlotte Fire Department operations section consists of more than 1,000 uniformed firefighters who are assigned to one of three shifts. Each shift works 24 hours at a time.

The number and type of fire apparatus that respond to an incident is determined by the nature of the emergency. Medical emergencies account for roughly 61% of the fire department's emergency responses. Each front line apparatus is staffed by firefighters certified as emergency medical technicians (EMT) who can provide basic life support medical care. This level of care includes the ability to defibrillate patients in cardiac arrest, administer oxygen, manually ventilate patients, bandage wounds, splint fractures, and provide cardiopulmonary resuscitation (CPR). A single fire apparatus (engine, ladder, or rescue) responds to all medical emergencies within the city. The fire department does not provide medical transport services. Patient transport is provided by a third service agency, Mecklenburg EMS Agency (MEDIC), within the city. MEDIC operates the ambulance service and provides advanced life support medical care. Each ambulance is staffed by at least one person certified at the paramedic level who can perform all basic and advanced life support procedures. Paramedics are capable of starting intravenous fluids, administering cardiac medications, performing electrocardiograms, and intubation. The fire department provides first response service to medical emergencies because there are significantly more fire apparatus than ambulances within the city and are usually in a position to reach incidents faster than the MEDIC units. Response statistics for the fire department to medical emergencies are included in the data set but do not include information about emergency medical services provided by MEDIC.

In addition to medical incidents, only a single fire resource responds to vehicle fires, residential fire alarms, motor vehicle accidents without entrapment, and other service calls that can be managed by one company. The department dispatches multiple fire resources to fire, rescue, and hazardous material incidents. A myriad of response criteria are used by the fire department to match the risk potential of each type of incident with a complement of resources. A low risk incident is one that is unlikely to expand and can be handled by one or two fire companies. As the risk level increases, so do the number of resources assigned. For example, a report of a residential structure fire will trigger a response of three engine companies, a ladder company, and a battalion chief. If the first unit on scene confirms that the residential structure is on fire, an additional engine company and a rescue company are also dispatched to the incident. The type of structure and number of persons that may be impacted by an emergency incident also figure into the risk level assessment. Structures deemed high risk by the department include schools, businesses, industrial sites, and high-rise buildings. The initial response to high risk structures is four engine companies, two ladder companies, one rescue company, and two battalion chiefs. Additional resources can always be dispatched to an incident at the discretion of the fire officers on the scene. The Charlotte Fire response data include the number of responding resources to each incident, which impacts allocation decisions. This dataset includes 84,023 incidents, which accounts for 131,907 unit responses. More than one unit responded to almost 20% of the incidents during FY2006, explaining the disparity between the number of incidents and the number of unit responses.

The response data variables will be linked to the block group explanatory demographic variables for the analysis. The variables include DEMAND, DEMANDFIRE, DEMANDEMS, DEMANDRESCUE, DEMANDHAZMAT, DEMANDALARMS, DEMANDCANCEL, DEMANDMISC, DEMANDSTRUCTURE,

DEMANDOTHER, DEMANDNMV, DEMANDMV, TOTALTIME, and ONSCENETIME. These dependent variables are described and defined below.

DEMAND is a ratio level measurement calculated for each block group to norm the variable. For the sample population of block groups (N=118), the mean number of incidents per block group was 488. The range of incidents per block group included a minimum of 7 and a maximum of 2819. The measure for demand was normed by calculating the total number of emergency incidents in each block group per 100 residents [DEMAND = # incidents/(population/100)].

The variable for DEMAND is generated by a myriad of incident types, and each one has the potential to be associated with different demographic characteristics. Therefore, in addition to evaluating the relationship to overall demand, it is also important to separate the different types of incidents. Incident type can be broken down into four or five broad categories (fire, medical, rescue, hazmat, other); however, I have chosen to separate demand into seven categories and then further divide fire and medical incidents into subcategories to capture more precision for the analysis. Each of the incident categories are measured at the ratio level and have been normed based on the population found in each block group. Just as the DEMAND variable was normed, each of the incident type variables is calculated to represent the number of incidents per 100 persons in the population. In particular, it is important to separate out the types of incidents because some are more emergent than others. For example, a small fire will become a big fire if left unchecked. Unfortunately, the available data does not provide enough information to measure severity for all incident types, which is why the ONSCENETIME and TOTALTIME variables are included.

DEMANDFIRE represents the number of incidents occurring in each block group that involved an actual fire. This variable does not represent the severity of the fire, only that there was an active fire. Therefore, it includes vehicle fires, structure fires, grass fires, rubbish fires, aircraft fires, and any other incident type where the presence of a fire was recorded in each block group. DEMANDFIRE was then broken down into two subcategories to separate fires involving structures and other types of fires. Specifically, DEMANDSTRUCTURE represents all fires that involved a structure, which is important not only for potential monetary losses but also potential threat to life. Structures include high rises, office buildings, school buildings, residential buildings, storage facilities, mobile homes, and outbuildings. Again, this variable does not represent incident severity, only the potential for a severe incident. DEMANDOTHER simply measures all other fires that do not involve a structure, which includes motor vehicle fires, brush fires, forest fire, and rubbish fires.

DEMANDEMS represents the number of emergency medical incidents occurring in each block group. Emergency medical incidents account for well over half of the calls for service. These incidents include all medical emergencies, trauma emergencies, motor vehicle accidents, and other incidents that required the fire department to provide medical care to a complainant. DEMANDEMS was then separated into two subcategories. Fire departments, including the Charlotte Fire Department, respond to many different types of medical incidents, which vary greatly in severity. The purpose for separating medical incidents into those not involving a motor vehicle (DEMANDNMV) and those involving a motor vehicle (DEMANDMV) was to better isolate and evaluate the affect of demographic variables on demand. In general, the majority of emergency medical incidents involving a motor vehicle occur on roadways, highways, and interstates. Although these transportation corridors pass through block groups, it is likely the relationship between motor vehicle accidents and the demographic characteristics are spurious. Medical emergencies not involving a motor vehicle are more likely to occur in or around where people reside or work, which is better represented by the block group demographic measures. Therefore, DEMANDEMS is separated into two additional variables: DEMANDNMV and DEMANDMV.

DEMANDRESCUE represents the number of incidents where a person was trapped or pinned by an object requiring the fire department to remove them from the situation. These incidents include motor vehicle accidents where a victim is entrapped by the wreckage, industrial accidents, trench incidents, and any other situation where fire service personnel had to extricate a victim using specialized equipment and knowledge. Overall, rescue situations were the least likely type of incident.

DEMANDHAZMAT measures the number of incidents where a hazardous material is involved. The most common of these incidents are cut natural gas lines, which leads to an active gas leak posing a fire and chemical hazard. In addition, any leak or spill of a chemical or other hazard (gasoline, diesel, milk, oil, etc.) requiring the fire department to mitigate the incident is included in this measure.

DEMANDALARMS measures the number of fire alarms occurring in each block group. This measure does not include an alarm that ends up being an actual fire event, which is relatively uncommon. Alarm activations that prove to be non-events are a problem all fire departments must manage. This measure essentially measures the number of responses to non-events based on alarm activations for fire or carbon monoxide situations. The ability to limit or eliminate responses to these non-events could significantly free up resources for more emergent events.

DEMANDCANCEL measures the number of times a unit(s) is dispatched to an emergency event and either cancelled prior to arrival or is unable to find the incident. Units are cancelled for a variety of reasons, some of which include a resident providing the correct pass code to turn off a fire alarm or a medical patient changing his mind about needing assistance. This measure also includes false calls for service. Often times, persons driving down the road will use their cell phones to report an incident, such as smoke in the area which turns out to be from a chimney and not a fire event. These types of incidents are costly for the fire department.

DEMANDMISC is the final demand category and includes all incident types that cannot be categorized with the other demand variables. These incidents include animal rescues (yes, getting cats out of trees), illegal burning, overcrowding, keys locked in a vehicle or house, standbys, and citizen complaints. Miscellaneous incidents tend to be non-emergent events, but generate demand for the fire department and therefore impact resource allocation.

In addition to the measures of emergency service demand, the time units spent on scene and managing incidents was also calculated from the response data. Specifically, two measures were calculated based on response time information. The first, TOTALTIME represents the time from when a unit is dispatched to the time the unit becomes available after each emergency incident [TOTALTIME = Available – Dispatch]. This is an important measure because each time a unit is dispatched it is unavailable to respond to an additional incident. Therefore, this measure not only captures response and on scene time, it also captures those incidents when units are cancelled after dispatch. TOTALTIME used in the analysis represents the total time units spent on incidents in each block group divided by the number of incidents to find an average.

The second time measure, ONSCENETIME, represents the amount of time units spent on scene mitigating incidents. This is measured from the time a unit arrives on scene to the time when the unit becomes available again. This measure is hypothesized to be representative of incident severity. As with total time, ONSCENETIME was calculated for each incident occurring in a block group and then divided by the total number of incidents to find an average [ONSCENETIME = Available – Arrival]. All incidents where a unit did not arrive on scene, such as when cancelled after dispatch, were coded as missing, to avoid skewing the data.

Univariate summary statistics for each of the fourteen dependent variables calculated from the Charlotte Fire Department response data are listed below in the table (Table 2). The mean and standard deviation values were calculated for the population of block groups and the randomly selected sample of block groups for each variable, which provides an opportunity to evaluate the validity of the sample.

Table 2: Dependent Variable Univariate Statistics

Dependent Variable Summary Statistics *(per 100 population)*				
	Sample (n=118)		Population (n=331)	
Variable	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**
DEMAND	17.05	30.67	15.81	22.09
DEMANDFIRE	0.7968	0.9381	0.814	0.7933
DEMANDSTRUCTURE	0.4008	0.4374	0.4077	0.3778
DEMANDOTHER	0.3958	0.5267	0.4062	0.4717
DEMANDEMS	10.89	20	9.906	14.33

Table 2: Continued

Dependent Variable Summary Statistics *(per 100 population)*				
	Sample (n=118)		Population (n=331)	
Variable	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**
DEMANDNMV	9.897	18.48	8.86	13.05
DEMANDMV	0.9415	0.5267	1.009	1.787
DEMANDRESCUE	0.0767	0.3889	0.0544	0.2541
DEMANDHAZMAT	0.4404	1.79	0.3525	1.11
DEMANDALARMS	1.858	5.508	1.72	3.686
DEMANDCANCEL	1.561	3.107	1.493	2.471
DEMANDMISC	1.429	1.542	1.47	1.531
TOTALTIME	0:15:41	0:02:12	0:15:44	0:02:27
ONSCENETIME	0:04:58	0:01:08	0:05:01	0:01:11

3.5 Combining the Data: GIS Layers

The 37 fire stations are strategically placed to minimize response times to each part of the city. However, the individual fire unit responding to each incident is the unit of analysis, not the station. This provides more variation and more accurately describes the impact of locational decisions. Again, seventeen of the fire stations house two front-line fire units, meaning the neighborhoods protected by these seventeen stations have more resources assigned. The block group data and the Charlotte Fire response data are linked using a geographical information system (GIS) program for each emergency incident.

ARCVIEW is the GIS program utilized to associate the block group and response data. The geocodes for each incident were pasted into a mapping program of the City of Charlotte containing the geolocations and borders of the 331 block group areas. Geocodes are simply X and Y map coordinates, which permit each emergency incident to be associated with the specific block group in which it occurred. Numerous GIS layers are used to associate the data sets. These include:

- *Layer 1*: City of Charlotte boundary with road system and neighborhood boundaries.
- *Layer 2*: Neighborhood demographic variables, such as population, race, appearance, economics, etc.
- *Layer 3*: Fire response district boundaries for each apparatus and station/apparatus location. Seventeen of these districts will have multiple emergency resources assigned.
- *Layer 4*: The FY2006 dataset includes the geocodes for each incident. Therefore, the sample of incidents can be located on the GIS map to associate it with a neighborhood and response area.

GIS provides a means to describe station locations and boundaries visually; however, the main purpose is to find relationships between the block group variables and the response variables. Each incident (n=84,023) is linked to the block group (n=331) where it occurred. Demographic and response information are then linked to create the actual data set for the analysis.

The combined emergency response and block group data were converted into an Excel spreadsheet document to calculate TOTALTIME and ONSCENETIME variables. This information was then pasted into the Statistical Package for the Social Sciences (SPSS). The SPSS program permits more detailed statistical analysis of the data. Specifically, multiple regression, correlations, and probability analysis were performed to find relationships between variables important to formulating an allocation strategy to improve service delivery.

3.6 Data Sampling Strategy

Each of the dependent and independent variables used in this analysis are measured at the block group level. The demographic independent variables were clearly calculated for each of the block groups in the city of Charlotte. The dependent variables were calculated from the response data which included 84,023 cases using GIS, EXCEL, and SPSS to generate block group level measures. A random sample strategy was then used to select 33% of the cases from the population of block groups (N=331). Each case represents a block group within the city limits where the fire department responded to incidents during fiscal year 2006. Numerous factors influence demand for emergency services, such as the season, day of the week, and hour of the day. The U.S. Fire Administration report, *The Seasonal Nature of Fires* (2005, January) indicates a relationship between time of year and fire rates. In particular, more structure fires are reported during the winter months, while an increase in other types of fires tends to occur during the spring and summer months. In addition, the report indicates a measurable increase in fire incidents during holidays, such as Christmas, Fourth of July, Thanksgiving, and Halloween. Another emergency service analysis conducted by the U.S. Fire Administration, *Fire Department Overall Run Profile* (2007, December) supports the seasonal effects on fire rates, while also showing no clear relationship between medical emergency incident rates and seasonal changes. The data does indicate a relationship between time of day and emergency service demand. National statistics demonstrate that the number of emergency incidents increases beginning around 0500 in the morning through 1800 in the evening before a slow decline begins for the remainder of the night time hours.

The size of the sample was selected to account for the variability between cases, while also attempting to maximize accuracy. Variability between cases for many of the variables is relatively high, because block groups represent fairly small areas that are relatively homogenous across a large geographical area. The City of Charlotte Fire Department responds to 300 or more emergency situations each day across the 331 block group areas. Clearly, some areas experience much higher demand than others. It is expected that selecting 33% of the block groups will provide a representative sample to model demand and demographic variables. The SPSS program was used to generate the random sample. The program randomly selected the 118 cases from the overall data set (n=331). This sample will permit a high level of precision, which is important when making decisions about the allocation of limited emergency resources.

3.7 Summary

The data described above will be used to test the hypotheses listed in Chapter 4. The block group level demographic data is optimal for this analysis because of the homogenous characteristics of those residing in these areas (Ostrom, 2000). This will result in a high level of certainty to when predicting emergency service demand and other response variables for each area to guide resource allocation decisions. Although each emergency incident is different, urban fire departments across the country are confronted with the same locational issues as those present in Charlotte. How do you find the optimal locations for limited emergency resources to maximize outcomes, which are measured by lives and property saved? This chapter outlined the data sources, described the variables, defined the measures, and explained the sampling strategy that will be used to complete this analysis.

CHAPTER 4: HYPOTHESES

4.1 Research Focus

The tax base capacity of most local governments is insufficient to fund the emergency resources necessary to manage increasing demand, while also meeting arbitrary service delivery benchmarks. National fire department incident statistics demonstrate this increasing demand, which show a 5.2% rise in call volume in 2006 compared to 2005. The number of medical emergencies responded to rose 4.8% while departments responded to 2.5% more fire events. On average, one of the 30,635 fire departments in the United States responded to a fire emergency every nineteen seconds during 2006. The direct dollar loss from fire exceeded $11 billion, which was the largest dollar loss measured during the previous ten years with the exception of 2003. Managing limited emergency resources in the presence of increasing demand challenges local decision-makers to find new ways to do more with less. Communities often struggle to balance the number of emergency resources necessary to maintain an acceptable level of community safety with public preferences for the myriad of other services desired at the local level (Donahue, 2004a; Kuehnert, 1999).

Providing emergency services is resource intensive, but so are most other local public sector services. The opportunity cost of providing emergency services can be high, especially when balancing the delivery of other important services. This situation is compounded by the persistent rising cost of energy and other cost factors. For example, fire apparatus are powered by diesel engines that get only six miles to the gallon. These mileage calculations decrease under emergency driving conditions, because vehicles are accelerated and decelerated rapidly. The City of Baltimore, for example, recently adjusted its emergency response policies to reduce fuel consumption. The city now triages incidents based on severity to determine how many units should be dispatched in an effort to reduce the number of emergency responses (Anderson, 2008). Local decision makers must adjust emergency resource deployment strategies because of limited available funding capacity to add or support their existing emergency services. This research effort will focus on developing an alternative model for fire service resource deployment and response to emergency events to improve efficiency.

The model is based on probability and risk analysis within the urban environment to evaluate fire service delivery needs. Geographic, structural, and socioeconomic community variables associated with changes in emergency service demand (fire suppression, rescue, hazardous materials, and emergency medical situations) guide the model algorithm. The allocation model currently used by most communities relies on response time benchmarks as the predominant criteria for locating emergency resources within a defined geographical area. The National Fire Protection Association (NFPA) standard 1710 provides an objective for paid fire protection services to place a fire apparatus and personnel on an emergency incident within four minutes of receiving a request for assistance 90 percent of the time. Allocating emergency resources based on the NFPA’s response time criteria or a different response time criteria requires limited resources to be dispersed equally throughout a community (Ammons, 2001).

A problem with this model is that it discounts the influence of community risk factors on emergency service demand. Different areas within a jurisdiction experience varying degrees of risk for fire or other emergency events based on geographic, social, and structural characteristics (Gyimah-Brempong, 1989; Hallstrom, Boutin, Cobb, & Johnson, 1993). Because of this, emergency incidents are not distributed evenly across geographic areas, which is problematic when using response time benchmarks to allocate emergency resources (Hammitt & Treich, 2007; Ostrom, Parks, & Whitaker, 1973). An alternative model must include factors associated with demand for emergency services to guide resource allocation decisions to improve service delivery metrics.

Population density statistics are frequently used by emergency service decision makers to justify the need for additional resources. Previous research has identified correlations between population density and demand for emergency services, but population density alone is only one factor associated with call volume. This statistic provides minimal information to guide public decision-makers in allocating emergency resources efficiently and effectively (Felder & Brinkmann, 2002). For instance, an inner-city neighborhood revitalization effort may spawn new high-density residential living opportunities. These new residential structures are likely to displace lower income persons who were living in older, dilapidated structures. Middle and upper income persons will occupy the new apartment and condominium buildings, which increase population density. What impact does such a situation have on the emergency services?

Based on population density measures, the emergency resources allocated to the inner-city neighborhoods would be maintained or increased. However, a decrease in demand for emergency services is likely to occur in this situation for a number of reasons. First, fire codes continue to evolve for new construction, requiring more fire stops, sprinkler systems, automated alarm notification devices, and the use of non-combustible construction materials. New buildings are less susceptible to significant fire events, because even when a fire occurs it is usually contained in the area of origin and the emergency services respond prior to the fire intensifying. Second, the upper and middle class occupants are demographically at lower risk for fire and are more likely to have healthcare options, which reduce their dependence on emergency resources for non-emergent illnesses. Instead, an increase in emergency service demand can be expected where the individuals displaced from the inner-city relocated even if they moved to an area with lower population density. Lower income persons tend to be less educated and live in older structures that often do not meet fire codes. This places them at greater risk for fire makes them and more prone to request medical services for non-emergent illnesses (Cubbin et al., 2000a). This example shows that risk level or the probability of needing the local emergency services is dependent on individual habits, which population density statistics do not capture (Walsh, 1998).

The challenge associated with any emergency resource allocation model is distributing scarce resources to their highest net present value. Communities invest large sums of public funds to provide emergency services to protect life and property. True emergency events are time sensitive, so any time a resource is unavailable or out of position to respond to an incident there is a reduction in service delivery effectiveness and efficiency. For example, if a fire apparatus and personnel are responding to an incident where mitigation is not time sensitive, the resource is not available to manage a life threatening emergency that may occur simultaneously elsewhere. A similar situation occurs when too many resources are located in low demand areas or too few are located in high demand areas. The large percentage of emergency responses to false alarms and incidents not involving a threat to life or property is a significant challenge emergency service decision makers must solve (Blackstone et al., 2005). When emergency service agencies respond with equal speed and urgency to non-emergency events as they do to emergency events, an undue burden is placed on limited resources. This also requires significant built in capacity to ensure emergency resources will be available for emergency events that do threaten life and/or property (Peters & Hall, 1999).

An alternative emergency resource allocation model based on characteristics associated with demand and incident severity could have far reaching implications for local emergency service delivery and public finance. The goal of a new model is to provide a template for policymakers to allocate emergency resources more efficiently and effectively based on the community characteristics that drive demand and are associated with time-sensitive emergency events. Predicting the future is rife with uncertainty, but based on the "law of large numbers" it is reasonable to expect that a model can be devised to estimate the probability of routine emergency events with a high level of certainty. This will provide better information to guide resource allocation decisions across the tens of thousands of local jurisdictions that provide fire and emergency medical services (Pindyck & Rubinfield, 2001; Walsh, 1998). A deployment strategy that is one size fits all is not realistic if a community expects effective and efficient emergency services, especially when considering the different economic and social constraints found in every community. Allocating resources based on an alternative model that accounts for individual community risk characteristics and probability assessment for emergency events will provide a mechanism to deliver these services more effectively and efficiently, which will reduce opportunity costs.

4.2 Response Time Benchmarks

The goal of any emergency resource deployment strategy is to reduce the loss of life and property associated with fire, hazardous materials, rescue, and medical events that afflict citizens. This requires emergency resources to be available and positioned to arrive in time to mitigate an incident and limit loss of life and/or property. Response time is the critical measure used throughout the emergency services industry to evaluate service delivery. The commonly accepted definition of a response time is the time from when a request for assistance is received by emergency dispatchers to the time when the first resource arrives at the incident address. Arbitrary response time benchmarks were developed by NFPA based on time-sensitive events, such as average time to flashover and maximum time following cardiac arrest for successful resuscitation (Kuehnert, 1999). “Flashover is the stage of a fire at which all surfaces and objects in a room or area are heated to their ignition temperature and flames develop on all contents and combustible surfaces at once” (Brannigan & Corbett, 2008, 82). NFPA 1710 recommends response times that do not exceed four minutes to 90% of incidents for fire departments staffed by paid personnel (Barr & Caputo, 2003). Most urban and suburban communities, to the extent possible, locate emergency resources to minimize response times to all areas within a jurisdiction. Exogenous factors and hesitancy on the part of public decision makers to use response data to predict future demand makes this deployment strategy resource intensive if response time benchmarks are going to be met. Deploying emergency resources in this manner decreases the efficiency and effectiveness of service delivery (Cubbin et al., 2000b).

Many emergency response issues are created when decision makers attempt to locate resources based on response time benchmarks. Demand is not evenly spread across a jurisdiction, so locating emergency resources to meet a response time criteria to all areas of a jurisdiction is problematic. This is especially true when multiple emergency requests are received simultaneously in the same response area (Peters & Hall, 1999). In this situation, the emergency resource assigned to an incident is no longer available to respond to other emergencies within its area, which can leave large coverage gaps until the assigned unit has completed the response. No matter the size, all local jurisdictions will experience this situation, which occurs more frequently in urban communities where call volume is higher. This strategy also does not spread workload evenly among the emergency resources. Equipment and personnel in low demand areas are under used while equivalent resources in high demand areas are over used, requiring more maintenance and premature replacement. In addition, as the workload on a resource increases, the jurisdiction it protects becomes more vulnerable. The more hours a unit is tied up on incidents, the fewer hours it is available to respond to additional incidents. This means that units from neighboring coverage areas will respond more frequently into high demand areas, creating additional coverage problems.

Few if any local government jurisdictions have the resources to meet stringent response time benchmarks for every emergency incident, because as demand increases the gaps in service also increase, making the community more vulnerable. The only way to avoid this situation is to better allocate scarce resources based on the probability of events that may cause loss of life and/or property occurring. However, the emergency services industry continues to subscribe to existing response time deployment models that require significant built in capacity to meet response time benchmarks. This fails to account for the economic reality of most local government's work, which usually does not permit the acquisition of adequate resources to meet these benchmarks while maintaining the capacity to respond to simultaneous emergency events.

4.3 Managing Limited Emergency Resources

The realities of limited resources require that policymakers make calculated decisions to maximize service delivery output. This is a difficult transition in decision making for government officials who are programmed to espouse reactive and not proactive policies (Burton, 2008). Reactive policy decisions prevent what Leeson (2007) describes as "type one policy errors." Instead, reactive policies subject public officials to committing "type two errors," which are more politically palatable. Current deployment strategies are reactive, providing the appearance of equality for all citizens. This strategy is subject to "type two policy errors," which occur when emergency resources are not available or are out of position to respond to time-sensitive emergency events. The strategy effectively deploys resources on a first come, first serve basis (Blackstone et al., 2005).

This method for distributing resources prevents citizens or even political leaders from monitoring effectiveness and efficiency. Asymmetric information makes it difficult for those outside of the fire service to recognize that a problem is created by this deployment strategy, which produces a potential moral hazard situation. Allocating resources on a first come, first serve basis gives the impression of equality, but it in fact creates a hidden action from the “customers” who are harmed by such policies. For example, if two neighbors dial 911 thirty seconds apart, the first caller will receive the closest unit regardless of the severity of the event. A unit from another area will respond to the call received thirty seconds later, which will increase the response time. The failure to triage these incidents could easily harm the second caller if his/her situation is more serious. The asymmetric information problem prevents the citizen from knowing when he/she is harmed. In such case, a moral hazard situation has resulted because the citizen is unknowingly harmed by the actions of the decision-makers (Brehm & Gates, 1999). The inability to identify the inefficiencies and other problems with this deployment model provide incentive to policy makers to continue with the status quo.

This also demonstrates how the established policy for locating resources is compromised when multiple incidents occur simultaneously in an area. Without considerable emergency unit redundancy built into the system, time-sensitive emergency incidents are more likely to receive delayed responses. When such an error occurs with the existing deployment model, the victims are often impossible to identify. This makes it difficult for citizens to hold anyone accountable. As in the situation above, the second caller does not know whether her emergency or her neighbor’s was more critical. She also is unlikely to know whether there was a longer than necessary response time. Because of this, the fire department can turn a blind eye to situations where the deployment strategy may have harmed rather than aided a citizen. The inability to identify victims of a reactive policy provides an incentive to maintain the status quo for locating local emergency resources.

Despite this finding, a more efficient and effective deployment methodology is a critical issue for the emergency services moving into the future. Emergency services are expected to reduce risk of loss from fire, rescue, hazardous materials, and medical emergencies to society, although it is neither reasonable nor possible to eliminate all risk (Rhoads, 1998). Evaluating community risk through probability assessments provides a valuable tool to better maximize the deployment of available resources. Clearly, the potential benefit of allocating emergency resources based on probability assessments has not been realized. However, decision-makers committed to public safety will have to find alternative methods to allocate emergency resources because existing allocation models are too resource intensive. A deployment model based on probability is subject to error, but it is likely that this error is less than that experienced with current allocation models.

4.4 Research Objectives

Many research questions must be posed to begin the analysis. This multi part exercise will evaluate demographic characteristics associated with higher or lower probability for emergency service responses into neighborhood jurisdictions. This exercise will also evaluate characteristics associated with the probability that emergency resources are available to respond and the likelihood of calls for service being time-sensitive emergency events. A non time-sensitive event can be defined as a situation that results in no action by the fire service to mitigate the incident. A time-sensitive emergency event is one that requires action by the fire service to resolve the situation. Many public sector leaders contend that it is not possible to determine the severity of an emergency until trained personnel arrive on scene, at which time it is too late to alter the response (Blackstone et al., 2005). This may or may not be true, but many high-performance emergency medical systems utilize fluid deployment strategies to locate ambulances in geographical areas based on the likelihood of an emergency event occurring. These systems rely on historical response and incident data to predict the location of future calls. This is more complicated for fire departments, because the service delivery platform is so broad. Unlike EMS agencies, fire departments must predict fire, hazardous material, rescue, and medical events. Rather than predicting risk at the individual level, this evaluation will focus at the neighborhood level. Neighborhoods tend to be homogenous (Ostrom, 2000). Therefore, associating neighborhood risk characteristics with resource availability may provide an alternative measure to guide allocation decisions.

Research to evaluate government performance and public administration processes to measure service inputs and outcomes are numerous (Donahue, 2004a). Government leaders have utilized performance measures for many years to earn the public trust and to provide more efficient services. Although measures of efficiency for some public services provide valuable information, most performance measures used to evaluate fire, rescue, and emergency medical services are not sufficient to determine effectiveness. These performance measures are what Swiss and Strauss (2005) label process measures and are not true outcome measures. Process measures provide information about how hard an organization is working, such as the average number of incidents a fire department responds to or average response times. Process measures provide valuable information but do not indicate much about the organizational outputs or outcomes that are synonymous with assessing efficiency or effectiveness.

Response time is a measure of "process." NFPA 1710 sets the standard for paid fire departments to arrive at fire and other emergency events at 4 minutes or less to 90% of calls. The four minute benchmark for fire incidents is based on average time to flashover. Humans, whether firefighters or civilians, cannot survive a flashover because temperatures often exceed 1000 degrees farenheight. Few if any fire departments have the resources to consistently meet this response time benchmark. Many factors beyond the fire service's control affect the time from fire ignition to arrival of emergency personnel and should be included in any deployment strategy. For example, higher income residents usually invest in monitored fire protection systems that detect fires soon after ignition and notify the fire department to respond. Investment in private fire protection, such as smoke detectors and sprinkler systems, is not common in lower socioeconomic communities. Those unable to afford private fire protection systems are at greater risk, because notification of a fire event is dependent on a human witness (Donahue, 2004b, Pratt & Zeckhauser, 1996).

In a world with unlimited resources, the response time benchmarks outlined in NFPA 1710 are ideal. A department meeting such criterion would essentially provide citizens within a community a 90% chance of receiving assistance within four minutes every time they called 911. However, this scenario is not practical for the majority of communities providing emergency services because the inordinate number of resources required to meet this standard are simply not available. In addition, this benchmark does not address the issue of emergency requests that are not time-sensitive and do not require a rapid response, but still tie up valuable resources (Blackstone et al., 2005). A more meaningful evaluation of fire service performance is how often resources arrive on an emergency incident in time to prevent loss of life and property. This measure is difficult to assess, but gets to the matter of efficiency. It is not efficient for fire apparatus to arrive on the scene of a false alarm or minor medical situation within three minutes while having a seven minute response time to a house fire. An efficient emergency services department gets resources to time-sensitive emergency events with urgency to limit loss of life and property, while handling less urgent requests in a manner that maintains maximum resource capacity for more critical incidents. Evaluating the severity of an incident prior to an emergency resource arriving on the scene is challenging, but clear indicators of severity are often present to help triage responses.

The goal of this research is to provide a model for improving fire service performance that is result oriented, not process oriented. Responding to non-emergency events in record time places more persons at risk than it benefits, wastes valuable resources, and has huge opportunity costs. Improving service delivery efficiency and effectiveness depends on separating emergency events, where response time and resource management are critical to preventing the loss of life or property from non-emergency events (Perrin, 1998). In addition, emergency service demand should influence where resources are located within a community. Response time is an important factor to consider, but should not be the dominant factor when locating resources. A more effective and efficient deployment strategy locates resources in areas of a community where demand and the likelihood of time-sensitive emergency events are the highest. This research focuses on neighborhood and emergency response variables in conjunction with probability analysis to construct an alternative model for emergency resource allocation.

4.5 Factors Influencing Fire Service Resource Deployment

Pre-hospital emergency medical service organizations are far ahead of the fire service in developing resource deployment strategies. Much of this is out of necessity, because insurance guidelines and other industry standards do not mandate a minimum number of emergency medical resources to lower insurance rates. Therefore, urban emergency medical agencies have had to find more efficient methods to allocate scarce resources that can effectively meet their stated mission. The single focus of these agencies provides the opportunity to utilize response information to evaluate future demand (Peters & Hall, 1999). Not only do many of these high performance agencies use response data to predict demand, but they also use key indicators to evaluate the seriousness of each call for service. Under this deployment model, a medical event that is rated a low priority will trigger a non-emergency dispatch for the responding ambulance. If a higher priority medical incident is received while a unit responds to a non-emergency event the unit can be diverted to the more serious call. Again, the single focus on medical emergencies makes it easier for these agencies to predict and prioritize responses.

The fire service as an organization is very different from a single focus emergency medical services agency. Pre-hospital emergency care is a relatively new service. It was only three or four decades ago that funeral home services provided antiquated pre-hospital emergency care. These services would respond and place patients in the unit and, depending on the injuries, either take the individual to the funeral home or to the hospital. Clearly, this was a conflict of interest, since the funeral service made more money if the patient went to the funeral home. In the past few decades, pre-hospital care has become highly developed. Emergency medical systems throughout the country provide advanced medical care on emergency scenes and also transport injured and sick patients (Bledsoe, Porter, & Shade, 1997). Many high performance systems that operate in the urban environment are labeled as third service systems. These systems provide response and transport services, but are usually assisted by the local fire department. To save money, most of these agencies work out of a central facility and deploy ambulance units throughout the response area based on the potential for a medical emergency. For example, ambulances are assigned to street corners in areas likely to experience an emergency medical incident, rather than being assigned to a permanent station facility. Fluid deployment strategies save on facility costs and permit the movement of limited emergency resources to meet changing demand.

This is not the case with the fire service, which has been in existence in one form or another since the colonial period. Fire stations in most cities have been in operation for decades and will not be moved no matter the service demands. Not only are there historical constraints, but it is costly to build and/or relocate fire stations. However, the emergency resources housed in these stations are subject to relocation. The exogenous influences on the fire service place significant constraints on how resources are located throughout a community, which makes it difficult to simply relocate assets. For example, the Insurance Services Organization (ISO) evaluates communities to set insurance rates based on local fire protection capabilities. These factors encourage political and bureaucratic decision-makers to locate emergency resources in ways that may not be the most effective or efficient but will meet ISO criteria to lower insurance rates (Coe, 1983).

The modern urban fire service provides a dynamic service delivery platform. These agencies respond to fire, rescue, emergency medical, hazardous materials, and other emergency incidents, which places a premium on allocation decisions to maximize resource capabilities. The dynamic service platform provided by most fire departments challenges the efficacy and practicality of the existing emergency deployment model, which ignores the expanded mission of the fire service. Emergency resources are not allocated based on any scientifically driven methodology, which generates a lottery type situation for consumers. Essentially, as more citizens call 911 for service, the chances of the next request receiving a timely response diminish because there are fewer resources available. This situation is exacerbated by the allocation strategy employed by the fire service industry, which ignores the reality of limited resources and demand for its assets.

Current allocation strategies attempt to distribute emergency units so every part of a community can be reached by an emergency resource within a defined period of time. For example, decision-makers may draw concentric circles around each station location on a map to show the land area an emergency resource from its stations can reach within six minutes. As a community grows, infrastructure is added, traffic congestion increases, and land area is annexed, gaps develop between the concentric response time circles which indicates apparatus under the best circumstances cannot meet the six minute benchmark. This strategy leads to wide variance in workload for apparatus and personnel because demand is not spread equally throughout a jurisdiction. Emergency apparatus in high demand areas may respond to six or seven times more incidents than units located in low demand areas. This deployment strategy also places more value on a statistical life in those areas with lower population density, since there are more emergency resources per person (Felder & Brinkmann, 2002).

Distributing resources equally is politically appealing, but when multiple emergency incidents occur simultaneously in an area coverage gaps lead to increased response times. Many of these potential incidents will not require a time sensitive response, but most departments fail to triage incidents based on severity. Instead, departments respond with the same resource complement and urgency to all requests for assistance. Responding to all incidents in the same way, without deference to the nature of the event, ties up valuable resources that might be needed to mitigate more critical situations. Community, socioeconomic and structural characteristics associated with emergency services demand vary not only between communities but within communities, challenging the true efficacy of a static emergency services deployment strategy.

4.6 Hypotheses for Emergency Service Demand

Emergency service demand is a product of structural and social characteristics found across communities, which makes it difficult to predict with a high level of certainty. The characteristics that raise or lower one's risk for experiencing a fire or other type of emergency are not necessarily the same as those associated with one's likelihood of calling for assistance from the emergency services. Risk for fire varies across neighborhoods in most communities. Neighborhood jurisdictions are populated by people with similar demographic characteristics and risk factors. For example, neighborhoods where much of the population is lower income likely cannot afford private fire protection equipment, such as smoke detectors or sprinkler systems or simply do not have the resources to perform routine maintenance on their places of residence. In these situations, more dilapidated residential structures are at greater risk for fire than neighborhoods with newer residential structures that have monitored fire protection systems. Therefore, it is assumed demand will be higher in neighborhoods with lower median household income, because factors likely to contribute to the ignition of a fire are more prevalent (Walsh, 1998).

Other neighborhood characteristics are also likely associated with demand for emergency services but may not be considered risks for emergency events. If your house catches on fire your education or income level do not matter; you will request assistance from the local emergency services. However, what if you break your arm, develop a headache or flu like symptoms, find water in your basement following a rain storm, have a smoke detector with a dead battery, or lock keys in your car? Will you call the local emergency services for assistance? Education and income levels, along with other factors are likely associated with neighborhood demand for emergency services. It is certainly true that lower income and less educated populations are at greater risk for fire and other types of emergencies, but these groups are also more likely to request assistance from local emergency service agencies for problems that other demographic groups would manage differently. In many ways, risk characteristics are related to causation of emergency events, while other factors are simply correlated with emergency events. Regardless, neighborhood characteristics associated with increased risk for emergency events or with increased likelihood of requesting assistance from the emergency services contribute to overall demand (Boyle & Jacobs, 1982).

Structural variables, such as building age and appearance, are likely to be associated with an increased or decreased risk of fire. Older structures and those not maintained are at increased risk for fire because wiring is often deficient and private fire protection systems are either not present or in disrepair. Building construction techniques also contribute to fire risk, because certain construction methods are more conducive to fire spread while others are better at compartmentalizing fire (Brannigan & Corbett, 2008). The renter versus homeowner variable is associated with property maintenance. Rental properties are more likely neglected placing them at increased risk for fire.

Economic risk variables are neighborhood per capita household income and percent of persons receiving food stamps. These factors are associated with risk for all emergency events. Lower income neighborhoods are at greater risk for fire and medical emergencies because most structures have inadequate private fire protection systems and residents often do not have healthcare options. Finally, social risk variables include neighborhood population, education levels, and percent elderly/youth. Populations that are less educated tend to be associated with higher demand on local emergency services than other socioeconomic groups. In addition, the young and old are more prone to medical emergencies and careless acts that increase the chance of fire events. Much variability in emergency service demand exists across the typical urban environment. The opportunity to explore relationships between demand and neighborhood characteristics has not been considered as a guide for emergency resource allocation decisions. The number of persons in an area certainly is associated with demand to some extent, but it is likely that stronger correlations to demand exist based on the specific characteristics found within a population.

Assuming that demand for emergency services is not completely random, it is logical that characteristics found within individual homogenous neighborhood areas within every community are associated with call volume variability. Establishing an association between call volume (DEMAND) and the community risk variables identified guides the first research question and subsequent hypotheses. Is emergency service demand (call volume) at the neighborhood level related to the structural, economic, and social characteristics?

Community Risk Hypotheses

H_{1A} (Structural Environment): The more dilapidated buildings become as they age or are neglected within a block group jurisdiction, the more demand emergency services will experience. There are a myriad of reasons that unmaintained structures and ones that have aged are at greater risk for fire, and may also serve as an indicator for predicting demand for other types of emergency services. Building codes and construction are key factors to the prevention and/or containment of fire. Over the past few decades, building codes directed at limiting fire risk have become a focus. These codes include strict requirements for electrical wiring, fire stops, and alarm systems for new construction; however, few if any codes are retroactive to buildings constructed prior to the code being implemented. This means older structures are more susceptible to fire and fire spread. For example, balloon frame construction was the technique used almost exclusively to construct wood buildings over two stories until the mid-1900s. This type of construction does not have fire stops between floors and permits fire to travel freely between wall studs from the basement to the attic, which poses a significant challenge to fire containment (Brannigan & Corbett, 2008). Fire stops and other construction methods are now required to help contain the spread of fire, but older neighborhoods within a community are more likely to have buildings that are more susceptible to fire and fire spread.

In addition to building construction techniques and codes, structures that are not maintained tend to be at greater risk for fire. This includes not performing routine maintenance, such as allowing grass or bushes to grow up on the side of a building. It also includes having clutter that may impede movement in and around a structure. Again, appearance or code violations may be systemic of economic limitations, but it is clear that unmaintained structures are at greater risk for fire. Therefore, one would expect areas within a community that are not well maintained and have more dilapidated buildings to place more demand on emergency resources allocated to those areas.

H_{2A} (Economic Environment): Block group jurisdictions within a community that are economically depressed will place more demand on local emergency resources. Economic conditions for each block group are measured using average household income, percentage of homeowners, and percentage of persons eligible for food stamps. Persons with fewer economic resources are more likely to rely on government services, in particular the emergency services, than persons with more resources and options. Economic condition is likely to contribute to risk for fire and medical emergencies. For example, those with more wealth will likely invest in private fire protection systems. This may include smoke detectors, fire extinguishers, or even a sprinkler system. Persons with more wealth are also likely to have more health care options, making them less likely to utilize the emergency services for routine medical situations, such as a headache or the flu. Again, as income decreases individuals have fewer options for obtaining health care or other services, making them more reliant on publicly provided services.

H_{3A} (Age Environment): The age of persons residing within a block group jurisdiction is associated with emergency service demand. Specifically, areas dominated by the old (over 65) and the young (under 18) are more likely to utilize the emergency services. The aged are at greater risk for fire and medical emergencies, as health and carelessness become contributing factors to risk for medical and fire events. The young tend to be more careless and take more risks that make them susceptible to medical and fire events, as well. Therefore, jurisdictions with higher percentages of the old or young are likely associated with more demand on emergency services than areas dominated by more middle aged persons.

H_{4A} (Educational Environment): The level of education of the persons residing within a block group is inversely associated with demand on emergency services. Risk is an individually based characteristic, as personal habits and actions are the predominant factors that raise or lower a person's likelihood of experiencing a fire or medical event (Walsh, 1998). As education levels within a community increase the demand on emergency services should decline, because persons are likely more informed about fire safety and health issues, avoiding the need to utilize emergency services. It is also likely that education is correlated with economic condition; however, the measure for education utilized is the percent of persons 25 years and older, who have graduated from high school or earned a graduate equivalent degree.

Predicting emergency service demand based on neighborhood risk factors provides the foundation for developing an alternative allocation model. The second phase is to find relationships between the neighborhood characteristics and the likelihood of a time-sensitive emergency event. Again, a time-sensitive emergency event is defined as an incident requiring a rapid response by emergency service resources to limit human injury, loss of life, or property damage. The outcome of most emergency service responses will not be altered by arriving a few minutes sooner; however, a delay of seconds can negatively affect the outcome of some incidents (Lerner, Maio, Garrison, Spaite, & Nichol, 2006). Maximizing efficiency and effectiveness requires differentiating between time-sensitive emergency events and non time-sensitive events. Non time-sensitive events are those where the outcome will not change with a rapid response.

Emergency incidents often fit into four broad categories: fire, rescue, emergency medical and hazardous materials. For the most part, any incident involving uncontrolled fire or hazardous materials is a time-sensitive emergency event. Incidents requiring special rescue operations, such as vehicle extrication, to free trapped victims are time-sensitive emergency events because most victims have suffered trauma. The final group of incidents falls into the emergency medical category. Time-sensitive emergency medical events include cardiac arrests, myocardial infarctions, choking, hypoglycemic attacks, anaphylaxis, and significant traumatic injuries. The list is long and situation dependent, making these events difficult to accurately delineate without individual level data.

It would be optimal to evaluate individual level data for each incident to determine the severity and its relationship to neighborhood characteristics; however, the available data does not contain the information necessary to perform such an analysis with a high level of confidence. An alternative to predicting incident severity is using incident data to evaluate on scene time as it compares to neighborhood characteristics.

On scene time is defined as the total time from when a unit arrives at an incident to when the unit departs that incident. In general, more severe incidents require longer on scene times because these incidents take longer to mitigate. The longer units are tied up on incidents the more opportunity for additional incidents to occur simultaneously, which requires units from outside of the area to respond. The number of hours per day the unit(s) assigned to a neighborhood are not available is associated with risk. Neighborhoods deemed more at risk based on demographic characteristics will increase demand on emergency resources, therefore reducing availability. Predicting on scene time based on neighborhood characteristics is the basis for the second research question and hypotheses. Is on scene time associated with neighborhood structural, economic, and/or social characteristics?

4.7 Hypotheses for On Scene Time

On Scene Hypotheses

H_{1B} (Structural Environment): Emergency resources will spend more time on scene in block group jurisdictions with more dilapidated and older structures. The time emergency resources and personnel remain working at an incident is associated with the severity of the situation. Regardless of the situation found when responders arrive, it is severity that determines the time required to successfully mitigate an incident. Therefore, areas with characteristics associated with increased fire risk will require longer on scene times than other areas. Clearly, fire events are the most time consuming incident type, so one would expect resources assigned to these areas will spend more time on scene during a year.

H_{2B} (Economic Environment): The economic circumstances found within each block group area are associated with the time emergency resources spend mitigating incidents. Lower income populations are more likely to utilize the emergency services, but one would also expect these populations to experience more severe emergency events. For example, the inability to purchase smoke alarms or monitored fire alarm systems means fires will burn longer before emergency resources are summoned to the event, making it more difficult to contain these incidents. Health care is another issue in areas with fewer economic resources, because much of the population will lack preventative medical care. This means medical situations are likely to be severe more often in these areas, requiring more time to resolve by emergency personnel.

H_{3B} (Aged Environment): Older and younger populations will be associated with more severe emergency events, which means emergency personnel will spend more time on scene in these areas mitigating situations. These age groups are at greater risk for being involved with a fire event, which is arguably the most time-sensitive and time consuming type of event for emergency personnel to manage. In addition, these age groups are also associated with more severe medical emergencies, which also require longer on scene times. Therefore, it is expected that these groups will be associated with emergency service on scene time.

H_{4B} (Educational Environment): Educational levels across block groups are inversely associated with on scene time of emergency responders. It is expected that areas with persons of less education will experience more severe emergency events than areas populated by more educated persons. Therefore, emergency personnel will spend more time on scene throughout a year managing incidents in areas where education is not as prevalent.

The goal of any emergency service resource allocation model is to locate units throughout a jurisdiction to maximize availability. Availability of the unit(s) assigned to a neighborhood is an important measure because this determines the likelihood a department can respond in a rapid fashion to a time-sensitive emergency event if necessary. In many ways, this concept of availability can be associated with playing the lottery. As more demand is placed on emergency resources or these resources are occupied more often, the probability of a resource being available when a citizen needs assistance decreases. Similarly, one's probability of winning the lottery decreases with more players which creates less incentive to participate. Most urban communities do not have the tax base or will to shift revenue from other services to add emergency resource capacity that is sufficient to manage changing demand. The only solution is to allocate existing resources more effectively and efficiently.

To this point, the research questions and testable hypotheses were formulated to build an alternative emergency resource deployment model. A new model to deploy scarce emergency assets is based on neighborhood characteristics associated with emergency service demand and risk assessments. The problem public decision-maker's continue to grapple with on a regular basis is how to allocate these resources in a manner that minimizes community risk. Exploring characteristics associated with the probability of one neighborhood experiencing an increased or decreased chance of emergency events over another begins to lay a foundation for developing a new model to guide more effective and efficient deployment of these finite resources.

The risk assessment for each block group in the city of Charlotte details the relationship between emergency assets and demand for those assets to mitigate emergency events. The research maps out this relationship created by the existing deployment strategy, which attempts to evenly distribute resources throughout a community with the primary goal to meet response time benchmarks. Because demand is not also evenly distributed throughout communities, such a strategy can lead to coverage gaps in service that have the potential to detract from service delivery. Recognizing that fire stations are not easily moved, the research focuses on the placement of emergency apparatus. It is reasonable that apparatus and personnel can, in most circumstances, move to address changing demand and risk characteristics associated with emergency incidents. Therefore, modeling the characteristics associated with demand for emergency services and the time limited resources are unavailable provides some guidance for more effectively locating emergency resources throughout a community to improve service delivery.

One can assume that block group areas with characteristics associated with demand and longer on scene times may require additional emergency assets over areas with less demand and shorter average on scene times. It is also possible that these two calculations could be paradoxical in some block groups, where overall demand may be high but the number of time-sensitive incidents is low. How such information is evaluated is really a value judgment, which is a reason each community provides a different level of emergency services. What this research adds to the field is information that could better inform decision-makers about how to locate scarce emergency assets under conditions of uncertainty.

A new fire service deployment model could have a significant impact on local, state, and federal public policy decisions. The ability to predict with a high level of confidence future emergency service demand, incident locations, and threat to life and property of emergency events will significantly impact issues related to public finance and emergency service outcomes. This is accomplished by allocating limited emergency resources to their highest net present value based on community risk characteristics associated with emergency service demand across block group areas.

4.8 Summary

The demographic and structural characteristics found in local communities are constantly changing, which poses many challenges for emergency service decision makers. The popular model used to guide locational decisions for allocating scarce emergency resources in most jurisdictions is not adaptable to a dynamic environment, because it is based on response time benchmarks and not service demand. This leads to fire stations being evenly dispersed geographically throughout each jurisdiction, so that under ideal conditions each citizen can be reached by a resource within a defined maximum response time. While resources are distributed evenly using this model, demand for these services is not. The goal of this research is to develop a set of criteria to guide the development of an alternative model based on demand for local emergency services at the neighborhood level.

To perform this analysis, emergency response data collected by the Charlotte Fire Department and block group demographic information will be compared to test the stated hypotheses. The block groups, which closely reflect the local neighborhood divisions, provide a relatively homogenous demographic resident profile and clearly defined geographic boundaries for the study. It is theorized that variance in structural and demographic variables common to all neighborhoods will be associated with increased or decreased demand for emergency services. Identifying these relationships will provide the foundation for this research effort to develop an alternative model for allocating scarce emergency resources based on the premise that neighborhoods change. If certain characteristics found in these neighborhoods are associated with emergency service demand, decision-makers can be more proactive in locating critical resources in the future. Therefore, as communities evolve, local emergency resources can be located in areas with characteristics consistent with increased demand to minimize risk.

Identifying variables associated with emergency service demand and on scene time provide an opportunity to infer the likelihood that emergency resource(s) assigned to each neighborhood will be available when requested. To date, these scarce resources respond on a first-come-first-serve basis without regard for the severity of an incident. This leads to inefficiency because resources are not used to their highest net present value. Based on this system, residents in neighborhoods with a low probability that an emergency resource will be available when requested are at greater risk, especially when the situation is time-sensitive. Residents in neighborhoods with higher probability measures are at lower risk. Therefore, performing probability analysis for resource availability could provide information to shift resources in an effort to more evenly disperse risk across a community. Keeping up with changing demand through such a model would permit proactive decision-making for locating resources, which could improve the efficiency and effectiveness of service delivery.

CHAPTER 5: EMPIRICAL FINDINGS FOR DEMAND

5.1 Introduction

The empirical findings derived from bivariate correlation and multivariate least squares analysis used to predict emergency service demand are presented in this chapter. It is expected that the information gained from this analysis will contribute to the overall goal of developing a valid model for allocating limited emergency service resources to maximize service delivery within local communities. The first part of this effort requires modeling demand for emergency service resources at the Census block group level. Again, block groups were chosen as the level of measurement because the fire service allocates emergency resources to defined geographical areas within communities. Block group divisions are characterized as being relatively homogenous based on the characteristics of those residing in these areas, which is optimal for evaluating relationships between demographic measures and emergency service demand. The block group areas also tend to parallel naturally forming neighborhood boundaries, which is the situation in Charlotte. For this analysis, block groups serve as proxies for neighborhood divisions. Empirical findings are derived from regression models that include explanatory demographic measures theorized to drive emergency service demand. The information gained through this analysis challenges the efficacy of the current model to allocate emergency resources, which is guided by response time benchmarks.

The dominant factor influencing how emergency resource allocation decisions are made in the city of Charlotte, as in the majority of communities across the country, is response time. Local public sector decision-makers often blindly allocate scarce resources in an effort to lower response times to the community as a whole. However, demand for these resources is not equally distributed, which raises questions about the overall efficacy of basing allocation decisions on response times. As with all public sector decisions, more equitable distribution of goods and services often comes at the expense of efficiency (Felder & Brinkmann, 2002). Identifying incidents or areas within a community that are more likely to require a rapid response to limit the loss of life and property is challenging, because, in general, emergency service systems, especially fire departments, are experiencing increased demand for service. Increased service demand is rarely accompanied by additional resources, so finding methods to allocate limited resources more effectively is important to avoid service delivery problems.

This research focuses on allocating resources based on a more utilitarian methodology, which is to distribute resources to provide the greatest good for the greatest number of citizens in a local area. This requires making hard decisions that may require leaving some parts of a community more exposed, as resources are moved closer to high demand areas to reduce overall risk. To date, locational decisions for emergency resources are not based on scientifically driven analysis. Many of the positive outcomes of this system occur by chance, rather than by informed decision-making. In fact, Koehler & Wrightson (1987) argue that public services associated with property conservation are located in greater quantities in areas that produce the most tax revenues. This raises the question of whether public resources should be allocated based on need or ability-to-pay. In most communities, this paradox produces much of the political debate about resource allocation regardless of the service, as politicians attempt to appease those who pay the majority of the taxes while also delivering services to those most in need. Inevitably, persons with fewer resources or who lack the ability to purchase resources are more likely to need the goods and services provided by the public sector (Boyle & Jacobs, 1982). Unlike other public sector services, the distribution of emergency service resources can make the difference between life and death, which often times has nothing to do with socioeconomic status. The findings from this research provide some definitive relationships between demographic characteristics and demand for emergency resources, while also demonstrating the dynamic nature of the emergency environment that makes prediction fraught with pitfalls.

5.2 Descriptive Information and Data

Many of the pitfalls associated with predicting demand in the emergency environment stem from variability across block group jurisdictions. In particular, the presence of outliers is a constant challenge to accurately modeling this environment. Every community, no matter its size, will have isolated pockets of high demand for emergency services. These high demand areas skew the data, and must be dealt with to perform meaningful analysis. Simply eliminating outliers, which is suggested by some, is not an option in this situation because the outlier measures are not only valid but common to all local communities. This makes it necessary to include the outliers in the analysis. A brief evaluation of the univariate statistics for the explanatory and dependent variables across block groups demonstrates the dynamic and varied environment that emergency service organizations must consider when allocating resources.

Although the variation is large among the explanatory variables across block groups, the distribution for each of the measures proved to be normal. The variation is a positive for evaluating meaningful linear relationships between the dependent and independent variables. The population measures were used to norm the dependent variables across block groups to make the information more comparable across the study area, since the variation in population was large. However, the remaining explanatory variable measures were included in the regression models as presented in Table 3. The main data issues related to skew and outliers were found with the dependent variables used to measure emergency service demand. The raw measurements for each of these variables are also presented in Table 3.

Table 3: Summary Statistics

Sample Block Group Data FY2006 N=118 Charlotte, N.C.	**Mean**	**Std Dev**	**Min**	**Max**
Explanatory Variables				
Population	2,506.95	2,261.97	271	14,386
Residential Units	1,073.09	909.15	156	5,371
% persons >65 years old	0.0963	0.0509	0.0190	0.2347
% persons <18 years old	0.2478	0.0704	0.0224	0.4354
% Appearance Violations	0.1999	0.1972	0.0000	1.0320
% Code Violations	0.0096	0.0199	0.0000	0.1806
Average Building Age	34.39	15.74	6.00	63.00
% eligible for Food Stamps	0.1099	0.1111	0.0000	0.6635
% Owners	0.5270	0.2492	0.0000	0.9581
Household Income	52,877.47	27,500.58	9,999	176,852
% High School Graduates	0.8188	0.1495	0.3784	1.0000
Dependent Variables				
Incidents per block group	282.16	331.47	7	2,819
Fire incidents	14.90	12.79	0	77
Structure Fires	7.63	6.71	0	42
Other Type Fires	7.26	6.86	0	35
EMS incidents	174.83	206.54	2	1,690

Table 3: Continued

Sample Block Group Data FY2006 N=118 Charlotte, N.C.	**Mean**	**Std Dev**	**Min**	**Max**
EMS w/o motor vehicle	157.42	185.81	2	1,511
EMS w/ motor vehicle	16.79	25.25	0	168
Rescue incidents	1.14	6.32	0	68
Haz-Mat incidents	6.36	14.07	0	146
Alarm incidents	31.77	50.74	0	424
Incident Cancelations	25.89	36.84	0	305
Miscellaneous incidents	27.26	27.00	0	230
Alarm incidents	31.77	50.74	0	424
Incident Cancelations	25.89	36.84	0	305
Miscellaneous incidents	27.26	27.00	0	230

The skewed data measurements for the dependent variables were expected based on the nature of the emergency service environment and the fact that a block group cannot have fewer than zero emergency incidents. A positive skew is common when there is a “floor” effect with data, which is the case when measuring emergency service demand. The frequency statistics for each demand variable and histograms reveal a clear “floor” effect for these measures. This is also easy to see when reviewing the summary statistics in Table 1. A disproportionate number of the measures across block groups are bunched up at the “floor.”[2] Rather than the data being evenly distributed across the range of measures for each block group, a majority of the block groups experience low demand for each of the incident situations.

A second issue that further skews the data is outlier values, which are present for each of the demand variables, making the skew problematic for conducting linear regression analysis. For example, four of the block groups experienced more than 100

[2] “Floor” is the lowest possible measurement value for a variable. In the case of demand, the lowest value is 0.

incidents per 100 persons (DEMAND), while the other 114 block groups sampled experienced fewer than 40 incidents per 100 persons. This issue is not isolated to overall demand. It is also a concern with the demand measures for FIRE, STRUCTURE, OTHER, EMS, EMSNMV, EMSMV, RESCUE, HAZMAT, ALARMS, CANCEL, and MISC. To perform multivariate regression and analyze bivariate correlations, these variables were transformed to normalize the data. This action limits the positive skew to avoid biasing the estimators, which can increase the chance of committing a "type I or II error."

The natural logarithm, rather than a higher power logarithm, was selected to transform the data. This normalized the data while also maintaining the integrity of the sample. Again, the outlier measures for demand are legitimate, so overly suppressing their effect on the analysis could also lead to inaccurate findings. Prior to calculating the natural log for the demand variables, a constant was added to the data to convert any measures less than 1, because a log cannot be calculated for such low values. Specifically, 1 was added to each data point in the sample, allowing all measures to be transformed using the natural log. The transformation reduced the skew in each of the demand variables to an acceptable level. In addition, this improved the linearity found between the dependent and independent variables, which was evaluated using scatter plots. After correcting the skew, bivariate correlations were calculated between each of the dependent and independent variables. These findings are displayed in Table 4.

The above bivariate correlations reveal some interesting and unexpected relationships. Based on the hypotheses, the most unexpected findings involve the lack of correlation between demand and persons over 65 years of age. This group is often found to be at higher risk for fire events than other age groups, not including those under the age of 5 (Gamache, 2003). It is likely that measurement problems contributed to this issue, as it is unclear how or to what extent assisted living facilities, which are prevalent in the sample community, were included. The data only reveal a lack of variation across the block groups, which might explain the insignificant findings between the elderly and demand for emergency services. The findings for the relationships between the young and demand is also unexpected, because all are negative. The hypothesized relationships were positive, as the young are often more prone to medical and fire related emergencies. Although the correlations are relatively weak between the young and demand, the inverse relationship is curious. This unexpected finding may have resulted because the measure is too broad, focusing on those under 18 years of age rather than on the very young (Gamache, 2003).

Table 4: Demand Correlations

Bivariate Correlations n=118	>65y/o	<18y/o	Food	Owner	Appear	Code	Build	Income	Educate
Demand	0.066	-.292**	.349**	-.324**	0.114	0.08	.334**	-.230*	-.333**
Demand	0.114	-.238**	.558**	-.556**	.412*	.265**	.574**	-.498**	-.547**
Fire	0.103	-0.169	.572**	-.491**	.313**	.223*	.499**	-.457**	-.525**
Structure	0.135	-.206*	.590**	-.465**	.346**	.284**	.479**	-.439**	-.482**
Other	0.066	-0.155	.478**	-.425**	.200*	0.084	.424**	-.374**	-.467**
EMS	0.092	-.216*	.605**	-.577**	.454**	.303**	.597**	-.530**	-.590**
EMSNMV	0.094	-.213*	.618**	-.561**	.459**	.312**	.600**	-.528**	-.593**
EMSMV	0.043	-.218*	.279**	-.509**	.223*	0.049	.323**	-.319**	-.338**
Rescue	0.178	-.376**	0.122	-0.173	-0.041	-0.044	0.088	-0.064	-0.091
HazMat	0.014	-.188*	.227*	-.358**	0.145	0.137	.357**	-.291**	-.420**
Alarms	0.152	-.281**	.185*	-.318**	0.073	-0.011	.232*	-0.140	-.215*
Cancel	0.045	-.239**	.461**	-.478**	.286**	0.140	.446**	-.452**	-.462**
Misc	.209*	-.368**	.443**	-.414**	.232*	0.138	.464**	-.368**	-.843**

Standard Log   *Significant @ .05 level   **Significant @ .01 level

Economic condition measured by the wealth variables is the predominant factor associated with demand for emergency services based on the bivariate correlations. This is expected, as those with less purchasing power tend to rely more heavily on public services (Lipsky, 1980). Clearly, EDUCATION, INCOME, OWNER, and FOOD are strongly correlated with most of the demand variables. These findings demonstrate a distinct inverse pattern between income and demand. Block groups with a higher percentage of persons eligible for food stamps are more likely to use the emergency services. In particular, these groups are highly correlated with emergency medical incidents that do not involve a motor vehicle and structure fires. The act of requesting assistance for a medical condition does not necessarily indicate the presence of a true time-sensitive emergency. In fact, block groups with more persons eligible for food stamps are also highly correlated with cancellations and false calls, which support the possibility that persons with less wealth have a lower threshold for requesting assistance from emergency services. The high positive correlation with cancellations is also consistent with the medical emergency response criteria in the city of Charlotte. The Charlotte Fire Department responds to medical incidents with the Mecklenburg EMS Agency (MEDIC). MEDIC dispatchers have the ability to screen calls for assistance to determine severity. When an incident is deemed “non-emergent” or the MEDIC ambulance arrives on scene first to a “non-emergent” situation, the responding fire apparatus is cancelled. Therefore, the high correlation to medical emergencies does not indicate severity, only demand or lack thereof.

This is not necessarily the case with fire incidents, and more specifically structure fires. Block groups with increased number of persons eligible for food stamps were highly correlated to structure fires, which is an important finding. Again, the structure fire variable was calculated for each block group to measure the number of fires that involved structures. The potential for death, injury, and property loss increases when a fire occurs in a structure, making these time sensitive emergency events. All fires, no matter how small, will grow if left unchecked. Therefore, this positive correlation is not only statistically significant but also significant to finding an alternative methodology to allocate scarce emergency resources to reduce loss of life and property. These findings are further supported by the inverse relationship found between income and education and the dependent variables for demand. As income or factors associated with wealth increase, demand for emergency services tends to decline. In particular, more wealthy areas are less likely to have structure fires or request medical assistance. There is also an inverse relationship between cancellations and wealth. This is important, because it indicates, to a certain extent, that persons residing in these areas have a higher threshold for calling 911, meaning they are less likely to call for non-emergent situations.

The structural characteristics, which include building age, appearance violations, and code violations, correlate in expected ways with the FIRE, STUCTURE, and OTHER demand variables. In particular, the variables for fire and overall demand are strongly correlated with building age, appearance violations, and code violations. As was hypothesized, structures that are not maintained or fall into disrepair are more susceptible to fire events (Duncombe, 1992). In many ways, these correlations also support the wealth effect, because lower income persons are less likely to have the resources to maintain and upgrade their places of residence. In addition, block groups with higher percentages of renters compared to owners are positively correlated to fire events. This is pertinent because it coincides with the structural characteristics finding that buildings not maintained are associated with more fires, which is often the case for rental properties. Obviously, it is not just the age or condition of the building, but the people who reside or work in these structures that increase the risk of fire or other emergency events (Duncombe, 1992).

Although the bivariate correlations lack controls, the findings do indicate important patterns between many of the independent and dependent variables. One can certainly infer from these calculations the importance of wealth and education when evaluating demand for emergency services. A final correlation to point out is that between education and miscellaneous incidents. This is relevant because it depicts the lower threshold for utilizing the emergency services by those who are less educated. In general, miscellaneous events are not emergencies. These situations involve animal rescues, water problems, replacing batteries in smoke detectors or carbon monoxide detectors, and other conditions that, more often than not, could be resolved without the fire department. It is evident that certain demographic characteristics are associated with increased reliance on the emergency services to solve emergent and non-emergent situations. Although the demand variables do not indicate severity, one can infer the relative nature and time-sensitivity based on the different demand models, which is important for organizing an alternate way to allocate emergency service resources.

5.3 Multivariate Regression Analysis

A quick look at the correlations between the independent and dependent variables demonstrates some clear relationships. However, these relationships do not control for the other interceding variables. A multivariate regression was performed to evaluate the association between each of the dependent demand variables and the explanatory variables. The scatter plots revealed linear relationships between the variables; however, multicollinearity proved to be a problem when including all of the independent variables in the regressions. Tolerance and variance inflation factor (VIF) scores consistently indicated collinearity problems with the education variable. According to Miles and Shevlin (2001), VIF scores near or above 4 indicate an actionable collinearity problem. This issue was further supported by the bivariate correlations, which indicated a strong relationship between the variables EDUCATION, OWNER, and INCOME. The variable for FOOD STAMPS was also strongly correlated to these economic measures; however, its relationship is in the opposite direction. When included separately in the regression models the VIF and tolerance scores are raised, but do not meet the criteria for being actionable.

To correct this problem, principal components analysis (PCA) was used to combine the highly correlated variables. A factor score was saved as a variable combining EDUCATION, OWNER, and INCOME. The new factor score serves as an explanatory variable and is labeled WEALTH, which resolved the collinearity issue. The variable for FOOD STAMPS remains in each of the models and was not included in the factor for WEALTH in order to maintain as much precision in predicting demand as is possible. The factor for WEALTH and the FOOD STAMP variable are paradoxically associated with the demand variables, which would not be detectable if all four variables were included in the principal components analysis.

The standardized regression coefficients (Beta scores) for the twelve multiple regression models are listed in Table 5. The WEALTH factor is included in each of the models, replacing the variables OWNER, INCOME, and EDUCATION.

Table 5: Demand Beta Coefficients

Multivariate Regression Beta Scores n=118	**AdjR^2**	**>65y/o**	**<18y/o**	**Appear**	**Code**	**Build**	**Food**	**Wealth**
Demand	*0.528*	-0.013	**-0.295****	0.036	-0.044	**0.248****	**0.240****	**-0.343****
Fire	*0.442*	0.011	**-0.205***	-0.091	-0.058	**0.211***	**0.364****	**-0.301****
Structure	*0.447*	0.029	**-0.268****	-0.02	0.039	0.128	**0.431****	-0.193+
Other	*0.347*	-0.038	-0.170+	-0.171+	**-0.176***	**0.254***	**0.321****	**-0.311***
EMS	*0.581*	-0.03	**-0.293****	0.054	-0.024	**0.247****	**0.277****	**-0.332****
EMSNMV	*0.586*	-0.033	**-0.293****	0.056	-0.012	**0.249****	**0.308****	**-0.297****
EMSMV	*0.250*	-0.021	**-0.250***	0.017	-0.167	0.113	-0.027	**-0.492****
Rescue	*0.142*	0.019	**-0.395****	-0.105	-0.037	-0.064	0.154	**-0.182**
HazMat	*0.217*	-0.116	**-0.234****	-0.152	-0.02	**0.255***	-0.076	**-0.425****
Alarm	*0.132*	0.044	**-0.262****	-0.063	-0.124	0.088	0.053	**-0.304***
Cancel	*0.391*	-0.095	**-0.313****	-0.05	-0.116	**0.210***	**0.216***	**-0.369****
Misc	*0.410*	-0.003	**-0.393****	-0.058	-0.062	**0.223***	**0.313****	-0.194+

+ Significant @ .10 level * Significant @ .05 level ** Significant @ .01 level

The adjusted R-square values are indicative of the ability to predict demand for emergency services using demographic explanatory variables across the population. These variables, and in particular the economic and structural measures, explain a great deal of the variance for many of the demand measures. The models that stand out are overall demand, fire demand, structure fire demand, EMS demand, and EMS demand for medical situations not related to a motor vehicle. These models have strong adjusted R-squared values, providing substantial information to better inform emergency service locational decisions. In addition, the models for miscellaneous demand and cancelled or false calls proved relatively strong.

A quick scan of the regression findings indicates explanatory variables measuring economic status are the most important to predicting demand for emergency services. The beta coefficients for the models predicting DEMAND, FIRE, EMS, and CANCEL are strongest for <18 years old, WEALTH and FOOD. In addition, the beta magnitude for FOOD is high concerning medical emergencies not involving a motor vehicle, structure fires, and other types of fires. This indicates that as socioeconomic status within a block group rises, one can expect a decrease in the number of requests for assistance from the emergency services. However, a decline in economic status appears to have a stronger positive relationship with demand for these services.

The explanatory variables measuring structural condition, with the exception of BUILD AGE, in each block group did not contribute a great deal to the models predicting demand. BUILD AGE was significant for overall DEMAND, FIRE, and EMS. Building age was hypothesized to be an important factor for predicting fires, especially those occurring in structures; however, the age of buildings proved insignificant in the model for structure fires. The findings for BUILD AGE are somewhat conflicting. BUILD AGE was significant for predicting overall fire demand, but not for fires occurring in structures. Charlotte is a relatively new city that has experienced a great deal of development over the past decade. One would expect older structures to be more susceptible to fire because of decay and systems that do not meet code (Duncombe, 1992). However, many of the techniques used in construction today are also very susceptible to fire. The development of lightweight trusses, for example, has made it more economical to build apartments and other residential structures in economically depressed areas. Lightweight truss construction is vulnerable to rapid fire spread, but it is likely the characteristics of the individuals who occupy these structures that make them more susceptible to fire (Schaffer, 1988). This is supported by the beta coefficients for WEALTH and FOOD associated with structure fire incidents, which are more influential for assessing risk. Building age and code violations were significant for predicting other types of fires, which is consistent with the literature.

Based on the findings for age, the hypotheses for these variables and their relation to demand must be rejected. Surprisingly, no significant relationships were found between the demand variables and the elderly. The lack of variation across block groups likely contributed to these findings. It is unclear whether the variable represents the actual breakdown of the population, because it is possible that nursing facilities and other assisted living communities were not counted or are dispersed in areas with a low percentage of elderly persons. Regardless, one would have expected a statistically significant relationship between demand and the elderly. On the other end of the age spectrum, the variable for the young proved to be inversely associated with each of the demand variables except OTHER. Again, the significant relationships were correctly hypothesized, but not the direction of the relationship. One would expect that as the percentage of young increases within a block demand for the emergency services would also increase. Much of the literature argues that the very young (ages less than 5) are at increased risk for medical and fire events over other age groups; however, the block group data used for this analysis was not detailed enough to isolate this age group (Gamache, 2003). Regardless, the relationship between percent under 18 and demand across block groups is inverse, which is opposite of the hypothesized relationship.

The model for predicting ALARMS was weak with an adjusted R-square value of .132. WEALTH was inversely associated with demand for alarm incidents and proved to be the only significant variable of consequence. One can infer that areas with more wealth are less likely to summon emergency services for alarms that prove to be non-events. This is further strengthened by the relationship between WEALTH and CANCEL, as more affluent areas are associated with fewer cancellations and false calls. This is balanced by the positive relationship between FOOD and CANCEL indicating a greater propensity for false or non-emergent events in areas that are more economically depressed. Finally, FOOD is positively related to demand for miscellaneous incidents. This is expected, as the nature of most incidents coded “miscellaneous” are non-emergent events that often could have been resolved by the complainant. This further supports Boyle and Jacobs’ (1982) findings that economically depressed areas use public services more frequently.

5.4 Problems with the Dataset: Mapping Residuals

The Census block group demographic data creates some issues when predicting emergency service demand. An issue that must be considered is that much of the information is derived from permanent residents. Therefore, during daylight hours much locational information changes, as residents travel to work, school or other locations. In addition, there are some areas that have relatively few residential housing units, such as the uptown area, airport, and highly commercial areas. To evaluate the impact of these areas on the findings, residuals for three of the demand models were mapped. Block groups where the standardized residuals for each model were more than or less than two standard deviations from the mean were highlighted on the maps located in the appendix to visually depict these phenomena.[3]

Insignificant regression findings for the >65 year old variable in each of the demand models was a catalyst for mapping the residuals. This population group was clearly identified in the fire service literature as being at much greater risk of injury and death from fire and other emergency situations. Therefore, residuals for the multivariate model for overall DEMAND, a bivariate model with the >65 year old variable and FIREDEMAND, and a bivariate model with the >65 year old variable and overall DEMAND were mapped. For each of the three models, DEMAND was under predicted based on the independent variables for block groups in the uptown and airport areas. This was expected because neither area has a high level of residential structures, which reduces the amount of valid demographic data for the analysis. However, the airport and uptown areas generate a large number of emergency incidents that fire department personnel respond to. Although these areas include few residents, each area experiences a large influx in population daily as people flow into these areas for work or travel. These non-permanent persons that flow in and out of these areas are captured by the DEMAND variables, but not by the explanatory demographic variables collected by the Census.

There were also areas where overall DEMAND was over predicted based on the explanatory variables. Each of the models to predict overall DEMAND had two block groups that fell two standard deviations or more below the mean. These areas were located on the periphery of the city, where population density is low. In fact, the vast

[3] See Appendix G, H, & I for residual maps of each demand model.

majority of the identified block group areas lie outside of the city limits. However, these block groups were included in the analysis because part of each block group is within the city limits and at least one emergency incident occurred within that area. A combination of low population density, low call volume, and the likely differences in population between day and night time hours are likely the reasons DEMAND was over predicted for these areas.

The residual maps help to validate the research findings for demand, as only a very few block groups proved to be outliers. These potential demographic anomalies were identified in Chapter 3, especially the potential impact of the airport property and uptown areas. However, each area includes some residential units, making it difficult to justify not including them in the original population of block groups from which the sample was drawn. However, it is evident that highly commercialized areas and others where residential population is low do not reflect the vast majority of the Charlotte area, which explains some of the unexpected findings from this analysis.

5.5 Fire Demand Model Discussion

It is evident that economic status is a strong predictor of demand for emergency services. More importantly, the characteristics of the population and not just the size of the population should be considered when allocating scarce resources to maximize service delivery. The above findings are not overwhelming but do provide a plethora of information to help develop a new methodology to locate emergency resources. The politically desired method for distributing public sector goods and services is often to maximize equality. This means that in the perfect world everyone residing in a community has the same chance that an emergency resource in their area will be available when requested. Equal access and service delivery is the foundation on which finite emergency resources are allocated in most communities. The distribution of these resources is most often based on an arbitrary response time benchmark. This strategy is effective as long as only one emergency incident occurs at a time within a response jurisdiction. Under such conditions, response time and service delivery are predictable. However, the emergency environment is dynamic, meaning that systems commonly experience high demand periods where many emergency incidents occur simultaneously. Once units begin to respond, availability and response time to additional incidents becomes random and unpredictable (Peters & Hall, 1999).

Although emergency resources may be distributed equally throughout a community, demand for these services is not equal. Therefore, equal distribution will inevitably disenfranchise high demand areas within a community. The above findings demonstrate that not only is demand not equally distributed throughout communities, but certain demographic characteristics are predictive of demand. Greater wealth and education in a particular area within a community correlates to lower demand for emergency services. The opposite is also true, as poverty inundates an area, as indicated by food stamp eligibility, demand increases, especially for medical and fire events. Based on this information, one might propose to simply relocate some emergency resources from economically stable areas to more impoverished areas to provide more effective service delivery.

Unfortunately, it is not as simple as just shifting resources based on demand characteristics found across a community. Increased demand does not necessarily indicate increased risk of death or property loss. This was made clear in an evaluation of emergency service responses by Blackstone et al. (2005), which found the majority of alarms received by police and fire departments prove to be non-events that waste valuable resources. The same explanatory variables in this analysis that proved predictive of fire and medical demand were also predictive of cancellations, false calls, and miscellaneous incidents. Not only do areas with higher rates of poverty utilize the emergency services for more fire and medical situations, they are also more likely to use these services for more frivolous reasons, such as replacing a battery in a smoke detector. Again, the threshold for calling 911 seems to be very different based on one's economic status. The question is how to separate out the likelihood of emergent incidents from those that are not emergent. Although the data available for this analysis is not complete enough to confidently make such assessments, one can infer from the above findings relevant information on this subject.

Evaluating the demand for fire responses provides an initial assessment of risk for life and property loss based on demographic characteristics. It is hard to triage fire incidents, especially those involving a structure because a fire event will continue to worsen if not attended to. It is clear that lower income areas are much more likely to have a fire event than higher income areas, but the overall number of fires within the city only accounts for roughly 6% of the call volume the fire department responds to. Still, fire does pose great risk to property and life. Therefore, it warrants attention from policy makers in the public safety sector. It is also important to balance the causal effects for the poor being more susceptible to fire events. A fire is, for the most part, a low probability/high consequence event. In many ways, an individual can reduce the chances of fire, especially in the home, by purchasing private fire protection goods and services

(Jones-Lee, 1974). For example, investing in smoke detectors or monitored alarm systems can substantially reduce the risk of a catastrophic fire event.

Fire protection systems purchased in the private sector are effective, because they continuously monitor environmental conditions. When a fire does occur, these systems alert the fire department to a fire condition during the incipient stage or beginning part of the fire event, which provides an opportunity for rapid extinguishment with minimal property loss or risk to life. In addition, occupants are alerted to the fire before it has the opportunity to spread, providing ample time for self-evacuation. Early recognition of a fire condition is critical to reducing the risk of death and property loss. Because these are low probability events, those with limited resources are not likely to purchase fire protection goods and services from the private sector in lieu of other necessities (Holt & Laury, 2002). Instead, these groups are more likely to rely heavily on the public sector to reduce their risk of property and life loss from fire, which is born out in the statistical findings compiled for this research.

Those with more resources and expendable income are more likely to invest in private fire protection systems. Not only do they have the means to invest in these products, but in many cases they have more to lose which provides additional incentive. Although those with more resources must still rely on the fire service if a fire does occur, the chances of death or injury are greatly reduced for these groups. Based on these findings, it is reasonable, if reducing risk to life from fire is the priority, to allocate emergency resources in greater numbers to areas that are economically depressed. Concentrating emergency resources in areas where people are more reliant on the service should reduce losses from fire events, without disproportionately increasing the risk to life in more economically stable areas.

5.6 Medical Demand Model Discussion

In addition to fire emergencies, public safety organizations must also weigh medical emergency demand when allocating resources. For this analysis, three models were derived to evaluate demand for emergency medical services. These involved using the explanatory variables to predict overall demand for medical services, demand for medical emergencies not involving a motor vehicle, and medical emergencies involving a motor vehicle. The model for medical emergencies involving a motor vehicle was weak, which was expected based on the demographic characteristics. Although certain groups are more at risk for being involved in a motor vehicle accident, such findings in this analysis are likely to be more spurious than predictive. The demographic explanatory variables did account for a significant proportion of the variance for overall medical demand and demand for medical assistance not involving a motor vehicle. These findings must be balanced by the high rate of incidents that prove to be non-emergent events, which is much more likely for medical situations (Felder & Brinkmann, 2002). Again, the decision to request assistance from the emergency services is an individual decision. The threshold for when to call and when not to call varies widely across a population, so sorting emergent and non-emergent medical incidents is challenging.

The analysis does support the prevailing belief espoused in the literature that economically depressed areas are correlated with greater demand for medical services. More educated and economically stable populations clearly generate less demand for these services. The real question, which cannot be confidently answered through this research effort, is which demographic variables correlate to medical incidents that are emergent. Time sensitive medical emergencies include heart attacks, diabetic situations, cardiac arrest, major trauma, and any other situation that poses an immediate threat to an individual's quality of life. For the most part, the majority of medical emergencies prove to be non-events or at least situations where a quick response by emergency workers is not necessary to prevent harm (Felder & Brinkmann, 2002). Based on the findings that more wealth and education are inversely correlated with miscellaneous and false calls, one can infer that groups with these characteristics are also less likely to request assistance for non-emergent medical conditions. The challenge is sifting through the data to determine if this is the case. Clearly, economic condition determines one's likelihood for requesting assistance for a medical condition, but this does not indicate whether the conditions are more often true emergencies. It is quite possible that economically stable and unstable areas experience the same chance or volume of time-sensitive medical emergencies, it is just in the more economically challenged areas that there are more non-emergent requests for service. In such a situation, resources must be allocated differently to maximize patient outcomes.

5.7 Summary

The analysis demonstrates that the economic condition of an area is the predominant demographic characteristic associated with overall demand for emergency service resources. Such a finding is not unexpected, as much of the literature on public sector resource allocation indicates that those with fewer resources are more dependent on public services (Lipsky, 1980). Although the findings are not particularly earth shattering, they do contribute to better understanding and substantiating the socioeconomic factors that drive demand on local government emergency services. By breaking down the incidents into eleven categories, it was possible to further isolate the demographic characteristics associated with different types of emergency events. Each of the demand models was significant; however, only the models for FIRE, STRUCTURE, EMS, EMSNMV, CANCEL, and MISC proved to have adjusted R-squares at or above .400. The other demand models were relatively weak, which may be a symptom of insufficient data for those types of incidents. Regardless, one would expect the models for FIRE, EMS, CANCEL, and MISC to be the strongest, because factors that influence demand associated with these types of situations are driven by individual condition.

One's risk for fire or a medical emergency is predominately determined by individual characteristics with minimal effect from environmental conditions. This is demonstrated by the weak correlations found between building age and fire events. It is plausible that much of the correlation between building age and emergency service demand is spurious. This relationship is more a factor of the characteristics of those who occupy and are charged with maintaining these structures than the structures themselves. True, the age of a building may be a contributing factor to a fire event or false alarm, but it is not likely that the age of a building influences the demand for emergency medical incidents or miscellaneous events. Finally, building age was not significant in the model to predict structure fire demand, which is where one would most expect to find a significant relationship if structural characteristics are reliable predictors of demand.

Therefore, the explanatory variables for economic condition are clearly the most influential for predicting emergency service demand. It is evident that the emergency service environment is dynamic. The location of emergency incidents is in many ways random, making them difficult to predict with a high level of accuracy. The uncertainty about where the next fire or cardiac arrest will occur is an important factor influencing the continued effort of public safety decision-makers to spread scarce resources equally throughout local communities. This speaks to the reactive nature of the public sector. The information gained through this analysis likely falls short of the threshold required to convince policy makers to allocate emergency resources more proactively. However, it provides a starting point to discover whether demographic characteristics, such as income or education, can be used to locate emergency resources to save more lives and reduce property damage over the current allocation model.

In many ways, this analysis further supports the random nature of emergency events. However, it also reveals the importance of income and education for reducing risk for fire events. This lends support to the idea of placing more emphasis on public education to encourage the use of private fire protection goods and services. Demand for the emergency services is clearly not completely random; however, prediction is fraught with pitfalls as the lowest risk area in a community could still experience a catastrophic emergency event. A more directed effort at higher risk areas in a community to increase the use of private fire protection systems could reduce the workload on emergency services, permitting more availability and better service delivery. Regardless, public managers have the capability to improve service delivery and outcomes by recognizing the different demand characteristics found within and across local communities.

CHAPTER 6: EMPIRICAL FINDINGS FOR TIME

6.1 Introduction

The empirical findings derived from bivariate correlation and multivariate least squares regression analysis used to predict the time emergency units spend managing incidents is presented in this chapter. Two time models are formulated; the first evaluates the average total time units spend on emergency incidents for each block group and the second evaluates the average time units spend on emergency scenes mitigating incidents. The theory behind the analysis is that the time units spend managing incidents is important to allocation decisions, because these are rivalrous services. When services have rivalrous consumption, one person's enjoyment of the service prevents another person's simultaneous enjoyment of that service, which is not consistent with a true public good (Weimer & Vining, 2005). This is important because while emergency units are responding to and managing incidents, no matter the severity, they are not available to manage additional emergency situations. Therefore, areas where demographic characteristics are associated with units spending more time responding to and managing incidents will experience a greater likelihood for simultaneous emergency situations to occur. When simultaneous incidents occur within the same response area, a unit or units from outside of the area must respond. This situation leads to prolonged response times, which may compromise the ability to prevent unnecessary loss of life or property.

Because most fire departments, including the Charlotte Fire Department, do not triage calls by severity, unit availability is important.

Emergency service systems, with few exceptions, assign incidents on a first come first serve basis. This creates a lottery like situation for the public sector “customer,” which is based on nothing more than luck. Response time to incidents is predictable when units are stationary in their assigned locations. If one assumes that an emergency system will never manage more than one incident at a time, equally distributing resources throughout a community based on a set response time criteria is logical. This distribution means the response time to every part of the community is predictable. Under such circumstances, everyone residing in the community could have a set expectation that if assistance from the emergency services is requested, a unit will always arrive within a specified time period. Therefore, depending on the length of that response time, residents within the community could more effectively manage risk associated with fire, medical, and other emergency incidents. However, this is not the case which prevents civilians from formulating a set expectation that a unit assigned to their area will be available to respond when requested. As with a lottery, as the numbers or participants increase the chances of winning decrease. The more time units spend unavailable managing incidents within each block group area, the greater the probability that unit will not be available to respond when requested. Therefore, it is theorized that areas where units spend more time responding to and managing incidents will be at greater risk of suffering losses. If demographic characteristics can then be used to predict TOTAL TIME and ON SCENE time, resources can be more effectively distributed to improve the likelihood that a unit will be available in each area when assistance is requested.

It is likely that the model for TOTAL time will not only capture unit workload, but also incident severity. Areas that experience more demand will have units that spend more time responding to and managing incidents. In addition, TOTAL time will rise in areas where incidents are more severe and take longer for emergency personnel to resolve. The advantage of modeling total time is that every type of incident is captured, including situations where responding units are cancelled prior to arriving on the scene. The information gathered through this model can then be compared to the information derived from the model predicting ON SCENE time.

The second model attempts to predict the time units spend on emergency scenes mitigating incidents. In many ways, it is theorized that time is a rough proxy for incident severity. Again, the available data is not sufficient to thoroughly and confidently assess incident severity across the wide spectrum of incident types. However, one can posit that more severe and complicated emergency situations will take longer for emergency responders to mitigate. For example, responders will spend more time extinguishing a building fire than extinguishing a dumpster fire. It is expected that identified correlations between ON SCENE time and the demographic explanatory variables will begin to isolate characteristics associated with more severe incident types. This is in accordance with the idea that DEMAND does not necessarily equate with incident severity, which is the measure emergency service allocation should be based on to maximize outcomes. Comparing these findings with those derived from the models to predict DEMAND will further inform the development of an alternative model for locating scarce emergency service resources in local communities.

6.2 Summary Time Statistics

Univariate statistics for the time measures do reveal the compressed nature of these measures. This is especially true for ON SCENE time when emergency medical incidents are isolated. It is important to remember that the times are averages calculated for each block group, which further depresses the variation in the summary statistics presented. Each of the variable measures was normally distributed and did not require any transformation for the regression analysis.

Table 6: Time Univariate Statistics

Summary Statistics for Time Variables n=118	**Mean**	**Std Dev**	**Min**	**Max**
Block Group Total Time	0:15:28	0:02:11	0:10:42	0:21:41
Block Group On Scene Time	0:04:53	0:01:08	0:02:53	0:09:03
Scene Time for Fires	0:05:20	0:02:20	0:00:00	0:15:16
Scene Time for EMS	0:04:19	0:01:03	0:01:44	0:06:52

6.3 Descriptive Information for the Time Variables

Bivariate correlation calculations were performed to evaluate the relationship between the explanatory variables and dependent variables. In addition to the two stated dependent variables (TOTAL TIME & ONSCENE TIME), on scene time for each block group was also calculated separately for fire and medical incidents. These additional variables were included to isolate the predominant type of emergency incidents in an effort to evaluate any potential associations with the explanatory variables. These correlations are presented in Table 7.

The bivariate correlations, in many ways, provide more information for understanding the pattern of demand for emergency services associated with demographic characteristics. Although many of the relationships are expected, some are conflicting. In general, time spent responding to and managing emergency incidents is longer for block groups that have more wealth and affluence. This finding is challenged by the strong significant relationship between ONSCENE and OWNER, APPEAR, and CODE, which is inverse. This seems to indicate that block groups with a higher percentage of owner occupied residential structures compared to renter occupied structures are associated with shorter on scene times, which is also true for areas with more appearance and code violations. One would expect that more dilapidated and neglected structures would be associated with increased on scene time, because such structures are more susceptible to fire spread.

Table 7: Time Bivariate Correlations

Bivariate Correlations for Time n=118	**>65y/o**	**<18y/o**	**Appear**	**Code**	**Build**	**Food**	**Own**	**Income**	**Educate**
TOTAL	0.028	-0.021	**-.436****	-0.179	**-.425****	**-.533***	**.331***	**.489****	**.394****
SCENE	-0.073	0.162	**-.427****	**-.272***	**-.493****	**-.367****	**-.457****	**.426****	**.423****
FIRE	-0.112	0.118	-0.168	-0.014	**-.262****	-0.111	0.021	0.072	0.162
EMS	-0.091	0.126	**-.348****	**-.182***	**-.370****	**-.368****	**.376****	**.462****	**.385****

***Significant @ .05 level** ****Significant @ .01 level**

The OWNER variable is highly correlated with INCOME and EDUCATION, which are descriptive of wealth. However, in this case, it appears that block groups with more renters, which are often associated with lower socioeconomics, are related to longer on scene times for emergency incidents. Although not consistent with the other wealth indicators, this finding is logical. Most rental properties are multi-family, meaning that they are usually larger structures than those used for single family occupancy. Fires in apartment buildings can be large, requiring many fire resources to extinguish. In addition, those residing in these structures tend to be at increased risk for such events.

However, based on the other time models, one might expect the block groups with more OWNERS to be associated with longer on scene times.

It is also curious, on the surface, that the significant associations between the structural characteristics (APPEAR, CODE, BUILDAGE) and dependent variables are negative. As buildings age they are thought to be more susceptible to fire events, which was supported by the FIRE DEMAND model (Duncombe, 1992). However, based on the above correlations, as structures age, become more dilapidated, and fail to meet code the time responders spend responding to and managing emergency situations declines. These findings are likely linked to the socioeconomic condition of the persons occupying these buildings, and do not reflect on the buildings themselves.

If time is assumed to be a proxy for incident severity, the correlation findings are quite relevant to formulating an alternative method to guide emergency resource allocation decisions. The correlation findings, when compared to the demand models, support the theory that longer on scene time is an indicator of incident severity. In particular, as indicators of wealth and economic stability for block group areas improve, the time responders spend managing incidents increases. The demand models indicated that as economic circumstances rise within block groups, the demand for emergency services declines. These findings support the belief that although there is an inverse relationship between DEMAND and WEALTH, incidents in these areas are likely to be more severe. This further supports the higher threshold persons with more wealth and education have when determining whether to engage the emergency services for assistance and further underscores the challenges to most effectively locate scarce public safety resources.

6.4 Multivariate Regression Findings

Four time models are presented to predict total time units spend responding to and managing incidents, time units spend on scene mitigating emergency situations, time units spend managing just medical calls for assistance, and time units spend managing fire calls using the demographic explanatory variables. The model to predict time units spend on scene managing fire incidents indicates a significant inverse relationship between BUILD and ON SCENE time, which is consistent with the findings from the other time models. However, the model itself for FIRE ON SCENE time is not significant (0.130), decreasing its value to the overall research effort. Therefore, much of the analysis discounts this model and focuses on the other three.

As with the DEMAND models, a factor for WEALTH that combines the explanatory variables OWNER, INCOME, & EDUCATION is used in each model to avoid multicollinearity issues. Unlike with the demand models, each of the dependent time variables calculated proved to be normal and did not require transformation. The beta statistics for each model are presented in Table 8.

Although the models are not particularly strong for predicting time, each provides some valuable information to the overall research effort. The adjusted R-squared values are significant at the .05 level for all models except FIRE ON SCENE. For the first model, the average total time for each incident occurring in the sample block groups was calculated. This served as the dependent variable, which was regressed against the explanatory demographic characteristics found in each block group. The strongest association was measured between the TOTAL TIME variable and the FOOD STAMPS variable. FOOD STAMPS serve as a proxy for economic status and are negatively associated with TOTAL TIME. This finding is expected based on the DEMAND models, which indicated a strong positive relationship with overall demand and cancellations. Again, the TOTAL TIME variable includes cancelled incidents. Therefore, as the number of cancelled incidents rises in a block group, the TOTAL TIME measure will decrease because of the influx of incidents with short time periods. It appears, based on this model, that block groups with declining economic conditions are associated with more requests for assistance from the emergency services, but the time per incident is shorter than that experienced in more economically stable areas.

Table 8: Beta Coefficients for Time

Multivariate Regression Beta Findings N=118	**AdjR^2**	**>65y/o**	**>18y/o**	**Appear**	**Code**	**Build**	**Food**	**Wealth**
Total Time	0.316	0.039	0.043	-0.174^{+}	0.142	-0.195^{+}	**-0.357****	0.073
On Scene Time	0.330	-0.001	**0.209***	-0.187^{+}	-0.009	**-0.220***	0.031	**0.318****
EMS On Scene	0.238	-0.111	0.135	-0.147	0.067	-0.053	-0.046	**0.390****
FIRE On Scene	0.037	-0.011	0.080	-0.135	0.116	**0.256***	-0.020	-0.064

+Significant @ .10 level ***Significant @ .05 level** ****Significant @ .01 level**

The second model isolates the time units spend on scene managing incidents. Therefore, incidents where units were cancelled prior to arrival for whatever reason are not included, because these situations skew the data biasing the estimators. Based on this model, three of the explanatory variables proved significant. The positive relationship between the variable for less than 18 years of age and on scene time is consistent with the literature, if time spent on scene is indeed a proxy for incident severity. Again, the young are thought to be at greater risk for fire and medical emergencies. In addition, the WEALTH factor is positively associated with ON SCENE, further supporting the belief that units spend more time managing incidents in more economically stable areas of the city. One can surmise that the association with longer ON SCENE times is reflective of more affluent persons being less likely to use the emergency services for frivolous or non-emergent situations. The model also corroborates the information found in the bivariate correlation calculations that BUILD AGE is inversely associated with ON SCENE time. This is likely more a reflection of the persons occupying these structures, because one would expect that as buildings age there is a higher propensity for fire events.

The final model isolates the time units spend on scene for medical situations in the sampled block groups. As with the overall ON SCENE variable, time spent on medical incidents is significantly related to the WEALTH factor. More affluent block groups are associated with longer ON SCENE times. This is not a definitive finding of severity but does begin to support such a theory. An issue with ON SCENE time for medical emergencies is the compressed nature of the measurements. For example, even for the most severe medical emergency units should not spend more than 10 to 15 minutes at the scene, which is different than a fire event. In addition, the fire service unit's ON SCENE time is affected by exogenous factors beyond its control, such as the arrival of the MEDIC ambulance. It is possible that this association between time and wealth is related to ambulance response time, which can inflate the ON SCENE time of fire units if the ambulance has a longer response to the scene. Under such circumstances, the fire unit ON SCENE time is artificially inflated while the unit waits for the ambulance to arrive. Taking this into consideration, the model provides information to support a more thorough investigation into the possibility that more affluent persons are likely to request assistance from the emergency services more often for time-sensitive situations.

6.5 Data Problems and Caveats

Modeling time for emergency units based on demographic characteristics proved to be a challenge, because whether aggregating TOTAL TIME or ON SCENE time numerous exogenous factors influence the measures. TOTAL TIME is not as problematic to measure as ON SCENE time, because the factors affecting TOTAL TIME still render the unit not available to respond to additional emergency situations. The purpose of calculating this measure was to capture not only every type of incident, but also travel time to these incidents. Averaging the total time for all units assigned to an incident is somewhat problematic, because outlier times can skew the measures. This situation occurs, for example, when multiple units are dispatched to a fire event that is extinguished quickly by firefighters or by an installed sprinkler system. Under such conditions, all but one or two units will be released from the incident, while the remaining unit(s) is likely to remain on location for an extended period removing water or waiting on a responsible party for the building to arrive and assume control.

Such situations will inflate TOTAL TIME. In the end, TOTAL TIME is a catch all measure for the average amount of time units are not available to respond to other incidents. This is an important measure for evaluating unit availability across block group areas based on demographic variables. Areas with inflated TOTAL TIME may indicate an increased chance the unit assigned will not be available to respond to an additional incident. In such a situation, a simultaneous incident will require a unit(s) from outside the area to respond, lengthening the response time which could be a problem if the incident is time-sensitive. Therefore, areas with low unit TOTAL TIME should be at less risk based on unit availability.

The more problematic issues revolve around the ON SCENE time measures, which have the potential to be influenced by a myriad of external factors. The main factor, especially related to medical incidents, is the time it takes for a MEDIC ambulance to arrive. MEDIC uses a fluid deployment system to locate its units. The system measures historical call volume statistics for different time periods of each day to locate its limited emergency resources. Therefore, ambulances are often more concentrated in high demand areas. This creates an interesting relationship between the fire resources, which are distributed in greater numbers more equally across the city than are MEDIC units. It is possible that the inverse association between ON SCENE time and WEALTH is more a reflection of the ambulance deployment methodology than incident severity. This would occur if MEDIC, recognizing lower demand in wealthier areas, shifted its resources to favor higher demand areas within the city. Therefore, when a medical incident occurs, no matter severity, in more affluent areas the ambulances are more likely to have longer response times. Under such conditions, the fire unit might have an inflated ON SCENE time not related to the type incident, because of the additional time spent waiting on the ambulance to arrive. Although this cannot be confirmed through the existing data set, it is plausible and deserves further consideration.

Another issue with ON SCENE time for medical situations is that the measures become compressed, limiting variability. Based on medical standards of care, units should not remain on scene for much longer than 10 to 15 minutes for the most severe situations. In fact, units may spend more time on non-emergent events because there is no medical reason to rush the patient to a hospital. Not having access to the actual patient care data reports makes it somewhat precarious to infer allocation decisions based on these models, because of the many threats to validity.

6.6 Discussion

The three models formulated to predict time emergency resources are engaged responding to and managing incidents with the demographic explanatory variables at the block group level provided mixed results. Once again, the economic indicators proved to be important for predicting unit workload. Units responding to incidents within areas that have more wealth will spend more time managing incidents. The causal effects of these findings are less clear, because there are certain threats to validity that cannot be controlled. Each of these threats has been described and requires further research to more thoroughly assess the true relationship between these variables. However, the data does provide initial findings that are consistent with the hypothesized relationships. For example, one would expect units to spend more time on scene at incidents occurring in areas with more affluence based on the literature and DEMAND models. Although DEMAND declines as WEALTH increases, it appears that the incidents in more affluent areas are more severe or at least require more time to be resolved than in lower income areas. This is further substantiated by the high number of cancellations and false calls received in lower socioeconomic areas of the city, which indicate a low threshold for requesting assistance from the local emergency services.

The wealth effect is important to predicting DEMAND and workload for emergency resources, but building age and the young were also significant in the ON SCENE time model. Building age was expected to influence ON SCENE time measures, because of the documented increased fire risk older buildings pose. However, this relationship was not supported by the analysis, which indicated that older buildings are associated with less ON SCENE time. This finding is likely spurious, influenced more by the risk factors associated with those who reside in older buildings than the buildings themselves. Another curious finding, only because the DEMAND models indicated a relationship contrary to that hypothesized, is the positive association with the young. Areas with higher percentage of persons under the age of 18 were associated with longer ON SCENE times, which were expected because this age group is perceived to be at increased risk for fire or medical situations.

6.7 Summary

The information derived from these models provides more of a foundation to build on than conclusive evidence on which to base a new deployment model. The major problem is the threats to validity associated with the time variables. It is possible that each of the variables are valid measures; however, more detailed review of the data must be undertaken before claiming with a high level of certainty that the information is valid. The most significant threat is to the ON SCENE time measures which are influenced by the response time of the MEDIC ambulance unit, among other factors. In particular, this is most problematic when trying to use time as a proxy for assessing incident severity. MEDIC utilizes fluid deployment strategies, which involve predicting demand based on historical response data. Therefore, it is possible that fire apparatus ON SCENE time for

EMS incidents is a reflection of MEDIC's deployment model, which changes by the hour as trends in demand shift. This compromises the ON SCENE measure as a proxy for severity. However, these measures are valid for assessing TOTAL time and ON SCENE time if evaluating the likelihood of unit availability across block group areas. Under such circumstances, the ON SCENE time reflects the true emergency service environment fire units respond within. For example, if the positive relationship between WEALTH and ON SCENE is caused by the deployment strategy utilized by MEDIC, which allocates fewer resources to lower demand areas, then such information is valid to consider when allocating fire service resources. In many ways the actual reasons for more extended ON SCENE time measurements in wealthier block groups is irrelevant, if the extended time is predictable. This still permits deployment decisions to be adjusted for such conditions, which impact unit availability.

When a fire unit is ON SCENE caring for a critical patient, extinguishing a fire, or waiting for an ambulance, the unit is not available to respond to other incidents. The challenges to validity for using time as a measure of incident severity may be problematic, but the information does provide important insight into factors associated with extended or shortened time periods units spend responding to and managing incidents based on demographic characteristics. This is important information for making allocation decisions, because the more time units spend unavailable the more risk their response area assumes. When combined with the information derived from the DEMAND models, this information is logical and telling about the emergency services environment. In short, the same demographic characteristics related to more DEMAND are also related to shorter ON SCENE and TOTAL time units are unavailable to respond across block group areas. Regardless of severity, this indicates that locating emergency units based on DEMAND or TIME is problematic, since these two measures work against each other. Average time calculations also conceal some of the details of the response information. For example, a high demand area could sustain more critical events than a low demand area, but the larger number of incidents when averaged together diminishes the impact on the analysis of the longer duration incidents.

In the end, more detailed incident level information needs to be collected to substantiate many of the findings related to these three models. It is relatively easy to infer from the findings some information that is useful to developing an alternative methodology for allocating scarce emergency resources. However, the block group level data on its own does not provide the detail necessary to confidently extrapolate each of the findings into the practical application of locating resources. The threats to validity have been noted and do cause one to pause when analyzing this information. However, the data does reveal some interesting correlations that provide a solid foundation for further study not only to substantiate the existing information, but also to have more confidence in the findings. The practical application of this information depends on ensuring a high level of confidence in the models.

CHAPTER 7: CONCLUSION

7.1 Introduction

This analysis produced numerous usable models to predict emergency service demand based on demographic population characteristics measured at the block group level. The city of Charlotte served as the study area, where data on the block group characteristics and emergency service response information was collected to conduct the research for this dissertation. A combination of bivariate correlations and multivariate linear regression was used to measure the relationships between the emergency response data and explanatory variables to build coherent models of demand and unit workload across the block group areas. These models demonstrated that the economic condition of persons residing in these homogenous areas were strong predictors of emergency service demand and workload. This information lays the groundwork to formulate an alternative model to locate emergency service resources more systematically across local jurisdictions to maximize service delivery outcomes.

The distribution of scarce resources challenges public sector agencies at all levels of government. These agencies are often castigated as being inefficient and ineffective, yet they are constrained by the ideals of the public sector to deliver services in a fair and equitable manner. These predominantly political constraints can be problematic when locating emergency service resources, because demand for these services is not equally distributed across local communities. This dissertation has put forth and tested a theory that population demographic characteristics drive demand for emergency services. By modeling these relationships, public sector decision-makers should be able to better locate these resources to enhance service delivery. Current resource allocation methodology often demands that decision-makers distribute emergency service units equally throughout local communities without regard to demand for these services. This leads to an unequal distribution of workload on the emergency service personnel. It also disenfranchises certain sectors within a community by delivering more service assets to low demand areas, while high demand areas receive inadequate resources to provide a comparable level of protection. Using this even-distribution strategy to allocate emergency service resources ignores the drivers of demand for these services, which arguably are demographic characteristics associated with wealth and education levels found within these areas. This research attempts to substantiate the relationships between demographic variables found at the neighborhood level (block group) and demand for emergency services to help guide the development of an alternative model to locate these finite resources to maximize outcomes.

In addition to exploring resource demand drivers, an effort is also made to model the relationship between demographic characteristics found in the population and the time emergency units spend responding to and managing calls for service. In particular, two models were formulated. The first tested the relationship between demographic characteristics and the total time units spent managing emergency incidents. Total time captures the time from when a unit is dispatched to the time the unit is available to respond to another incident. This measure includes calls in which the unit was cancelled prior to arrival on scene, and all other responses for each block group. A second model utilizes on scene time as the dependent variable. The time units spend on scene across block groups does not include cancellations, because for cancelled incidents the responding units never arrive on scene to record a valid time for the measure. Therefore, only those incidents where a unit actually arrives were included in the models. This measure is theorized as a proxy for incident severity and workload across the block group areas. Time is an important factor to the emergency services because consumption is rivalrous, meaning that when simultaneous emergency situations occur in the same response area a unit from another area must respond. This is problematic because the response times are extended and the area where the unit responds from is without protection for the duration of the incident.

7.2 Problems with the Current Locational Methodology

The findings derived from this research challenge the established model for locating emergency resources used by local decision-makers across the country. The current locational model is problematic for two particular reasons: 1. Emergency resources are scarce and 2. Emergency service agencies are subject to managing simultaneous incidents. The fact that resources are limited means that public decision-makers must make hard choices about how to distribute these resources, which is influenced by a myriad of factors and interests. The fire service, among other public sector agencies, is famous for complaining that service delivery is ineffective because of inadequate resources. The lack of ingenuity and pressure from exogenous interests paralyze the creation of alternative methods to better allocate these resources. Again, the number one factor is response times, which are directly related to the number of available resources a community can harness. Clearly, the more units spread out in a community, the lower the response times. Exogenous groups, such as the National Fire Protection Administration (NFPA) or Insurance Services Organization (ISO), place significant pressure on fire service administrators to locate units in a way that reduces response times to all areas of a defined jurisdiction (Granito, 2003).

Response time benchmarks espoused by the NFPA and ISO are partially derived from efforts to limit loss of life and property resulting from low probability emergency events, which include structure fires and cardiac arrests (Shpilberg, 1977). The goal to arrive on scene within four minutes of the dispatch is to contain fires before flash over and improve the chance of reviving victims suffering cardiac arrests.[4] These and other situations emergency service personnel manage are time-sensitive events, meaning the faster that units arrive on scene the better chance to prevent the loss of life and property (Kuehnert, 1999). However, the majority of incidents that emergency service personnel respond to are not time-sensitive situations where the outcome will be affected by a sub four minute response time. As is substantiated in the literature, certain demographic characteristics are linked to increased risk for being afflicted by a time sensitive emergency situation. In addition, persons with fewer economic resources rely more heavily on emergency services than those who are more economically stable (Gamache, 2003; Lipsky, 1980). Recognizing that emergency service resources are limited yet attempting to distribute them evenly has the effect of disenfranchising areas with more people and areas that have demographic characteristics consistent with increased risk. In

[4] Flash over is defined as the stage of a fire at which all surfaces and objects in a room or area are heated to their ignition temperature and flames develop on all contents and combustible surfaces at once (Brannigan & Corbett, 2008). The probability of a person suffering cardiac arrest (heart stops beating) to survive declines by about 10% for every minute care is not provided (cardiopulmonary resuscitation). Therefore, after 10 minutes in cardiac arrest without care a person statistically has zero chance of survival. Each of these events is extremely time sensitive.

effect, public decision-makers who espouse distributing these resources evenly place a higher value on statistical lives of those residing in lower risk and lower density areas of a community (Felder & Brinkmann, 2002).

The service delivery limitations of scarce resources are further exacerbated by the opportunity for simultaneous emergency incidents to occur in the same response area. This creates numerous challenges for emergency service units, but in particular it nullifies the benefits of using response time as the primary benchmark for locating resources evenly across a community. As Peters and Hall (1999) note, once units begin to respond to calls for service, response time becomes a random variable. Therefore, the logic behind the current deployment model to place an emergency resource within a certain response time of every person in a community becomes ineffective. Because areas with higher demand and more severe incidents will overwhelm the assigned emergency resources, all additional calls for service will result in extended response times. This is a reason that time units spend responding to and managing incidents was calculated for each block group and compared to demographic characteristics. Presumably, block groups with characteristics associated with units that spend more time responding to and mitigating incidents will be at greater risk based on the current locational strategy, because the more time a unit assigned to an area is unavailable the greater likelihood of a simultaneous incident occurring.

7.3 Jefferson versus Hamilton Allocation Strategy

Emergency service decision-makers continue to apply a methodology that relies on response times to evenly distribute emergency resources despite the inefficiencies and service delivery problems with this framework. The hesitancy to be innovative and use data to better inform locational decisions is ignored by public sector decisions-makers for a myriad of reasons. Much of the reason for this is the political and institutional culture of the public bureaucracy, which on the whole subscribes to a more Jeffersonian ideology for organizing public sector service delivery (Wood & Waterman, 1994). As Sylves (2004) points out in his paper about emergency managers, leaders who follow a Jeffersonian system work to organize service delivery to satisfy political interests that pervade a community. This is in contrast to organizing service delivery based on outcomes, which is espoused by Jefferson's counterpart Alexander Hamilton. Hamilton, according to Sylves (2004), argues that public services should be delivered based on outcomes derived from empirical analysis. The idea of "Customer satisfaction in government has a ring of Jeffersonianism" (Sylves, 2004, 31). A clear principal-agent relationship exists between the "customers" and emergency service managers, just as a relationship exists between these managers and the political representatives, which drives the emphasis on equal distribution of resources among the public. Although politically appeasing, such a strategy may not maximize potential outcomes from the limited emergency service resources available.

Unfortunately, the information or data required to make more proactive locational decisions to maximize outcomes is often not readily available (Swersey & Ignall, 1991). As Sylves (2004) points out, the data that is collected by public sector bureaucracies is often "coded," making it extremely difficult to draw out meaningful findings to improve service delivery. Public sector data, such as performance measures and budgets, are challenging for outsiders of the bureaucracy to decipher, because the numbers do not always provide a clear picture of service delivery. This situation proved prophetic for completing this dissertation. A great volume of data is available on the fire service, but it is often basic, hard to access, difficult to interpret, and at times inaccurate. Because of this, it is challenging to meet the ideals of Hamilton's theory on organizing public sector service delivery based on outcomes. This is one reason public sector managers often default to the Jeffersonian way of delivering public sector goods and services (Sylves, 2004).

The purpose of this research is in many ways an effort to stimulate a more Hamiltonian methodology to locate and manage local emergency services. This requires empirical analysis of the data to find better ways to generate more positive outcomes, which requires proactive policies. Here again is a major stumbling block to changing the current method for allocating emergency resources. As Leeson (2007) describes in his analysis of the government's response to Hurricane Katrina, public sector officials have an incentive to be reactive and overly cautious when formulating policy to avoid committing "type I policy errors." These are errors that result when a proactive policy falls short of its goal or does not provide the intended benefits. These policy errors are problematic for politicians because proactive policies are overt, which is in stark contrast to reactive policy initiatives. Reactive policies are subject to "type II policy errors," but these errors are less costly to political actors because responsibility for such failures is more diffuse. This makes it difficult to hold specific policy makers accountable. The current locational model is reactive and generates endless "type II errors." However, it is difficult to identify those who are most harmed by such a policy because when an emergency unit does not arrive in a timely manner, the "customer" does not have the information to understand the reasons behind the delayed response or whether the delay increased loss. This information asymmetry creates a moral hazard situation, which benefits the agent (fire department) who is not held accountable for the misappropriation of resources (Friedman, 2002). This provides an incentive to policy makers to maintain the status quo for locating scarce emergency resources.

Allocating emergency resources based on demand for these services would require proactive policy initiatives derived from statistical analysis of data. Such actions would draw the attention of the public, especially as emergency resources were moved from one location to another to satisfy demand. One can imagine the citizens' concern when they are accustomed to seeing two fire apparatus in their area fire station, and then one day they notice there is only one. The perception would be of decreased protection, which would not become a significant problem until a high profile incident occurred resulting in loss of life and property. At this point, the political pressure could become intense, as residents blame the loss on the public sector decision-maker's proactive policy to shift an emergency resource from their area to a higher demand area.

When decision-makers implement proactive policy initiatives it is easier for the public and other principals to identify victims if failures occur, which increases political scrutiny (Leeson, 2007). It does not matter whether the proactive policy led to more effective and efficient locational decisions that reduced overall loss of life and property, because the costs, no matter how big or small, are more visible, while any benefits remain unclear and hidden to the average observer. This is not the case with policy initiatives that encourage equal distribution of scarce emergency resources, which are reactive in nature, as it is almost impossible with such policies for the public or even the agents to identify victims when failures occur. Therefore, there may be many costs and few benefits associated with a reactive policy, but the inability to clearly identify these costs make reactive policies appealing to government officials who fear public scrutiny.

The incentive structure in the public sector favors reactive policies and a commitment to more Jeffersonian ways of managing service delivery. This impedes public managers from being innovative when locating emergency service resources (Sylves, 2004). In addition, the emergency service environment is highly dynamic. This makes it difficult to predict demand with enough confidence to overcome the incentive to be reactive, which became evident in performing this analysis. There are simply incalculable influences on demand, only a very few of which can be measured. An effort was made to identify some factors that drive demand for emergency services in an effort to build a model for locating these scarce resources more effectively through proactive policy initiatives.

7.4 Review of Empirical Findings and Analysis

The empirical findings from this research support the ability to develop an alternate means to locate resources to improve service delivery based on scientific data analysis. Although this analysis just scratched the surface of such an effort, the findings provide a foundation to build upon. The analysis was based at the Census block group level, because these groups most closely reflect the naturally formed neighborhood areas in most communities. The block groups, like neighborhoods, are demographically homogenous, providing valid measures for assessing emergency service demand (Ostrom, 2000). In addition, emergency resources are often located throughout communities in a manner that permits the response areas for fire service units to correlate with the block group boundaries. For the most part, the unit or units located in each fire station have a primary response area that usually includes three to five block group areas. When conducting this analysis all information was calculated for each block group, and not based on unit response areas.

A myriad of theoretical models to predict emergency service demand were formulated based on the explanatory demographic characteristics. Multivariate least squares regression was used to evaluate the capability of the models to predict emergency service demand at the block group level. The explanatory variables can be placed into three categories: economic, structural, and social. Specifically, the economic measures were household income, percent of persons receiving food stamps, percent owners versus renters, and percent of persons 25 and older completing high school. Structural measures included average building age, percent of appearance violations, and percent of code violations. In addition, the variables for percent of persons over 65 years of age and percent of persons under 18 years of age were included as explanatory social variables. Because of some collinearity issues with the economic variables, a factor was calculated to combine INCOME, OWNER, and EDUCATION. All explanatory variables were included in each analysis to predict demand.

A majority of the hypothesized relationships between the dependent and independent variables were substantiated by the analyses. The economic variables proved most important in each of the demand models. FOOD and WEALTH were significant at the 0.05 level in the models for overall demand, fire demand, EMS demand, and cancellations. These findings substantiated the hypotheses stated in Chapter 3 that economic status is inversely associated with demand for emergency services. Such findings were expected because as wealth increases so does one’s ability to purchase fire and medical goods from the private sector to lower risk. For example, more wealthy persons are likely to invest in fire prevention and detection products, such as smoke detectors or monitored alarm systems to reduce fire risk. In addition, those with more resources and education clearly have a higher threshold for requesting assistance. This can be inferred from the correlation with reduced demand and is further substantiated by the inverse relationship with cancellations and miscellaneous calls. It appears that in wealthier and more educated areas citizens are less likely to utilize the emergency services for non-emergent events, which is consistent with the literature that those with less wealth rely more heavily on the public sector (Lipsky, 1980).

The structural characteristics did not provide much predictive power based on the model statistics. The age of buildings across block group areas was weakly correlated to demand, but not to the extent that was hypothesized. The percentage of appearance and code violations across block group areas proved not to be significant in most of the models. These findings were somewhat puzzling, but point to the idea that individual characteristics are more influential in determining risk of fire and medical events, than structural characteristics in and of themselves. Older buildings may be more prone to fire because of construction techniques, antiquated wiring, and/or insufficient fire protection systems. However, building age is certainly less influential on emergency service demand than the persons who occupy the buildings, which appear to be captured best by the economic measures.

The remaining explanatory variables measured differences in population age. These variables included the percentage of persons over sixty-five years old and less than eighteen years old found in each block group area. Both variables were hypothesized to be positively associated with demand, because these age groups have been identified to be at increased risk for fire and medical events. The percentage of people over sixty-five years old was not significant in any of the demand models, and all of the bivariate correlations were extremely weak. The variable for percentage of young or those under eighteen years of age was significant at the 0.05 level in each of the demand models; however, the relationship was opposite of that hypothesized. To better understand these relationships with the social variables more data needs to be collected. It is unclear whether, for example, measuring youth between 0 and 18 is too large of a range, and whether the findings are spurious or legitimate. While the information serves as a catalyst to perform more analysis, it is not a proxy for action.

On the surface, the demand models indicate that economic status of persons in a community is a strong predictor of emergency service demand. Clearly, those who have more are less likely to use the emergency services; however, these findings tell little about incident severity, which is a critical component for developing an alternative method for locating scarce resources. Demand is just one factor, because the number of incidents in an area fails to completely demonstrate true need for these services. Therefore, the time units spend in each block group responding to and managing incidents was calculated as a proxy for unit workload and incident severity. Each of the models to test the stated hypotheses for TOTAL TIME and ON SCENE time on their own proved inconclusive. Again, the economic variables were the most predictive in each of the models, indicating that socioeconomic status is associated with the workload placed on the assigned emergency units across block groups. In particular, WEALTH was positively associated with ON SCENE time, while FOOD STAMPS proved insignificant in this model. In addition, BUILD AGE was inversely associated with ON SCENE time. In the model to predict TOTAL TIME, FOOD STAMPS had a significant (0.05 level) inverse relationship with TOTAL TIME. Although many factors threaten the validity of findings from these models when evaluated independent of other information, they are quite informative when compared to the information derived from the demand models.

In short, the demand models indicate that distressed economic areas utilize the emergency services more frequently than more wealthy areas. As economic status declines within block groups, the demand for fire and medical emergencies rises along with demand for miscellaneous or non-emergent assistance and the number of cancelled incidents increase. This is combined with the findings that more wealthy areas are inversely associated with cancellations and miscellaneous incidents. Based on this information, one might suggest simply locating more emergency resources in low income areas because they appear to be more likely to have fire and medical events than the more wealthy areas. However, the associations established between economic status and the propensity to call for non-emergent (MISC) situations or the likelihood of a cancelled or false call raise other questions about locating resources. Economic stability appears to be associated with lower demand, but when assistance is requested in these areas the data suggests a higher probability that the incident will be time-sensitive. Although not conclusive, it is reasonable to infer that more wealthy areas have a much higher threshold for requesting assistance from the emergency services than distressed areas. This is further substantiated by the TOTAL TIME and ON SCENE models which, at the very least, indicate that emergency units on average spend more time in the more wealthy neighborhoods responding to and managing incidents.

The time models, when compared to the demand models, paint a clearer picture of the relationship between demographic characteristics and need for emergency service assistance. Areas with more wealth are less likely to call for assistance, but when they do units will spend more time mitigating the incident situation. One can infer that based on this comparison, calls for services in more economically stable neighborhoods tend to be more severe, since overall they require more time to mitigate. This is further substantiated by the opposite situation in the lower income block groups, where time units spend responding to and managing incidents is inversely associated with economic conditions. Based on the demand models, persons residing in economically distressed block groups have a higher propensity for calling 911 for situations that are minor in nature and do not require much time for emergency service personnel to mitigate. The significant positive relationship between lower economic conditions and cancellations and miscellaneous incidents also indicates that persons in these areas use less discretion when deciding whether to call for assistance. Some of this lack of discretion is explained by limited alternatives. A person who does not have healthcare coverage or cannot get a landlord to respond to a broken water pipe is left with few options but to request assistance from the emergency services. Although this raises demand, these are not time-sensitive incidents, and could be treated differently to better allocate resources toward those areas where potential loss of life and property are more likely based on demographic characteristics.

In many ways the findings presented in this research are conflicting, especially for developing an alternative methodology for locating emergency resources. On the one hand, it is evident that certain demographic characteristics are associated with more or less demand for these services. However, the same characteristics associated with decreased demand appear to be associated with a higher likelihood of time-sensitive incidents, while those characteristics associated with higher demand are also linked to more non-emergent situations. Yet these findings are descriptive of the emergency environment and quite informative for evaluating where to locate emergency resources to better maximize outcomes. This is best exemplified in a qualitative thought experiment, which applies the information derived from this analysis to the actual emergency service environment.

7.5 Economic Outlier Block Group Comparison

Two outlier block groups were identified based on economic conditions to evaluate the types and numbers of emergency incidents. To identify these block groups, the high and the low measures for each of the four economic variables were used: OWNER, INCOME, FOOD STAMPS, and EDUCATION. Although no block group contained the high or low extreme for all four variables, two block groups did stand out based on the numbers. The two block groups selected were linked to the neighborhood area each sits within to provide more contexts for the discussion. At the low end, the Southside Park/York Road neighborhoods located in the west side of the city had the lowest household income, lowest high school graduation levels, less than 5% of the population own their homes, building age far exceeded the mean across the city, and food stamp eligibility was well above the mean city average making this one of the most distressed areas based on economic conditions in the city of Charlotte. On the other end of the wealth spectrum, the Foxcroft neighborhood, located on the south side of the city, had the highest household income levels, over 95% are high school graduates, 80% are homeowners, and no one is receiving food stamps. A table of these findings is provided below.

Table 9: Demographic Information for Outlier Areas

Comparison of Demographic Information for Outlier Areas	**Mean Values**	**Southside/York Road**	**Foxcroft**
Food Stamps	0.1099	0.3493	0.0000
Owner	0.5270	0.0565	0.7902
Income	$52,877	$9,999	$176,852
Education	0.8187	0.3784	0.9501
Build Age	32.50 years	46 years	32 years

These two outlier neighborhoods depict the gap between economic conditions that exist within the city of Charlotte, which puts into perspective the challenges associated with allocating public goods and services. The demand for emergency services and types of incidents that occurred in each of these neighborhoods is almost as striking. A table of incident types is provided below.

The difference in demand associated with economic condition is clearly demonstrated in Table 10. What is not clear is the severity of incidents and their time-sensitive nature. The ability to relate this information to the demographic variables would make it more evident where resources should be located to maximize incident outcomes. What is evident though is the availability of units that could be gained in each of the areas if responses were based on incident severity. For example, if units had either not responded or responded but remained available to the miscellaneous situations and alarms in the Southside/York neighborhood area, the overall workload or demand on these units would fall by almost 100 incidents. Such a change in response strategy would certainly mean that units would be available more time during a day, which would result in a lower probability that a time-sensitive emergency would receive a delayed response. It should also be noted that response time to the Foxcroft neighborhood is shorter than that to the Southside/York neighborhood. This likely indicates that simultaneous incidents are occurring in the Southside/York area, requiring units from other areas to respond more often.

Table 10: Response Data for Outlier Areas

Comparison of Response Data for Outlier areas	Southside/York Road	Foxcroft
Total Incidents	575	43
Incidents per 100 persons	40.41	6.99
Total Fire Incidents	31 (5%)	1 (2.3%)
Fires per 100 persons	2.18	0.16
Structure Fires	13	0
Other Fires	18	1
Total EMS Incidents	369 (64%)	20 (46.5%)
EMS per 100 persons	25.93	3.25
EMS w/o motor vehicle	325	16
EMS w/ motor vehicle	43	4
Total Alarms	50 (8.7%)	13 (30.2%)
Total Cancelations	68 (11.8%	3 (7%)
Total Miscellaneous	40 (7%)	6 (14%)
Average TOTAL TIME	18 minutes, 12 seconds	17 minutes, 41 seconds
Average SCENE TIME	12 minutes, 2 seconds	13 minutes, 13 seconds
Average Response Time	4 minutes, 56 seconds	4 minutes, 29 seconds

7.6 Locating Resources Based on the Findings: A Practical Application

The city of Charlotte continues to grow in population and area as people move from other locations and the city annexes unincorporated land. Since 2005 the Charlotte Fire Department has built three new fire stations and is considering two more in 2009. Recently, in December of 2008, a station with one engine company was placed into service at the intersection of Pineville-Matthews Road and Providence Road (Arboretum area) in the south side of the city. Concurrently, the city was also considering whether to build a station on the east side near the intersection of North Sharon Amity and Central Avenue (Eastland Mall area). This situation provides another opportunity to use the findings from this analysis to quantitatively evaluate these locational decisions based on demographic characteristics and potential future demand for services. Below is a table of the demographic characteristics for each of these areas. As with most fire stations across Charlotte, the primary response area consists of about five block group areas. Therefore, the five block group areas closest to the subject fire station locations were selected for the following comparison. The demographic measures were averaged across the five areas for each station location..[5]

Table 11: Station Location Comparison Information

Demographic Comparison for Station Location Areas			
	Mean Values	**Eastland Area**	**Arboretum Area**
	(n=331)		
Food Stamps	0.1099	0.1499	0.0111
Owner	0.5528	0.3397	0.6277
Income	$56,478	$41,024	$77,733
Education	0.8228	0.8264	0.965
Build Age	34.3	33.4	20.4

[5] Station #39, which is located at the Arboretum, was placed into service December 2008. The Eastland block group area does not have a fire station.

The demographic data presented in Table 11 indicates the stronger economic conditions in the Arboretum area of the city versus those found in the Eastland area. Based on these numbers and the findings in the analysis, it is expected that demand for emergency services in the Eastland area will exceed that in the Arboretum area. Education is comparable across these two areas, but there is a large difference between INCOME, OWNER, and FOOD STAMPS indicating more risk for fire and medical emergencies in the Eastland area. This becomes even more evident when evaluating the number and types of incidents that occurred in each of these areas during FY2006, which is presented in Table 12.

Table 12: Station Comparison with Response Information

Comparison of Response Data for Station Location Areas	**Eastland Area**	**Arboretum Area**
Total Incidents	530	122
Incidents per 100 persons	16.42	5.67
Total Fire Incidents	23.4	6.4
Fires per 100 persons	0.72	0.3
Structure Fires	14.8	2
Other Fires	806	4.4
Total EMS Incidents	356	63
EMS per 100 persons	11.06	3.2
EMS w/o motor vehicle	326.8	61.4
EMS w/ motor vehicle	28	7.4
Total Alarms	33.8	16.6
Total Cancelations	65.4	10.4
Total Miscellaneous	44.2	15.6
Total Fire Losses ($)	$59,504	$17,020
Average TOTAL TIME	18 minutes, 51 seconds	18 minutes, 18 seconds
Average SCENE TIME	11 minutes, 52 seconds	12 minutes, 24 seconds
Average Response Time	5 minutes, 52 seconds	5 minutes, 38 seconds

Based on the demographic and response information, the findings from this research would support placing an emergency services station in the Eastland area over the Arboretum area. The demand differences are stark, but again it is not clear which area is more at risk for time-sensitive fire and medical emergencies. However, the time variables calculated for each block group are telling, especially for decision-makers who are very concerned with reducing response times. The Eastland area block group bucks the trend between time and demographic characteristics that have been established in this dissertation. In this situation, TOTAL TIME and response times to incidents in the Eastland area exceed those in the Arboretum area. Not using time as a proxy for incident severity, these findings do likely indicate that there is an increased probability of simultaneous incidents occurring in the Eastland area, placing additional workload on the assigned units.

The surrounding stations to the Eastland area are the busiest by call volume in the city. The demand for emergency service resources in the Arboretum area is consistent with the demographic characteristics tested for this dissertation associated with decreased demand. The fire stations surrounding the Arboretum area, as opposed to the Eastland area, experience some of the lowest workload based on call volume. Although it is not possible to evaluate incident severity or the potential for time-sensitive events in each of these areas with the available data, one can infer that a time-sensitive event in the Arboretum area would be more likely to receive a timely response than a similar situation in the Eastland area based on unit workload and proximity. The other finding of significance between these two areas is the average monetary losses attributed to fire. The Eastland area experienced three and a half times more monetary loss than the

Arboretum area. Based on this practical application of the demographic characteristics, economically depressed neighborhoods have more need for emergency resources than economically stable areas.

7.7 Future Research Possibilities

The goal at the outset of this dissertation was to predict emergency service demand and workload with enough confidence to use the findings to formulate a new model for locating emergency resources. It is safe to acknowledge that the information derived from the analysis falls well short of this goal. However, the findings are applicable to guiding resource location decisions with some caveats, which is hopefully demonstrated through the practical application examples. This alone makes the research relevant, and hopefully contributes to the field of study. It also should stimulate future research efforts to develop more confident models for predicting demand and incident severity based on demographic characteristics.

Monetary loss statistics across block group areas must also be measured to evaluate whether such losses are associated with certain demographic characteristics. During FY2006, monetary losses attributed to fire exceeded $16.5 million in the city of Charlotte. Modeling these losses could provide further information to guide emergency service resource location decisions to maximize outcomes. Regardless of demand, areas that experience increased monetary losses need additional resources over those that have a lower probability of suffering losses. Clearly, monetary losses are not the only losses that occur from fire and other emergency incidents. People are injured or killed each year from these events, and these statistics must also be included in any effort to find different methods to locate emergency services. How such measures correlate to demand is unclear, but it is likely that the demographic characteristics found throughout the population are predictive of these losses.

Losses associated with fire and other emergency situations are important to evaluate in conjunction with probability analysis to estimate the chance of time-sensitive events and unit availability across block areas. Such analysis requires incident level data to assess incident severity, so that the probability findings derived have a high level of confidence associated with them. Formulating an alternative model for locating emergency resources requires an understanding of the true risk factors for time-sensitive fire and medical events. Although the emergency services environment is highly dynamic, it is likely that models can be developed to locate resources that reduce overall risk to local communities from fire and medical situations that are far more effective than the current distribution model. Political and public sector incentives work against the implementation of such an effort, but to date, little attention has been paid by fire service leaders to innovate and formulate a new method to better utilize limited resources. Such a situation may become a necessity in the future, as demand continues to rise and public sector economic conditions further limit the number of resources available to protect the public.

7.8 Conclusion to the Conclusion

The purpose of this dissertation was to challenge the established reactive locational models that pervade the fire service industry. Fire service leaders continue to spend inordinate amounts of time fighting for additional resources and then complaining when those resources are not granted. The industry has become so reliant on resources to meet response time benchmarks that when the resources are not available effectiveness declines. The reality is that the fire service industry has minimal political capital, because most citizens do not believe they will ever need the emergency services. In addition, these services are human intensive, making them prime targets when funds are reduced to balance budgets. It is true that in the public sector demand will meet supply (Wood & Waterman, 1994), which is a reason the public sector is not capable of operating completely efficiently. However, responsible public sector leaders should be in a perpetual search for new ways to distribute limited resources to maximize outcomes, especially when the outcomes are measured based on number of lives saved and property conserved.

If nothing else, this research provides evidence that it is possible to utilize empirical analysis to evaluate data to guide the development of more effective locational models. It is unclear whether the findings in this research are conclusive to the point that they can be confidently used to alter emergency service resource allocation. However, the practical application of these findings is apparent in the analysis of the city of Charlotte's decision to build a new fire station in the Arboretum area. It is unclear the exact reasons why the Arboretum location was chosen over the Eastland location, but the analysis substantiates the value of the findings from this research. A comparison of the economic conditions across these two areas appears to indicate that one area is economically stable and the other is not. This situation is further substantiated when evaluating the types of incidents in each area, number of incidents, and average times. Information to predict monetary losses and probability of time-sensitive emergencies based on the demographic characteristics further justify locating an emergency service resource in one area over the other. In the end, the fire station was constructed at the

Arboretum location which, if nothing else, does lend credence to the belief that public sector decision-makers are not conducting scientifically driven empirical analyses when determining where to locate scarce resources.

This is not an effort to be critical of the practical allocation decisions made by the city of Charlotte, but it does demonstrate the potential value of this research. Demographic characteristics across block groups are predictive of demand. If these indicators are ignored when locating scarce emergency resources, service delivery and outcomes will suffer. It is unclear what the future holds for the emergency services, but the most likely scenario is that demand will continue to increase while local resources decline. Public sector decision-makers can remain resistant to change or embrace the available information in order to allocate these resources to more effectively prevent the loss of life and property.

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APPENDIX A: SPECIAL APPARATUS

BRUSH TRUCK (5)

Modified ¾ ton standard 4-wheel drive pick-up truck units. These units have a mounted water pump and 250 gallon water tank. A booster reel with nozzle is also included to extinguish brush fires. In addition, these units carry rakes, shovels, and a chain-saw to assist with clearing and extinguishing brush fires. The 4-wheel drive feature allows the trucks to be driven into more remote areas that cannot be reached by standard fire apparatus.

TANKER TRUCK (5)

These apparatus are similar to the engine company design used by the Charlotte Fire Department. The main difference with the tanker apparatus is that each carries 1000 gallons of water and 300 gallons of foam concentrate. The tankers not only provide water when hydrants are not readily available, but are also an integral part of the aircraft crash rescue platform.

HAZARDOUS MATERIAL TRUCK (3)

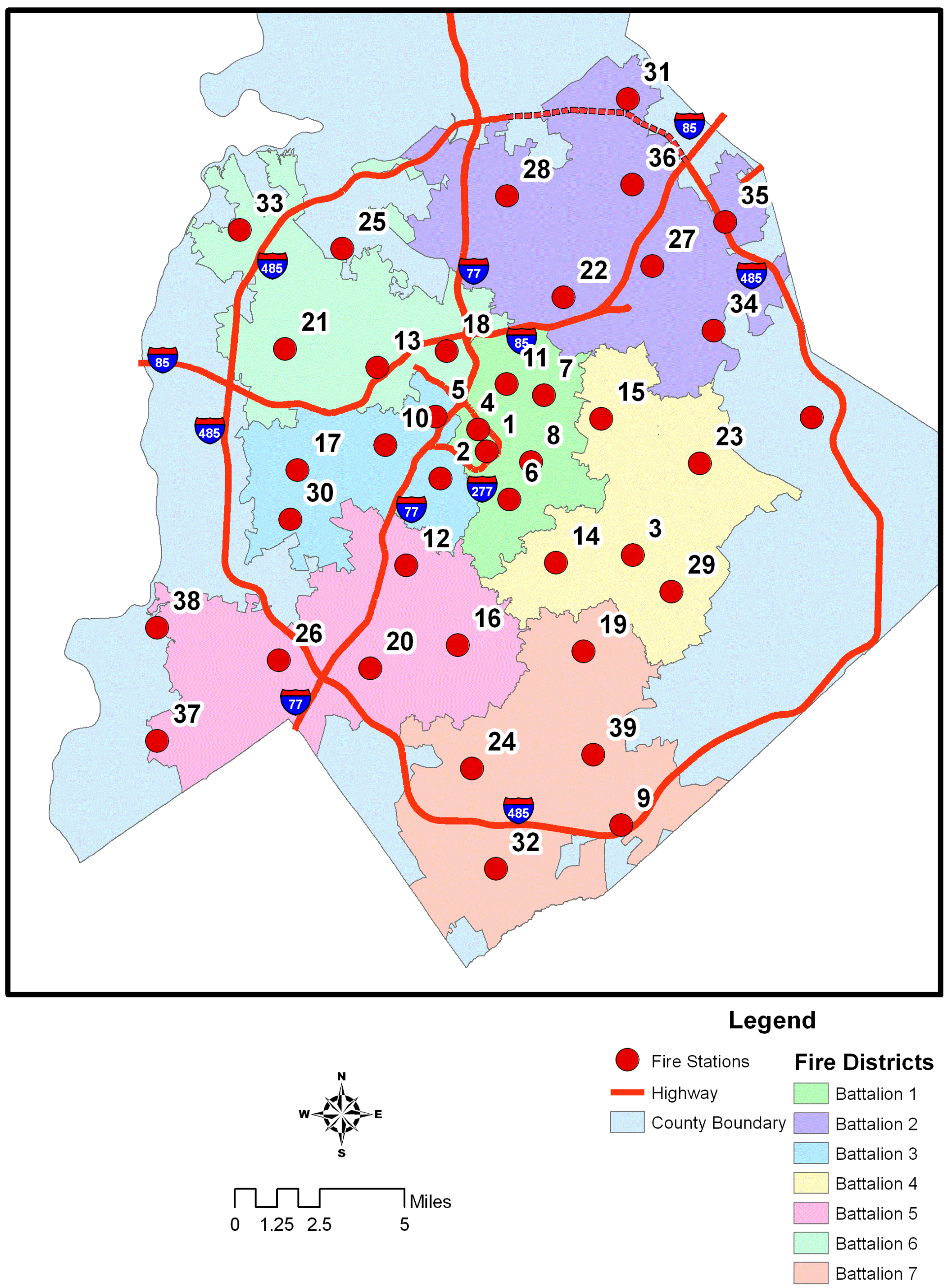
These units are similar to the rescue apparatus, except they carry equipment to manage hazardous material releases. These apparatus carry reference materials and computers to identify chemicals, and the equipment to mitigate, and then decontaminate rescuers who may have come into contact with the hazardous material. These units respond to gas leaks and other hazardous conditions across the region.

URBAN SEARCH & RESCUE TRUCK (2)

Two tractor drawn trailers are stored at Fire Station #11, which contain a cache of equipment for performing trench rescue and USAR operations. Each truck contains raw materials for shoring up building and trench collapses, including saws, hydraulic shores and tools, search cameras, listening equipment, and other assets to affect rescue in collapse situations. Each time these units are dispatched, they respond with a rescue company.

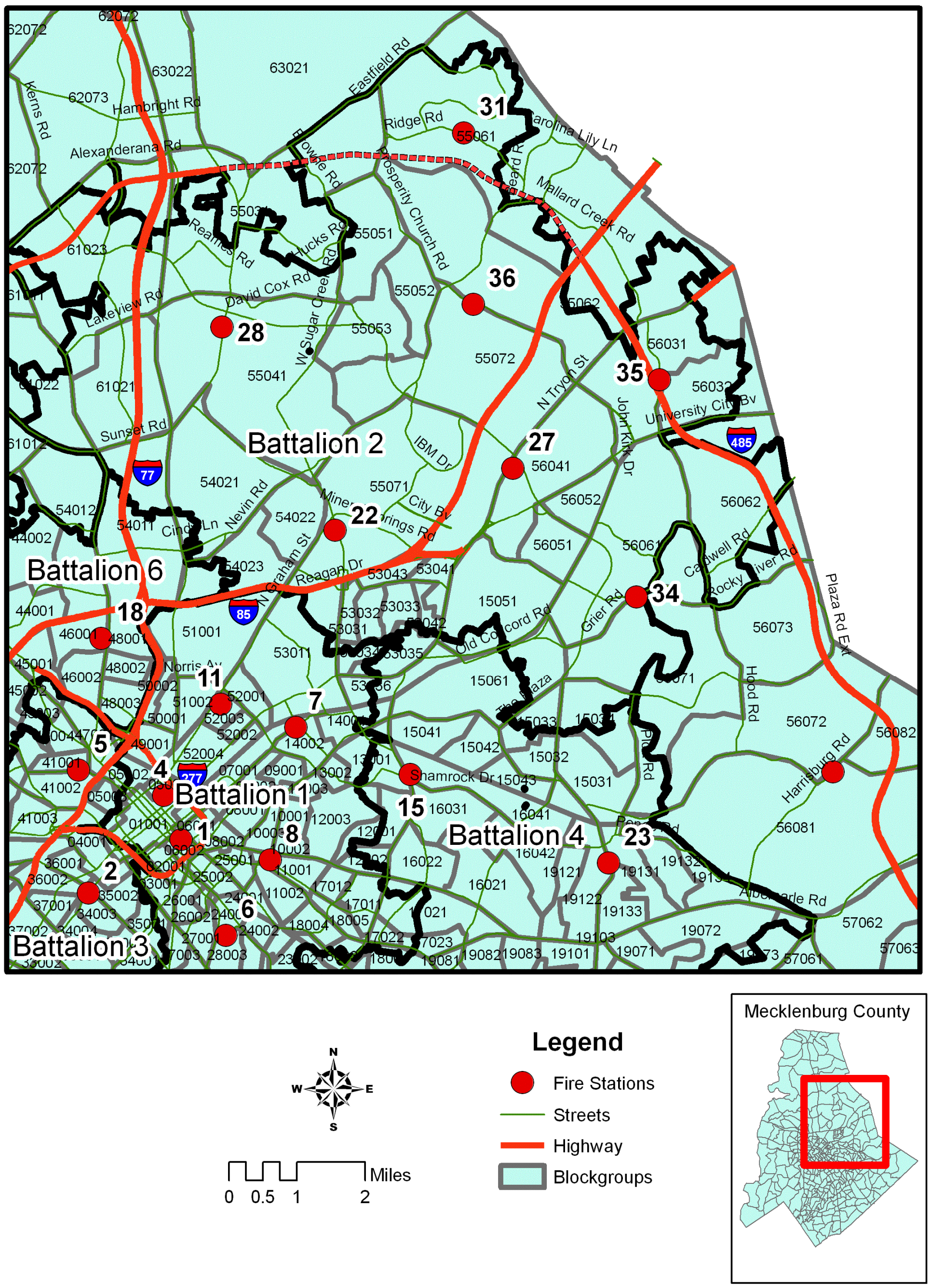
APPENDIX B: FIRE STATION LOCATIONS

Fire Stations and Districts

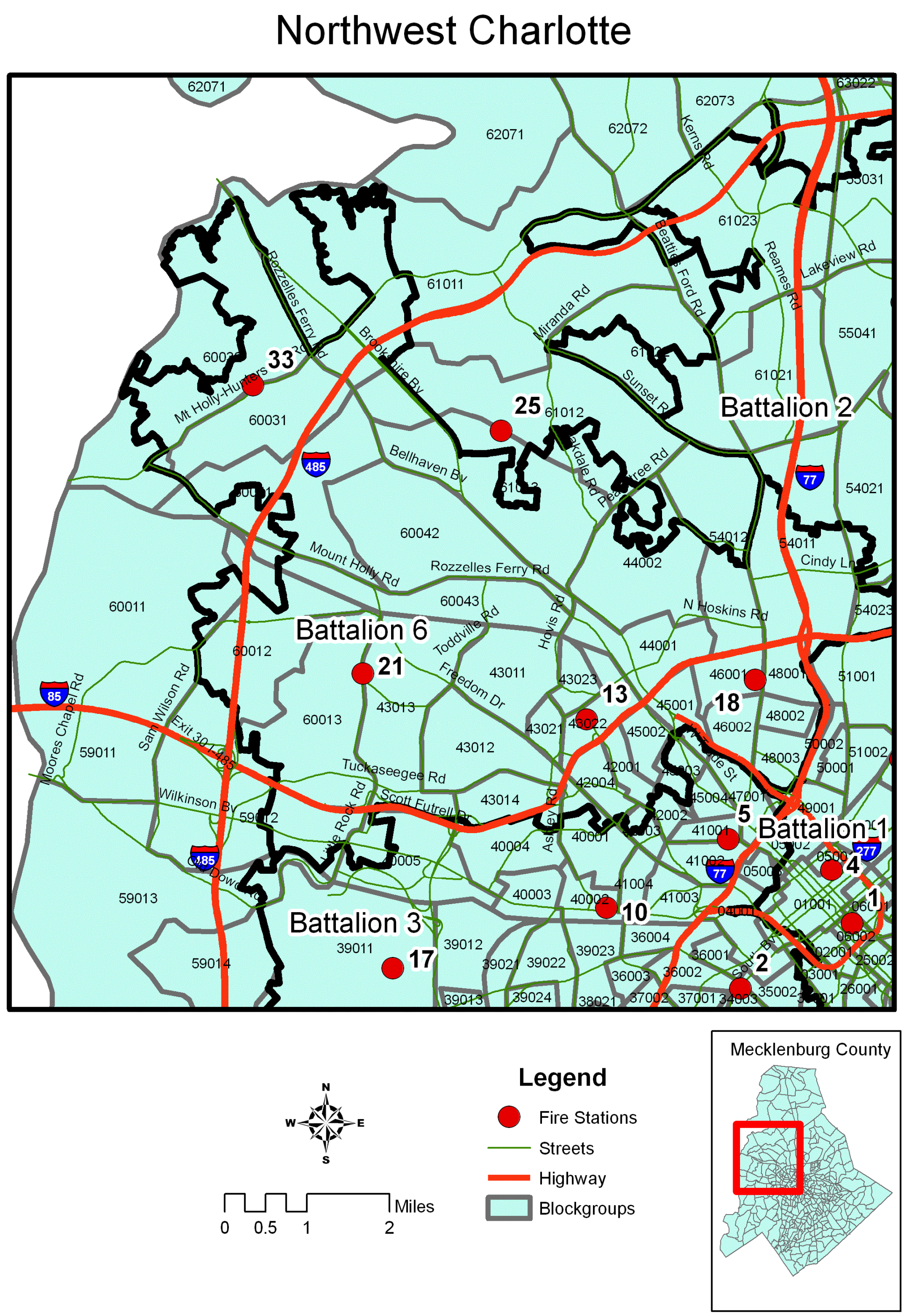


APPENDIX C: NORTHEAST BLOCK GROUPS

Northeast Charlotte

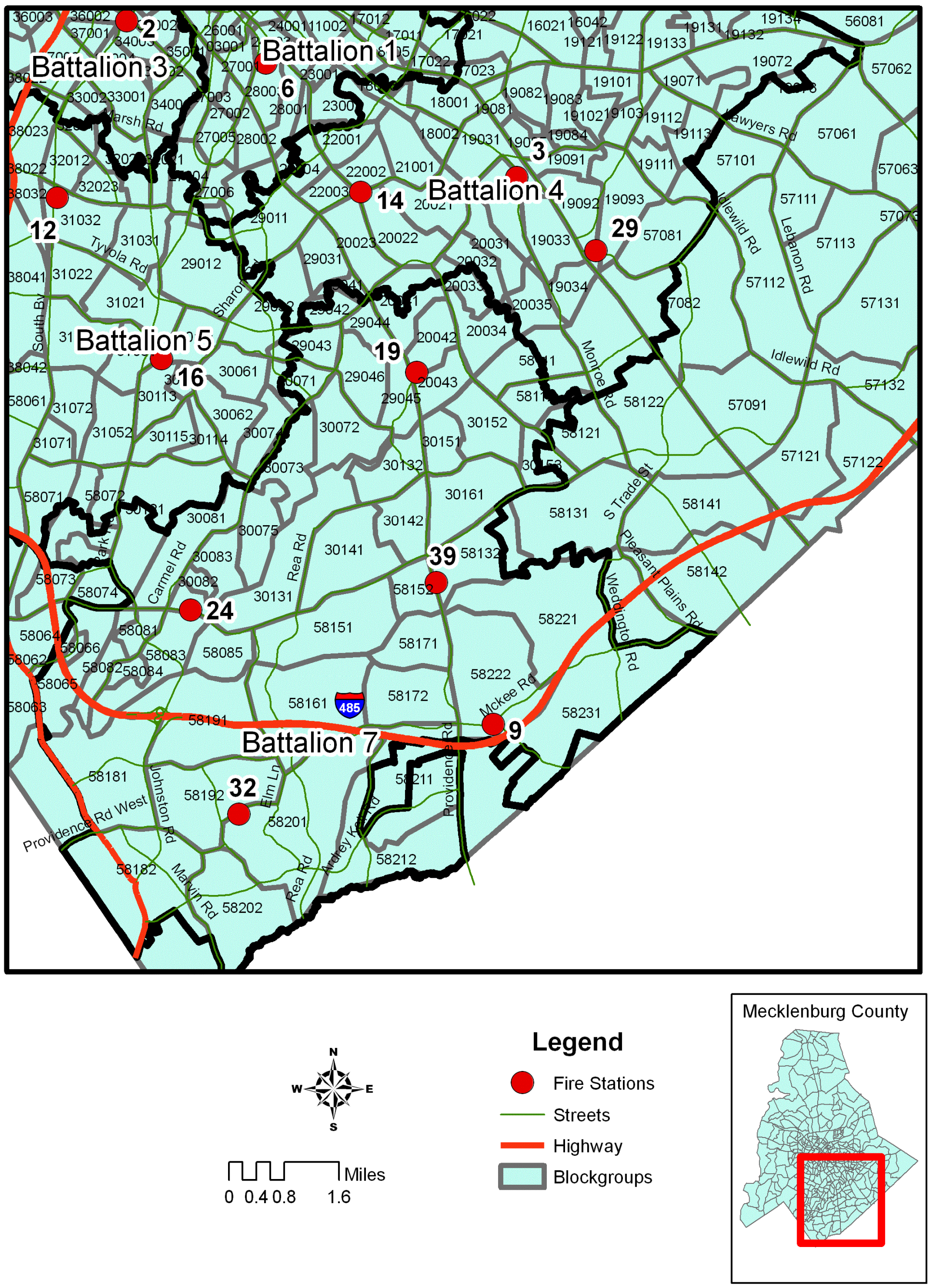


APPENDIX D: NORTHWEST BLOCK GROUPS



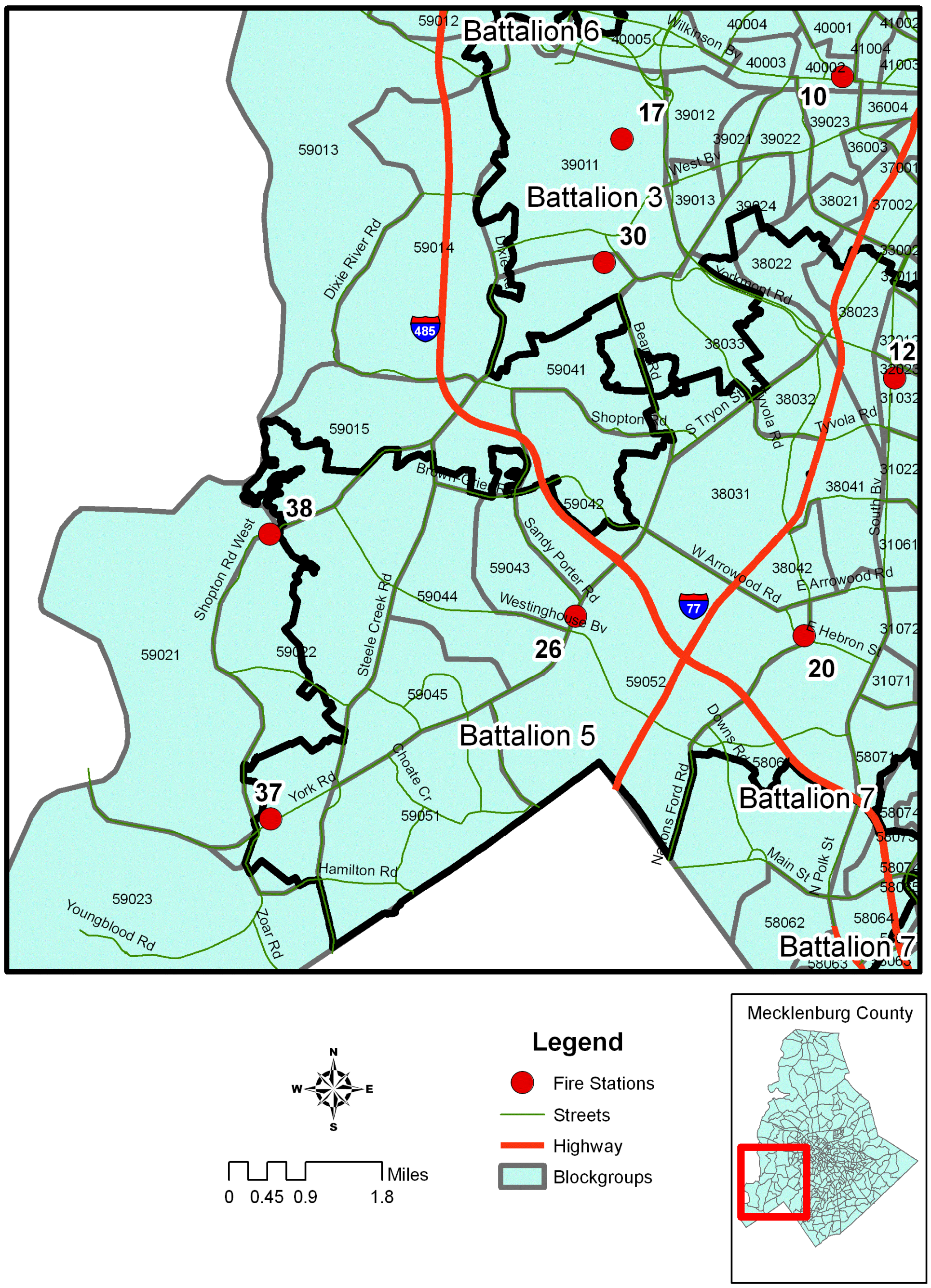
APPENDIX E: SOUTHEAST BLOCK GROUPS

Southeast Charlotte

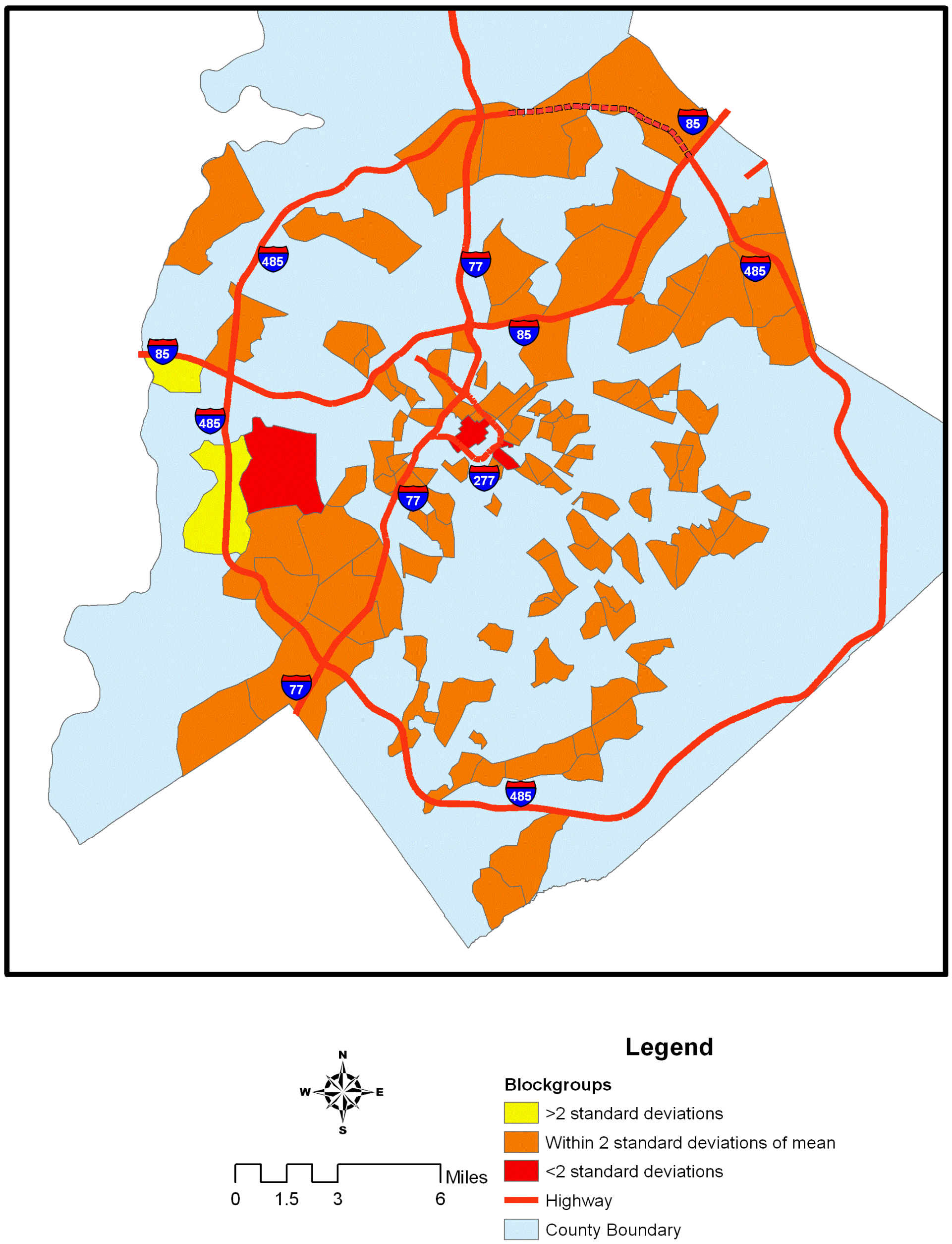


APPENDIX F: SOUTHWEST BLOCK GROUPS

Southwest Charlotte

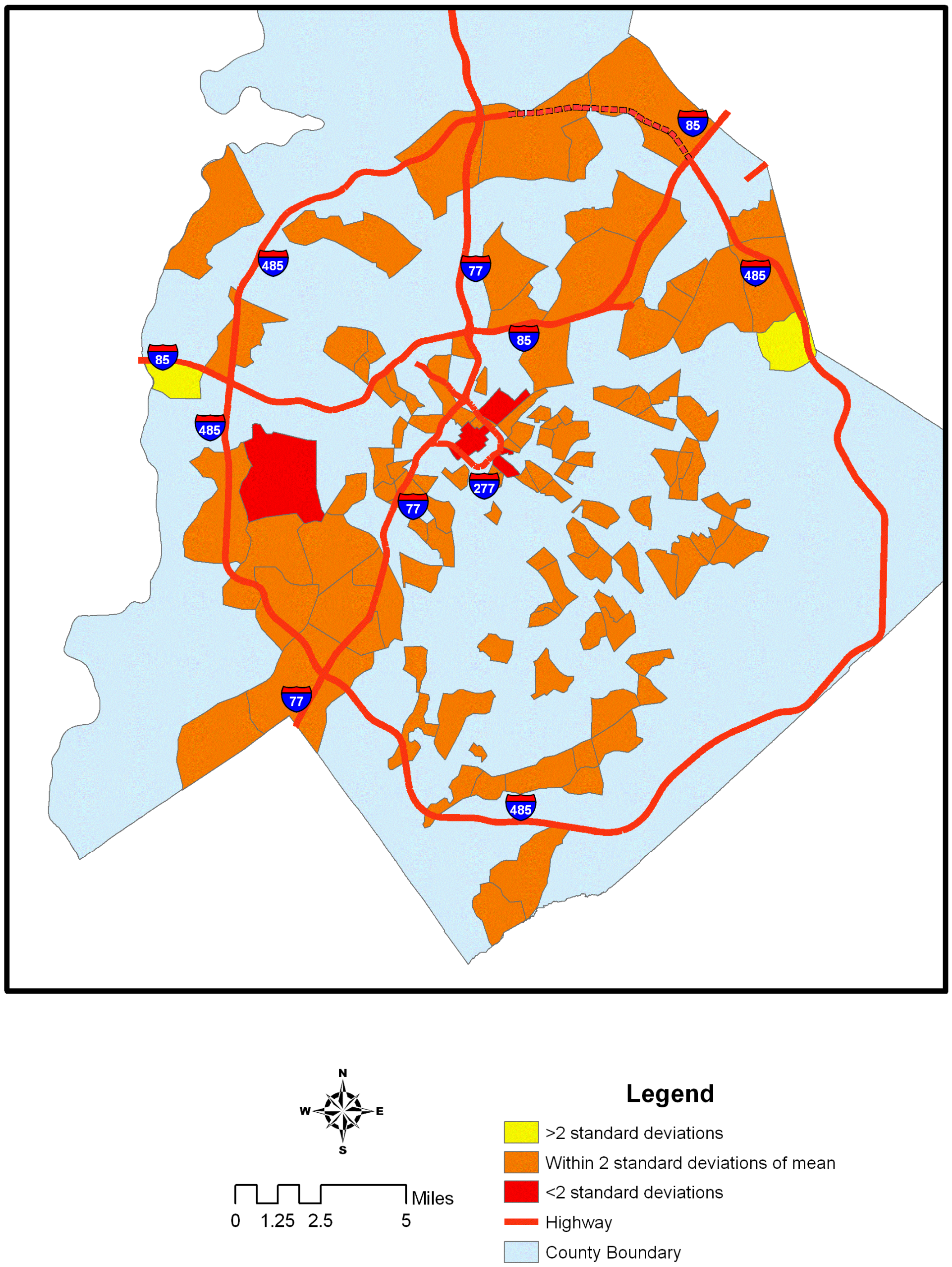


APPENDIX G: MAPPED RESIDUALS FOR OVERALL DEMAND



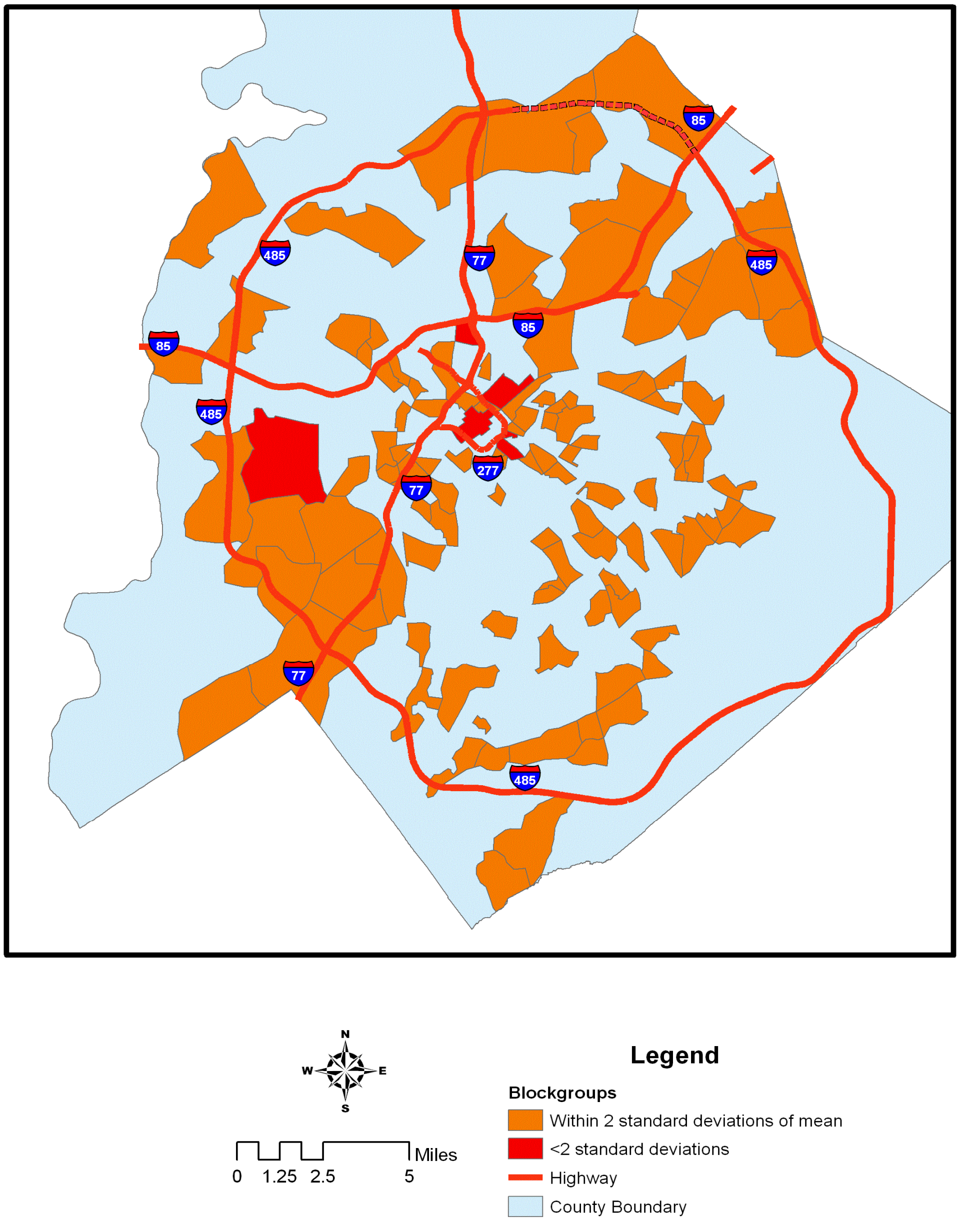
Sample Block Groups (n=118)
Standardized residuals mapped for multivariate regression model
(all demographic variables = independent & DEMAND = dependent)

APENDIX H: MAPPED RESIDUALS FOR BIVARIATE DEMAND



Sample Block Groups (n=118)
Standardized residuals mapped for bivariate regression model
(>65 year old = independent variable & DEMAND = dependent variable)

APENDIX I: MAPPED RESIDUALS for BIVARIATE FIREDEMAND



Sample Block Groups (n=118)
Standardized residuals mapped for bivariate regression model
(>65 year old = independent variable & FIREDEMAND = dependent variable)