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SPRAWL, EQUITY AND FIRE DEPARTMENT RESPONSE TIMES ACROSS
THE U.S.

By

Matin Katirai
B.A., York University, 1999
M.P.H., University of Kentucky, 2005

A Dissertation
Submitted to the Faculty of
College of Arts and Sciences at the University of Louisville
in Partial Fulfillment of the Requirements
for the Degree of

Doctor of Philosophy

School of Urban and Public Affairs
University of Louisville
Louisville, Kentucky

May 2009

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A Dissertation Approved on

March 24, 2009

by the following Dissertation Committee:

Dissertation Director

DEDICATION

This dissertation is dedicated to my loving family

Mr. Hormoz and Mrs. Vida Katirai

And

Mrs. Whitney Jeanne Katirai

And

Layli Carmel Katirai

ACKNOWLEDGEMENTS

I would like to thank my major professor, Dr David Simpson, for his guidance and patience. I also would like to thank the other committee members, Dr. Hank Savitch, Dr Lauran Heberle, Dr Steven Koven, and Dr. Sumei Zhang for the useful comments and assistance over the past several years. Furthermore I would like to acknowledge the assistance that I received from Chief Chris Aponte from the Harrods Creek Fire Department, Battalion Chief Major John Stich from the Lyndon Fire Department, and Chief Jack Reckner from the Jeffersontown Fire Department. I also would like to express my thanks to my wife, Whitney for her patience and understanding during these past few years that I worked on my dissertation.

ABSTRACT

SPRAWL, EQUITY AND FIRE DEPARTMENT RESPONSE TIMES ACROSS THE U.S.

Matin Katirai

February 24, 2009

This dissertation is an examination of fire department response times in eight major cities of the United States including Houston, TX, Charlotte, NC, St. Paul, MN, Portland, OR, Seattle, WA, Louisville, KY, San Francisco, CA and Miami, FL. This study investigates and analyzes fire protection as an urban service as measured by response times, first through proportional access by looking at socio-economic status (SES), and secondly through spatial access by examining several different aspects of urban sprawl. Response times were regressed as the main dependent variable with SES and urban sprawl variables in the quantitative portion of the study. Results indicated that response times did vary by the SES nature of the fire district and that sprawl did affected response times. The quantitative results were followed by a qualitative study which examined the quantitative results from 3 local fire chiefs.

This dissertation is divided into 5 chapters. Chapter one gives an overview of the dissertation along with stating the hypothesis, and significance of this dissertation. Chapter two is an overview of the literature which focuses on urban

service provision, fire protection as an urban service, response times, the locations of fire stations, fire districts, urban sprawl, and the measurement of equity and sprawl. The literature is used as a guide in framing the study. Chapter 3 is the methodology section which discusses the data and how the variables were selected. In chapter 3 there is also a description of the statistical models and how the models were derived. Chapter 4 is the results section and provides an analysis of the descriptive statistics, regression results, and an spatial analysis of data for four cities. The results section also includes the qualitative section which has interview data from 3 fire chiefs in Louisville-Jefferson County. In chapter 5 I discuss the results, make recommendations, and list possible limitations to this study and areas for future research.

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CHAPTER 1

INTRODUCTION

Fire emergencies demand an immediate response by fire departments so that precious lives may be saved. Fire departments provide a critical public service to city residents. How those services are distributed in a city will have a tremendous impact upon how timely residents will receive a response. Robert Lineberry (1977) argued that services such as fire provision were not distributed in a discriminatory fashion, while others such as Rich (1982), and Duncombe (1991) believed that services were distributed in a manner that was unfavorable to people in lower socio-economic classes within a city. Others such as Drier, Mollenkopf and Swanstrom (2004) have made the argument that “place matters” and where one lives in an urban area will have a major impact upon the quality of life and the services that are received. Urban sprawl, the pervasive development pattern of the United States, is also a part of this place matter argument. The issue of service provision in sprawled metropolitan areas creates social justice and inequity concerns with those in declining inner cities receiving inadequate services. Sprawl creates inefficiencies in service provision and has negative externalities, such as congestion, which also impact public safety.

In this dissertation I will investigate and analyze fire protection as an urban service, first through proportional access by looking at various socio economic factors, and secondly, through spatial access by examining several different

effects of urban sprawl. I believe where one lives in a city will have a significant impact on how a fire department responds to an emergency. The inspiration of this study comes from the response to Hurricane Katrina. The first goal was to investigate if there was any level of institutional discrimination within the fire rescue system, and second to examine the impact of the landscape and the characteristics associated with it on response. More specifically in this dissertation I will analyze the response times of fire departments as a measure of service provision at the fire district level by using spatial and socio-economic characteristics within eight major US cities including Louisville, Ky., Houston, Tx., San Francisco, Ca., Miami, Fl., Seattle, Wa., Portland, Or., Charlotte, N.C. and St. Paul, Mn.

Two main research questions will be addressed in this dissertation. The first research question will examine if there is equity and proportional access to fire protective services. Socioeconomic characteristics will be used to determine if differences exist in response times at the fire district level. The next research question will examine access to services from a spatial perspective. Specifically the influence of urban sprawl on response times will be addressed. In order to investigate the influence of urban sprawl on response times many facets of urban sprawl will be considered, such as: density, mix of land uses, street configuration, dependence upon the automobile, commuting times and distance from the center of the city. Quantitative and qualitative analyses will be used in an examination of cities and their fire districts.

1.1 Hypothesis

Several scholars have argued that people in lower socio-economic groups are marginalized when it comes to resource distribution and services provision, while others believed that this is not the case. I hypothesize that that there is discrimination when it comes to resource allotment, and that the poor will be underserved, especially with a service like fire provision. Where people live in a city will have a major determination on what sort of fire protection services they receive. I also hypothesize that sprawl will also have a major detrimental effect on a service such as fire provision by lengthening response times.

1. Response times will vary by the socioeconomic characteristics of the people living in the fire district.
 - a. This question will measure if there is equity and proportional access to fire services through response times. Factors to be examined include: race, poverty status, housing tenure, property values, property taxes, and household income.
2. Fire districts that have a greater degree of urban sprawl will have longer response times when compared to fire districts that are less sprawled.
 - a. This question will measure if there is access to fire services through response times from a spatial perspective. Sprawl for the purpose of this study will be identified by several factors including densities,

street access, segregated land uses, vehicle ownership, commute times and distance from the center of the city.

1.2 Importance of Study

This study is important because it examines the service equity of critical life and property saving services of fire fighters and their departments. This study scrutinizes how critical life-saving city services are distributed, either on a need-and-actual-loss basis or a potential loss basis. If fire services are distributed on a need basis than theoretically the underprivileged should have better access to fire protection services and therefore quicker response times. It is critical that the underprivileged within inner cities have better access to fire protective services because fire follows poverty. If fire services are distributed based on potential loss, then areas with greater property values will have better access to fire protection services and quicker response times. This means that people in poorer areas will experience inequality in receiving fire protection services. If this is the case, then cities and fire departments need to change the methodology in which they decide where to place new fire stations so that the underprivileged would be better served.

Sprawl has been the dominant force in shaping the American landscape for several decades. There are several different reasons why urban sprawl has become the predominant settlement pattern in American cities. Policies at the national level, such as the Interstate Highway Act, to local policies, such as zoning laws and fire codes, have been responsible for promoting low-density developments on the periphery of cities. Services cost more to provide in

sprawled areas, and some cities will attempt to minimize their costs by limiting services. Many have also argued that urban sprawl takes away resources from those living within inner cities. Cities that are sprawled will have to spread their resource geographically to be able to cover all their residents within a city. This study has great importance because it critically examines empirically fire protective services and sprawl. This study also could add further evidence that sprawl jeopardizes the quality of life of individuals who live in these types of developments because of slower response times for critical-life saving services. One of the many causes of sprawl has been state and local regulations that mandate low-density housing and wide streets to accommodate fire trucks and equipment. The low density housing and wide streets caused by these regulations are typical of urban sprawl and may have ultimately been counterproductive because they cause fire protective services to be spread thin across a city. Sprawl also will contribute to increased traffic and congestion due to the car-friendly nature of the development patterns; however, lower densities counteract congestion. This study will examine the relationship between fire protective services and urban sprawl and determine if slower response times are typical in sprawled areas, which should be considered as an additional cost of living in such an area.

1.3 Contribution of this Study

This study contributes to the existing knowledge base in several manners. First, I am using a rich data set with information from eight different cities across the country. Second, the unit of analysis that I am proposing to use in this study

is the fire district and has not been used in a national assessment of response times. My analysis contributes to the field of sprawl and service provision from the perspective of fire protection services, as measured in response times. This study also examines if there is proportional access to fire protective services for underprivileged groups.

1.4 Organization of the Study

Chapter two will be a comprehensive examination of the literature in the field. Sections in literature review include: urban service provision, fire protection, response times, fire station locations, fire districts, fire codes, urban sprawl and the measurement of urban sprawl and equity. The literature will then be summarized and existing gaps in the research will be identified. Chapter three discusses the methodology of the study by providing a detailed description of the data, quantitative analysis used to test the hypothesis, description of dependent and independent variables, and qualitative analysis. Chapter four will list the results from the quantitative analysis, the qualitative case studies and a spatial analysis of maps. Chapter five will be an in-depth discussion of the findings along with policy recommendations for areas of future research and the conclusions from findings.

CHAPTER 2

LITRATURE REVIEW

2.1 Urban Service Provision

City governments are charged with providing a safe environment for their citizens. Public safety, such as police, fire and emergency medical services (EMS), are key services needed within urban centers to ensure that everyday life and business can operate routinely. Urban service delivery is a hotly contested issue because it has a direct impact upon the population's wellbeing, especially services such as police and fire. One reason for this controversy in service provision as identified by the literature is due to how a city's resources are distributed (Lineberry ,1977). Service provision also has been contentious because it relates to discrimination in city policies that affect service provision (DeHoog, 1997). The significance of race as a factor in policy decisions in service distribution may have diminished, but racism has not disappeared when it comes to the allotment of scarce resources at the city level (Bullard 2000). Cities have limited budgets and where the funding is allocated makes a significant difference in the daily lives of individuals and this is especially true with a service such as fire protection. If there is racism and inequality in resource allotment pertaining to fire protection this will directly bring harm to those who were not provided with an adequate share of fire protective services. It is in a city's interest

to operate as efficiently as possible and this efficiency has a delicate balance between taxes and services (Peterson, 1981). In an effort to be efficient cities will attempt to provide the minimum with respect to service provision in order to find that balance between taxes and services that Peterson discusses, and many feel that it is the poor and underprivileged that suffer and not the wealthy especially when it comes to public safety.

Lineberry (1978) identified several areas of major concerns with respect to the study of service distribution and urban public policy. These issues were about the size of the jurisdiction providing a service and how large should a service provision unit be so that responsiveness, equity, and efficiency are maximized (Lineberry, 1978). There are several reasons why this is important to this study, first, because fire services are distributed through fire districts which are special jurisdictions that have the sole responsibility of providing one particular service. Second, responsiveness, equity and efficiency are extremely relevant to fire protection. Responsiveness is important to fire protection because it is absolutely necessary to respond to fire emergencies as quickly as possible. Efficiency is critical because the services provided are so expensive and because fire protection is a capital intensive service (stations, vehicles, etc.). Equity is important because fire protection is a service that needs to be equitably distributed.

Cities are separated into socio-economic and spatial groupings that are influenced by government policies, distribution of wealth, racial and economic discrimination, real estate practices, access to housing, the job market, zoning,

suburban incorporations, transportation networks, along with many other factors (Lineberry 1977; Dreier et al., 2004). Many of these factors negatively affect the underprivileged, and because of this, people may have the perception that there is a lack of responsiveness, equity and efficiency when it comes to providing public safety.

Equity is a term that has been mentioned several times, but before there is any further discussion about the term, there needs to be a description of what equity means. Equity has been described as a normative concept that is different from equality, which is an empirical term and can be tangibly verified (Chang, 2002). Equity is normative in nature because there are judgmental and moral tones especially about the distribution of resources (Braveman and Gruskin, 2003). Braveman and Gruskin (2003) assert that equality should be evaluated based on specified measurable outcomes that leave out the judgment factor. There has been a considerable amount of research within the field of health on the term of equity and access to health care that can readily be applied to public services, and especially a service such as fire protection. Equity within the health field has been associated with the distribution of resources, expenditures, utilization, and access to services (Waters, 2000). A lack of access to health resource within deprived communities has been identified as a primary source of poor health status and inequity (Pearce et. al, 2007). With respect to fire protection a lack of access to resources would mean greater loss associated with fire, both a loss of life and property. All residents within a community should be regarded as equals to every other resident within the community, and should

have similar access to services, however, the issue is that people are not able to live equidistant from services and new facilities should be built so that equal access is attained (Lucy et al., 1977). People who live the closest to a fire station will receive better service, with respect to response times, when compared to those who live further away.

Measuring equality in service distribution is a challenging concept. The first reason why equality is a challenging notion to quantify is that there are questions of how equality should be, in fact, measured, and second, there is also a lack of clearness as to which group (s) should be focused on that are defined by race, income, gender, etc (Oliver, Healey, and LeGrand, 2002). Another reason as to why equality is a potentially difficult concept to measure is that the service needs from different regions within a city will vary considerably and by providing the exactly equal services to unequal consumers will result in severe inequalities (Rich, 1977). Equality and who gets what share of a city's services is extremely relevant to fire protection as certain groups will require the services more than other groups. In most cases inner cities have populations who are service dependent because of age, illness, and a lack of income (Wolch, 1979). The poor, elderly, and racial minorities who live in substandard housing in the inner cities are disproportionately affected by fires, and therefore depend on fire protective services more than other people (Lineberry 1977; Jennings 1999). Rich (1982) identified that service provision is not equal across an urban area and some citizens will receive more or better public services than others. Fire protection is one service that is likely to vary significantly across communities

with respect to income and taxes (Duncombe, 1991).

The literature has identified that certain groups and certain areas within cities will receive varying levels of fire services; some are better off while others are not. Cingranelli (1981) was able to identify that African-American neighborhoods did receive lower levels of fire service than comparable white neighborhoods, and that fire expenditure was higher in areas with industrial and commercial activity. These areas with the higher levels of expenditure should in theory have better levels of services. Individuals who live in certain neighborhoods will receive advantages that come along from living in such settings, while others will live in areas that pose major disadvantages because the quality of public services are inferior as there is a great variation in the fiscal capacity of poor and wealthy municipalities (Swanstrom et al. 2002; Dreier, et al. 2004). There also will be variations of services that are supplied between one community and another community because of fiscal capacity, the cost of supplying the service, and the demand for the service (Peterson, 1981). Cities also face vulnerability from budget uncertainty as the economic environment can change quickly from year to year, which will influence how public services are demanded and provided (Dumcombe, 1991). In today's tough economic climate where cities are facing major budgetary problems and are trying to find ways to reduce their budgets this is especially the case.

It is commonly believed by many that the underprivileged receive inferior quality of services in a discriminatory fashion. However, Lineberry (1977) was able to demonstrate that the urban "underclass theory", which states that

services will be distributed in a manner that is discriminatory against minorities and low-income people, is incorrect and that underprivileged do not generally receive the poorest public services. In New York City it was found that both wealthy and underprivileged income groups were receiving superior police and fire protective services, and that the middle class fared the worst (Sanger, 1982). This may be related to the fact that New York city redeployed its fire companies because of union demands for balanced workloads so high incident fire areas received more personnel and fire equipment(Viteritti, 1982). Interestingly, this is a situation where the union plays a role in deciding where services should be provided rather the fire department self determining that there was a greater need in those particular areas.

Urban services are delivered in several different ways. Services can be delivered "through its own employees in house or in one of several alternative quasi-market mechanisms, such as contracting out, franchising, service shedding, volunteers, vouchers, coprovision, or coproduction" (DeHoog, 1997: 7). In some instances public services will be contracted out to private firms to provide particular services. Cities seeking to lower their cost burden because of lower tax revenues and diminishing state and federal funding may seek to reduce their costs by privatizing fire services (Guardino, Haarmeyer, and Poole, 1993). Previously there was limited contracting of public safety such as police or fire suppression (ICMA, 1989). More recently however, there have been a greater number of communities that have opted to use privatized fire services especially in the south and west (Guardino, Haarmeyer, and Poole, 1993). Arizona is a

prime example of state where several of its communities utilize privatized fire protection services.

The literature in this section has been key in indentifying that service provision will vary at the community level and this is extremely pertinent to fire protection as any variation in this particular service at the community level will have potentially harmful consequences. The services will vary because of several factors such as cost of providing the service, how the service is distributed, and the demand of that service that is affected by the population that utilizes that service. As service provision varies at the community level certain groups, such as the poor and racial minorities, may be negatively affected when it comes to resource allocation. However, the literature also has identified that this is not always the case and that the poor are not always worse off.

2.2 Fire Protection

Fire protection is a critical urban public service that cities provide. Fire protection is essential and ensures the safety and welfare of individuals who live and work in cities. Fire protection is an important urban public service because fires have the ability to wreak major havoc upon cities as witnessed in the major conflagration of Chicago in 1871 and the fire following the San Francisco earthquake of 1906 (Platt, 1999). Fire departments have more responsibilities than just extinguishing fires, such as providing emergency medical assistance, conducting search-and-rescue operations and dealing with hazardous material accidents. Fire departments played major roles in search-and-rescue operations after the 9/11 attacks and in the aftermath of Hurricane Katrina in New Orleans.

Unlike many other western nations where there is a strong role for the nation-state to respond to emergencies, the United States is highly decentralized and the first line of responsibility for public protection lies with local government, and this usually falls to police and fire men and women (Drabek, 1985). Fire fighters also provide specialty services of swift-water rescue, along with urban search and rescue and are professionals who have had training in search-and-rescue techniques and will respond to emergency events (Dynes, 1970). Fire departments also play a role in the ensuring that development meets safety standards. The other, and main, role that fire departments provide is protection against fires. Fires exact a major social and economic toll upon cities (see Table 1). Several thousand individuals die each year and billions of dollars of damage accrue.

Table 1: Fire Loss in the U.S

Year	Fires	Deaths	Injuries	Direct Dollar Loss In Millions	Adjusted Dollar Loss*
1998	1,755,000	4,035	23,100	\$8,629,000,000	\$10,976,410,000
1999	1,823,000	3,570	21,875	\$10,024,000,000	\$12,475,370,000
2000	1,708,000	4,045	22,350	\$11,207,000,000	\$13,494,090,000
2001	1,734,500	3,745	20,300	\$10,583,000,000	\$12,390,180,000
2002	1,687,500	3,380	18,425	\$10,337,000,000	\$11,913,810,000
2003	1,584,500	3,925	18,125	\$12,307,000,000	\$13,868,250,000
2004	1,550,500	3,900	17,875	\$9,794,000,000	\$10,750,170,000
2005	1,602,000	3,675	17,925	\$10,672,000,000	\$11,330,020,000
2006	1,642,500	3,245	16,400	\$11,307,000,000	\$11,629,050,000
2007	1,557,500	3,430	17,675	\$14,639,000,000	\$14,639,000,000

Source: U.S. Fire Administration, 2008: U.S. National Fire Statistics. Adjusted to 2007 Dollars.

Fire protection takes up a considerable portion of city budgets. Table 2 displays the budgets for fire departments for 28 cities and the overall budgets. Spending ranges from a low of 10 percent to high of nearly 30 percent of overall

city budgets. Cities spend more on fire protection than on any other service, with the exception of policing and road construction (Lineberry, 1977). Large portions of fire expenditures go toward the salaries of fire fighters and equipment.

Table 2: City Fire Expenditure

City Name	2005 Population	Total Fire Expenditure	City Budget	% of Total Budget
Franklin, IN	19,463	\$3,467,127	\$11,790,254	29.41%
Davenport, IA	98,359	\$11,069,000	\$39,926,512	27.72%
Mount Vernon,	14,375	\$2,416,713	\$8,749,563	27.62%
Ashland, KY	21,981	\$4,192,082	\$18,070,826	23.20%
Paducah, KY	26,307	\$4,951,000	\$24,331,520	20.35%
Helena, MT	25,780	\$2,441,000	\$12,177,317	20.05%
Montpelier, VT	8,035	\$1,587,018	\$7,921,736	20.03%
Charlotte, NC	540,828	\$70,328,127	\$363,133,000	19.37%
Houston, TX	2,016,585	\$293,242,005	\$1,561,544,400	18.78%
Redlands, CA	63,591	\$10,032,886	\$55,521,115	18.07%
Hattiesburg, MS	44,779	\$5,776,985	\$32,075,797	18.01%
Tampa, FL	303,447	\$50,428,886	\$300,999,479	16.75%
Elizabethtown,	22,542	\$3,260,000	\$19,698,463	16.55%
Cheyenne, WY	53,011	\$7,962,640	\$48,431,616	16.44%
Annapolis, MD	35,838	\$8,339,580	\$52,920,640	15.76%
Berkeley, CA	102,743	\$18,111,000	\$115,114,006	15.73%
Twin Falls, ID	34,469	\$3,237,624	\$21,202,362	15.27%
Miami, FL	362,470	\$76,487,399	\$512,507,527	14.92%
Mobile, AL	198,915	\$24,162,331	\$173,461,646	13.93%
Charleston, SC	96,650	\$13,676,485	\$98,340,943	13.91%
Palm Springs, CA	42,807	\$6,831,000	\$51,603,943	13.24%
Portland, OR	64,249	\$15,193,000	\$117,437,236	12.94%
Gatlinburg, TN	3,382	\$2,305,353	\$17,961,315	12.84%
International Falls,	6,703	\$530,808	\$4,263,981	12.45%
San Francisco, CA	719,077	\$224,715,517	\$1,967,808,000	11.42%
Louisville, KY	265,000	\$45,298,500	\$437,232,800	10.36%
Xenia, OH	24,164	\$1,350,000	\$13,719,604	9.84%
Tacoma, WA	193,556	\$34,901,000	\$356,106,650	9.80%
SOURCE: 2005 City Budgets, DPI Project.				

Other major expenses for fire departments, regardless of size, include fire vehicles, such as engines or pumper trucks, and training (Compton and Granito, 2002). As cities come under budgetary pressures they will seek to reduce staffing and will close stations to save money (Scawthron, O'Rourke and Blackburn, 2006). Cost is major consideration in providing fire safety, and fire departments are encouraged to improve cost effectiveness which is a struggle to find the right balance between cost and an acceptable level of service provision (Puchovsky, 1996). As fire protection takes up a considerable portion of a city's budget, the key question should be: where will the staff reductions take place, and what stations will be closed? Is staffing reduced equally across the board, or are certain areas affected disproportionately by these decisions on where to provide fewer services? The ideal situation would be to reduce the services provided in areas that have the least need for the service and not areas that make considerable use of the service.

Not all cities across the nation will be in similar financial situations; some are experiencing financial distress while others may be experiencing prosperity, so some fire departments may expand while others might experience declines in staffing that will affect the level of services that are provided. Decisions by cities to reduce funding in times of fiscal distress will often impact services such as fire protection and will most assuredly have an impact on providing an adequate response. In a local example of this, in 2008 the City of Louisville faced a \$20 million budget short-fall and Mayor Jerry Abramson closed one of the city's downtown fire stations to save \$500,000 (Halladay, 2009). The result of the

station closure will be that those who lived in close proximity to the fire station will now have longer response times in waiting for fire services.

The fire department provides a public good that helps maintain the preferred state of reducing fire loss for a community, and the benefits will be confined to the residents of that community (Ostrom, Tiebout and Warren, 1961). Ostrom et al. (1961) assert that by viewing a public good that maintains the preferred state, such as the reduction a loss from fire, will allow for a degree of quantification and measurability criteria at the metropolitan level, which is important for this study because the goal is to take fire protection as a service and quantify the service and use this measurability criterion provided through response times to examine differences that exist at the metropolitan area.

2.3 Response Time

In this study, response times are the major dependent variable of service provision for the fire department. The National Fire Protection Agency (NFPA) defines response time as “the time that begins when units are en route to the emergency incident and ends when units arrive at the scene (NFPA, 2004:24).” The NFPA is the major national authority on fires, electrical, and building safety in the United States. The NFPA was formed for the purpose of standardizing sprinkler systems in buildings in Northeast states at the end of the 19th Century (Kaplan, 2003). The NFPA standard for response time is four minutes for the arrival of the first engine company at a fire-suppression incident and or 8 minutes or less for the first full assignment at the incident.

The NFPA also requires that fire departments across the country to establish a 90 percent compliance with response time objectives and that an annual review of service delivery and response time objectives should take place for each geographic area. The Boston Globe in a national examination of response times was able to find that just 58 percent of fire departments in 2005 were meeting national response time standards, and this figure had fallen from a high of 75 percent in 1986 (Dedman, 2005). A few fire departments across the country have adopted the NFPA standards, and many communities do not even keep track of response times (Dedman, 2005). Limits on response times are put into place so that a specified time period will not lapse before a response can occur to any fire (Toregas and Swain, 1971). Having a rapid response time is critical within urban areas as the close proximity of buildings and higher population densities may potentially lead to major fire losses (Ganito, 1986).

The medical emergencies that fire departments respond to also require immediate attention as survival rates will most definitely be dependent upon swift medical attention by trained emergency professionals (Cote, 2003). In the United States, average response times for emergency medical services in 2002 were 6.51 minutes for urban fatal crashes (Lambert and Meyer, 2006). Response times in a station's response area can be from 2 minutes up (Cote, 2003). A recent study of fire departments by the Boston Globe found that response times were growing longer especially within suburban areas of Boston and other major American cities as there has been major growth in these suburban areas but staffing had been reduced (Dedman, 2005).

Time is the most critical element when any emergency incident is reported, especially ones that deal with fire, as fire growth may expand at a rate of many times per volume and the time between fire ignition and fire suppression has a direct relationship with fire loss (Cote, 2003). Fires spread fast, and for fire departments to be minimally effective in suppressing a fire the first responding fire fighting vehicle must reach the scene within 10 minutes of the alarm (Ganito, 1986). Any delay in the response could be the cause of loss of life or property.

There are several factors that will have a considerable impact upon response times and should be taken into consideration when planning to reduce response time. One of the most important factors that affects response time is travel distance, which is the distance that the fire vehicle has to travel from the station to the location of the fire, and the total number of fire stations in an area (Halpern, 1979). Other critical factors that have been found to influence response times include sprinklered vs. nonsprinklered, commercial vs. residential, and multifamily vs. single-family residential (Cote, 2003). Many of these factors will be affected by a city's fire code requirements.

Response time is an ideal indicator that can be used to gauge a level service provision that is provided by the fire department. Achieving a level of service equity with response times as an indicator would usually mean that all areas should have roughly similar responses and that resources would have to be disseminated on the basis of calls rather than population (Lucy et al., 1977). Areas with higher needs should therefore be allocated more resources to reduce response times. However, if parity is sought out through population rather than

need, then equity cannot be achieved in an indicator such as mean fire loss (Lucy, 1981).

There is a clear case of who has the highest need, and consequently quicker response time, for fire protection services. Jennings (1999) in his comprehensive literature review of socioeconomic indicators of fire incidence in residential areas identified poverty, owner occupation, sub-standard housing, population density, overcrowding, lack of supervision for children, drug and alcohol abuse, missing smoke alarms, poor heating, and immigrants, as characteristics of areas with high fire incidence. Areas with all these characteristics would have a greater need for fire protective services and quicker response times. It is more than likely that these areas are found within inner cities. It is also these demographic characteristics of the population that will affect the frequency of fire occurrences, which will have an impact upon response times (Ganito, 1986). Areas where different conditions exist, such as better insurance policies, improved heating, parental supervision of children, sprinkler systems in homes, will have less of need for fire protective services when compared to their inner city counter parts.

There have been a very few studies that have critically examined response times of the fire department as a measure of service equity. One study by Gomersall (2002) of the Cincinnati Fire Department was able to demonstrate that the fire department responded equitably without regard to socioeconomic characteristics of the neighborhood. Gomersall (2002) also found that straight line distances were not an important factor in response times, but that the

number of corners that a fire truck had to turn was the major influence on response times.

2.4 Fire Station Location

Response times will be greatly affected by where a community decides to place fire stations. Fire stations are a part of the overall package of fire service provision as fire engines and fire fighters are dispatched from the fire station to respond to an emergency. According to the International City/County Management Association's (ICMA) (2002) *Managing Fire and Rescue Services*, basic deployment concept calls for fire stations to be located in such a way to create an orderly network of stations from which emergency services are delivered in a timely manner. Therefore, communities with higher population densities and heavy traffic should have a greater number of fire stations. Communities that also want to have narrower streets and want to reduce response times should have a greater number of fire stations so that they can meet the demand of their respective areas that they are responsible for (Ewing, Stevens and Brown, 2007). However, the selection of fire stations sites becomes complicated sometimes because of standards. The siting of fire stations has been highly influenced by the Insurance Services Offices (ISO) guidelines (ReVelle, 1991). These guidelines and standards demand that fire stations be placed in close proximity to highly insured and expensive public and private buildings because of potential for loss (Lucy, 1981). These standards are detrimental to the poor, racial minorities and those who live in substandard housing because response times will be higher for these groups and lower for

those such as businesses that are located close to a fire station. Both Cingranelli (1981) and Sanger (1982) were able to confirm that allocation of fire services favored areas with commercial activity. These standards are biased because they are based on potential loss, rather than actual loss. Areas that have higher actual loss and need should in have a greater number of facilities.

Several aspects are considered by fire departments when deciding where to build a fire station, such as operating costs, practicality, public reaction, environmental consideration, design, support, and the most important aspect which is providing the best possible protection to the area (Rosenhan, 1986; Owen and Daskin, 1998; Compton and Granito, 2002). In the Fire Chiefs Handbook, Coleman (2003) indicates that response times are an important consideration for site selection of fire stations and that it is essential that any site meet response time criteria set out by the department or national standards. Excessive response times translate into increased risk from an emergency (Compton and Granito, 2002). Response time can be reduced by selecting fire station locations based on the amount of time that it takes to travel from station to incident scene (Cote, 2003). Both social and geographic characteristics of an area that are to be protected by a fire station are critical elements in the planning of where to build a fire-station, such as waterways, mountains, valleys, highways, one-way streets, and railroad crossings that may limit response routes and times (Rosenhan, 1986). In the NFPA's Fire Protection Handbook, Roshenhan (1986) identified that some areas in a community will be higher risk than other areas for fires because of the types of facilities that are located within those areas, such as

industrial, institutional, mercantile, and multifamily dwellings, and that it would be undesirable to locate a station within those areas. Areas that usually have multifamily dwellings are located within inner cities where the poor and minorities are located. If these areas that have multifamily dwellings are undesirable for fire stations, then these people are disadvantaged with regards to response time because they have the greater need for the service, and therefore stations should be placed in these areas.

2.5 Fire Districts

The fire district is the unit of analysis of this study. The fire district is a special unit of government that provides the specialized service of fire protection. A fire district is a special district or jurisdiction unit of government. These special districts perform local governmental functions within a specified geographical boundary with powers of taxation, issuing debt, and appropriating private land for public use (Burns, 1994). The fire district is an important concept for this study because fire protective services are distributed at fire-district level, and statistics, such as response times, are collected at the fire-district level.

Cities in the United States are responsible for providing many services and take on a considerable portion of financial burden unlike many other Western nations. Services are primarily funded through property taxes, payroll taxes and other fees. The fire department is one of these services that receive its funding from the general budget of a city funded by local taxes. However, because of competition among cities within metropolitan areas, many municipalities will be hesitant to raise fees and taxes to provide better services because wealthier

citizens may leave and move to a lower-cost areas (Peterson 1981; Swanstrom et al., 2002). Disparity in funding between different areas within a city will lead to varying levels of service provision. Some fire districts will have more man-power and better response times than other fire districts. It is this variation in the level of service provision in fire districts that makes them the ideal unit of analysis for measuring equality among the different inhabitants of the districts, and especially the groups identified in the literature such as the poor and minorities. Another primary justification for comparing various units of government, such as cities or special districts, is that all elected officials and decision makers are subject to similar groups of pressures and competing interests (Peterson, 1981).

Many large cities across the United States are increasingly reliant on the use of special governmental districts to provide service and tax differentiation and to provide local citizens with an array of choices (Baer and Marando, 2001). In many instances individuals will seek out communities that best satisfy their preferences for those specific public goods (Tiebout, 1956). Each community or jurisdiction will be entitled to a level of spending that is directly proportional to the taxes that are paid (Boyne, Powel and Ashworth, 2001). An example of this would be a household that opts to live in an area with its own private police force as response times and service from smaller police departments tend to be faster when compared to a larger police force (Ostrom, 2000). Over the past 50 years, the majority of new governments have been special districts (Burns, 1994). Table 3 illustrates the dramatic increase in special-district governments over that time. Table 3 also indicates that the population served per district has also decreased

by 35% of the past 50 years. This could possible indicate an improvement in services. In the last Census of governments there were a total of 5,743 fire protection districts, or 16.2 percent of the total number of special unit districts across the country.

Table 3 – Special Units of Government in the U.S.

Year	# of Special District Governments	Population	Population/District
1952	12,340	151,325,798	12,263
1962	18,323	179,325,176	9,787
1972	23,885	203,211,926	8,508
1982	28,078	226,545,805	8,068
1992	33,131	248,709,873	7,507
2002	35,356	281,421,906	7,960

Source: U.S. Census Bureau, Governments Division. List of Governments 2002 Edition.

2.6 Fire Codes

Fire codes are safety standards that are established by various groups to protect buildings and individuals from fires. Fire codes are meant to impact the landscape by making it easier for fire departments to respond to emergencies that should help reduce response times. Fire codes also provide building standards to make them more likely to withstand fires. The NFPA is one organization that establishes fire codes that cities and states adopt. Fire codes have come about as a result of tragic events, such as the Chicago fire of 1871, the San Francisco earthquake and fire of 1906, the 1903 Iroquois Theatre fire in Chicago, and the 1911 Triangles Shirtwaist Factory Fire in New York City (Kaplan, 2003).

According to Duany, Plater-Zyber and Speck (2000) fire departments and

fire codes will have a considerable impact upon street layout and urban sprawl because of requirements needed for response. In order to reduce response times fire departments will have standards that require wider streets so that large fire trucks can maneuver (Duany et al., 2000). The NFPA has several different guidelines and general requirements that impact street widths and the location of structures. For example, the NFPA (1993) has requirements that include: road width should be at least 24 feet wide, turns should have a minimum radius of 100 feet, fire lanes should be at least 20 feet in width from the road edge to the structure, and structures with greater than 1000 square feet of floor area shall not be set back more than 50 feet from street and have at least 14 feet of clearance over the width of the street.

These standards that dictate road widths and similar design elements, according to Ewing et al. (2007), are the biggest obstacle to having skinny streets as state and local fire codes will most likely follow these national standards. These road width standards which should allow for quicker access for the fire department contribute to urban sprawl and create problems, including an increase in major car accidents, a reduction in pedestrian-friendly areas, and encouraging people to drive faster, which will create traffic congestion and lead to an increase in response times for the fire department (Duany et al., 2000). According to Baar (1996), another manner in which fire regulations and codes have contributed to sprawl is the limitation of the construction of multifamily dwellings. The limitation of development of multifamily dwellings began to happen as early as in the 1890's when cities, such as Philadelphia and Chicago,

began to use fire codes to prevent the construction of buildings more than four stories (Baar, 1996).

2.7 Sprawl

Urban sprawl should be an important topic of consideration for fire departments and emergency response because the location of stations and the ability of fire engines to navigate will be highly influenced by the pattern and layout of the landscape. Duany et al. (2000), Ewing et al. (2007), and Baar (1996) all indicated that fire codes have contributed to sprawl for various reasons such as street layout, the discouragement of multifamily dwellings and affects on traffic. Sprawl is also an important topic because it will also affect how services are distributed within a community. Sprawl has also been identified as creating fiscal disparities between communities which leads to inequality (Squires, 2002). No discussion of sprawl would be adequate without attempting to define the term. Within the body of literature there are no common definitions, and there have even been a few attempts to operationally define sprawl (Galster, Hanson, Ratcliffe, Coleman, and Freihage, 2001). One of the more robust definitions of sprawl was characterized by Galster et al. (2001: 5) where they define sprawl as “a pattern of land use in an urban area that exhibits low levels of some combination of eight distinct dimensions: density, continuity, concentration, compactness, centrality, nuclearity, diversity, and proximity”. Their definition is more tangible than others because their eight dimensions of sprawl allow for it to be easily operationalized.

Another useful definition of sprawl is provided by Burchell et al. (1998) in

the book, *The Cost of Sprawl-Revisited*. Burchell et al. (1998) characterize sprawl as low density, unlimited, noncontiguous growth and consumption of agricultural lands that creates a total reliance upon the automobile. Millions of Americans spend a considerable portion of their day commuting in their automobiles to work in downtown cores from suburban neighborhoods. Development, both residential and commercial, that usually takes place in a sprawled environment is highly segregated and land uses are not mixed (Burchell et al, 2005). Sprawl has been fueled by the automobile, and our overabundant reliance on this mode of transportation (Burchell et al., 2005). Automobiles are needed to travel between homes and commercial areas because of this highly segregated pattern of land use.

Bruegmann (2005), in his work *Sprawl, a Compact History* concedes that sprawl is this infinitely complex term, which accurately defines an attitude rather than any particular condition. Never- the-less, Bruegmann (2005) defines sprawl as urban development that is scattered, without systematic public planning at low-densities. Sprawl is not a new occurrence but rather it is one that has been around for quite a long time, and the aspect of sprawl that is rather new (within past century), is that sprawl has become a mass phenomenon made available by improvements in modern technology such as the automobile (Bruegmann, 2005).

Duany et al. (2000) in *Suburban Nation* describe sprawl as an outgrowth of modern problem solving and a system for living. Their definition for sprawl is slightly different than the other definitions mentioned above. In *Suburban Nation* sprawl is characterized by five different components that are strictly isolated from

one another and include: housing subdivision, shopping centers, office parks, civic institutions, and roadways. Roadways are the arteries that are essential in connecting the four disassociated components with one another and the automobile is the main choice of transportation for those roadways (Duany, et al. 2000). The high reliance on single occupied automobile results in higher than normal traffic load, even in smaller sparsely populated areas, according to Duany et al (2000).

Urban sprawl has been fueled by several factors that have highly contributed to the suburbanization of the country. The factors include a substantial gain in population, high rates of crime in central cities, racial composition of urban areas, technological advancements, availability of land, rising affluence, and consumer inclinations for low-density living (Nivola, 1999; Gordon and Richardson, 1997; Bruegmann, 2005). The largest contributor to urban sprawl, that has had more of a substantial impact than any other factor, is the impact of governmental policies. Most of these policies are federal in nature.

Many experts in the field point to policies such as the Federal Interstate Highway and Defense act of 1956 that acted as catalysts to make the automobile and highways the primary route and mode of transportation in the United States today (Drier et al, 2004; Savitch, 2000). The Federal Interstate Highway and Defense act was largely a national-security strategy that occurred during the Cold War and would help facilitate the decentralization of cities to minimize the damage from a nuclear strike. The Federal Interstate Highway and Defense Act was coupled with other policies such as the Highway Trust Fund. The Highway

Trust Fund is a self-propagating mechanism that provides a constant allocation of funding for road construction through the collection of taxes from gasoline (Nivola, 1999). The highway trust fund system was used to build approximately 41,000 square miles of roadways, and levels of spending were in the vicinity of \$20.5 billion in 1997 on an annual basis (Drier et al, 2004). Funding in the United States for transportation is heavily biased in the favor of highway construction as roadways receive close to 84 percent of the total output of federal spending, and this is mainly due to its funding apparatus (Savitch, 2000). Others have disputed this argument, that funding is biased towards highway construction, and in fact claim that on a per passenger mile basis public transit is much more heavily funded (Gordon and Richardson, 1997). The argument of Gordon and Richardson is flawed, however, as they fail to consider additional costs of pollution, congestion, and parking that should be considered into the pricing of fuel as it is in Europe (Ewing, 1997).

The US system of taxation also bears a great deal of responsibility for promoting urban sprawl. Levels of taxation on gasoline in the United States are the lowest in the developed world and prices in Europe are approximately three times as high (Ewing, 1997). The minimal tax rate helps explain the phenomena of American consumers driving larger automobiles and with more frequency than the Europeans and Japanese (Nivola, 1999). Sales taxes on automobiles are approximately 37 times higher in Denmark and 9 times as high in the Netherlands when compared to the United States (Nivola, 1999). This combination of low taxes on both fuel and the automobile encourages Americans

to drive without considering all subsidies that are provided. If individuals had to bear the full brunt of the costs they might opt to live in neighborhoods that were not so heavily reliant on the automobile.

Not all the blame can be placed entirely upon national policies for creating urban sprawl. Policies at the city level also bear some of the responsibility for creating this phenomenon of sprawl. Cities are limited in the types of policies that they can pursue and in many instances in the United States, cities are placed in competition with one another for attracting business and, will opt for policy decisions that enhance the local economy and bring in greater tax revenue and increase property values through development (Peterson, 1981). Land developers, real estate interest, and local politicians will seek to enhance the value of land by attracting capital investment, tourism and other types of economic activities to regions (Savitch and Kantor, 2002). Making the land accessible via transportation is one way to add value to land, and it is this practice of making the land reachable by means of rapid transportation that has resulted in the pattern of sprawl that exemplifies most US cities (Gonzalez, 2005). One other example of how local policies will exacerbate sprawl is that many cities will utilize zoning laws to mandate low density, high cost homes, at the periphery of cities. These types of developments will generate a significant amount of property taxes.

There have been several commonalities in the aspects of sprawl that were defined by the literature. One of the most consistent terms that appeared was low density. "Density of a place refers to the quantity of people, households, or

employment distributed over a unit of area such as an acre, square kilometer, or square mile". (Frumkin, Frank, and Jackson, 2004: 6) In an area that is considered to be sprawled, densities will be low in population and the number housing units per square mile. Although it should be noted that the term low density is relative to the specific area, because what may be considered to be a low population density in Europe may considered to be a high density in America.

Transportation patterns and automobile use were also synonymous with definitions of sprawl. Specifically, sprawled cities have a very high dependency on the automobile for a mode of transportation. This high dependency on the automobile in sprawled suburban areas has created a major externality, and perhaps the greatest complaint about sprawl, which is traffic congestion (Burchell et al., 2005). Traffic congestion should be of great concern to emergency response. Congestion on the roadways will reduce the ability of a fire department to respond in a timely manner.

Sprawl has a great impact on how resources are distributed in cities. Sprawled developments end up costing cities more in providing services. The cost of infrastructure will be more in sprawled developments because each yard of liner infrastructure, such as water or sewer, will serve fewer households (Burchell et al., 2005). Other services, such protective ones like policing and fire, will have escalating costs as cities that have populations and economic activities spread apart across the region and in low density suburbs (Stephens and Wikstrom, 2000). The reasons for the high cost of protective services are similar to the reasons for the high cost of infrastructure; similar types of resources are

needed to provide safety to fewer households. Suburban sprawled developments have a high ratio of public to private expenditure which makes these areas difficult to pay for even at modest rates of taxation (Duany, et al. 2000).

2.8 Measurement of Equality

The measurement of equitable resources distribution is a difficult task. The health care field has been quite progressive in the measurement of access to health care resources, especially to underprivileged populations. This study can apply some of concepts that have been used in the analysis of access to health care resources for underprivileged populations. Need is an important concept in the measurement of access to health care resources. Need of a certain resource will be determined by the behavior, environment, and characteristics of the population such as age, gender, culture, and economic status (McLafferty, 2003).

Equity within the healthcare sector has been calculated by using models that examine health status, distribution of resources, expenditures, utilization, and access (Waters, 2000). Expenditure and the distribution of resources (stations) are widely available information that fire departments keep track off, which will be very useful for this study. Access to health care services will vary due to the fact that the supply of where health care resources locate and where people live are not homogeneously distributed (Luo and Wang, 2003). Access to health care can be directly related to fire fighting services, as where people live and the location of fire stations may not be uniformly distributed.

The use of GIS has been quite prevalent in the analysis of access to health care resources. Demonstrating a lack of access in health care can be

accomplished by overlaying areas of outcomes of health on political boundaries along with various socioeconomic factors (Phillips, Kinman, Schnitzer, Lindbloom and Ewingman, 2000). Bravemen and Gruskin (2003) identified this as measuring equality based on outcomes. In this study the outcome of health is the response time, because the longer the response time the more detrimental it is to the populations health, and the political boundary is the fire district, which can be accomplished through using multiple layers of information through a GIS. The literature has been helpful in identifying socio-economic factors that can be used to measure along with response times. Race was mentioned several times by the likes of Lineberry (1977), Jennings (1999), Cingranelli (1981), and Bullard (2000) as an important feature in service provision. This will be one of the factors that is measured along with response times. Other important socioeconomic factors identified in the literature that can be quantified include income, taxes, housing, and poverty by Duncombe (1991), Lineberry (1977), Oliver, Healy and Legrand (2002).

2.9 Existing Gaps in Research Area

The literature has shown that there will be a variation of services that are provided within cities and between cities. Bullard (2000), Peterson (1981), Rich (1977), Duncomb (1991), Drier et al (2004) each indicated that service distribution within cities is not likely to favor the poor, and service provision will vary based on the fiscal capacity of the city. Cingranelli (1981) identified that blacks received inferior fire service when compared to their white counterparts. Lineberry (1977) argued that the poor were not underserved when it comes to

service distribution within cities. Sanger (1982) was able to demonstrate that the underprivileged did not receive the poorest level of fire service in New York City. The question is who is actually right? Are the poor and underprivileged underserved, or are they not? The literature indicates that socially disadvantaged groups, such as the poor, racial minorities, elderly, and single parents have the highest need for fire protection. These groups have the highest rates of actual loss. Reville (1991) indicated that the insurance industry has some pull as to where fire stations should be located. The insurance industry recommends that fire stations be built close to areas with higher valuation, and both Cingranelli (1981) and Sanger (1982) found this to be true. The standards by the ISO are based on potential loss rather than actual loss and this would indicate that fire services are not equitably distributed. The major literature within the fire-fighting field that discuss the placement of fire stations such as the ICMA's *Managing Fire and Rescue Services*, the NFPA's *Fire Protection Handbook*, and the *Fire Chief's Handbook*, all indicated that stations should be placed in a manner which reduces response times. However, in the *Fire Chiefs Handbook* it was also stated that some areas may be undesirable locations for placement of fire stations. Many of these undesirable locations, such as near industry or multifamily dwellings, are locations where the poor live. The question that arises is who has the greater need for these services? Is it the poor in the inner cities, or the wealthy who are well insured?

We know that it is in a city's interest to maximize efficiency. Sprawl reduces a city's ability to be efficient because service costs remain the same for

fewer numbers of individuals. Sprawled developments are ideal for fire departments because they have wider streets and low-density development partly because of city, state and national fire codes. Do these requirements hurt the ability to fight fires in a timely manner because of the sprawl aspect and traffic congestion? It is in the city's interest to reduce its cost burden. Does this affect how services are provided, especially an important service like fire rescue as measured by response times? Many cities experience fiscal crisis and downturns in the economy and may opt to cut back fire services because it takes up a considerable portion of a city's budget. Will the poor be the first ones to lose a fire station or will it be in the suburbs? Very few studies have looked at response times of fire departments. Gomersoll's (2003) study was an individual case study of Cincinnati which attributed the response time of the fire department to the number of corners an emergency vehicle must take. Urban sprawl along with the distribution of fire stations was not considered in Gomersoll's analysis.

CHAPTER 3

METHODOLOGY

3.1 Data

Response time data at the fire district level for the 2006 time period were retrieved from eight different fire departments across the United States. I was personally involved with the team that devised a method for the selection of cities developed for a National Science Foundation project entitled “Measuring Cross Community Disaster Preparedness.” The first step in the city selection process was developing a disaster exposure model. The objective of this selection process was to allow cities to be identified based on two variables, hazard experience and population size. It was determined that only larger cities should be selected for this study, based on the availability of GIS data, and that larger cities were more likely to have fire districts. Another reason for opting to use larger cities over smaller ones was that large cities experience a heightened degree of social, economic and political fracturing especially in areas of income, race and political affiliation (Solecki 1999).

In terms of hazard experience there is research that describes a “disaster subculture” (Wenger, 1978) in communities that have more and continuous experience with hazards. These communities are expected to have different perspectives on hazards than cities that experience hazards as well as a different

financial investment in preparedness activities. The hazard exposure was determined by the use of the Spatial Hazard Events and Losses Database for the United States (SHELDUS) managed by the Hazards and Vulnerability Research Institute at the University of South Carolina (Hazards & Vulnerability Research Institute, 2007). The hazard exposure of cities was ranked high, medium, or low, was based on the total of disasters in the last 20 years from the SHELDUS database. The high, medium and low exposure rank was determined by using the natural breaks/jenks method in ESRI's ArcGIS 9.2 software package. The SHELDUS database was the best option to help identify the hazard experience for each city in the United States. SHELDUS was created from various governmental sources including the U.S. Geological Survey (USGS) and the National Climatic Data Center (Cutter and Emrich, 2005). Prior to SHELDUS, the United States did not have any organized central inventory of disaster events and losses associated with disaster events (Cutter and Emrich, 2005). SHELDUS is a county-level hazard data set covering 18 different natural hazard events types that include thunderstorms, hurricanes, floods, wildfires, and tornados. Each hazard event in the database includes the beginning date, location (county and state), property losses, crop losses, injuries, and fatalities that affected each county. Based on the data available to define hazard experience an assumption was made that if the city is within the county that has experienced the event then the city has also and this was another reason that I opted to use larger cities as this is a valid assumption for the larger cities.

The SHELDUS database was queried to identify hazard exposure at the

county level. Specifically, the database was queried to identify total number of all hazard events in the U.S. by county. This data was then divided into three categories by using the natural breaks/jenks methodology from ArcGIS to determine high, medium, low hazard exposure. Jenks or a natural break grouping determines the most adequate arrangement of values into classifications by comparing the sum of squared differences of values from the means of their classes (BioMedware, 2005).

A city shapefile layer (a point file for every major populated place in the United States) in GIS was overlaid on top of the county hazard exposure layer. The first step was to break down the city layer into three different city shapefiles, one for cities with high exposure, one for cities with medium exposure and one for cities with low exposure. This was accomplished by using the select by location feature in ArcGIS. First counties with greater than or equal to 50 hazard events were selected for the highest hazard exposure category. Then the select-by-location menu was chosen; features (cities) were selected from the city layer that had their centroid in the county hazard exposure layer using the selected features (highest exposure) from the county hazard exposure. This was then repeated for medium and low exposure cities. Cities were then selected to get varying degrees of hazard exposure (please see, Table 4).

Table 4 – City Size Classification and Hazard Exposure

City	Hazard Exposure	ICMA* City Population Classification
Miami-Dade FL	Medium Exposure	1,000,000 and over
Houston TX	High Exposure	1,000,000 and over
San Francisco CA	Low Exposure	500,000 to 1,000,000
Louisville-Jefferson KY	Low Exposure	500,000 to 1,000,000
Charlotte NC	Medium Exposure	500,000 to 1,000,000
Seattle WA	Medium Exposure	500,000 to 1,000,000
Portland OR	Low Exposure	500,000 to 1,000,000
St Paul MN	Low Exposure	250,000 to 499,999

Source: DPI Project

Fire departments provided data that included response times in minutes, fire district names, and a list of fire stations. Two GIS shapefile layers were also obtained from each fire department, which were used for analysis and included a polygon fire district layer and a fire station point layer. Shapefiles of census tract information were obtained from the Environmental Systems Research Institute (ESRI) GIS data set. Variables at the census tract level will be retrieved from the U.S. Census Bureau for the year 2000 and include: Household income, population, total number of housing units, racial composition of the population, housing values, real estate taxes, home ownership rates, single detached homes, population living in poverty, and commuting times.

GIS was be used to aggregate the data from the census tract level to the fire-district level. A problem arises of what to do with census tracts that are within

two different fire districts. Weighted areal interpolation is a method that is commonly used within GIS to deal with the problem of alignment between units of measurement, in this case between census tracts and fire districts. Specifically, "areal interpolation is a family of processes by which counts aggregated to a set of zones are reassigned to a different set of zones that describes the same region," (Mennis, 2003:1). Fire district boundaries (source zone) were assigned to the corresponding census tract (intersection zone) as a function of the fire-district area contained within the territory of the intersection zone. This approach of weighted areal interpolation has an assumption that data are equally distributed within each region (Flowerdew and Green, 1992). The key rationale for using areal interpolation method is that it maintains the pycnophylactic property, meaning that people are not created or destroyed during the redistribution process of the data (Mennis, 2003). Values that are non-population counts such as median household income, or median property value will be assigned to the centroid of the census tract. The centroid will be used to get an aggregate value for value-based variables, such as income, for each fire district and that values for census tracts that are within multiple fire districts can be only be used once.

Several steps were required for the data processing component of this study so that the data could be used in SPSS for regression analysis. The following is how census data was taken and joined with GIS data and aggregated to the fire-district level for each city using GIS. The first step was to create a census tract shapefile layer for each city and this was accomplished by using

ESRI's main census tract shapefile layer for the entire country and using the clip geoprocessing tool, which cuts out one layer based on the shape of another layer. The fire district shapefile was used to clip the census tract layer for each city. Each city then had a corresponding census tract shapefile. These census tract shapefiles then needed to be projected in a specific geographic coordinate system, and a corresponding shape file was created and was called census_tract_projected. Projection of the shapefile was an important step because having a projection would allow for determination of an area for each census tract. Each census tract shapefile layer was then projected to the fire district shapefile that were in the state plane coordinate system. The next step was to calculate an area for each census tract and this was done by creating a field called "oldArea" and using the XTools extension in ArcGIS. Census data for each city was then exported (transfer of data from one program to another) from Microsoft Access into ArcGIS in a Dbase (DBF) table. The DBF table was then joined to the census tract shapefile layer table based on the Federal Information Processing Standards (FIPS) Codes which was common to both tables. This shapefile of the census tracts for each city along with the joined DBF table of census data was used to create a new shapefile layer using the export feature tool. The next step was to overlay the fire district shapefile layer over the census tract shapefile layer to associate a census tract with a corresponding fire district boundary. This was accomplished with the identify tool that was used to compute the geometric intersection of the fire district on the census tract layer for each city. A new shape file was then created after this step and was called

census_tract_identify. A new data field was created in the table and was called newArea. This field in the database was populated by using the XTools extension to calculate the area of each newly created polygon from the census_tract_identify shapefile. A new field called areaPercent would have to be calculated which was determined by dividing the newArea field from the census_tract_identify shapefile and the oldArea field from the census_tract_projected shapefile. This field called areaPercent would give the total percentage of each census tract within each fire district. This field would be used for areal interpolation. A new field was created for each variable within the table and was called for example newPopulation, NewPopulationDensity, etc. The areaPercent field was multiplied by population field to create newPopulation, and this was done for every census variable. The final step for areal interpolation was to create one last shapefile, which would have one polygon for each fire district. This was done using the dissolve tool which aggregates polygons based on a common field, and in this case the census tracts were dissolved based the fire district they corresponded with. Each new polygon for the fire district has a statistical summary field for each of the census variables that are aggregated from each of the census tracts within each of the fire districts.

3.2 Quantitative Analysis

Average response time in seconds at the fire-district level is the dependent variable for the analysis. The unit of analysis is the fire district and there is a total 184 fire districts with response times for this study. In section 3.3 there is an explanation of why variables were selected, using the literature as a

guide to identify the variables along with a description of each variable. The regression equations are specified below in section 3.4 where there is a description of how the models were derived.

There were also control variables in each of the models that included population density, home density, area of the fire district, and per capita expenditure. The outcome of the linear regression models were beta coefficients for each independent variable which explains a possible unit change in the dependent variable. Another outcome was R^2 which is a figure that explains how much variation in the dependent variable is explained by the model. There is also a section of descriptive statistics that examines the number of observations, means, standard deviations, minimum, and maximum value of the data set. There was also an analysis to examine if the data was normally distributed. This was accomplished with two statistics, skewness and kurtosis, which are descriptive statistics. A normal distribution would be indicated by skewness value of 0 and a kurtosis value of 0. Skewness measures symmetry of the data-set and negative values indicate a left-skewed data, while positive numbers indicate right-skewed data. Kurtosis measures the peak of the data set and its distribution around the mean. Skewness and kurtosis are important indicators because if the majority of the data are not normally distributed then this will be a signal to use the logarithm of the values for all the variables in the model. Statistical analysis of the data was performed in SPSS and the data was maintained in a Microsoft Access Database.

3.3 Variable Selection and Description

3.31 Selection of Equality and Sprawl Variables

The urban service provision section has helped identify key socio-economic factors for analysis and for the measurement of equality. Lineberry (1977) and Jennings (1999) identified that the poor and racial minorities living in substandard housing were disproportionately affected by fires. Oliver, Healey, and LeGrand (2002) identified groupings based on race and income when it comes to measuring equality in service provision. Sanger (1981) identified that the wealthy and poor received superior fire service. Duncomb (1991) pointed out that fire services would vary across a community based upon income and taxes. Based on these findings several key variables have been identified including race, poverty, income, housing, and taxes. These are variables that are readily available or can be easily derived and quantified from the census which then can be regressed with response times to determine if linear relationships exist.

There have been several attempts by fellow researchers to quantify urban sprawl, and outcomes of urban sprawl. The purpose of this section is to identify some of the common variables or indicators that have been utilized. The first, and most common measure that was identified in the sprawl literature is residential density (see, Table 5). Galster, et al. (2001) describes density as the number of residential units per square mile. Ewing, Pendall and Chen (2002) in their analysis of sprawl for Smart Growth America also identified residential and population density as an indicator for sprawl. Glaster et. al (2001) indentified mixed uses, which is the extent of which to two or more different land uses exist

within the same area. When land uses are not mixed they are segregated and the segregation of land uses was an indicator of sprawl that was identified by Ewing et al. (2002). They measured this through the percentage of the population that was within one mile of an elementary school and this is also related to Galster et al's (2001) proximity indicator. Home type was also identified as a way of identifying urban sprawl and both Burchell et al. (2005) and Ewing et al. (2002) identified single family detached homes as a character of areas that are sprawled.

Table 5 – Sprawl Indicators

Sprawl Indicator	Description	Source	Source
Density	Residential Density	Galster et al. (2001) - <i>Wrestling Sprawl...</i>	Ewing et al. - Smart Growth America
Segregated land uses	% of residents with elementary school 1 mile away	Ewing et al. - <i>Smart Growth America</i>	
Home type	Single detached homes	Burchell et al. (2005) - <i>Sprawl Costs</i>	Ewing et al. - <i>Smart Growth America</i>
Street Accessibility	Average Block Size	Ewing et al. - Smart Growth America	
Vehicle Ownership	Vehicles per Households	Burchell et al. (2005) - <i>Sprawl Costs</i>	Ewing et al. - Smart Growth America
Commute Times	Census commute time in minutes	Burchell et al. (2005) - <i>Sprawl Costs</i>	Ewing et al. - Smart Growth America
Centrality	Distance from CBD	Galster et al. (2001) - <i>Wrestling Sprawl...</i>	

Other sprawl related factors that were easily quantifiable were related to the automobile. Commuting times from home to work and vehicle ownership rates were both viewed as outcomes of urban sprawl by Burchell, et al. (2005) and Ewing et al. (2002). Street accessibility also was used as an indicator of urban sprawl. Sprawled areas were seen as having poor street accessibility, because of the average block size was considerably larger for areas that were sprawled compared to areas that were not sprawled (Ewing et al., 2002). Congestion was also identified as being associated with sprawl by Burchell, et al (2005) and Ewing et al. (2002).

GIS was used to calculate several of the sprawl indicators. The indicators derived from the use of GIS included the segregated land use variable, street accessibility, congestion, and centrality. The segregated land use measure was determined through the percentage of the population within one mile of an elementary school. ESRI has a shape-file layer of schools. This layer of schools was cross referenced with a list of elementary schools from each city. If the school was not on the ESRI school layer it was geocoded (a process of taking an address and assigning latitude and longitude coordinates so that file can be displayed in a GIS) and added to the file. Block groups were used for population and a one mile buffer was placed around the school to select all the block groups that fell within one mile of the school buffer. The street accessibility and congestion variables were calculated using the selected by location tool. Using the ESRI street shapefile layer all the streets within a fire district were selected. Then using the statistics tool this provided a mean length for a street segment

within a fire district and this tool also provided a summary field which summed all the street segments within the fire district to provide an overall street mile length to calculate a population per street mile. Finally GIS was used to determine the distance from each fire district to the CBD. A centroid for each census tract was created. The location of the CBD was then determined from Google Earth, and geocoded into the GIS. Then using an analysis tool in an extension of ArcView GIS, the length between each census tract centroid to the CBD was calculated. These values were then aggregated to the fire-district level to provide an average distance to the CBD.

3.32 Descriptions of Variables

This section describes each variable, how the variable is calculated, along with the source of the data. Table 5 provides a summary of this information for a straightforward reference.

Dependent Variables in Analysis

Average Response Time in Seconds for the Fire District. Unit of analysis: Fire District. Source: Various city fire departments.

Independent Variables in Analysis

Area

Total area of the fire district divided by the number of stations within a fire district. Source: Various city fire departments;

Per Capita Expenditure (Expend)

This is the total funding for the fire department divided by the population that is served by the fire department. In most cases this was a group-level indicator. Louisville had different values for each of its fire districts. Source: Various city fire departments; Source U.S. Census Bureau, Census 2000 Summary File 1 (SF 1) 100-Percent Data.

Population Density (PopDen)

Total population of the fire district divided by total area of fire district., to give population per sq. mile. Source U.S. Census Bureau, Census 2000 Summary File 1 (SF 1) 100-Percent Data. Fire District Data provided by Fire Departments in GIS shapefile format.

Housing Density (HomeDen)

Total number of homes in fire district divided by total area of fire district to give number of homes per sq. mile. Source U.S. Census Bureau, Census 2000 Summary File 1 (SF 1) 100-Percent Data. Fire District Data provided by Fire Departments in GIS shapefile format.

Nonwhite Population (Race)

Percent of Total nonwhite population of fire district. Calculated by white population – 1. Source U.S. Census Bureau, Census 2000 Summary File 1 (SF 1) 100-Percent Data.

Poverty

Percent of Population living in poverty for the fire district which uses the Census Bureau and the federal government's official poverty definition. Population living in poverty divided by the total population. Source U.S. Census Bureau, Census 2000 Summary File 3 Sample Data.

Housing Ownership (HomeOwn)

Percent of homes that are owner Occupied within fire district. Calculated as owner occupied homes divided by total homes in fire district. Source U.S. Census Bureau, Census 2000 Summary File 3 Sample Data.

Detached Homes (Home Type) (DetHse)

Percent of homes that are single detached. Single detached homes divided by total number housing units within fire district. Source U.S. Census Bureau, Census 2000 Summary File 3 Sample Data.

Vehicles / Household (VehHH)

Total number of vehicles divided by the total number of households. Source U.S. Census Bureau, Census 2000 Summary File 3 Sample Data.

Average Commute Time (AvgCTime)

Total travel time in minutes to work. Calculate average travel time of commuters at tract level by taking the midpoint of the travel time category and multiplying by the total number of people for the category and then summing the total value of all minutes divided by total number of people for the tract to give an average travel time per person. Source U.S. Census Bureau, Census 2000 Summary File 3 Sample Data.

Home Value (HomeVal)

Aggregate value (dollars) for all owner-occupied housing units in structure divided by total number of owner-occupied housing units . Source U.S. Census Bureau, Census 2000 Summary File 3 Sample Data.

Real Estate Taxes (RealTax)

Aggregate Real Estate Taxes: total amount of all real estate taxes on the entire property (land and buildings) payable in 1999 to all taxing jurisdictions, including special assessments, school taxes, county taxes divided by total number of owner-occupied housing units. Source U.S. Census Bureau, Census 2000 Summary File 3 Sample Data

High-Income Households (HighInc)

Percent of household that earn above \$75,000 per year (1999), divided by total number of households for the fire district. Data Source: U.S. Census Bureau, Census 2000 Summary File 3 Sample Data

Population Per Street Mile (PopStMile)

Total Population of fire district divided by the total length of all roadways within fire district. Data Source: Census 2000 Summary File 1 (SF 1) 100-Percent Data; ESRI Street Data file

Street Segment Length (StreetSeg)

Average street segment length in feet. Data Source ESRI Street Data file.

Elementary School (ElmSch)

Percentage of residents of the fire district that are within 1 mile of an elementary school. Source: Census 2000 Summary File 1 (SF 1) 100-Percent Data; ESRI;

Distance from Central Business District (CBD)

Distance of each census tract centroid to the central business district, aggregated to the fire district. Source of CBD location google map. ESRI.

Table 6 – Variable Summary Table

Variable	Description	Equation	Literature Source
Area	Area of fire district divided by # of fire stations	1 to 14	(Halpern, 1979)
Expend	Per capita expenditure	1 to 14	(Waters, 2000)
PopDen	Population per sq. mile	1 to 7	(Galster et al, 2001); (Ewing et al, 2002)
NonWhite	% of non white population	1	(Lineberry, 1977); (Jennings, 1999); (Oliver, Healey, and LeGrand, 2002)
Poverty	% of population living below poverty level	2	(Lineberry, 1977); (Jennings, 1999); (Oliver, Healey, and LeGrand, 2002); (Sanger, 1981)
HomeOwn	% of home owners that earn under \$29,999	3	(Lineberry, 1977); (Jennings, 1999)
HomeVal	Average home value	4	(Lineberry, 1977); (Jennings, 1999)
RealTax	Average property taxes per home owner	5	(Duncomb, 1991)
HighIncome	% of households that earn \$75,000+	7	(Sanger, 1981); (Oliver, Healey, and LeGrand, 2002); (Duncomb, 1991)
HomeDen	Total number of homes per sq. mile	8 to 14	(Galster et al, 2001); (Ewing et al, 2002)
AvgCTime	Average commute time to work in minutes	9, 9a	(Burchell et al, 2005); (Ewing et al, 2002)
VehHseHold	Vehicles divided by number of households	10, 10a	(Burchell et al, 2005); (Ewing et al, 2002)
PopStreetMile	Population divided by total road mi. in district	11, 11a	(Galster et al, 2001); (Ewing et al, 2002), (Burchell et al, 2005)
StreetSeg	Average street segment length	12, 12a	(Ewing et al, 2002)
ElmSchool	% of population within 1 mile of school	13, 13a	(Ewing et al, 2002)
CBD	Average distance of fire district to the CBD	14, 14a	(Galster et al, 2001)

3.4 Regression Equations and the Development of the Models

The first seven equations looked for proportional access. These models were used to determine if a linear relationship existed between response times, and the nonwhite population, population living in poverty, home ownership, home values, real estate taxes, and high-income households that earn greater than \$75,000. There also were control variables that included the population density, area of the fire district, and the per capita expenditure of the fire department. The next 12 equations were used to determine if linear relationship existed between response times and detached housing, vehicles/household, average commute time, population per street mile, street segment length, elementary school access and distance to the CBD.

Several different permutations were attempted before the final models were derived. The first model that was examined was to regress response times with all the equity variables while controlling for various factors. There also was a similar model but with all the sprawl variables and response times along with the control variables.

Response time = $f(\text{area, expend, popden, homeden, nonwhite, poverty, homeown, homevalue, realtax, HighIncome})$.

Response time = $f(\text{area, expend, popden, homeden, detHse, AvgCTime, VehHseHold, PopStreetMile, StreetSeg, ElmSchool, CBD})$.

However, the issue with these models that made them problematic was multicollinearity. Many of the variables are related to one another and by putting them all within one model distorts the results. It would be difficult to gauge the full

impact of each variable on the dependent variable because many of the variables are related to one another. A similar variation of each model also was examined but included a dummy variable for each city to get a more precise picture of how each variable affected the cities.

Response time = f(area, expend, popden, homeden, nonwhite, poverty, homeown, homevalue, realtax, HighIncome, Charlotte, Houston, Louisville, Seattle, Portland, St. Paul, Miami).

It was determined that it would be more effective if a new variable was created for each city, which contained a particular factor such as nonwhite. The variable was created by multiplying the dummy variable for a particular city and the socioeconomic variables, such as nonwhite or poverty, to create a new interaction variable, which was named using the city name followed by the variable that it was multiplied with, such as CharlotteNonwhite. This field was populated with only Charlotte's nonwhite values for each fire district, and every other fire district that was not in Charlotte would have a value of 0 for this data field. This was done for each city, except for St. Paul because St. Paul has just three fire districts. So every city dummy variable was multiplied by every indicator to create an indicator for each city which created an additional 42 different variables for the equity models and 42 different variables for the sprawl models. These 42 variables were then included into each model, however the results were too complicated having so many different independent variables.

Response time = f(area, expend, popden, homeden, Nonwhite_i, CharlotteNonwhite_i, HoustonNonwhite_i, LouisvilleNonwhite_i, PortlandNonwhite_i, SanFranciscoNonwhite_i, SeattleNonwhite_i, MiamiNonwhite_i, Poverty_i, CharlottePoverty_i, HoustonPoverty_i, LouisvillePoverty_i, PortlandPoverty_i, SanFranciscoPoverty_i, SeattlePoverty_i, MiamiPoverty_i, HomeOwn_i, CharlotteHomeOwn_i, HoustonHomeOwn_i, LouisvilleHomeOwn_i, HomeVal_i, CharlotteHomeVal_i, HoustonHomeVal_i, LouisvilleHomeVal_i, PortlandHomeVal_i, SanFranciscoHomeVal_i, SeattleHomeVal_i, MiamiHomeVal_i, PortlandHomeOwn_i, SanFranciscoHomeOwn_i, SeattleHomeOwn_i, MiamiHomeOwn_i, HighIncome_i, CharlotteHighIncome_i, HoustonHighIncome_i, LouisvilleHighIncome_i, PortlandHighIncome_i, SanFranciscoHighIncome_i, SeattleHighIncome_i, MiamiHighIncome_i)

Other models were also examined including grouping similar variables together in a model, like nonwhite and poverty, or homeown and homeval along with the three control variables. Once again there were issues with multicollinearity as the variables were related.

Response time_i = f(Area_i, Expend_i, PopDen_i, Nonwhite_i, Poverty_i)

Response time_i = f(Area_i, Expend_i, PopDen_i, HomeOwn_i, HomeVal_i)

It was determined that it would be most effective to examine each variable in a separate model on its own along with the control variables. Seven interaction variables, one for each city were also included for each of the cities, except for St Paul. The overall variable would be representative for St. Paul. Equation 1 through 7 represents these models which look at the equality indicators. The sprawl models were also similar. There was only one difference as there are two models for each sprawl indicator. One model with the entire group variable not stratified by the city (no city-interaction variable), and the second model with the city-interaction variable.

Race Model

1. Response time_i = f(Area_i, Expend_i, PopDen_i, Nonwhite_i, CharlotteNonwhite_i, HoustonNonwhite_i, LouisvilleNonwhite_i, PortlandNonwhite_i, SanFranciscoNonwhite_i, SeattleNonwhite_i, MiamiNonwhite_i)

Poverty Model

2. Response time_i = f(Area_i, Expend_i, PopDen_i, Poverty_i, CharlottePoverty_i, HoustonPoverty_i, LouisvillePoverty_i, PortlandPoverty_i, SanFranciscoPoverty_i, SeattlePoverty_i, MiamiPoverty_i)

Housing Tenure Model

3. Response time_i = f(Area_i, Expend_i, PopDen_i, HomeOwn_i, CharlotteHomeOwn_i, HoustonHomeOwn_i, LouisvilleHomeOwn_i, PortlandHomeOwn_i, SanFranciscoHomeOwn_i, SeattleHomeOwn_i, MiamiHomeOwn_i)

Home Value Model

4. Response time_i = f(Area_i, Expend_i, PopDen_i, HomeVal_i, CharlotteHomeVal_i, HoustonHomeVal_i, LouisvilleHomeVal_i, PortlandHomeVal_i, SanFranciscoHomeVal_i, SeattleHomeVal_i, MiamiHomeVal_i)

Property Tax Model

5. Response time_i = f(Area_i, Expend_i, PopDen_i, RealTax_i, CharlotteRealTax_i, HoustonRealTax_i, LouisvilleRealTax_i, PortlandRealTax_i, SanFranciscoRealTax_i, SeattleRealTax_i, MiamiRealTax_i)

Income Model

6. Response time_i = f(Area_i, Expend_i, PopDen_i, highIncome_i, CharlotteHighIncome_i, HoustonHighIncome_i, LouisvilleHighIncome_i, PortlandHighIncome_i, SanFranciscoHighIncome_i, SeattleHighIncome_i, MiamiHighIncome_i)

Home Density Model

7. Response time_i = f(Area_i, Per Capita Expenditure_i, HomeDen_i, DetHse_i)
 - a. Response time_i = f(Area_i, Expend_i, HomeDen_i, DetHse_i, CharlotteDetHse_i, HoustonDetHse_i, LouisvilleDetHse_i, PortlandDetHse_i, SanFranciscoDetHse_i, SeattleDetHse_i, MiamiDetHse_i)

Commute Time Model

8. Response time_i = f(Area_i, Expend_i, HomeDen_i, AvgCTime_i)
 - a. Response time_i = f(Area_i, Expend_i, HomeDen_i, AvgCTime_i, CharlotteAvgCTime_i, HoustonAvgCTime_i, LouisvilleAvgCTime_i,

Portland_iAvgCTime_i, SanFrancisco_iAvgCTime_i, Seattle_iAvgCTime_i,
Miami_iAvgCTime_i)

Vehicle Ownership Model

9. Response time_i = f(Area_i ,Expend_i, HomeDen_i, VehHseHold_i)

- a. Response time_i = f(Area_i ,Expend_i, HomeDen_i,
VehHseHold_i,Charlotte_iVehHseHold_i, Houston_iVehHseHold_i,
Louisville_iVehHseHold_i, Portland_iVehHseHold_i,
SanFrancisco_iVehHseHold_i, Seattle_iVehHseHold_i,
Miami_iVehHseHold_i)

Congestion Model

10. Response time_i = f(Area_i ,Expend_i, HomeDen_i, PopStreetMile_i)

- a. Response time_i = f(Area_i ,Expend_i, HomeDen_i, PopStreetMile_i,
Charlotte_iPopStreetMile_i, Houston_iPopStreetMile_i,
Louisville_iPopStreetMile_i, Portland_iPopStreetMile_i,
SanFrancisco_iPopStreetMile_i, Seattle_iPopStreetMile_i,
Miami_iPopStreetMile_i)

Street Length Model

11. Response time_i = f(Area_i ,Expend_i, HomeDen_i, StreetSeg_i)

- a. Response time_i = f(Area_i ,Expend_i, HomeDen_i,
StreetSeg_i,Charlotte_iStreetSeg_i, Houston_iStreetSeg_i,
Louisville_iStreetSeg_i, Portland_iStreetSeg_i, SanFrancisco_iStreetSeg_i,
Seattle_iStreetSeg_i, Miami_iStreetSeg_i)

Land Use Model

12. Response time_i = f(Area_i ,Expend_i, HomeDen_i, ElmSchool_i)

- a. Response time_i = f(Area_i ,Expend_i, HomeDen_i, ElmSchool_i,
Charlotte_iElmSchool_i, Houston_iElmSchool_i, Louisville_iElmSchool_i,
Portland_iElmSchool_i, SanFrancisco_iElmSchool_i, Seattle_iElmSchool_i,
Miami_iElmSchool_i)

Distance to the CBD Model

13. Response time_i = f(Area_i ,Expend_i, HomeDen_i, CBD_i)

- a. Response time_i = f(Area_i ,Expend_i, HomeDen_i, CBD_i,
Charlotte_iCBD_i, Houston_iCBD_i, Louisville_iCBD_i, Portland_iCBD_i,
SanFrancisco_iCBD_i, Seattle_iCBD_i, Miami_iCBD_i)

3.5 Qualitative Analysis

Following the quantitative analysis there was a case study of three different fire districts from Louisville (Jefferson County). These case studies were an in-depth investigation of several factors. First, there was a comprehensive examination of the fire departments. Aspects of the fire department that were analyzed include: management structure of the fire department, the Insurance Services Office rating for the fire department, fire department budget, personnel, vehicles, funding spent on training, location of new fire stations, shut down fire stations, and similar issues. The next aspect that was examined is a closer focus on the fire districts within with a complete assessment of the demographic profile and the characteristics of the landscape that make up each of the fire districts. Most importantly there was a comprehensive examination of the most salient variables from the quantitative analysis for each of the fire departments to get a clearer picture of the why results turned out the way that they did.

The Institutional Review Board (IRB) process was followed. All the required documentation, such as a copy of the interview questions and informed consent were submitted to the IRB for approval before the interviews took place. The IRB classified this project as exempt.

3.51 Survey Questions for Qualitative Analysis

1. In Your opinion what is the most influencing factor on fire department response times?
2. Do the allocation of resources such as personal, vehicles, stations, etc. have an impact on response times?
3. Would you say that in certain cities the lower income areas are disadvantaged with respect to response times?
4. Would you say that in certain cities that fire districts with higher-cost housing have better response times?
5. Would you say that in certain cities that fire districts with higher rates of property taxes have better response times?
6. It was found in this study it that in certain cities that lower income areas were disadvantaged with respect to response times, however this was not the case for all cities as reverse was found to be true. Would you have any possible explanations for this?
7. Similar to the previous question, in certain cities fire district's with higher cost housing had better response times, however once again this was not the case for all cities as reverse was found to be true. Would you have any possible explanations for this?
8. In this study it was found that the higher the rate of property taxes, the worse the response time. Would you have any possible explanations for this?
9. What do you think has the greatest influence on response times for a fire district (increases response time)?
 1. Commuting Time
 2. Vehicle Ownership
 3. Population Density (Population per street mile)
 4. Length of the Block
 5. Diversity of land use
 6. Distance from the center of the city
 7. % of detached housing

10. Commuting times within the fire district were found to be the most correlated with longer response times, would you agree with this and why do you think this would be the case? What would you recommend to deal with this?
11. The length of the street block was found to be the (2nd most) correlated with longer response times, would you agree with this and why do you think this would be the case? What would you recommend to deal with this?
12. Population density and congestion were found to be the correlated with longer response times, would you agree with this and why do you think this would be the case? What would you recommend to deal with this?
13. Do issues with response times ever affect cities or fire department policies in any way?

CHAPTER 4

RESULTS

4.1 Description of Cities

Table 7 displays a breakdown of the total number of fire districts for each city and some other general information. Miami-Dade has data from two separate Fire departments (F.D.), the City of Miami F.D. and Miami-Dade F.D., which is the rest of the county outside of the city limits of Miami. In total there were 63 fire districts, 14 for the city of Miami F.D., and 49 for Miami-Dade F.D. Total area served by both fire departments was approximately 838 square miles (35 square miles for the city of Miami, 802 square miles for the Miami-Dade department). The average size of a fire district was 2.5 square miles for the City of Miami F.D., and 16 square miles for Miami-Dade F.D. and 13 square miles for both F.D. combined. The minimum value for a size of a fire district was 0.60 square miles, and the maximum was 127 square miles. In total, there were 63 fire stations for both fire departments. The total population for the Miami-Dade area was 2.4 million people. The City of Miami accounts for 15 percent of the total population. The average population per fire district was roughly 30,000, with a minimum of 1,300 and a maximum of 70,000 (based on 2000 census figures).

Table 7 – Cities and Fire District Information

City	2000 Population	Fire Districts	Stations	Area Served Mi. Sq	Avg Area / District
Miami-Dade, FL	2,253,362	63	63	837.58	13.29
Houston, TX	1,953,631	21	110	616.5	29.36
San Francisco, CA	776,733	10	42	43.18	4.32
Louisville-Jefferson County, KY	693,604	20	56	392.6	19.63
Charlotte, NC	540,828	7	39	287.39	41.06
Seattle, WA	563,374	32	36	82.55	2.58
Portland, OR	529,121	28	30	154.12	5.5
St Paul, MN	287,151	3	16	64.17	21.39

There were a total of 21 fire districts in the City of Houston. The area served by the fire department is 616 square miles, the largest of any single fire department in this analysis. The mean size of a fire district within Houston was 29 square miles, with a minimum size of 3 square miles and a maximum of 78 square miles. Houston has a total of 110 fire stations, also the greatest number of fire stations for a city in this analysis. The total population served by Houston was approximately 2.07 million. The average population per fire district was close to 90,000 people, with a minimum of 4,800 and a maximum of 190,000.

San Francisco had 10 fire districts, with a total area of 43 square miles. The average size of a fire district in San Francisco was approximately 4.3 square miles. The minimum size of a fire district was 1.8 square miles and the maximum was 9.3 square miles. There were a total of 42 fire stations in San Francisco. The

total population served by the San Francisco Fire department was roughly 770,000 people. The average population per fire district was roughly 76,500 people. The minimum was 22,000 and the maximum was 126,000 people.

Louisville-Jefferson County, Kentucky, had 20 different fire departments. Louisville-Jefferson County was unique because of the number of fire departments that it had. These fire departments include: Buechel, Camp Taylor, Dixie Suburban, Eastwood, Fairdale, Fern Creek, Harrods Creek, Highview, Jeffersontown, Lake Dreamland, Louisville, Lyndon, McMahan, Middletown, Okolona, Pleasure Ridge Park, Shively, St. Matthews, and Worthington. The total area that was served by all 20 fire departments was 390 square miles. The City of Louisville Fire Depart was responsible for the greatest area within Louisville-Jefferson County with 62 square miles. Pleasure Ridge Park and Fern Creek also had very large areas. Dixie Suburban had the smallest area with 1 square miles in total. The average area for all the fire districts combined within Louisville-Jefferson County was close to 20 square miles per station. There were a total of 56 fire stations for the 20 fire departments. The Louisville fire department had 22 of the 56 fire stations. Total population served by all 20 fire departments was 690,000. The average population per fire district was roughly 34,000. The Louisville Fire District accounted for nearly 250,000 people, which was the largest fire district. The Dixie Suburban Fire District was the smallest in size, and also had the smallest population that was served.

Charlotte has one fire department with seven fire districts. The total area that the Charlotte F.D. serves is 290 square miles. The average area per fire

district is roughly 40 square miles, which is the largest average area for fire districts for all the cities. The minimum value of a fire district within Charlotte is 21 square miles and the maximum is 61 square miles. Charlotte has a total of 39 fire stations. Total population served by the Charlotte F.D. is 540,000. The average population per fire district is 77,000, with a minimum of 42,500 and a maximum of 126,000.

Seattle had one main fire department with 32 fire districts. The total area served by the Seattle F.D. is roughly 83 square miles. Seattle has 36 fire stations in operation. The average size of a fire district within the jurisdiction of the Seattle F.D. is roughly 2.6 square miles, the smallest average size of fire districts in this study. The minimum value was 0.4 square miles, while the maximum was 4.5 square miles. The total population that is served by the Seattle F.D. is approximately 560,000 people. The mean population served per fire district is close to 16,000 people. The minimum value for population for a fire district was roughly 3,100 people, while the maximum value was 41,000 people.

Portland has 28 fire districts, with a total of 30 fire stations. The total area served by the Portland F.D. is roughly 154 square miles. The average size of a fire district within Portland is 5.5 square miles. The smallest fire district in size was 1.6 square miles, while the largest was 18 square miles. Total population served by the Portland F.D. is close to 530,000 people. The average population per fire district is 19,000 people. The minimum value for population for a fire district is 1,200 people and the maximum value was 37,000.

St. Paul was the smallest city in the analysis, and also had the fewest

number of fire districts, at three. The St. Paul fire department has 16 fire stations to cover a total area of 64 square miles. The average area of a fire district in St. Paul was 21 square miles, and the smallest area of a fire district was 17 square miles, while the largest was 29 square miles. The total population that is served by the St. Paul F.D. is close to 290,000 people. The average population per fire district was close to 100,000 people, with a minimum of 87,000 and maximum of 113,000 people.

4.2 Descriptive Statistics

There were a total of 184 records for the entire data set. The dependent variable in the analysis was response time in seconds. The mean average response time for all fire districts was 337 seconds, with a median of 335 seconds and a minimum of 182 seconds and a maximum of 820 seconds, refer to table 8. Seattle had the lowest average response time at 252 seconds, while Houston had the highest average response time at 408 seconds, refer to table 9. The standard deviation was 79 seconds. The response time variable was close to being normally distributed as indicated by a skewness of 0.10 and a Kurtosis of -0.85.

The mean area per station was 7.72 miles, with a median of 4.35 miles. Miami-Dade had the highest average of miles per station with a value of 13.27, while San Francisco had the only 1.02 miles per station. There was great variability in the range of this data set as indicated by a low minimum of 0.39 and a high maximum of 127.4 miles per station. The standard deviation was 13.94

miles per station. Square miles per station were not normally distributed and were heavily skewed as indicated by a skewness of 5.88 and a kurtosis of 41.49.

Per capita expenditure was a group-level indicator and had a mean of \$213 per capita for all the fire districts, and a median of \$219. Charlotte, Houston, Portland, San Francisco, Seattle, Tampa, and St. Paul all had one value per city for the per capita expenditure, as the total fire department budgets were not allocated according to the fire district. Louisville had a different budget for each of its fire districts. There was also one budget for the city of Miami, and a budget for the remainder of Dade County. San Francisco had the highest per capita expenditure at \$313 per person, while Louisville-Jefferson County had a value of less than half of San Francisco at \$122 per person. The minimum of the per capita expenditure was \$44, which was from the Dixie suburban fire district in Louisville-Jefferson County. The maximum per capita expenditure was from San Francisco at \$313 per person. The standard deviation was \$55. Per capita expenditure was not normally distributed as it had a skewness of -0.74 and a kurtosis of 0.35.

Population density had a mean of 5,743 people per square mile and a median of 4,328 people per square mile. The minimum was 197 people per square mile, while the maximum was 35,613 people per square mile. San Francisco had the highest average population density per fire district at 20,969 people per square mile., while Louisville had the lowest at 1,933 people per square miles. The standard deviation was 5,804. Population density was not normally distributed as indicated by a skewness of 2.90 and a kurtosis of 10.32.

Similar to population density, home density also had a great range. The mean home density was 2,594 homes per square mile, with a median of 1,772 homes per square mile, with a minimum of 65 and a maximum of 21,444 homes per square mile. Both Louisville and Charlotte were tied for the lowest average home density per fire district at 857 homes per square miles, while San Francisco had the highest average home density at 10,454 homes per square mile. Home density was not normally distributed and had a skewness of 3.41 and kurtosis of 14.43. The data was right-skewed and had very high peaks within the dataset.

The mean for percentage of the population that was nonwhite was 33 percent, with a median of 27 percent. The standard deviation was 22 percent for the entire dataset. The minimum of the dataset was close to 5 percent while the maximum was 92 percent. San Francisco had the highest mean per fire district of nonwhite people at 50 percent, while Houston was also very close at 49 percent. Louisville had the lowest proportion of nonwhite people per fire district at 19 percent. The nonwhite data was not normally distributed, although it was not highly skewed either in any major direction with a skewness of 0.70 and a kurtosis of -0.65.

There was a great variation in level of poverty. The mean rate for percentage of the population living in poverty for the entire data set was 15 percent. The median was 13 percent, with a standard deviation of 9 percent. The minimum was a low of 2 percent, while the maximum was 55 percent. Houston and Miami had the highest average rates of poverty at roughly 19 percent. Louisville had the lowest rate of poverty at roughly 8 percent. The standard

deviation was 9.5. The data for poverty was not normally distributed as indicated by a skewness of 1.26 and a kurtosis of 1.84.

The mean for home ownership rates for the entire data set was 55 percent, while the median was 58 percent. The minimum value was 5 percent while the maximum value was 92 percent. Louisville had the highest average rate of home ownership, with close 68 percent of the city's population being home owners. San Francisco had the lowest average rate of home ownership with 33 percent of population being home owners. The standard deviation was 18 percent. The data for home ownership was close to being normally distributed. The skewness was -0.62 and the kurtosis was 0.02.

The majority of homes were single detached as the mean for the entire dataset was 51 percent. The median value was 56 percent. The minimum was 1 percent, while the maximum was 91 percent. San Francisco had the lowest mean for single detached homes at 18 percent. Miami also had an average of 46 percent, which was lower than the overall average. Louisville had the highest average of single detached home at 71 percent, which was significantly higher than the average for the entire data set. The standard deviation was 23 percent. The data was not normally distributed, however, it was also not very skewed as it was only slighted left-skewed with a skewness of -0.64 and had a kurtosis of -0.55.

The mean number of vehicles per household was 1.48, while the median was 1.53 vehicles per household. The low of the data set was 0.46 cars per household. The high of the data set was 2.16 vehicles per household. Louisville

had the highest average of 1.7 vehicles per household. San Francisco had the lowest average of 1.1 vehicles per household, and was well below the mean for the entire dataset. The standard deviation was 0.32. The data was not normally distributed, and was left-skewed with a skewness of -1.01 and had a kurtosis of 1.45.

The average commute time for all the cities within the data set was 27.9 minutes. The median for the data set was 27.6 minutes. The minimum of the dataset was 19 minutes, while the maximum was 40 minutes. St. Paul had the lowest average for commute times of 22.6 minutes. Louisville also had a low average commute time of 23 minutes. San Francisco had the highest average commute time of 32 minutes, while Miami also had a high average commute time of 31 minutes. The standard deviation was 4.3. The data was close to being normally distributed, although it was slightly right-skewed and had a skewness of 0.41, and a kurtosis of -0.33.

The mean for home prices for the entire dataset was approximately \$199,000, with a median of roughly \$150,000. The standard deviation of the dataset was \$129,000. The minimum home value was approximately \$44,000, while the maximum was \$790,000. Houston had the lowest average home prices at close to \$114,000. San Francisco had the highest average home values at approximately \$550,000. Seattle also had an average home value that was about \$100,000 higher than the average for the entire data set at \$295,000. The data was not normally distributed and was right-skewed. Average home value had a skewness of 1.78, and a kurtosis of 3.78.

The mean for property taxes for the entire data-set was approximately 1 percent of total property value. The median was also roughly 1 percent. The standard deviation was 0.37%. The minimum property tax value for the eight cities was 0.01 percent. The maximum property tax value was 2.15 percent of total property value. San Francisco had the lowest average property tax rate for all the cities at 0.29 percent of property values. Portland had the highest average rate of property taxes at 1.53 percent. Houston also had a higher average rate of property taxes at 1.52 percent. The data was close to being normally distributed. The data was slightly left-skewed and had a skewness of -0.16 and a kurtosis of 0.41.

The mean for the percentage of high income households (that earn over \$75,000 per year) was 23 percent. The median for the dataset was 20 percent. The standard deviation was 12 percent. The minimum for the data-set was 3 percent, while the maximum was 68 percent. San Francisco had the highest mean for all the cities with close to 35 percent of all households earning greater than \$75,000. St. Paul and Miami had the lowest mean for household earning above \$75,000 at 19 percent. The data was right-skewed with a skewness of 0.97, and a kurtosis of 0.92.

The mean population per street mile was 320 people per mile of roadway. The median was 272 people per mile of roadway. The minimum value for population per street mile was 48, while the maximum value was 1437 people per mile. Louisville had the lowest average population per street mile at 209 people per mile of roadway. Charlotte also had lower values at 210 people per

mile of road way. San Francisco had the highest average at 837 people per mile of road way. The standard deviation of the data set was 219. The data was not normally distributed, was right-skewed, and had a skewness of 2.57 and a kurtosis of 7.45.

The average street segment length for all the cities was 446 feet. The median for street segment length was 417 feet. The minimum value of street segment length was 232 feet and the maximum value was 1193 feet. As expected, San Francisco had the lowest average of street segment length at 360 feet. Portland and Seattle also had averages that were lower than the overall mean at 370 feet. Louisville had the highest average street segment length at 557 feet. Houston also had high values, with an average at 520 feet. The standard deviation was 123. The data for street segment length was not normally distributed, was right-skewed and had a skewness of 2.22. The kurtosis was 9.33.

The mean for the population living within 1 mile of an elementary school for all the fire districts was 76 percent. The median was 97 percent. The minimum value was 0 percent, while the maximum was 100 percent of the population of the fire district living within 1 mile of an elementary school. Charlotte had the highest mean, with 99 percent of its population living within 1 mile of an elementary school. San Francisco and Houston also had high percentages of their population living within 1 mile of an elementary school at 98 percent and 96 percent. Miami had the lowest average rate with only 47 percent of its population living within 1 mile of an elementary school. The standard

deviation was 34 percent. The data was not normally distributed. The data was left-skewed and had a skewness of -1.14 and a kurtosis of -0.18.

The mean distance from the Central Business District was 7.1 mile. The median was 5.7 mile. The minimum for the dataset was 0.04 mile, while the maximum was 27.5 mile. Both Miami and Louisville had the highest averages for distance from the CBD at 9.8 mile. Charlotte had the lowest average at 1.8 mile. The standard deviation was 5.16 mile. The data was not normally distributed. The data was right-skewed and had a skewness of 1.11 and a kurtosis of 1.25.

Table 8 – Descriptive Statistics for Entire Data Set

Variable	N	Mean	Median	St Dev	Skew	Kurt	Min	Max
Response Time (Seconds)	185	337	335	73	0.10	-0.85	182	537
Station Area (miles)	185	7.72	4.35	13.94	5.88	41.49	0.39	127.4
Expenditure	185	\$213	\$219	\$55	-0.74	0.35	\$44	\$313
PopDen (pop/sq. mi.)	185	5,743	4,328	5,804	2.90	10.32	197	35,613
HomeDen (homes/sq. mi.)	185	2,594	1,772	3,068	3.41	14.43	65	21,444
% Non White	185	33%	27%	22%	0.70	-0.65	5%	92%
% Poverty	185	15%	13%	9%	1.26	1.84	2%	55%
% HomeOwn	185	55%	58%	18%	-0.62	0.02	5%	92%
% DetHse	185	51%	56%	23%	-0.64	-0.55	1%	91%
Veh/Hhold	185	1.48	1.53	0.32	-1.01	1.45	0.46	2.16
AvgCTime (minutes)	185	27.90	27.56	4.30	0.41	-0.33	19.55	40.28
Home Value (\$)	185	\$199,274	\$153,214	\$129,140	1.78	3.78	\$43,746	\$791,186
% Property Tax	185	1.00%	1.06%	0.38%	-0.16	0.41	0.01%	2.15%
HighIncome (% households over \$75,000)	185	23%	20%	12%	0.97	0.92	3%	68%
Pop/ Street Mile	185	320	272	219	2.57	7.45	48	1,437
StreetSeg (feet)	185	446	417	123	2.22	9.33	232	1,193
ElemSchool	185	76%	97%	34%	-1.14	-0.18	0%	100%
CBD (Miles)	185	7.10	5.68	5.16	1.11	1.25	0.04	27.51

Table 9 – Descriptive Statistics Stratified by City

Variable	Charlotte	Houston	Louisville	Portland	San Francisco	Seattle	St. Paul	Miami
Response Time (Seconds)	319	408	283	297	327	252	291	396
Station Area (Sq. Miles)	8.25	6.54	6.92	5.5	1.02	2.51	4.22	13.27
Expenditure	\$130	\$151	\$122	\$236	\$313	\$219	\$146	\$244
Population	77,300	92,339	34,218	19,004	76,421	16,249	101,394	29,652
Households	30,812	34,019	14,176	8,025	32,496	7,504	39,641	10,077
PopDen (Pop/Sq. Miles)	1,987	3,588	1,933	4,390	20,969	6,576	4,901	5,903
HomeDen (Homes/Sq. Miles)	857	1,439	857	2,049	10,454	3,293	1,518	2,422
% Non White	45%	49%	19%	21%	50%	32%	31%	34%
% Poverty	12%	19%	8%	14%	13%	13%	15%	19%
% HomeOwn	53%	45%	68%	53%	33%	47%	55%	53%
% DetHse	57%	52%	71%	58%	18%	52%	51%	46%
Veh/Hhold	1.59	1.49	1.73	1.49	1.07	1.42	1.41	1.51
AvgCTime (Minutes)	26.00	29.00	23.00	24.00	32.00	25.83	22.58	31.31
Home Value	\$173,824	\$114,235	\$147,365	\$204,229	\$548,907	\$295,923	\$129,013	\$145,069
% Property Tax	0.88%	1.52%	0.73%	1.53%	0.29%	0.69%	1.06%	1.17%
High Income (% households over \$75,000)	25%	20%	27%	20%	35%	27%	19%	19%
Pop/ Street Mile (total population/ total street miles)	210	298	209	238	837	313	310	336
StreetSeg (Feet)	501	520	557	370	360	370	438	469
ElemSchool	99%	96%	80%	89%	98%	91%	78%	47%
CBD (miles)	1.80	8.06	9.78	4.36	3.70	4.09	9.42	9.84

4.3 Regression Results

Model 1, refer to Table 10, displays the results of the linear regression analyses concerning the association between response time and proportion of the nonwhite population, while controlling for area, expenditure, population density and the individual city nonwhite values.

Table 10 – Model 1 Results

1 (Non White) $R^2 = 0.782$			
Variable	β	Sig	Std. Err
Constant	2.732	***	(0.142)
Area	0.059	***	(0.016)
Expend	-0.086		(0.055)
PopDen	-0.029	*	(0.016)
NonWhite	-0.028	**	(0.013)
Charlotte_NW	-0.004		(0.007)
Houston_NW	0.025	***	(0.006)
Louisville_NW	-0.025	***	(0.007)
Portland_NW	-0.006		(0.007)
San Fran_NW	0.025	***	(0.008)
Seattle_NW	-0.018	**	(0.007)
Miami_NW	0.028	***	(0.007)

Model 1 and all the models were log-log models. The R^2 for the model 1a was 0.78, which indicates that 78 percent of the variation of response times was explained by this model. The signs of the coefficients were intuitively correct for the model, with some exceptions. The area variable was significant and had a positive sign in every socio-economic model, which was as expected. This indicates fire districts that are larger in area with fewer stations can expect to have longer response time. Population density in model 1a was only significant at the 90 percent level; however the negative coefficient was not expected. Fire

districts with greater population density can expect to have shorter response times. The non-white variable, which is indicative of St. Paul, was found to be significant at the 0.05 level. Fire districts that have a greater non-white population can expect to have shorter response times, overall. At the city level the Houston, San Francisco, and Miami nonwhite variable were found to be significant at the 95 percent level or higher and had positive coefficients. This indicates that the higher the proportion of nonwhites in those particular cities, the longer the response times. Louisville, and Seattle also had coefficients that were significant at the 95% level or higher but had negative coefficients. This indicates that the higher the proportion of nonwhites in those particular cities, the shorter the response times. Since Model 1 and all the models are log-log specification models, the coefficient can be interpreted as a direct percentage change in the dependent variable. The estimates represent elasticities. For the purpose of explanation, a 10 percent change in value will be used for the interpretation of the coefficients. A 10 percent increase in the area of a fire district will result in an increase in response times by 0.59 percent, while holding all else constant, refer to table 10. A 10 percent increase in population density will reduce response times by 0.29 percent while holding all else constant. A 10 percent increase in the non-white population of the fire district will increase response time by 0.28 percent, while holding all else constant.

Table 11 – Summary Table for Results of 10% Elasticities for Equity Models

Model	R ²	Elasticity	Sig
1	0.782	10% inc in nonwhite pop. will result in a 0.28% dec in RT (St. Paul)	**
		10% inc in the nonwhite pop. in Houston will result in a 0.25% inc in RT	***
		10% inc in the nonwhite pop. in Louisville will result in a 0.25% dec in RT	***
		10% inc in the nonwhite pop. in San Fran will result in a 0.25% inc in RT	***
		10% inc in the nonwhite pop. in Seattle will result in a 0.18% dec in RT	**
		10% inc in the nonwhite pop. in Miami will result in a 0.28% inc in RT	***
2	0.796	10% inc in the pop. in poverty will result in a 0.65% dec in RT (St. Paul)	***
		10% inc in the pop. in poverty in Houston will result in a 0.65% inc in RT	***
		10% inc in the pop. in poverty in Louisville will result in a 0.33% dec in RT	***
		10% inc in the pop. in poverty in San Fran will result in a 0.23% inc in RT	***
		10% inc in the pop. in poverty in Seattle will result in a 0.23% dec in RT	***
		10% inc in the pop. in poverty in Miami will result in a 0.31% inc in RT	***
3	0.722	10% inc in homeowners in Houston will result in a 1.89% dec in RT	***
		10% inc in homeowners in Louisville will result in a 5.68% inc in RT	***
		10% inc in homeowners in Portland will result in a 2.37% inc in RT	***
		10% inc in homeowners in Portland will result in a 2.85% inc in RT	***
		10% inc in homeowners in Miami will result in a 0.88% dec in RT	*
4	0.766	10% inc in the home value in Houston will result in a 0.13% dec in RT	***
		10% inc in the home value in Louisville will result in a 0.21% inc in RT	**
		10% inc in the home value in San Fran will result in a 0.17% inc in RT	**
		10% inc in the home value in Seattle will result in a 0.01% dec in RT	**
		10% inc in the home value in Miami will result in a 0.20% inc in RT	***
5	0.779	10% inc in property taxes will result in a 0.66% inc in RT (St Paul)	***
		10% inc in property taxes in Houston will result in a 0.43% inc in RT	***
		10% inc in property taxes in San Fran will result in a 0.58% inc in RT	***
		10% inc in property taxes in Miami will result in a 0.45% inc in RT	***
6	0.748	10% inc in high income households will result in a 0.51% inc in RT (St. Paul)	*
		10% inc in high income households in Houston will result in a 1.04% dec in RT	***
		10% inc in high income households in Louisville will result in a 1.14% inc in RT	***
		10% inc in high income households in Portland will result in a 0.73% inc in RT	**
		10% inc in high income households in Seattle will result in a 1.67% inc in RT	***
		10% inc in high income households in Miami will result in a 0.79% dec in RT	***
Inc - Increase, Dec - Decrease, RT - Response Time			

A 10 percent increase in the nonwhite population of Houston will result in a 0.25 percent increase in response time, while holding all else constant, refer to table 11 for a summary table of elasticities. A 10 percent increase in the nonwhite population of Louisville will result in a 0.25 percent decrease in response time, while holding all else constant. A 10 percent increase in the nonwhite population of San Francisco will result in a 0.25 percent increase in response time, while holding all else constant. A 10 percent increase in the nonwhite population of Seattle will result in a 0.18 percent decrease in response time, while holding all else constant. A 10 percent increase in the nonwhite population of Miami will result in a 0.28 percent increase in response time, while holding all else constant.

Table 12 – Model 2 Results

2 (Poverty) $R^2 = 0.796$			
Variable	β	Sig	Std. Err
Constant	2.722	***	(0.139)
Area	0.050	***	(0.016)
Expend	-0.100	*	(0.055)
PopDen	-0.025	*	(0.015)
Poverty	-0.065	***	(0.016)
Charlotte_Pov	-0.008		(0.007)
Houston_Pov	0.026	***	(0.006)
Louisville_Pov	-0.033	***	(0.008)
Portland_Pov	-0.006		(0.008)
San Fran_Pov	0.023	***	(0.008)
Seattle_Pov	-0.023	***	(0.007)
Miami_Pov	0.031	***	(0.007)

Model 2, refer to Table 12, had similar results to Model 1 and displays the results of the linear regression analyses concerning the association between response time and proportion of the population living in poverty and the control variables. The R^2 for the model 1b was 0.80. The control variables had almost similar outcomes to Model 1. The only major difference was that the per capita expenditure was found to be significant at the 90 percent level. The expenditure variable had a negative coefficient, which was expected and indicates that the higher the level of per capita spending the lower the response time will be. The overall poverty variable was found to be significant at the 0.01 level and had a positive coefficient, which was intuitively correct. The positive sign on the coefficient indicates that the greater the proportion of the population living the poverty within a fire district, the shorter the response times will be. The city level poverty variables for Houston, Louisville, San Francisco, Seattle, and Miami were all found to be significant. Houston, San Francisco, and Miami all had positive coefficient signs, while Louisville and Seattle had negative coefficients. The positive coefficients indicate that the higher the percentage of the population living in poverty the longer the response time. The negative coefficient indicates the higher the percentage of population living in poverty the shorter the response time. A 10 percent increase in the area of a fire district will result in an increase in response times by 0.50 percent, while holding all else constant. A 10 percent increase in population density will result in a decrease in response times by 0.25 percent, while holding all else constant. A 10 percent increase in the population living in poverty, will result in a 0.65 percent decrease in response time, while

holding all else constant. A 10 percent increase in the population living in poverty in Houston will result in a 0.26 percent increase in response time, while holding all else constant. A 10 percent increase in the population living in poverty in Louisville will result in a 0.26 percent decrease in response time, while holding all else constant. A 10 percent increase in the population living in poverty in San Francisco will result in a 0.23 percent increase in response time, while holding all else constant. A 10 percent increase in the population living in poverty in Seattle will result in a 0.23 percent decrease in response time, while holding all else constant. A 10 percent increase in the population living in poverty in Miami will result in a 0.31 percent increase in response time, while holding all else constant.

Table 13 – Model 3 Results

3 (OwnHse) R ² = 0.722			
Variable	β	Sig	Std. Err
Constant	2.353	***	(0.122)
Area/Station	0.083	***	(0.017)
Expend	0.048		(0.050)
PopDen	0.007		(0.015)
OwnHse	0.013		(0.041)
Charlotte_OH	0.184	*	(0.096)
Houston_OH	-0.189	***	(0.056)
Louisville_OH	0.568	***	(0.022)
Portland_OH	0.237	***	(0.022)
San Fran_OH	-0.008		(0.026)
Seattle_OH	0.285	***	(0.021)
Miami_OH	-0.088	*	(0.056)

Model 3, refer to Table 13, displays the results of the linear regression analyses concerning the association between response time and proportion of home owners, while controlling for area, expenditure and population density. This model had comparable results to the two preceding models. The R^2 for the Model 3 was 0.72, which was lower than the other two models. The area control variable was significant and positive. None of the other control variables were found to be significant. The overall home owner variable was not found to be significant. There were several individual city home owner variables that were found to be significant at the 95 percent or higher level including Houston, Louisville, Portland, and Seattle. Miami and Charlotte were significant at the 90 percent level. Charlotte, Louisville, Portland, and Seattle had positive coefficients while Houston and Miami had negative coefficients. A positive coefficient indicates that the higher the rate of homeownership the greater the response time. A negative coefficient indicates that the higher the rate of homeownership the lower the response time. A 10 percent increase in home ownership rates in Charlotte will result in a 1.8 percent increase in response times, while holding all else constant. A 10 percent increase in home ownership rates in Houston will result in a 1.9 percent decrease in response times, while holding all else constant. A 10 percent increase in homeownership rates in Louisville will results in a 5.7 percent increase in response times, while holding all else constant. A 10 percent increase in homeownership rates in Portland will results in a 2.4 percent increase in response times, while holding all else constant. A 10 percent increase

in home ownership rates in Miami will result in a 0.9% decrease in response times, while holding all else constant.

Model 4, refer to table 14, displays the results of the linear regression analyses concerning the association between response time and home values, while controlling for area, expenditure and population density. The R^2 for the model was 0.77 which indicates that 77 percent of the variation of response times was explained by this model. The area control variable was significant and positive. None of the other control variables were found to be significant.

Table 14 – Model 4 Results

4 (HomeVal) $R^2 = 0.766$			
Variable	β	Sig	Std. Err
Constant	2.655	***	(0.169)
Area	0.071	***	(0.015)
Expend	-0.051		(0.058)
PopDen	-0.019		(0.015)
HomeVal	-0.006		(0.023)
Charlotte_HV	-0.003		(0.006)
Houston_HV	-0.013	***	(0.006)
Louisville_HV	0.021	**	(0.005)
Portland_HV	-0.004		(0.005)
San Francisco_HV	0.017	**	(0.007)
Seattle_HV	-0.001	**	(0.005)
Miami_HV	0.020	***	(0.005)

The overall home value variable was not found to be significant. City home value variables that were found to be significant at the 95 percent level with a negative coefficient were Houston and Seattle, while Louisville, San Francisco

and Miami were significant but had positive coefficients. A negative coefficient indicates that the higher the home value, the lower the response time will be. The positive coefficient indicates that the higher home value the higher the response time. A 10 percent increase in the home value in Houston, would result in a decrease in response time by 0.13 percent, while holding all else constant. A 10percent increase in the home values in Louisville would result in a 0.21percent increase in response times, while holding all else constant. A 10 percent increase in home values in San Francisco would result in a 0.17 percent increase in response time, while holding all else constant. A 10 percent increase in home values in Miami would result in a 0.20 percent increase in response time, while holding all else constant.

Table 15 – Model 5 Results

5 (RealTax) $R^2 = 0.779$			
Variable	β	Sig	Std. Err
Constant	2.816	***	(0.169)
Area/Station	0.04	**	(0.015)
Expend	-0.064		(0.058)
PopDen	-0.029	**	(0.015)
RealTax	0.066	***	(0.023)
Charlotte_Tax	0.006		(0.006)
Houston_Tax	0.043	***	(0.006)
Louisville_Tax	-0.012		(0.005)
Portland_Tax	0.003		(0.005)
San Fran_Tax	0.058	***	(0.007)
Seattle_Tax	-0.009		(0.005)
Miami_Tax	0.045	***	(0.005)

Model 5, refer to Table 15, displays the results of the linear regression analyses concerning the association between response time and property-tax rates, while controlling for area, expenditure and population density. The R^2 for the model was 0.78 which signifies that 78 percent of the variation of response times was explained by this model. In this model the area control variable had a positive coefficient and was significant at the 95 percent level. The population density control variable was found to be significant and had a negative coefficient that signifies the higher the population density the lower the response time. The overall property tax variable was found to be significant at the 99 percent level and had a positive coefficient. The higher the rate of property taxes the greater the response time. Houston, San Francisco and Miami were all found to be significant at the 99 percent level, and had positive coefficients that indicate that the higher the rates of taxes the higher the response time. A 10 percent increase in the property tax rate in Houston would result in a 0.43 percent increase in response times, while holding all else constant. A 10 percent increase in property taxes in a San Francisco would result in a 0.58 percent increase in response times, while holding all else constant. A 10 percent increase in property taxes in a Miami would result in a 0.45 percent increase in response times, while holding all else constant.

Table 16 – Model 6 Results

6(HighIncome) $R^2 = 0.748$			
Variable	β	Sig	Std. Err
Constant	2.526	***	(0.157)
Area	0.080	***	(0.016)
Expend	-0.010		(0.062)
PopDen	0.000		(0.015)
Inc3	0.051	*	(0.030)
Charlotte_HighIncome	0.062		(0.042)
Houston_HighIncome	-0.104	***	(0.030)
Louisville_HighIncome	0.110	***	(0.038)
Portland_HighIncome	0.073	**	(0.031)
San Fran_HighIncome	-0.069		(0.056)
Seattle_HighIncome	0.167	***	(0.032)
Miami_HighIncome	-0.079	***	(0.029)

Model 6, refer to Table 16, displays the results of the linear regression analyses concerning the association between response time and proportion of high income households while controlling for area, expenditure and population density. The R^2 for the model was 0.75. The area control variable had a positive coefficient and was significant at the 95 percent level. None of the other control variables were found to be significant. The overall HighIncome variable was significant at the 90 percent level. The individual city HighIncome variables were found to be significant for Houston, Louisville, Portland, Seattle, and Miami. Houston and Miami had negative coefficients which indicate that the higher the proportion of households who earn over \$75,000 the lower the response time. Louisville, Portland, and Seattle had positive coefficients which indicate that the higher the proportion of households who earn over \$75,000 the higher the response time. For a 10 percent increase in the proportion of households who

earn over \$75,000 in Houston you would expect a 1 percent decrease in response time, while holding all else constant. For a 10 percent increase in the proportion of households who earn over \$75,000 in Louisville you would expect a 1.1 percent increase in response time, while holding all else constant. For a 10 percent increase in the proportion of households who earn over \$75,000 in Portland you would expect a 0.73 percent increase in response time, while holding all else constant. For a 10 percent increase in the proportion of households who earn over \$75,000 in Seattle you would expect a 1.7 percent increase in response time, while holding all else constant. For a 10 percent increase in the proportion of households who earn over \$75,000 in Miami you would expect a 0.8 percent decrease in response time, while holding all else constant.

Model 7, refer to table 17, displays the results of the linear regression analyses concerning the association between response time as the main dependent variable and the proportion of detached housing as the main independent variable, while controlling for area of the fire district, expenditure of the fire department, and home density. All these models were log-log models. The R^2 for model 7 was 0.30. The area control variable was significant at the 99 percent level and had a positive coefficient. The expenditure variable was a significant at the 95 percent level, and had a positive coefficient, which is not intuitively correct.

Table 17 – Model 7 Results

7 (DetHse) $R^2 = 0.304$			
Variable	β	Sig	Std. Err
Constant	1.992	***	(0.126)
Area	0.113	***	(0.032)
Expend	0.153	**	(0.053)
HomeDen	0.000		(0.028)
DetHse	0.027	*	(0.016)

Table 18 – Model 7a Results

7a (DetHseCity) $R^2 = 0.649$			
Variable	β	Sig	Std. Err
Constant	2.441	***	(0.127)
Area/Station	0.094	***	(0.020)
Expend	0.026		(0.053)
HomeDen	-0.02		(0.017)
DetHse	-0.02		(0.037)
Charlotte_DH	0.159		(0.106)
Houston_DH	-0.2	***	(0.056)
Louisville_DH	0.486	***	(0.123)
Portland_DH	0.147	***	(0.046)
San Fran_DH	-0.03		(0.041)
Seattle_DH	0.142	***	(0.040)
Miami_DH	-0.08	**	(0.040)

The positive coefficient for expenditure indicates that the higher the level of per capita spending, the greater the response time. The detached housing variable was only significant at the 90 percent level, and had a positive coefficient. For a 10 percent increase in the size of the area one could expect an increase of 1.1 percent in response times, while holding all else constant. For a 10 percent increase in expenditure you would expect that response times to

increase by 1.5 percent while holding all else constant. For a 10 percent increase in proportion of detached housing you would expect a 0.3 percent increase in response times.

Model 7a, refer to Table 18, is similar to model 7 the only difference is that model 7a also has the variables for each city's proportion of detached housing. The R^2 for Model 7a was 0.65, which indicates that 65 percent of the variation in response times is explainable by this model. The area control variable was found to be significant with a positive coefficient, similar to Model 7. None of the other control variables were found to be significant. The overall detached housing variable was not significant at any level in this model. Detached housing variables for Houston and Miami were found to be significant at the 95 percent level or higher and both had negative coefficients. This indicates that the higher the level of detached housing, the lower the response time. Louisville, Portland and Seattle also were also significant, at the 99 percent level, and had positive coefficient. The positive coefficient indicates that the higher the level of detached housing the higher the response time. For a 10 percent increase in detached housing in Houston one would expect a 2 percent decrease in response time, while holding all else constant, refer to table 19 for a summary of elasticities for all the sprawl models. For a 10 percent increase in detached housing in Louisville, one would expect a 4.9 percent increase in response times, while holding all else constant. For a 10 percent increase in detached housing in Portland, one would expect a 1.5 percent increase in response times, while holding all else constant.

Table 19 - Summary Table for Results of 10% Elasticities for Sprawl Models

Model	R ²	10% Elasticity	Sig
7	0.304	10% inc in detached housing will result in a 0.27% inc in RT	*
7a	0.649	10% inc in detached housing in Houston will result in a 2.00% dec in RT	***
		10% inc in detached housing in Louisville will result in a 4.86% inc in RT	***
		10% inc in detached housing in Portland will result in a 1.47% inc in RT	***
		10% inc in detached housing in Seattle will result in a 1.42% inc in RT	***
		10% inc in detached housing in Miami will result in a 0.80% dec in RT	**
8	0.486	10% inc in AvgCtime will result in a 7.5% inc in RT	***
8a	0.77	10% inc in AvgCtime in Houston will result in a 0.73% inc in RT	***
		10% inc in AvgCtime in Louisville will result in a 0.49% dec in RT	**
		10% inc in AvgCtime in San Fran will result in a 0.66% inc in RT	**
		10% inc in AvgCtime in Seattle will result in a 0.42% dec in RT	**
		10% inc in AvgCtime in Miami will result in a 0.70% inc in RT	***
9a	0.609	10% inc in VehHH in Houston will result in a 8.94% inc in RT	***
		10% inc in VehHH in San Fran will result in a 3.4% inc in RT	*
		10% inc in VehHH in Miami will result in a 7.2% inc in RT	***
10	0.35	10% inc in PopStMile will result in a 1.8% inc in RT	***
10a	0.774	10% inc in PopStMile in Houston will result in a 0.46% inc in RT	***
		10% inc in PopStMile inLouisville will result in a 0.46% dec in RT	***
		10% inc in PopStMile in San Fran will result in a 0.43% inc in RT	***
		10% inc in PopStMile in Seattle will result in a 0.21% dec in RT	*
		10% inc in popStMile in Miami will result in a 0.46% inc in RT	***
11	0.401	10% inc in streetSeg will result in a 0.81% inc in RT	***
11a	0.771	10% inc in streetSeg in Houston will result in a 0.38% inc in RT	***
		10% inc in streetSeg in Louisville will result in a 0.27% dec in RT	**
		10% inc in streetSeg in San Fran will result in a 0.39% inc in RT	***
		10% inc in streetSeg in Seattle will result in a 0.22% dec in RT	**
		10% inc in streetSeg in Miami will result in a 0.39% inc in RT	***
12	0.288	10% inc in ElmSchool will result in a 0.36% dec in RT	**
13	0.325	10% inc in CDB will result in a 0.48% inc in RT	***
13a	0.704	10% inc in CBD in Houston will result in a 1.46% inc in RT	***
		10% inc in CBD in San Fran will result in a 1.59% inc in RT	***
		10% inc in CBD in Miami will result in a 1.37% inc in RT	***
Inc - Increase, Dec - Decrease, RT - Response Time			

For a 10 percent increase in detached housing in Seattle, one would expect a 1.4 percent increase in response times, while holding all else constant. For 10 percent increase in detached housing in Miami one would expect a 0.8 percent decrease in response time, while holding all else constant.

Table 20 – Model 8 Results

8(AvgCTime) $R^2 = 0.486$			
Variable	β	Sig	Std. Err
Constant	1.429	***	(0.126)
Area	0.084	***	(0.022)
Expend	-0.011		(0.043)
HomeDen	-0.007		(0.020)
AvgCTime	0.750	***	(0.091)

Model 8, refer to Table 20, displays the results of the linear regression analyses concerning the association between response time as the main dependent variable and average commute times as the main independent variable, while controlling for the area of the fire district, expenditure of the fire department and home density. The R^2 for the model 8 was 0.49. The area control variable was significant at the 99 percent level and had a positive coefficient. None of the other control variables were significant. The average commute time variable was significant at the 99 percent level and had a positive coefficient. This indicates that the greater the average commute time, the longer the response time will be which is intuitively correct. For a 10 percent increase in average commute times, one would expect a 7.5 percent increase in response times.

Table 21 – Model 8a Results

8a (AvgCTimeCity) $R^2 = 0.770$			
Variable	β	Sig	Std. Err
Constant	2.642	***	(0.193)
Area	0.057	***	(0.017)
Expend	-0.065		(0.057)
HomeDen	-0.029	**	(0.014)
ComTime	0.033		(0.094)
Charlotte_CT	-0.011		(0.022)
Houston_CT	0.073	***	(0.019)
Louisville_CT	-0.049	**	(0.021)
Portland_CT	-0.010		(0.020)
San Fran_CT	0.066	**	(0.026)
Seattle_CT	-0.042	**	(0.020)
Miami_CT	0.070	***	(0.020)

Model 8a added the individual city commute time variables to model 3a. The R^2 for the model 8a was 0.77. The area control variable was significant at the 99 percent level and had a positive coefficient. The home density control variable was significant at the 95 percent level, and had a negative coefficient. This indicates the higher the home density the lower the response time. The overall commute time variable in model 8a was not significant. The individual city commute time variables for Houston, Louisville, San Francisco, Seattle and Miami were found to be significant at the 95 percent level or higher. Houston, San Francisco and Miami had positive coefficients, while Louisville and Seattle had negative coefficients. For a 10 percent increase in commute times in Houston, one would expect an increase of 0.7 percent while holding all else constant. For a 10 percent increase in commute time in Louisville, one would expect a 0.5 decrease in response time, while holding all else constant. For a 10

percent increase in commute time in San Francisco, would expect a 0.7 percent increase in response times, while holding all else constant. For a 10 percent increase in commute time in Seattle, one would expect a 0.5 decrease in response time, while holding all else constant. For a 10 percent increase in commute time in Miami, would expect a 0.7 percent increase in response times, while holding all else constant.

Table 22 – Model 9 Results

9(VehHH) R ² = 0.296			
Variable	β	Sig	Std. Err
Constant	2.060	***	(0.118)
Area	0.141	***	(0.026)
Expend	0.116	**	(0.047)
HomeDen	0.027		(0.023)
VehHH	0.053		(0.066)

Model 9, refer to Table 22, displays the results of the linear regression analyses concerning the association between response time as the main dependent variable and the number of vehicles per household as the main independent variable, while controlling for the area of the fire district, expenditure of the fire department and home density. The R² for the model 9 was 0.30. Both the Area and expenditure control variables were found to be significant at the 95 percent level or higher and had positive coefficients, which were similar results to model 8. The vehicles per household variable was not found to be significant.

Table 23 – Model 9a Results

9a (VehHH) $R^2 = 0.609$			
Variable	β	Sig	Std. Err
Constant	2.355	***	(0.146)
Area/Station	0.044	**	(0.022)
Expend	0.034		(0.056)
HomeDen	0.002		(0.018)
VehHH	-0.140		(0.152)
Charlotte_VHH	0.313		(0.198)
Houston_VHH	0.894	***	(0.177)
Louisville_VHH	0.085		(0.171)
Portland_VHH	0.213		(0.169)
San Fran_VHH	0.340	*	(0.190)
Seattle_VHH	0.053		(0.163)
Miami_VHH	0.722	***	(0.166)

Model 9a, refer to Table 23, added the individual city vehicles per household variables to the Model 9. The R^2 for the Model 9a was 0.61. The area control variable was significant, and had a positive sign for the coefficient. Houston and Miami were both significant at the 99 percent level and had positive signs for their coefficients. San Francisco was significant at the 90 percent level, and also had a positive coefficient. For a 10 percent increase in the vehicles per household in Houston, one would expect a 8.9 percent increase in response times, while holding all else constant. For a 10 percent increase in the vehicles per household, one would expect a 3.4 percent increase in response times in San Francisco, while holding all else constant. For a 10 percent increase in the vehicles per household in Miami, one would expect a 7.2 percent increase in response times, while holding all else constant.

Table 24 – Model 10 Results

10(PopStMile) $R^2 = 0.350$			
Variable	β	Sig	Std. Err
Constant	1.884	***	(0.121)
Area	0.133	***	(0.024)
Expend	0.140	***	(0.045)
HomeDen	-0.067	**	(0.032)
PopStMile	0.180	***	(0.045)

Model 10 displays the results of the linear regression analyses concerning the association between response time as the main dependent variable and the population per street mile as the main independent variable, while controlling for area of the fire district, expenditure of the fire department, and home density. The R^2 for the Model 10 was 0.35. The control variables for this model were all found to be significant. Both area and expenditure were significant at the 99 percent level and had positive coefficients. The home density variable was significant at the 95 percent level and had a negative coefficient that indicates the higher the home density the lower the response time. The population per street mile variable was also significant at the 99 percent level. For a 10 percent increase in the population per street mile one would expect a 1.8 percent decrease in response times, while holding all else constant.

Model 10a, refer to Table 25, added the individual city population-per-street-mile variables to the Model 10. The area and home density control variables were found to be significant and had similar outcomes to Model 10. Houston, San Francisco and the Miami population per street mile variables were all significant at the 99 percent level and had a positive coefficient which

indicates that the higher the population per street mile the longer the response time.

Table 25 – Model 10a Results

10a (PopStMileCity) R ² = 0.774			
Variable	β	Sig	Std. Err
Constant	2.775	***	(0.157)
Area	0.067	***	(0.016)
Expend	-0.083		(0.060)
HomeDen	-0.025	**	(0.021)
PopStMile	-0.027		(0.033)
Charlotte_PSM	-0.008		(0.013)
Houston_PSM	0.046	***	(0.011)
Louisville_PSM	-0.032	***	(0.012)
Portland_PSM	-0.004		(0.011)
San Fran_PSM	0.043	***	(0.014)
Seattle_PSM	-0.021	*	(0.011)
Miami_PSM	0.046	***	(0.011)

Louisville was significant at the 99 percent level, while Seattle was significant at the 90 percent level and both had negative coefficients. For a 10 percent increase in the population per street mile in Houston one would expect a 0.5 percent increase in response times, while holding all else constant. For a 10 percent increase in the population per street mile in Louisville one would expect a 0.3 percent decrease in response times, while holding all else constant. For a 10 percent increase in the population per street mile in San Francisco one would expect a 0.4 percent increase in response times, while holding all else constant. For a 10 percent increase in the population per street mile in Seattle one would expect a 0.2 percent decrease in response times, while holding all else constant.

For a 10 percent increase in the population per street mile in Miami one would expect a 0.5 percent increase in response times, while holding all else constant.

Table 26 – Model 11 Results

11(StreetSeg) R ² = 0.401			
Variable	β	Sig	Std. Err
Constant	0.552	*	(0.289)
Area	0.131	***	(0.023)
Expend	0.165	***	(0.044)
HomeDen	0.088	***	(0.024)
StreetSeg	0.461	***	(0.081)

Model 11, refer to Table 26, displays the results of the linear regression analyses concerning the association between response time as the main dependent variable and the length of the street segment as the main independent variable, while controlling for area of the fire district, expenditure of the fire department, and home density. The R² for the Model 11 was 0.40. The control variables for this model were all found to be significant at the 99 percent level and all had positive sign for their coefficients. This was a reverse pattern for the home density variable, which in Model 11 had a negative coefficient. The street segment variable was found to be significant at the 99 percent level and had a positive sign, which indicates that the longer the length of the street segments the longer the response time will be. For a 10 percent increase in the average street length one would expect response times to increase by 4.6 percent while holding all else constant. In Model 11a, refer to table 27, the individual city street segments variables were added to Model 11. The R² for the model 11a was 0.77. The area control variable was significant at the 99 percent

level and had a positive sign for the coefficient. Similar too many of the previous models the street segment variables for Houston, San Francisco and Miami were all significant at the 99 percent level and had positive signs for the coefficients.

Table 27 – Model 11a Results

11a (StreetSegCity) R ² = 0.771			
Variable	β	Sig	Std. Err
Constant	2.363	***	(0.157)
Area	0.059	***	(0.016)
Expend	-0.065		(0.060)
HomeDen	-0.011		(0.021)
StreetSeg	0.101		(0.033)
Charlotte_SS	-0.006		(0.013)
Houston_SS	0.038	***	(0.011)
Louisville_SS	-0.027	**	(0.012)
Portland_SS	-0.003		(0.011)
San Franc_SS	0.039	***	(0.014)
Seattle_SS	-0.022	**	(0.011)
Miami_SS	0.039	***	(0.011)

This indicates that the greater the length of the street segment the longer the response time will be. Louisville and Seattle were both significant at the 95 percent level and had negative coefficients. For a 10 percent increase in the average length of a street segment in Houston one would expect a 0.4 percent increase in response times, while holding all else constant. For a 10 percent increase in the average length of a street segment in Louisville one would expect a 0.3 percent decrease in response times, while holding all else constant. For a 10 percent increase in the average length of a street segment in San Francisco one would expect a 0.4 percent increase in response times, while holding all else constant. For a 10 percent increase in the average length of a street segment in

Seattle one would expect a 0.2 percent decrease in response times, while holding all else constant. For a 10 percent increase in the average length of a street segment in Miami one would expect a 0.4 percent increase in response times, while holding all else constant.

Table 28 – Model 12 Results

12 (ElmSch) R ² = 0.288			
Variable	β	Sig	Std. Err
Constant	2.124	***	(0.121)
Area	0.152	***	(0.027)
Expend	0.069		(0.050)
HomeDen	0.039		(0.026)
ElmSch	-0.036	**	(0.018)

Model 12, refer to Table 28, displays the results of the linear regression analyses concerning the association between response time as the main dependent variable and the proportion of the population that lives within one mile of an elementary school (Elmschool variable) as the main independent variable, while controlling for area of the fire district, expenditure of the fire department, and home density. The R² for the model 12 was 0.29. The area control variable was significant at the 99 percent level and had a positive coefficient. The other control variables were not found to be significant. The Elmschool variable was significant at the 95 percent level and had a negative sign for the coefficient, which indicates that the higher the proportion of the population living within one mile of an elementary school the lower the response time will be. For a 10 percent increase living within one mile of an elementary school one would expect a 0.2 percent decrease in response times, while holding all else constant.

Table 29 – Model 12a Results

12a (ElmSchoolCity) $R^2 = 0.362$			
Variable	β	Sig	Std. Err
Constant	2.172	***	(0.128)
Area	0.138	***	(0.028)
Expend	0.072		(0.049)
HomeDen	0.025		(0.028)
ElmSchool	0.044		(0.399)
Charlotte_ES	1.025		(3.491)
Houston_ES	-0.524		(0.480)
Louisville_ES	0.049		(0.401)
Portland_ES	-0.014		(0.405)
San Fran_ES	-0.465		(0.922)
Seattle_ES	0.258		(0.410)
Miami_ES	-0.096		(0.399)

In Model 12a, refer to Table 29, the individual city Elmschool variables were added to Model 12. The R^2 for the Model 12a was 0.36. The area control variable was significant at the 99 percent level and had a positive sign for the coefficient. None of the individual city level Elmschool variables were found to be significant.

Table 30 – Model 13 Results

13 (CBD) $R^2 = 0.325$			
Variable	β	Sig	Std. Err
Constant	2.056	***	(0.113)
Area	0.134	***	(0.025)
Expend	0.108	**	(0.046)
HomeDen	0.028		(0.023)
CBD	0.048	***	(0.017)

Model 13, refer to Table 30, displays the results of the linear regression analyses concerning the association between response time as the main dependent variable and the distance from the CBD as the main independent variable, while controlling for area of the fire district, expenditure of the fire department, and home density. The R^2 for the model 13 was 0.32. Both the Area and expenditure control variables were found to be significant at the 95 percent level or higher and had positive coefficients. The CBD variable was significant at the 99 percent level and had a positive sign for the coefficient which indicates the greater the distance from the CBD the longer the response time. For a 10 percent increase in the distance from the CBD one could expect a 0.5 percent increase in response times while holding all else constant.

Table 31 – Model 13a Results

13a(CBDcity) $R^2 = 0.704$			
Variable	β	Sig	Std. Err
Constant	2.597	***	(0.128)
Area	0.068	***	(0.028)
Expend	-0.054		(0.049)
HomeDen	-0.006		(0.028)
CBD	-0.041		(0.399)
Charlotte_CBD	0.082		(3.491)
Houston_CBD	0.146	***	(0.480)
Louisville_CBD	-0.034		(0.401)
Portland_CBD	0.001		(0.405)
San Fran_CBD	0.159	***	(0.922)
Seattle_CBD	-0.064		(0.410)
Miami_CBD	0.137	***	(0.399)

In Model 13a, refer to Table 31, the individual city CBD variables were added to model 6a. The R^2 for the model 13a was 0.70. The area control variable was significant at the 99 percent level and had a positive sign for the coefficient. The CBD variables for Houston, San Francisco and Miami were all significant at the 99 percent level and had positive signs for their coefficients. For a 10 percent increase in the distance from the CBD in Houston one would expect a 1.5 percent increase in response times, while holding all else constant. For a 10 percent increase in the distance from the CBD in San Francisco one would expect a 1.6 percent increase in response times, while holding all else constant. For a 10 percent increase in the distance from the CBD in Miami one would expect a 1.4 percent increase in response times, while holding all else constant.

4.3 Spatial Analysis

Figure 1 (Appendix 1) displays a map of the percentage of the nonwhite population at the census tract level for Houston, Texas (and all of Harris County) along with fire district boundaries. The percentages are displayed through four categories using quartiles. The lowest percentages are represented by the yellow color, which is less than 20 percent nonwhite, while the highest percentages are represented by the dark red, which greater than 59.01 percent nonwhite. The thick black lines on the map represent the fire districts for the Houston Fire Department. The CBD is represented by a red star on the map. The highest proportions of nonwhites in Houston are concentrated within the central portion of the city, surrounding the CBD. There are at least 40 census tracts in this area that are greater than 90 percent nonwhite population. More specifically, areas including the southwest, south central and north east of the CBD have the

highest concentrations of nonwhites. Areas of Houston that have higher concentrations of whites include the northeast, northwest, and eastern portions of the city. There is also a swath just west of the CBD that also has higher concentration of whites.

Figure 2 displays a similar map of the percentage of the nonwhite population in Louisville, Kentucky. There is a similar coloring scheme to this map as the lowest percentages of nonwhites are represented by the yellow color, which is less than 6 percent nonwhite, while the highest percentages of nonwhites are represented by the dark red, which are greater than 35.01 percent nonwhite. Nonwhites are concentrated within two main areas in Louisville. The first area with the highest concentration of nonwhites is in north west Louisville. There are at least 35 census tracts within this area that fall within the last quartile with the highest proportion of nonwhites. There are 15 census tracts in this area that have at least a population of 90 percent nonwhite or greater. The CBD can also be found in this part of the city. The second area with higher concentrations of nonwhites can be found towards the center of Louisville-Jefferson County. There are six census tracts in this cluster of high proportion of nonwhites, which range from 40-90 percent nonwhite. The south-west and south-central edge of the county generally have the lowest percentage of nonwhites and highest concentration of whites.

Figure 3 displays a map of the nonwhites in Seattle, Washington. The percentages are displayed through four categories using quartiles. The lowest percentages are represented by the yellow color, which is less than 13 percent

nonwhite, while the highest percentages are represented by the dark red, which are greater than 40.01 percent nonwhite. The thick black lines on the map represent the fire districts for the Seattle Fire Department. The highest concentrations of nonwhites are found within the southern portion of Seattle. There were at least 36 census tracts within this cluster in the last quartile in the south of Seattle that had as a minimum a 40 percent nonwhite population. The north and the west generally had lower concentrations of nonwhites, although in the far north of the city there were higher concentrations of nonwhites in the 3rd quartile between 20-40 percent nonwhite.

Figure 4 displays a map of the proportion of nonwhites by census tract in Miami-Dade, Florida. This map has a similar color scheme to the other previous maps. The census tracts can fall within four categories that have been divided into quartiles. The yellow color represent the lowest proportion of nonwhites, which is below 10 percent, while the dark red color represent the census tracts with the highest proportion of nonwhites which is greater than 52.01 percent. Nonwhites are heavily concentrated in within northern Miami-Dade, directly north of the CBD. There are 70 census tracts in this area that have the highest concentration of nonwhites, and approximately 24 of those census tracts have greater than 90 percent nonwhites. The area just directly west of the CBD has the lowest concentrations of nonwhites.

Figure 5 is a map that displays the proportion of people that are living in poverty at the census tract level in Houston, Texas. This map has a similar coloring scheme, as the previous maps. The data is broken down into 4

categories using the quartiles. The yellow represents the lowest quartile, which is less than or equal to 5 percent of the population living in poverty. The dark red is the highest category of a population living in poverty and represents at least 23.01 percent or greater living in poverty. This map is very similar to nonwhite map, although there are some minor differences. Poverty is concentrated within the center of Houston, around the CBD, especially towards the east. The difference between the nonwhite map and the poverty map was that there were also high concentrations of nonwhite towards the southwest, and while there are high rates of poverty in the southwest of Houston, they are not as high as around the CBD, and towards the east of the CBD. There are several census tracts that have at least 40 percent of the population or greater living in poverty.

Figure 6 displays rates of poverty in Louisville, Kentucky. The areas with the highest rates of poverty, exactly match those areas that have the highest concentrations of nonwhites within the city. The north west of the city has the largest cluster of a population living below the poverty line. At least 20 of Louisville 170 census tracts with the highest rates of poverty, greater than 30 percent, are found within this area. In general the west of Louisville has higher rates of poverty when compared to the east. Rates of poverty were very low in the eastern portion of Louisville, when compared to the rest of the city.

Figure 7 displays a map of the proportion of people that are living in poverty at the census tract level in Seattle. Overall the rates of poverty were lower in Seattle, when compared to Houston or Louisville. Seattle followed a similar pattern to the other two cities in that areas with high poverty coincided

with areas that had high proportions of nonwhites. Poverty was concentrated in the southern section of the city, south of the CBD. There were roughly 25 census tracts around the CBD that had the highest concentrations of poverty where between 15-50 percent of the population was living in poverty. Poverty was not confined to the southern portion of Seattle, as there were a few census tracts in the north of the city that fell in the group with the highest rates of poverty.

Figure 8 displays rates of poverty in Miami-Dade, Florida. The areas with the highest rates of poverty, exactly match those areas that have the highest concentrations of nonwhites within the city. As nonwhites were heavily concentrated in within northern Miami, directly north of the CBD, so to were the highest rates of poverty within the city. Anywhere between 25-65 percent of the population in this area just north of the CBD was living below the poverty level. There were at least 60 census tracts in this high concentration area that fell within the highest rate of poverty category. There were also a few census tracts in the south that fell into the highest category of poverty. Directly south west of this area with the high rates of poverty was an area that had the lowest rates of poverty within the city.

Figure 9 displays a map of the homeownership rates in Houston. The data was divided into four categories using quartiles. The lowest rates of home ownership were represented by yellow and included of rates of less than 33 percent owner occupied. Dark red represented the category with the highest rates of homeownership, and greater than 74.01 percent owner occupied. The general pattern was the rates of homeownership were the lowest in the center of

the city. The further away from the center the higher the rates of ownership. This map had the reverse pattern of the other two previous maps for Houston. The highest rates of ownership were found within the north-east and north-west of the city. There were also other sporadic areas across the city with high rates of home ownership.

Figure 10 is a map of homeownership rates in Louisville. The data was divided into four categories using quartiles, the lowest category being represented by yellow with rates of ownership less than 47 percent and the highest being represented by dark red with ownership rates of greater than 76.01 percent. This map displays similar patterns to the homeownership map of Houston, and was somewhat the reverse of the other two previous maps of Louisville. The lowest rates of homeownership were around the CBD. The further away from the center of the city the higher the rates of home ownership. The highest rates of ownership were at the edges of the county.

Figure 11 displays a map of homeownership rates in Seattle. The color scheme was similar to the other maps. The lowest rates of home ownership were represented by yellow and included of rates of less than 35 percent owner occupied. Dark red represented the category with the highest rates of homeownership, and greater than 67.01 percent owner occupied. Similar to all the other cities homeownership rates were lowest in the area surrounding the CBD. Rates of homeownership gradually increased the further away from the CBD. However, this pattern was not as distinct in Seattle, as it was in other locations. The largest cluster of the highest rates of homeownership was found in

the north eastern section of the city. In general the edge of the city had higher rates of home ownership compared to the central section of the city. Rates of homeownership were not as high in Seattle as they were in Houston and Louisville.

Figure 12 displays a map of homeownership rates in Miami. Similar to the other maps, the lowest rates of home ownership were represented by yellow and included of rates of less than 31 percent owner occupied. Dark red represented the category with the highest rates of homeownership, and greater than 76.01 percent owner occupied. Similar to all the other home ownership maps, rates of ownership were lowest surrounding the CBD, in north eastern section of Miami-Dade in the city of Miami. Areas west and south west of the CBD had the highest rates of home ownership. Miami was similar to the other cities in general as the further the distance from the CBD the higher the rates of homeownership.

The next series of maps were those of average home values. Figure 20 displays a map of average home values by census tracts in Houston. Average home values were divided into four categories using quartiles. Yellow represents the lowest home values, with values of less than \$26,000. The dark red represents the area with the highest home values in Houston with values of greater than \$80,000. Home values were the lowest surrounding the CBD, especially around the central eastern sections of the city. Home values in this part of the city were very low, with an average below \$20,000. The farther away from this part of the city the higher the home values, especially towards the edge of the city and county. Home values were generally higher in the northern

sections on Houston, towards the north-west and north east. One area that had the highest homes values of the city was towards the west of the CBD. This was the same swath of census tracts that had higher proportions of whites. The average home values in this area were around \$250,000, however there were many homes that were well above this value and were in the range of \$400,000 to \$800,000.

Figure 13 displays a map of home values in Louisville. Yellow represents the lowest home values, with values of less than \$40,000. The dark red represents the area with the highest home values in Houston with values of greater than \$97,000. Louisville has a very distinct pattern. Home values were much higher in the eastern portion of the city when compared to the western portion of the city. The northeastern section of the city had the highest home values in the city, with prices ranging between \$250,000 - \$350,000. Similar to Houston, home values were the lowest surrounding the CBD. This area of the city in the northwest of Louisville had very low home values with the average being less than \$23,000.

Figure 14 displays a map of home values by census tract in Seattle. Yellow represents the lowest home values, with values of less than \$88,000. The dark red represents the area with the highest home values in Houston with values of greater than \$192,000. Home values in general were much higher in Seattle when compared to Houston or Louisville. Similar to the other two cities, home values were lowest surrounding the CBD. Homes values were around \$40,000 on average. The northern and western section of Seattle had higher

home values and in fact the highest values where in the northwest where the average home price was between \$300,000- \$500,000.

Figure 15 displays a home values in Miami. Yellow represents the lowest home values, with values of less than \$36,000. The dark red represents the area with the highest home values in Houston with values of greater than \$100,001. Similar to all the other cities, the lowest values in Miami were found around the CBD, or just directly north of the CBD. On average, homes were less than \$20,000 in this area. The north-eastern section of the Miami had lower home values in general when compared to the rest of the city. The west and south-west of the CBD had the highest home values. Homes on average were around \$250,000 in the south west section of Miami, and around \$150,000 in the west. The highest home values were generally found in census tracts that were along the coast, just south west of the CBD and ranged in price between \$400,000 and \$800,000.

Figure 16 displays a map of property tax rates in Houston. Tax rates were divided into four groups, using quartiles. Yellow represent the lowest tax rates, less the 1.3 percent. Dark red represents the highest tax rate, with values greater than 1.81 percent. The general pattern is that rates are the lowest towards the center of the city. The highest tax rates are out towards the suburbs outside of the central city. Directly around the CBD rates are about 0.8 percent of the property overall value on average. The census tracts with the lowest rates of property taxes were however not all concentrated together in one particular area of the city. The highest rates of taxation where in most cases on the edge of the

city or outside of the city limits found in Harris County. Rates were on average greater than 2 percent of overall property value on an annual basis. There were also a few areas within the city on the extreme edge in the north east and south east that did have rates higher rates, greater than 2 percent average.

Figure 17 displays a map of property tax rates in Louisville. The coloring scheme was similar to the previous map, and divided up using quartiles. Yellow represent the lowest tax rate in Louisville with values less than 0.67 percent, while dark red represents the highest tax rates greater than 0.80 percent.

Property tax rates in Louisville were much lower than in Houston. Louisville also displayed a different pattern than Houston. The major difference was that tax rates in Louisville were the lowest in the suburbs that were the farthest away from the CBD, although there were several census tracts in northwestern Louisville that did have low rates of property taxes. Rates were higher towards the center of the city. In fact, the highest rates, greater than 0.90 percent were all found within the boundaries of old Louisville. The eastern portion of the city in general did have some areas that had higher rates of property taxes.

Figure 18 displays a map of property tax rate in Miami, Florida. The color scheme was similar to the previous map, and divided up using quartiles. Yellow represent the lowest tax rate in Miami with values less than 1 percent. Dark red represents the highest tax rates greater than 1.41 percent. Property tax rates in Miami were higher than in Louisville, but were lower than in Houston on average. Miami did not display any major patterns like the other two cities. Tax rates were low immediately surrounding the CBD. The northern section of Miami

tended to have the lower rates of property taxation. There was no area with a major concentration of the highest rates of taxation as the census tracts with the highest rates were spread throughout the city although they were away from the CBD.

Figure 19 through 22 are maps of average commute times for Houston, Louisville, Seattle, and Miami. Average commute times were divided into four categories using quartiles. Yellow represents the lowest commute time, while dark red represents the highest category for commute times. Commute times were lowest in Louisville and highest in Miami. All four maps generally indicate similar patterns. Commuting times are commonly the lowest around the CBD and the center of each city. The further one gets from the center of the city towards the suburban locations of each city the higher the average commute time. There is an exception to this, however, and that is the areas with higher concentrations of nonwhites which are usually close in proximity to the CBD also have higher commute times.

Figure 23 through 26 are maps of response times at the fire district level superimposed on the census tracts for Houston, Louisville, Seattle, and Miami. Response times were divided into 4 categories using quartiles. Yellow represents the lowest response time, while dark red represents the highest response times. Figure 31 displays a map of response times for Houston. Response times were the lowest around the CBD and just north and south of the CBD. The fire districts that were farther away from the center of the city had response times that were higher when compared to the center of the city. Generally speaking the

highest response times were in the fire districts that were at the edge of the city. Figure 27 displays a map of response times for Louisville and was somewhat similar to the map of Houston. The similarity was the lowest response times where in the center of the city around the CBD and the highest were towards the edge of the city. However, there were a few fire districts that were also out in the suburbs outside of old Louisville that also fell into the lowest category for response times. The highest response times in Louisville were found in the in the south-west and north east of the city. Figure 28 displays a map of response times in Seattle. Similar to both Houston and Louisville, the lowest response times were found in the center of the city. However, there were also a few fire districts that were not in the center of the city and fell within the lowest response time category as well. Generally the highest response times were out from the center of the city and small clusters of the fire districts with higher response times could be found in the north-east and south-west. Figure 34 displays a map of response times of Miami. Miami's map was very similar to Houston, and displayed very similar patterns. The lowest values for response times were found in the center of the city towards the CBD and the further away from the center of the city, generally speaking, the higher the response times.

4.5 Qualitative Results

The qualitative research in this study is a further in-depth analysis of the most salient results of the quantitative portion. Three fire districts within Louisville-Jefferson County were examined in-depth. Furthermore, the qualitative research draws on the expertise of fire chiefs from several different fire departments within Louisville-Jefferson County, Kentucky to explain factors that influence response times. Specifically the intent of this portion of the research was to get the experience from fire chiefs who experience fire fighting in different types of urban environments and to get the perspective from an urban district fire chief, an urban suburban fire chief and a fire chief from a totally suburban fire district. The three fire departments and districts that were included for this portion of the study were Lyndon, Jeffersontown and Harrods Creek.

The Lyndon fire protection district and Fire Department was the urban fire district. An attempt was made to interview fire personnel from the Louisville Metro Fire department for the urban fire district; however, the public information officer was away on sick leave. Lyndon was selected as an alternative. The urban/suburban mix fire district was the Jeffersontown fire protection district and fire department. The suburban fire district was Harrods Creek. Each fire district had different management structures, with some similarities. Lyndon had a Chief, followed by three battalion chiefs.

Jeffersontown had a Chief followed by an assistant chief. Jeffersontown also had three chiefs for the different divisions in the department including fire prevention, training and maintenance. Harrods Creek had a chief followed by an assistant chief. Harrods creek also had three division chiefs.

Table 32 – Fire Department and Fire District Data

	Lyndon	Jeffersontown	Harrods Creek
Response Time	3:28	5:03	5:45
Stations	2.00	3.00	2.00
Career Fire Fighter	27	48	35
Volunteer Fire Fighter	15	5	25
Budget	\$2,835,894	\$4,725,791	\$2,553,500
Per Capita	\$94	\$148	\$167
ISO	3	2 (3/9)	3
Vehicles	5	6	6
Runs	2,172	1,640	556
Population	30,315	31,960	15,288
Homes	14,028	12,980	6,187
Area (Sq Mi)	10.13	25.25	20.09
Pop Den (Pop / Sq Mi)	2,992	1,266	761
Home Den (Homes / Sq Mi)	1,385	514	308
Avg Income (Income/Household)	\$64,887	\$61,881	\$131,630
Average Home Value	\$158,996	\$141,649	\$318,379
Tax Rate	\$0.10/ \$100	\$0.10/\$100	\$0.10/ \$100

Source: Lyndon, Jefferson and Harrods Creek Fire Departments, 2009.

Lyndon was the smallest fire districts of the three, with a total area of 10.1 sq. mi., refer to Table 32. Jeffersontown was the largest fire district at 25 sq. mi., while Harrods Creek had an area of 20 sq. mi.. Lyndon had the shortest average response time at 3:28, while Harrods Creek had the greatest average response time at 5:45.

Both the Lyndon and Harrods Creek Fire Departments have two fire stations, and Jeffersontown has three fire stations. Lyndon has a total of 27 career fire-fighters, and 15 volunteer fire-fighters. Jeffersontown has a 48 career fire-fighters, and five volunteers. Harrods Creek has a 35 career and 25 volunteer fire fighters. Harrods Creek had the greatest proportion of volunteer fire fighters at 42 percent, while Jeffersontown had the lowest proportion of volunteer fire

fighters at 9 percent. Jeffersontown had a budget of \$4.7 million, the highest of the 3. Lyndon had a budget of \$2.8 million and Harrods Creek had a budget of \$2.5 million. On a per capita basis for expenditure Harrods Creek had the highest dollar amount at \$167 per individual in the fire district, while Jeffersontown was \$148 and Lyndon was \$94 per individual. Lyndon and Harrods Creek both had ISO ratings of 3, while Jeffersontown had multiple ratings. The actually city of Jeffersontown has a rating of 2, while outside of the city boundaries has a ISO rating of 3, and some parts of the fire district have an ISO rating of 9, which means that in those particular areas homes are at least 1000 feet away from a fire hydrant. Lyndon has five vehicles in total, while both Jeffersontown and Harrods Creek both have six vehicles. Lyndon had 2,172 runs in total and 2,007 were non-fire runs. This includes medical, false alarms, Haz Mat, Other Hazardous Calls, and mutual-aid calls. There were about 105 fire calls in total for Lyndon. Jeffersontown had a total of 1,640 runs and Harrods Creek had a total of 556 runs.

Jeffersontown had the largest population at approximately 32,000 people while Lyndon had approximately 30,000 people. Harrods Creek had the smallest population at roughly 15,000 people. Lyndon had the highest population density at nearly 3,000 people per sq. mile. Jeffersontown had a much lower population density then Lyndon and was approximately 1,260 people per sq. mile. Harrods Creek had the lowest population density among the three, at around 760 people per sq. mile. Lyndon had the greatest number of homes, at around 14,000 while Jeffersontown had 13,000 homes and Harrods Creek had the fewest number of

homes at about 6,200. Similar to population density, home density was the highest in Lyndon at about 1,400 homes per sq. mile. Jeffersontown had a much lower home density at about 500 homes per sq. mil. and Harrods Creek had the lowest home density at approximately 300 homes per sq. mi.. Both average home values, and house hold income were the highest in Harrods Creek. Home values were around \$320,000, while household income was about \$130,000. Jeffersontown had both the lowest average home values and household income. Home values were around \$140,000 and household income was about \$62,000.

The first question asked of the Fire Chiefs was “What is the most influencing factor-(s) on fire department response times?” The Lyndon fire chief believed that man power, was the most important factor in determining response time, especially the number of staff in quarters and manning an apparatus. Other factors that the Lyndon fire chief thought were important were infrastructure, mainly the road system, and unknown factors such as rail crossings, weather, downed trees and power lines, flooding, and construction. According to the Jeffersontown fire chief, time of day was a major factor that influences response time because of traffic conditions, and whether or not the fire fighters were awake (because of 24-hour shifts). The Jeffersontown fire chief also thought that other important factors were the environmental aspects of the district such as the topography and geography of the area, and weather conditions. The Harrods Creek fire chief said that resources and man power where the most significant factors that influence response times; however, other factors such as geography, the placement of stations, and traffic conditions were also important factors to

consider. There were several common responses among the three fire chiefs on the factors that influenced response times, mainly staffing, traffic conditions and geography. There were no surprises with the fire chief's responses as they were areas that were covered during the literature review.

Question 2 asked if "the allocation of resources such as personnel, vehicles, stations, etc. has an impact on response times". The response of the Lyndon Fire Chief was that the allocation of resource has the greatest impact on response times. The positioning of resources is critical, and strategic planning is of utmost importance especially for future growth. Deciding how equipment should be manned and where they should be placed is important. The level of staffing is not necessarily that important, but how many staff are in quarters and on duty is very important. If the department relies more heavily on volunteer staff rather than full-time staff then response times will suffer. The Jeffersontown Fire Chief also believed that the allocation of resources was equally important in determining of response times. Resources should be distributed based on two factors, demographics and whoever has the greatest need. The Harrods Creek fire chief also believed that the allocation of resource was one of most influencing factors of response times. The problem is that sometimes when new growth at the edge of the district occurs, new developments are far away from the current stations, and fire departments do not have the resource to build a new station around the new growth and response times will be affected. The distribution of resources was important to all three fire chiefs in determining response times. There were also a few other important factors that were identified such as

response times suffering at new housing developments and that resources should be distributed based on demographics and need. It was important that this chief mentioned that resources should be distributed based on need and demographics and not solely based on a population, as this would lead to disparities.

Question 3 was “Would you say that in certain cities that lower-income areas are disadvantaged with respect to response times?” The answers to this question by all three fire chiefs were unanimous, and it was of no surprise . All three believed that lower SES areas should not be disadvantaged with response times, and in fact, lower-income areas should actually have better response times. The Lyndon Fire Chief believed that lower income areas within inner cities have full time staff, and the infrastructure hasn’t changed and therefore stations are in place and manned. However, the Lyndon chief believed that economic factors could very likely affect this. Stations could be closed down in an economically depressed area, and this would most certainly affect response times as they would have to be served by another station or district. The Lyndon fire chief pointed out this was currently going on in the Louisville Metro Fire District, a station was recently lost because of the city’s bad economic situation. The Jeffersontown Fire Chief said that although fire follows poverty, that response times should not be worse off in lower-income areas. Resources are distributed on who needs and therefore people in higher poverty areas should have more resources so they shouldn’t be disadvantaged with regards to response times. The Harrods Creek fire chief also had a similar opinion that

resources are distributed based on demand and that lower income areas should not be disadvantaged. Lower income areas have a greater demand for services so more resource will be placed in those areas and should consequently have better response times. If low income areas were disadvantaged, I don't believe that these chiefs would actually admit this because this question has serious implications for equity and it is such a sensitive subject.

Question 4 was the opposite of question 3 and was "Would you say that in certain cities that fire districts with higher cost housing have better response times". Similar to the answers to the previous question, the responses were unanimous, and because in the previous question all three indicated that resources are distributed based on need, that wealthier areas should in fact have greater response times. The Lyndon Fire Chief didn't think that areas with higher cost housing should have better response times, but they should actually have worse off response times because big homes are on bigger parcels of land, and the homes are spread farther apart and stations are also spread farther apart so fire trucks should actually take a longer time in getting to the wealthier homes. The Jeffersontown Fire Chief also did not believe that areas with wealthier homes would have better response times. If it were the case that the wealthier area had better response time than it might have something to do with the funding levels. This was an interesting qualifying statement that was made that if wealthier areas did have better response times that it was strictly related to higher levels of funding. The lower socio-economic status area might have lower levels of funding than a wealthier area and might have to rely on volunteers

which would increase response times. The fire chief from Harrods Creek also did not think that areas with higher cost housing should not have better response times. However, the Harrods Creek Fire Chief made the same qualifying statement that the Jeffersontown chief said, that if response times in wealthier areas were better than it would most certainly have to do with levels of funding. Certain areas may have better funding so they can afford more staffing, better equipment and could as a result have better response times. The Harrods Creek fire chief also thought that if an area that had the wealthier homes were in was a smaller independent fire department then perhaps they could have better response times. The Harrods Creek fire chief thought that smaller fire departments were more efficient especially when it comes to management and can readily make changes more easily than a larger fire department when a problem is found like response times and address the issue.

Question 5 examines the fire chief's opinions on rates of property taxation and its affect on response times. The question was "Would you say that in certain cities with higher rates of property taxes would fire departments have better response times". There seems to be some level of consensus about this question between the three chiefs. The Lyndon fire chief believed if there were high rates of taxation then a department would be able to afford having full time staff, rather than relying upon volunteers and also having better equipment and stations which would lead to better response times. The Jeffersontown Department Chief also believed that a higher rate of taxation would lead to better response times, if there were greater funding which would be used for more resources. However,

total funding depends on the population density of the fire district. The greater the density of the fire district the greater the amount of funding that is available. The Harrods Creek fire chief also believed that a higher rate of property taxation would lead to better response times because of more staffing. Louisville – Jefferson County Suburban fire districts have a rate of \$0.10 per \$100 of real property (home and vehicle). The Harrods Creek fire chief pointed out that other areas such as Indianapolis have property tax rates of \$0.24 - \$0.38 per \$100 of real property and Cincinnati has a rate of \$0.17 per \$100. The suburban fire protection districts in Louisville have to do with less funding, when compared to other similar cities. After several questions it is very apparent that funding is of utmost importance. This question was related to funding and in the previous questions issue of funding arose and the point was made very clear that higher levels of funding for an area would lead to better response time and this could be the potential reason for why higher SES areas could potentially have better response times. .

The next three questions were about the specific results from the equity portion of the quantitative analysis. Question 6 asked why “in certain cities lower-income areas were disadvantaged with respect to response times.....Would you have any possible explanations for this?” All three fire chiefs were somewhat surprised with these results, and did not think that it would be possible for lower SES areas to be disadvantaged with response times. The Lyndon fire chief thought that in certain areas, especially that were economically challenged, may have closed down fire stations as a measure of cost-cutting and this would most

likely affect response times. The Lyndon Chief believes that in economically difficult times local governments resort to shutting down stations and consolidating them which will result in response times going up.

The Lyndon chief also mentioned that a proposition in California closed several fire stations which may have impacted response times in that state. Other factors that will influence response times include a change in the infrastructure, plant closures and urban development that results in traffic change. The Jeffersontown Fire Chief believed that areas with higher density and in poverty have a greater need for resources, because fire follows poverty. These areas should have more resources according to the Jeffersontown Fire Chief, however if stations are busy responding to calls fire engines from other locations may have to be brought in, which will increase response times. The Harrods Creek fire department found the result to be surprising and counterintuitive because low-income areas should have a higher volume of calls, and therefore more resources which should lead to better response times. The explanations that were provided in my opinion were not sufficient and give the impression of an excuse. If the reason why some lower SES areas are disadvantaged with response times is because of funding and resources this would indicate that fire provision is not distributed based on need. Areas that have the highest need should not have station closures as this would jeopardize people within those areas.

Question 7 was similar to question 6 and asked for explanations of why “in certain cities would fire districts with higher cost housing have better response

times". The response to this question was somewhat similar to the previous question and the fire chiefs were again surprised by the results. Similar rationale as the previous question was used by two of the chiefs, who said wealthier areas could potentially have greater funding which would allow for the acquisition of greater resource and staffing which would all lead to lower response times.

The Lyndon Fire Chief said that he could only speak of his experience from his fire district, and didn't know why in those cities results would end up the way that they did. In Louisville-Jefferson County more affluent areas are served by independent fire departments rather than one big fire department and funding that is raised for fire is only spent on fire which is more efficient, where in other cities that might not be the case and fire departments might have to fight for funding from a city's general fund. The Lyndon Fire Chief also believed that some wealthier areas would also have greater funding which would lead to more staffing and resources which would lead to lower response times. The Jeffersontown Fire Chief said that areas with more density, usually lower income areas, will have more demand for services so greater demand could put a strain on services which would increase response times. The Harrods Creek Fire Chief believed that there could be some political reasons for areas with higher-cost housing having better response times. Perhaps there could be some people with political power living in areas where services are improved because a certain politician lives in that area. The Harrods Creek Fire Chief gave the example of a fire district in Jefferson County where they brought in an ambulance because of a city councilor who had experienced a heart attack. The ambulance was kept in

the district for several years, however, the cost was too great to keep it there.

The Harrods Creek Fire Chief gave the example of his district that has very expensive housing; however they lack the population density to support having additional resources so they don't have better response times when compared to other areas with lower cost housing.

Question 8 examined why it was found that "the higher the rate of property taxes, the worse the response time?" All three Chiefs gave explanations, some of which were related to one another as to why some areas would have higher rates of taxes, but worse off response times. Mainly that poor areas may not be able to achieve similar levels of funding with the same tax rate when compared with an affluent district or area. The Lyndon fire chief thought that the area with the higher rates of taxation could be in an economically depressed area, which is a plausible explanation. These impoverished areas would need higher rates of taxation to get similar response times or staffing levels as other areas that were not economically depressed. The Lyndon fire chief gave the example of the Black Mud Fire Protection District in Jefferson County. He said that this was an indigent fire district and several years ago they were collecting taxes at a rate of \$0.10 per \$100 of real property, while Lyndon was collecting taxes at the rate of \$0.06 per \$100 of real property. The district was eventually absorbed by another fire district because they were unable to provide adequate services to their residents.

The Lyndon Fire Chief also mentioned that the urban tax rate in Louisville was higher than the suburban tax rate and that the urban response time was most likely not the fastest. In fact, Lyndon has the fastest average response time

in the Louisville-Jefferson County at 3:28, while Louisville Metro has an average response time of 3:45. Districts outside of the Louisville urban service district have more money and can afford more stations and have smaller service areas. The Lyndon fire chief also said that “smaller fire departments do everything the same as large departments, but do it with fewer people which means lower costs. Unions don’t like that, and Louisville has a good union.” The Harrods Creek Fire chief also mentioned the Louisville fire fighters union. He said that Louisville annexed the Oxmoor area but did not provide additional resources to this area. No new stations were built out in the Oxmoor area by the Louisville Urban Fire department. The union contract also prohibited any suburban fire departments from responding to an urban district and so he felt as if this was taxation without representation. He thought that this would increase response times in that particular area, and they also would have the higher tax rates of the urban service district, which are around \$0.22 to \$0.25 per \$100 of real property.

Similar to the Lyndon Fire Chief, the Harrods Creek Fire Chief also believed that poor areas would have to compensate for not being able to collect enough tax revenue from their residents so higher tax rates would be required. The Jeffersontown Fire Chief believed that question about taxing rates and response times has to do with how the fire departments and districts are funded. He said that the Jeffersontown Fire Protection District has its own taxing authority for the fire department and that the funds only come from Jeffersontown, while Louisville funds the fire department from the general fund and funds come from

all of Jefferson County. He also mentioned that Louisville has different taxing sources that go into the general fund pool, such as the employment tax.

The next series of questions deal with the spatial and sprawl component of the study. The questions asked each of the fire chiefs what they believed had the biggest impact in slowing down their response times from the following seven options including: commuting times, vehicle ownership, population density, length of the block, divert of land use, distance from the center of the city, and proportion of detached housing. Each of the fire chiefs gave a different answer on which affected his fire district the most and this depended on where each of the fire stations was located within the county such as urban, urban/suburban, and completely suburban. It makes sense that each different area would be faced with different challenges that are brought on by urban sprawl, and that not each area would have a similar problem. The Lyndon Fire Chief selected commuting time as having the largest impact on response times in his district. He said that almost every factor is planned for except for traffic conditions and that traffic patterns and the time of day have a huge impact on response times. The Jeffersontown Fire Chief said that distance from the center of the city had the largest impact on response times in his district. He said that there was a considerable amount of new development at the edge of his fire district and no new fire stations had been built around the new developments at the edge of the county and district. The Harrods Creek Fire Chief said that they were most affected by population density, or a lack of it. The Chief said that the low density

within the fire district limits the departments funding, which affects staffing and resources and impacts response times.

Question 10 examines the role of commuting and the impact of traffic on response times for each of the fire districts and asks the chiefs for suggestions on how to deal with issue. Two of chiefs, one from the urban and the other from the urban/suburban mix fire districts thought that traffic was a major impediment to their department in responding to an emergency. Lyndon was greatly affected by traffic and commuting. The Lyndon Chief said that all the suburban fire districts came together and implemented a policy of having the closest station respond to a fire, regardless of the fire district and political boundary. Their GIS dispatching system would take into account time of day and other factors before dispatching a certain department to a fire. However, the union for the Louisville Fire department prevents other districts from responding to fires within the Louisville fire district unless a certain level of alarm is hit or they call and ask for assistance. According to the Lyndon fire chief, one of the main reasons for this program being implemented was because of traffic congestion in certain fire districts which made it very difficult to respond to fires especially around rush-hour times. Fire chiefs will usually ask developers for multiple access points into developments and industrial parks, however the developers will argue that building additional roads will cost too much.

The Jeffersontown fire district also has a problem with traffic and responding to emergencies at certain times of the day. The Jeffersontown chief gave an example of the industrial park within his district that has 30,000 people

working in it. The chief said that this industrial park only has one way in and one way out, and when an emergency occurs at rush-hour time when people are either leaving or coming to work it creates a major problem for the fire department in responding to an emergency. A major problem is not the amount of congestion, but the congestion outpacing the ability of the infrastructure to handle increased traffic. The Harrods Creek Fire Chief agreed that traffic conditions and commuting was a problem for responding to emergencies, however, because Harrods Creek was so sparsely populated that traffic was not a major concern for his district. The Harrods Creek Chief suggested that having more stations spread out around the district and staff would help reduce problems associated with traffic conditions.

Question 11 examined the length of street blocks and their impact on response times. Two of the three chiefs had problems with this issue of their fire department being affected by street connectivity. The Lyndon fire chief said that Lyndon was not really affected by the length of street blocks (street segment) because they were based on a grid system and that there was good street connectivity within Lyndon. This would be expected in any major urban area as having smaller street blocks and great access. According to the Lyndon Fire Chief connectivity is very important for fire departments as fire fighters need multiple access points to get to specific locations for quick response. This was also an important point for the Jeffersontown fire chief as connectivity is a major problem. Short blocks are easy to navigate but large ones are not, and sometimes fire fighters get lost responding to an emergency, and if the block is

very large then the fire trucks will have to take a greater amount of time to get around the block again to respond to the emergency. This is an important point that the Jeffersontown Chief conceded, that on occasion fire fighters do get lost and make mistakes which can potentially contributed to greater response times, which the shape of the landscape will affect. The Harrods Creek Fire district was also affected by block length. The chief said that the homes in this Harrods Creek fire district are spaced far apart on long winding roads and long driveways sometimes with gates and trees that doesn't allow for the passage of fire vehicles that makes it very difficult to get to some emergencies quickly

The last question of the survey asked if response times ever affected policies of fire departments or cities in any way. All three fire chiefs said yes to this question, that response times will affect policies and cities. The Lyndon Fire Chief said that response times will tell you when another station is needed, or when more resources are needed. The Lyndon fire chief pointed to the example of the policy to share resources between the suburban fire departments regardless of political boundary as a prime example of how response times affect fire department policies. The Jeffersontown fire chief said that response times will tell you where resources need to be assigned and whether or not a new station needs to built or a station needs to be expanded and renovated. The Jeffersontown Chief also said that sometimes fire department policies are influenced not by wanting better protection and reducing response times, but by keeping insurance rates down for businesses. The city and the economic development people will approach fire departments and tell them that they need

to build a fire station in close proximity to a new commercial development. Developments need to be within 5 mi. of a fire station to get good ISO ratings. The city and the developers tell the fire department that without the good ISO ratings, businesses will not come to the new developments. So instead of placing the station where it is truly needed, stations will be placed in locations that will lower insurance rates for businesses. This is a common practice of the development community and the fire department. The Harrods Creek Fire Chief gave an example of how response times affected policy. He said that in an adjacent fire district an influential person had died and the fire department had no ambulance at the time. Due to the death of this prominent individual an ambulance was placed in this fire district. The Harrods Creek Fire Chief believed that response times will influence how resources are distributed and administered within a fire district.

In summation this section was significant that all the chiefs believed that resources were disseminated on need and not potential loss. None of the chiefs believed that the lower SES areas should be disadvantaged with response times. When the results of the study were revealed to the chiefs that in certain cities the lower SES areas were disadvantaged and conversely the wealthy were advantaged, they were all surprised. Levels of funding were used as the main rationale by the chiefs to explain why these possible consequences could have come about.

CHAPTER 5

DISCUSSION, RECOMMENDATIONS AND CONCLUSIONS

5.1 Discussion

Equality

“All Americans, white or black, rich or poor, are entitled to equal protection” (Bullard, 2002:7). Based on the findings within this study, this does not seem to be the case as poor minorities are worse off than their wealthier white counterparts depending on what city they live in and what part of the city they come from. These findings partly confirm the hypotheses, while some of the other findings may create more questions. The first major finding is that response times did vary by the socio-economic status (SES) of the people in the fire district. Outcome of the analyses signified that the results varied by the city and within the cities themselves. These findings would confirm and be in line with findings of Duncombe (1991), Rich (1982), Peterson (1981) and Drier et al. (2004) which indicated that services do vary across and between communities and that service provision is not equal. Several of the statistical models confirmed the hypothesis that response times did vary by the SES of the fire district, and more specifically, that the poor and minority populations were worse off with respect to response times, while the wealthy were better off in some cities. Based on these results fire protection resources are not distributed based

on need, contrary to what the fire chiefs said in the qualitative section, but rather on potential loss, which is inequitable. If the main reason for this discrepancy is because of funding, as identified as one of the potential reasons by the fire chiefs, then shouldn't areas with greater need have greater funding?

The first model to indicate that response times did vary by the SES of the fire districts population was the nonwhite model. Nonwhites were disadvantaged with respect to response times when area, expenditure, and population density were controlled for in Houston, San Francisco and Miami. The opposite was true for nonwhites in Louisville, Seattle and St. Paul. The second model to indicate that response times did vary by SES was the model that examined people living in poverty. Those living below the poverty level in Houston, Miami and San Francisco were worse off than people who were not living in poverty with respect to response times, which is inequitable.

These findings are consistent with a study that was conducted by Southwick and Butler (1985) which found that poverty and higher density was consistently linked with fire loss in larger cities. Houston is most likely affected by poverty, while San Francisco by density. Once again, the reverse was true for people living in poverty in Louisville, Seattle and St. Paul as response times were more favorable in the areas with higher poverty when compared to areas that had fewer people who were not living in poverty. The housing tenure model also indicated that response times varied by the SES of its population. Areas with greater concentration of home-owners in Houston and Seattle had more favorable response times when compared to areas in those cities with fewer

home owners. Areas with higher concentrations of homeowners are usually white and are able to organize and mobilize when concerns arise at the neighborhood level and home owners can demand that action be taken, such as lobbying for greater fire protection (Bullard, 2000). Areas with higher concentrations of home owners in Louisville, San Francisco, and Miami had worse response times when compared to areas with lower concentrations of homeowners.

The home value model was able to demonstrate that response times varied by the average price of a home within a fire district. Fire districts with higher home values in Houston and Seattle had more favorable response times when compared to fire districts with lower home values. The opposite was true for Louisville, San Francisco and Miami as areas with higher home values had response times that were not favorable. Fire districts with higher rates of property taxation were worse off for response times in Houston, San Francisco and Miami. The statistical model which looked at high income households and response times also signified that results varied by the SES and were inequitable as households that earned greater than \$75,000 in Houston and Miami were better off with respect to response times. The reverse was true in Louisville, Portland and Seattle and households who earned more than \$75,000 were worse off for response times.

The results indicate that people in lower SES groups have poorer response times (when controlling for several factors) in some cities and better off in others. People in lower SES groups were worse off in cities like Houston, San Francisco and Miami, but they were better off in cities like Louisville and Seattle.

There are possible explanations of why people of lower SES were worse off in certain cities like Houston, Miami, and San Francisco while they fared better in cities like Louisville or Seattle. One of the more obvious explanation is size of the cities that were compared as Houston, Miami and San Francisco were much larger than Louisville or Seattle. Houston is the fourth largest city in the country. Related to this is the proportion of minorities and people living in poverty are much higher in cities like Houston and Miami when compared to Louisville and Seattle. Approximately 50 percent of the population in both Miami and Houston were nonwhite and close to 19 percent of population was living below the poverty level. The proportion of nonwhites was much lower in Louisville with 19 percent of the population being nonwhite, and 32 percent for Seattle. The levels of poverty were also much lower in both Seattle and Louisville, with 8 percent of the population living in poverty in Louisville and 13 percent of the population in Seattle was living in Poverty. San Francisco also had higher proportion of nonwhites, however, the level of poverty was much lower than Houston and Miami.

Based on the maps it is evident that nonwhites and people living below the poverty level were concentrated in Houston, Louisville, Seattle, and Miami. Powell (2002) explains that when poverty and the social problems that are associated with poverty are concentrated within inner cities that the problems are isolated on the "minority" side of the city boundary, and that suburban whites are spared from having to share the fiscal and social burdens associated with the problems of the inner city. Drier et al. (2004) have identified many social and

economic disparities between inner cities and suburbs. Houston is one city that demonstrates many of these disparities that these authors discuss. Houston is a city that has pursued a policy of low taxes and low public services (Savitich and Kantor 2002). The existence of neighborhoods with unique service needs, such as greater fire protection, creates the potential for inequitable service delivery (Rich, 1978). Inner city neighborhoods are unique and require greater fire protection services. This is one reason why minorities fared worst in Houston. During the interview in the qualitative section one of the chiefs said that it was most likely that the low-income areas faced station closings as possible rationale of why minorities experienced worse conditions with respect to response times in cities such as Houston and Miami. If this was the case that a lower SES area with greater need for services experienced a station closures, then this would be a clear example of inequality. With some further investigation it was found that the Houston Fire Department closed three fire stations within the last decade. Two of the three fire stations were located within the fire district with the CBD that was among the lowest for housing values within Houston and had the highest proportion of minorities and people living in poverty. Stations closures could also related to declining populations within an area, and because these closures occurred in the downtown section of Houston it is plausible that the area experienced a declining population. Louisville also has recently shut down a station within its urban fire district close to south-west Louisville near the CBD. All the fire chiefs said that response times would go up as a result because crews have to come from farther distances to respond to an emergency. According to

the Louisville daily paper, *The Courier-Journal*, by shutting down the station the city will save approximately \$500,000 and will reassign 12 fire-fighters.

High-income households were better off in Houston and Miami which is inequitable because it means these groups do have the same level of need as low income groups. High income households were worse off in Louisville, Portland and Seattle. Lower-income fire districts utilize fire services more than affluent areas. If there is a greater need for fire services in these districts than fire crews stationed in the lower-income areas and their services will be will be used more often and crews might have to sent in from other areas to compensate for the greater volume of work. However, according to all three fire chiefs in Louisville-Jefferson County resources are disseminated based on need, so, in fact, these lower-income areas should have greater resources and poor people should have shorter response times, but this is not what is actually occurring in Houston in Miami which indicates inequality in these cities. It seems as if resources were distributed based on need in Louisville and to a lesser extent in Seattle as areas with lower SES had better response times. In every model people in the lower socio-economic status groups fared better with respect to response times in Louisville when compared to people in the higher socio economic groups. The same was generally true for Seattle, except for in the model with home values, which demonstrated that the higher the costs of housing within the fire district the lower the response time. This would seem to be in line with Lineberry's findings (1977) that the poor are not worse off, at least in Louisville. These findings from Louisville and Seattle would confirm what the fire

chiefs said in the qualitative interviews, that resources are distributed on need because people in the lower socioeconomic status groups did better with response times as a measure of service. However one fact that contradicts this finding is that during the qualitative interviews it came out that the economic development people in Louisville put pressure upon the fire departments to build fire stations near new commercial developments for the purpose of achieving lower insurance rates. If new fire stations are not placed in these locations then the fire chiefs are warned that businesses will not locate in these developments. If this is the case that resources and services are not always distributed based on need but rather on potential loss. This would confirm the findings and results from previous studies of Lucy (1981), Cingranelli (1981), and Sanger (1982).

Sprawl

The second major finding of this dissertation is that urban sprawl does affect response times and that it does endanger people. However the findings depend on the city. Sprawl factors increased response times which put people's lives at risk in Houston, Miami and San Francisco, which were in line with my hypothesis. However, San Francisco is not considered a sprawled city and is actually a very dense and compact city and the linear relationships could be as a result of the high density of the city. Sprawl did not seem to hinder fire response in Louisville and Seattle, and in fact, the opposite may have occurred which is counter intuitive. The sprawl factors that had the greatest influence on response times were commuting times, population per street mile, the length of the street segment and the number of vehicles per household. Other sprawl factors also

affected response times to a lesser degree. In the qualitative section it was identified that fire districts, depending on where they are located will be impacted by sprawl factors in different ways. For example traffic and congestion was the biggest problem for the Lyndon (urban) fire district, which is an applicable finding to San Francisco's results. However, Lyndon did not have problems with connectivity as their street system is based on a grid and they have smaller street blocks, which would also apply to San Francisco.

Areas with detached housing had higher response times in general, however when cities were examined on an individual basis the results were surprising. In both Houston and Miami the higher the proportion of detached housing, the lower the response time which would indicate that inner city areas with fewer single family detached homes have longer response times. This is the goal of fire codes that discourage multifamily dwellings in favor of single detached homes that fire response will be able to maneuver more efficiently in areas with less density. The findings from this model for Houston and Miami are in line with the other findings from the equity models as areas that are usually far away from the inner city have a higher proportion of detached housing and in Houston these results are favorable towards those who live in detached housing. In Louisville, Portland and Seattle the higher the proportion of detached housing the higher the response time. These findings are not favorable towards people who live in detached housing.

The impact of commuting times, congestion and automobile ownership on response times in Houston, Miami and San Francisco was no surprise and are

very clear. These factors were all identified as problems by the fire chiefs within the qualitative analysis. These factors are dangerous to peoples lives, because they increase response times. Commuting times in Houston, San Francisco and Miami negatively affected response times, while the opposite was true for Louisville and Seattle which was somewhat unexpected. Vehicle ownership in both Houston and Miami also negatively affected response times. Population per street mile, a proxy measure for congestion, negatively affected response times in Houston, San Francisco and Miami. The opposite was true for Louisville and Seattle and the higher the population per street mile the lower the response times.

The worsening traffic conditions within the suburbs have been as a result of a rapid increase in population, vehicle ownership, and vehicle usage within these sprawled areas (Burchell et al., 2005) Traffic conditions have a major impact on how fire departments respond to emergencies. Fire departments respond to traffic accidents, and if there are a considerable amount of accidents this will prevent the fire department from responding to fire emergencies in a decent time, which puts people's lives in jeopardy. Traffic of an entire community may solely rely on a single road and this may entirely be the case in suburban regions and as a result may be congested for a great portions of the day, and if an accident occurs, the entire road system is basically useless until the problem is cleared (Duany et al.,2000). Sprawl has also made traffic conditions worse because of the combination of longer trips, and a higher proportion of people

using private automobiles results in greater miles driven on the roadways (Burchell et al., 2005).

The fire chiefs in the qualitative analysis stressed that traffic had a major impact on response. During certain times of the day responding to emergencies becomes increasingly difficult because of grid lock on the roadways. This is especially the case in Houston, where response times were greatly affected by commuting and congestion. Houston is a city that is known for sprawl and has a combination of low-density living and an absence of mass transportation system which has brought traffic congestion to the point of suffocation (Savitch and Kantor, 2002). Louisville was one of the smaller cities in this study, and although in the regression results it does not seem to be affected by commuting, it still faces problems with traffic congestion as pointed out during the qualitative section. Based on a study that was conducted by the Brookings Institute (2002) on Louisville, the percentage of the congested lane miles in the region increased from 36 percent to 55 percent between 1990 and 2000. This rise in congestion according to the study poses a serious threat to the quality of life.

Based on the findings from the spatial analysis, commuting times were still the highest in the suburban regions on each of the 4 cities that were examined, and the lowest towards the center of the city. The traditional pattern of commuting has been that people from the suburban neighborhoods commute to the CBD to their place of employment. Although many jobs are still located within the CBD, some people may no longer work in the downtown core, as many places of employment have scattered throughout the metropolitan area. Suburban areas

are home to many new office parks and small downtowns that located at major intersections at the edges of cities (Jargowsky, 2002). People may now travel from one suburban location where they live to another suburban location where their place of employment is located. According to Jargowsky (2002) when companies decide to locate within suburban regions, this creates a spatial mismatch, and people located within the urban core, especially the underprivileged are unable for various reasons to get to those particular jobs. This could also be another reason for the lower commuting within the downtown core.

There were some interesting results from the length of the street segment, proportion of the population within 1 mile of an elementary school and the distance from the CBD. The length of the street segment was a proxy measure for the size of the block. The results demonstrated that the length of the street segment affected response times. In the general model for the length of the street segment the longer the length of the street segment the longer the response times. The results with the individual cities are more interesting as findings indicate that the longer the length of the street segment in Houston, San Francisco and Miami the longer the response time, while the opposite is true for Louisville and Seattle the longer the length of the street segment the lower the response time. The general model for land use was measured through a proxy variable which measured the percentage of the population living within 1 mile of an elementary school. The results indicate that the higher the proportion of the population living within 1 mile of an elementary school the lower the response

time. However the model which includes the cities was unable to find any relationships.

There were some positive associations with the distance of the fire district from the CBD and response times that indicated that the farther away the fire district was from the CBD, the higher the response time. In model which stratified that data by cities it was found that in Houston, San Francisco, and Miami the further the distance from the CBD the higher the response time. In the qualitative section the Jeffersontown Fire Chief said that distance from the center of the city was a big problem for his fire district. A considerable amount of new development had occurred at the fringes of the Jeffersontown district and these new developments were very far from the existing fire stations that were located within the older areas of the district, and no new stations had been built to accommodate this development so response times at these suburban locations had suffered. Sprawled developments challenge public safety because the long distances and single-entry subdivisions make it difficult to provide adequate services with reasonable response times (Duany et al., 2000). These new development at the fringes of cities such as Houston or Miami might not have fire hydrants in close proximity so tanker trucks need to be used to provide water supply for fighting a fire which will take additional time for the vehicle to arrive on scene. In the qualitative section it was identified that some locations in the Jeffersontown Fire District are located at the fringe of the county and have an ISO rating of 9, which indicates that homes are at least 1,000 feet away from a fire hydrant and this could be why in Houston and Miami the farther away from

the CBD, the higher the response times. Water supply and fire hydrants should not be a problem in San Francisco as the city has established a wide network of cisterns, pump stations, and a pipe network to provide water for fire department as the city learned a tough lesson from the 1906 earth quake as the main problem was a lack of water to fight the fire that resulted after the earth quake (Scawthorn, Yamada, and Lemura, 2007).

Are Sprawl and Equity Related?

The findings regarding the sprawl factors were expected, that sprawl would at least in some cities endanger people because of its effects on lengthening response times. However, these findings seem somewhat contradictory at a first glance as one might expect that if sprawl would negatively affect response times, then areas that have higher concentrations of people in lower socio-economic classes, who are usually concentrated within the inner cities should have better response times, yet the opposite was true in Houston, Miami and San Francisco. Some might say, so what why does it matter that that people who live in sprawled areas have longer fire department response times, that these people can “afford” to have longer response times.

However, based on the results from the analysis of this study, I argue that not only are people who are living in sprawled areas affected by greater response times, but people who are living in the inner cities are also affected by this. Communities that are sprawled have spread their resources too thin and both groups of people who live in the inner cities and people who live in sprawled developments are negatively affected when it comes to service provision. Drier,

et al (2004) identify when people try to maximize their personal well-being by living in sprawled suburban developments their choices create social costs that affect everybody, even the wealthy. Duanay et al. (2000) discuss a study of suburban Milwaukee where the residents pay \$5,000 in property taxes, but services cost the city more than \$10,000 on an annual basis. Sprawled developments usually require greater funding for fire protection because the costs for providing equipment increases as new homes that require protection are in outlying areas that do not have adequate water supply so fire departments may have to spend \$200,000 for tankers that provide water in remote locations (Livingston, Ridlington, and Baker, 2003). Livingston et al. (2003) were able to demonstrate that a community of 50,000 developed at one home per 1.6 acres would need approximately eight fire stations to provide adequate services, for a total cost of \$12 million, however by developing more compactly the same population could be served by 4 or 5 stations for a total cost of about \$6-7.5 million. Cities need to make up the balance of this cost discrepancy somewhere. What ends up happening is that all residents end up paying for the services of those who live in suburban areas, or municipalities will provide fewer public services (Burchell et al., 2005). Those who suffer the greatest from a lack of fire protection are not those who live in wealthy neighborhoods, but are the poor who live in the inner cities. The fire chief from the completely suburban fire district in Louisville explained that in his district there were no fires within the past 18 months for which to respond.

A study conducted by Savitch, Collins, Sanders and Markham (1993) found that central cities and their surrounding suburbs and regions were highly interdependent. Furthermore Savitch et al. (1993) were able to demonstrate with strong statistical correlations that suburbs benefit when their core cities are viable. This was a study that examined economic prosperity; however, I believe that it could also be applied to the example from this study. Generally speaking, the results indicated that when the lower socio-economic groups concentrated within inner cities fared worse, so did the suburban areas of those cities primarily in Houston and Miami. When the reverse occurred and the lower socioeconomic groups did not fare worse in Louisville and Seattle, the suburban areas also did a better job at providing better fire protection to the outlying areas.

Fire-fighters in Louisville Jefferson County get training from different sources than fire fighters who are trained at one unified fire department. The urban fire district is trained in one location and the fire fighters from the suburban fire district are trained at another location. Perhaps by splitting up the training, fire-fighters are able to focus on the needs of their particular location. Fire fighters for example from a fire department in Houston or Miami who work in an inner-city fire district might be relocated to a suburban fire district and take along with them the training and mentality that is prevalent within that district.

Another explanation for the results of why sprawl did not negatively affect response in Louisville is the structure of fire districts and departments. Results indicate that sprawl did not impede the ability of fire departments to respond to emergencies within Louisville-Jefferson County. The results of the Louisville

were very different from the Houston and Miami. Seattle also had somewhat similar results to Louisville. The fire department system in Louisville is very different from the other cities. Each fire district within Louisville-Jefferson County has its own department, and is a separate jurisdictional entity, compared to Houston and Seattle which have one unified fire department and Miami which has a fire department for the city and another fire department for the rest of the county. The suburban fire departments in Jefferson County have set up a mutual-aid agreement that will allow during certain times of the day when traffic conditions are unfavorable for the nearest fire department to respond to an emergency regardless of the district that the emergency is located in. It appears as if this policy has been beneficial to suburban residents of Jefferson County as they are not negatively affected by sprawl.

The results may also have something to do with the fire districts being independent in Louisville and being a special unit of government. Burns (1994) identified that these special district governments, which provide services such as fire provision, build exclusionary walls against lower SES groups to protect themselves from the taxes and problems of older cities and this would be very relevant to the findings for Louisville. As lower income areas within the inner cities have a greater number of fires, fire protective services are utilized more often and therefore cost more. In the qualitative section it was identified that suburban residents in Jefferson County have a tax rate of \$0.10 per \$100 of real property, while the residents of urban fire district have a rate that is at least twice that of the suburban rate. These individuals who live in these independent fire

districts have their tax dollars only going to their district and the funds are strictly used for fire-fighting within their district. By having these independent fire districts wealthier people are isolating themselves from the costs of those who live in the urban fire district and make greater use of fire services.

Based on the qualitative and quantitative research of this study, smaller fire departments (in Louisville) are more effective and efficient than one very large fire department. This is consistent with other findings that have found small and medium sized police departments perform more effectively than larger police departments and they are more cost efficient (Ostrom, 2000). Hirsch (1964) and Ostrom, Tiebout, and Warren (1961) also have found that services are not always best delivered through a one major governmental source, but through different governments that vary in scale and geography. This was the case for the fire departments in the Louisville-Jefferson County. For example, per capita funding for the Lyndon Fire District was \$94, \$148 for the Jeffersontown fire district and \$167 for the Harrods Creek Fire District. Per capita funding in Houston was higher than Lyndon and Jeffersontown at \$151; however, Houston was much lower than the other major cities. Per capita funding for Miami City was \$211 and \$253 for Miami-Dade and \$313 per capita for San Francisco. Both Jeffersontown and Harrods Creek fire departments are fire districts that are of a suburban nature and therefore per capita costs are higher because similar services have to be provided to fewer number of residents.

It was found in Houston, Miami and San Francisco that the higher the rate of property taxes, the higher the response time. One would expect the opposite

to occur, if greater revenue meant improved service, however, this wasn't the case. The fire chiefs said that greater resources and funding should reduce response times, however, based on the findings from this analysis this wasn't the case. The expenditure control variables were significant (at 95 percent or higher) in several models. The coefficient in every case was positive, which indicates the higher the per capita spending the higher the response time. At first glance this seems counter intuitive, however if we examine the per capita spending levels of Lyndon, Jeffersontown and Harrods Creek Fire Districts, the spending level increase per capita and response times go up. However, this is in line with my hypothesis that sprawled areas cost more in services and have worse response times. However, higher spending doesn't necessarily mean inefficient services; it could be that as demand for the service increase, such as fire protection, that governments purchase more services, and expenditures increase (Peterson, 1981). Residents are choosing a bundle of goods and services, in this case fire protection, and they have different per capita costs than the urban areas because of less demand for the uses of the fire protection services.

Sprawl did not seem to affect response times in Seattle. The structure of the Seattle Fire Department was different from Louisville, but was similar to Houston's. One possible explanation for sprawl not having a major impact on Seattle is that Seattle is not a city that has a considerable amount of sprawl. According to study that was conducted by Smart Growth America, Seattle ranked 44th out of 83 metro areas that were ranked for sprawl. Furthermore Seattle was ranked 63rd out of 83 for accessibility of street network. Seattle had an average

street segment length of 370 feet, the second lowest average in this study just behind San Francisco. Houston was ranked 32nd overall in the sprawl index and 36th for accessibility of its street network. The closer the sprawl index score is to 1, the greater the degree of sprawl.

Based on the interviews, the fire unions have strong control over how and where resources are deployed. Although there is not a considerable amount of empirical evidence from this study, the fire chiefs from the interviews said that a strong union in the Louisville Metro Fire Department prevented a mutual aid agreement, which would allow for the suburban fire departments to respond to an emergency within the Louisville urban fire district. These findings are in line with Viteritti's (1982) findings of the New York firefighters union which had strong control over where resources were placed so that there would be greater presence of fire fighters in high demand areas. Although in the New York case the union was not detrimental to fire response, the actions of the Louisville firefighters seems to be counterproductive for fire protection to the residents of the urban fire district. By preventing an agreement of this nature, the Louisville Fire Department potentially could raise costs because there would be greater demand for work for its employees where they could possibly be awarded overtime pay. A study by Marlow and Orzechowski (1996) found that unions adversely impact productivity and raise the costs of providing services through the public sector.

5. 2 Recommendations

One of the first recommendations that I would make based on the findings of this study are to promote smaller, independent fire departments. These smaller fire departments have demonstrated more effective ability to respond quickly to a call than one large unified fire department for an entire city. I am however not advocating for exclusionary districts that are able to isolate themselves from the cost associated with providing services to the inner cities. Perhaps there needs to be a way to share funding at regional level. The structure of the Louisville-Jefferson County fire services is an example of how other cities could model their fire protective services. In addition, Louisville-Jefferson County leads by example and by having a mutual-aid agreement that allows a nearest fire station to respond to an emergency during certain times of the day, such as rush hour, which will allow for speedier response times. Another recommendation I would make is to prevent the union from having control that would prohibit a mutual-aid agreement from allowing another fire district to respond to an emergency if that district and department can respond to the emergency faster.

Developers should not have the ability to put pressure on fire departments to build new fire stations for commercial areas on the fringes of cities so that lower insurance rates could be possible for commercial interests. This takes away resource from where they are needed, in areas of the inner-city where the services are utilized the most because cities have limited funding. Efforts should be made by city planners, fire departments, and developers to create new developments that are not automobile dependent with smaller street blocks and

smaller road segments. By reducing congestion on the road ways and providing public transportation options this will help in reducing response times because there will be fewer people driving. Lambert and Meyer (2006) also made a useful policy suggestion in their study on sprawl and EMS response times that city and county governments should create impact fees for new developments for the cost of extending fire, police and emergency services to these outlying areas. If developers do not want to pay these additional costs of developing in these outlying areas then greater efforts need to be made to develop within existing city areas that need infill. Related to Lambert and Meyer's (2006) suggestion that developers should pay additional costs, Deyle and Smith (2000) have argued that property owners who face additional costs, such as hazardous conditions, should pay the additional costs of emergency services based on their relative risk, which would provide a disincentive to new sprawled developments. If both developers and consumers are hit with higher costs associated with the risk of living in sprawled areas than people may reconsider their choices on where to live.

Previous studies have shown that fire follows poverty, and in this study it was demonstrated that people in poverty in Houston and Miami have worse off response times when controlling for several factors. Efforts have to be continually made to reduce levels of poverty so that the number of fires and the demand for fire services will eventually be reduced. Additionally the quality of housing should be improved within inner cities with protective measures such as sprinklers. Fire departments, in cities such as Houston or Miami that have higher proportions of

minorities and people who live in poverty should make greater efforts to reexamine response times and SES factors so that areas that have the highest need receive the greatest protection and not the reverse. What the suburban fire chief from Harrods Creek said during the qualitative section was very striking; that there had been no fire within his district within the past 18 months and it would be great if this could be said about an inner-city fire district.

5. 3 Conclusions

Results from this dissertation indicate that fire protective services do vary within a city and between cities. There was inequality in Houston and Miami and to a lesser extent in San Francisco as lower socio-economic groups fared poorly with respect to fire service as measured by response times, while in other cities such as in Louisville and Seattle this was not the case and resources have been distributed based on need and not potential loss. Similarly, sprawl factors negatively affected response times in the same cities that were inequitable, mainly Houston and Miami, while in Louisville and Seattle response times were not affected by sprawl in a negative manner. The intent of this study was to demonstrate if any correlations existed between response times, socio economic status and urban sprawl and the findings indicated that these correlations did exist. It was never the objective of this dissertation to prove causation but merely to investigate how sprawl impacted fire service provision and if certain groups within a city have equitable access to fire protective resources. Eight cities including Charlotte, North Carolina, Houston, Texas., Louisville, Kentucky,

Portland, Oregon., Seattle, Washington, St. Paul, Minnesota, San Francisco, California., and Miami, Florida where included in this study. Based on these findings I would claim that people in lower SES have equitable access to fire protective services in cities like Louisville and Seattle and that fire protection services are distributed on need, while in Houston and Miami lower SES people do not have equitable access to resources. One major limitation is that there were only these eight cities within the study, which makes it very difficult to have external validity and apply these results to other cities. In reality cities are these dynamic places that have multiple dimensions and components that impact a service like fire provision as measured through average response times. This study only examined a few of these factors. I believe that there are some issues with selection bias and the cities in this study as this was not a true random sample. The problem was the data could be collected from the city if the city was willing to share both its fire department and GIS data, and this did not always happen. The dependent variable in this analysis was response time, which is an average and averages also have problems associated with them.

I believe that the results do confirm my hypothesis that response times did vary by socioeconomic status of the inhabitants of the fire district. People in lower socio-economic status groups were negatively affected by longer responses times in Houston and Miami and to a lesser extent in San Francisco. It was also found that the wealthy were better off in other cities, such as Houston, as they have lower response times and this ultimately translates to fire services being distributed based on a potential for loss rather than actually loss which is

inequitable. People in lower socioeconomic status groups in Louisville and Seattle were better off with respect to response times. My hypothesis was correct for Houston and Miami as sprawl factors negatively impacted response times and jeopardize people's lives in these cities. Sprawl however did not negatively impact response times in Louisville and Seattle.

Three fire chiefs, one from an urban fire district, one from an urban/suburban mix and one from a suburban fire district also were interviewed for this study. Some good insight was gained from these interviews. All of the fire chiefs believed that resources were distributed on need for services and that the lower-income groups should have been better served with lower response times, and were surprised when this wasn't the case in all the cities. All the chiefs also believed that sprawl had a major impact on response times and that different aspects of sprawl affected each district differently depending on where they were located within the city. Other important findings from the qualitative section were about the mutual aid agreement between the Louisville suburban fire districts, the impact of union's and developers on fire services.

Further study is needed on this topic with both more empirical and qualitative evidence. It would be beneficial to have data from other fire departments that were structured in a similar fashion to the Louisville-Jefferson County Fire District, with an independent fire department with its own taxing authority for each district. It would also be valuable for future research to observe response time data for multiple years to examine the influence of different political administrations and fire protection. Although the recommendation was

made that cities should have several smaller independent fire departments it is completely possible that the results for Louisville ended up the way they did because of other unforeseen spurious reasons. It also would be beneficial to interview all the fire chiefs from each city. This way insight from each region could be gained and the qualitative results of each city could be discussed with that city's fire chief. Conduction the analysis at a smaller scale of geography, such as at the census tract level, would provide further insight into this topic as more variation occurs at the census tract level. It would be beneficial as a part of that analysis to examine the characteristics and features of each census tract that a fire station is located in. Having cities of different sizes also makes it very difficult to compare one to another, as a cities vary in size, sprawl, composition and many other areas. Each city is unique in its own manner which makes it very difficult to compare, and it would be beneficial if similar cities could be examined for a study of this nature in the future.

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Appendix 1 - Maps

Figure 1

Figure 9

Nonwhite Population in Louisville-Jefferson, KY

Data from 2000 Census. Red star indicates CBD.

Figure 10

Figure 11

Nonwhite Population in Miami-Dade, FL

Data from the 2000 Census. Red star indicates CBD.

Figure 12

Figure 13

Population living in Poverty in Louisville-Jefferson, KY

Data from 2000 Census. Red star indicates CBD.

Figure 14

Population Living in Poverty in Seattle, WA

Figure 15

Population Living in Poverty in Miami-Dade, FL

Data from the 2000 Census. Red star indicates CBD.

Figure 16

Figure 17

Home Ownership Rates in Louisville-Jefferson, KY

Figure 18

Home Ownership Rates in Seattle, WA

Data from 2000 Census. Red star indicates CBD.

Figure 19

Home Ownership Rates in Miami-Dade, FL

Data from the 2000 Census. Red star indicates CBD.

Figure 20

Figure 21

Figure 22

Figure 23

Average Home Values in Miami-Dade, FL

Data from the 2000 Census. Red star indicates CBD.

Figure 24

Figure 25

Figure 26

Figure 27

Figure 28

Figure 29

Figure 30

Commute Times in Miami-Dade, FL

Figure 31

Figure 32

Figure 33

Figure 34

Appendix 2 - Interviews

Fire Department: Lyndon

Position: Battalion Chief Stich

14. In Your opinion what is the most influencing factor on fire department response times?

Staffing in quarters or on apparatus so response can be imitated. Infrastructure, road system what are the barriers, rail crossings, weather → trees, flooding, power lines down. Unknown factors such as traffic accidents, construction that unaware off, some route blockage.

15. Does the allocation of resources such as personal, vehicles, stations, etc. have an impact on response times?

Yes, # 1 impact is positioning of resources. Strategic planning is important on where to place stations for future growth. Where stations should be placed. How should the equipment be manned. Not staffing numbers necessarily but staffing in quarters makes big difference from having volunteer staff big delay in getting volunteers to scene to fight fire.

16. Would you say that in certain cities that the lower income areas are disadvantaged with respect to response times?

No don't think so. Lower income areas in inner city areas have full time staff, infrastructure hasn't changed. Stations are in placed and staffed. Don't see a lot of change in area street wise. But there can be economic factors that affect this. The closing down of station. So area that loses a station will have to be served by another district or station, but wont be as quickly as previously.

17. Would you say that in certain cities that fire districts with higher cost housing have better response times?

No, typically areas with higher cost housing shouldn't have better response times. Will be longer response times. 3:35 Lyndon area response time. Get bigger parcels of land, homes spread out further apart, stations further apart. Takes trucks longer time to get there. Response time is drawn by need. Where ever has most need will have most resources similar to police protection, not based on having equality on response times.

18. Would you say that in certain cities that fire districts with higher rates of property taxes have better response times?

Yes, they are able to afford full time staffing, rather than having volunteers. Areas with more money have better stations, better equipment. Economically depressed areas could have stuff that is not the greatest.

19. It was found in this study it that in certain cities that lower income areas were disadvantaged with respect to response times, however this was not the case for all cities as reverse was found to be true. Would you have any possible explanations for this?

Not knowing about the city, they have gone through stations that have closed. Those poor areas were served by more stations, but as a means for cost cutting they shut down the stations in the poor areas. In California proposition 44 came in and saw a flurry of station closers. In economic hard times governments will shut down stations and consolidate. Response times will go up. Other things → change in infrastructure, plant closures, urban development that results in change in traffic flows and roads, some type of service change. In older cities fire stations where only designed for horse and buggy. So had to be much closer for communication. IF fire people would run to fire station (prior to telephone) and notify of fire.

20. Similar to the previous question, in certain cities fire district's with higher cost housing had better response times, however once again this was not the case for all cities as reverse was found to be true. Would you have any possible explanations for this?

Could be because of smaller service district? Are all areas served by the same fire department? District within fire department. Have Louisville fire department in urban

area and more affluent areas are served independent fire district and departments. More efficient because of taxing, from the comes from the fire district and is only spent on fire. So money collected from Lyndon stays in Lyndon and is spent on fire \$0.10 per 100. Every penny is spent on fire. Don't have other agencies fighting for dollars. Can position stations closer together have smaller area. In more affluent areas would receive higher funding have better staffing. Metro govt no control over us.

21. In this study it was found that the higher the rate of property taxes, the worse the response time. Would you have any possible explanations for this?

If area getting \$0.12 per \$100 rather maybe because the area is economically depressed. In order to get the same response time or staffing would need higher rate of tax to get a similar results. Black mud fire district economically depressed area. Revenues were dwindling. Wanted to share resources, with rest of county however, they were absorbed. They were getting \$0.10 per \$100 while Lyndon was getting \$0.06 per \$100 because they were economically depressed. The urban tax rate in Louisville is higher than the suburban tax rate. Urban response time is probably not the fastest. Other districts outside of urban area have more money so can afford more stations and have smaller service areas. In smaller fire departments we do everything the same as the large department but do it with fewer people. Unions don't like that. Louisville has good union.

22. What do you think has the greatest influence on response times for a fire district (increases response time)?

- 8. Commuting Time *** Traffic Patterns have biggest impact.**
9. Vehicle Ownership
10. Population Density (Population per street mile)
11. Length of the Block
12. Diversity of land use
13. Distance from the center of the city?
14. % of detached housing

Have planned for other factors, its not unknown. We know what to expect. Can't avoid traffic and commuting. We are affected the most by traffic, for example at the busiest intersection at 5:00 in the afternoon we will be impacted for sure.

23. Commuting times within the fire district where found to be the most correlated with longer response times, would you agree with this and why do you think this would be the case? What would you recommend to deal with this?

What we have done is implemented closest station response regardless of the fire district and political boundaries that the fire is in. When we have an incident in our district, however if its closest to Harrods creek they may be the ones to respond. Or if there is some issue with traffic and we cant get to the fire, then another department will responds. Cad dispatching system accounts for certain situation which will account for that. We have dropped the kingdom barriers. However, Louisville still has the barriers and the Union prevents other districts from responding. So we don't go into the urban service district until a certain level alarm is hit or they call us.

24. The length of the street block was found to be the (2nd most) correlated with longer response times, would you agree with this and why do you think this would be the case? What would you recommend to deal with this?

That will have some effect, doesn't really affect us in Lyndon because we are on a grid system. One factor for those areas that are affected by it is on where resources are placed. A lot of times fire stations are placed in central areas. Have to be prepared to move from that central area. It may no longer be central point in district. Middletown did that a few years ago when they changed their headquarter location. Didn't do for economic reasons, but because old location was no longer at central point of district service wise. Lyndon in 60's located second station across railroad track on Westport road so that they would have equipment on both sides of the railroad. Picked location that was central. Need multiple access points into developments for connectivity. However developers will argue with chiefs saying why do you need another road here, it cost too much. Developers do not want to emergency services. Want to develop land than pass it off to somebody else than it becomes problem of the city if there are problems with access.

25. Population density and congestion were found to be correlated with longer response times, would you agree with this and why do you think this would be the case? What would you recommend to deal with this?

Greater density in urban areas and more vehicles on the road more congestion. In rural areas won't have traffic levels, however roads aren't as good. We run into (not amount of congestion) but congestion outpacing infrastructure. So as area grows faster than road allow this creates a major problem.

26. Do issues with response times ever affect cities or fire department policies in any way?

Yes, will affect another station is needed or dispatched to an incident. We came up with policy to share resource to reduce response times regardless of political boundaries. Staffing on equipment.

- We have been downgrading emergency response. What was emergency 2 years ago is not today. Traffic accidents, heart attacks. Definitions change of emergency. You risk a lot to save a lot and vice versa. Should be looked at all data. Trick to fool public is response time of first arriving unit → fire chief arrives at scene to scope out area, then trucks get there. Public wants to know when does unit get there, so response time of apparatus and command officer.***

Fire Department: Jeffersontown

Position Fire Chief Jack Reckner

27. In Your opinion what is the most influencing factor on fire department response times?
Time of day of the incident ie rush hour, are the fire fighters asleep, awake because of 24 hour shift. Environmental factors → weather. Industrial park and traffic conditions high traffic area with lots of congestion. Topography of area, geography.

28. Does the allocation of resources such as personal, vehicles, stations, etc. have an impact on response times?
Yes, resources need to be deployed based on demographics. Will have a large impact on response times.

29. Would you say that in certain cities that the lower income areas are disadvantaged with respect to response times?
No, even though fire follows poverty. Resources are based and distributed on who needs them the most and people in areas that are higher poverty should have more resources so shouldn't be disadvantaged with response times.

30. Would you say that in certain cities that fire districts with higher cost housing have better response times?
Would say no, but could be because of funding maybe. Tax revenues higher in east end, lower in west end. Lower SES areas could have all volunteer fire fighters.

31. Would you say that in certain cities that fire districts with higher rates of property taxes have better response times?
Maybe if that means greater funding and leads to more resources and better resources. Depends on density of population.

32. It was found in this study it that in certain cities that lower income areas were disadvantaged with respect to response times, however this was not the case for all cities as reverse was found to be true. Would you have any possible explanations for

this? ***Louisville used block development grand funds to by fire trucks. Depends on how resources were allocated. Poverty is a big factors. You can over allocate. Areas with more density can have more fires, fire is attracted to poverty. If trucks and stations are busy responding to fire, trucks from other districts will respond which will increase response times.***

33. Similar to the previous question, in certain cities fire district's with higher cost housing had better response times, however once again this was not the case for all cities as reverse was found to be true. Would you have any possible explanations for this?

The more density an area has the more fires it will have. Lower SES areas have more demand for services so greater demand could put strain on services.

34. In this study it was found that the higher the rate of property taxes, the worse the response time. Would you have any possible explanations for this?

Depends on taxing authority, does funding come from general fund or does fire district have taxing power. Jeffersontown only gets money from Jefferson town. Louisville gets money from all county in general fund. Also tax from employment. Urban service area different than suburban areas.

35. What do you think has the greatest influence on response times for a fire district (increases response time)?

- 15. Commuting Time
- 16. Vehicle Ownership
- 17. Population Density (Population per street mile)
- 18. Length of the Block
- 19. Diversity of land use
- 20. Distance from the center of the city? *****
- 21. % of detached housing

Distance form CBD most important for Jefferson Town. The areas on the edge of the district have much worse response times, because fire stations are so far away.

36. Commuting times within the fire district where found to be the most correlated with longer response times, would you agree with this and why do you think this would be the case? What would you recommend to deal with this?

Yes. Traffic is really bad. We have industrial park with 30,000 people working there. Only 1 way in and 1 way out. Commuting burden huge. ISO ratings have nothing to do with good protection, no correlation. No greater than 5 miles rule. TO KEEP

INSURANCE RATING DOWN. Rules made from 1912 from horse and buggy time. Economic development people need fire stations to get good ISO ratings, or development will not come. With a station close by people will get good ratings with lower rates of insurance.

37. The length of the street block was found to be the (2nd most) correlated with longer response times, would you agree with this and why do you think this would be the case? What would you recommend to deal with this?

**Yes, fire trucks need to get to location ASAP, however difficult with problems with connectivity. Short blocks easy to get around, long blocks not. If got lost have to go all the way around takes a lot of time.
Adequacy of fire protection ordinance.**

38. Population density and congestion were found to be the correlated with longer response times, would you agree with this and why do you think this would be the case? What would you recommend to deal with this?

Not surprising, more demand more pull for resources. Residential sprinklers will reduce the need.

39. Do issues with response times ever affect cities or fire department policies in any way?

Yes have weakness will try to shift policy by assigning resource to different areas. Renovate stations or build new ones. Jeffersontown had station in industrial park, however no longer needed it so closed it down.

Fire Department	Harrods Creek Fire Department
Position	Chief Aponte

40. In Your opinion what is the most influencing factor on fire department response times?

Resources, where resources are placed, where stations are placed, man power, money, geography, speed ie average speed is about 25mph because of all stops, lights, traffic, weather, Availability of man power, money all tied together, geography. Avg speed 24 mph. Geography where station is placed.

41. Does the allocation of resources such as personal, vehicles, stations, etc. have an impact on response times?

Yes one of the biggest factors for influence, hope that your station is in the best location. But sometimes you have a station in a district and all new homes and development in that district are very far away from station, which is bad for response times. 20sq miles for 2 station don't have resource to add new stations, hope we have best locations.

42. Would you say that in certain cities that the lower income areas are disadvantaged with respect to response times?

No the opposite is true. Poor areas have greater demand for services so more resources will be placed in those areas so should have better response times. Seem to be based on run volume. Lower SES areas have greater demand so more demand. Suburban areas more run volume will be higher and will have more resources. Should be better response.

43. Would you say that in certain cities that fire districts with higher cost housing have better response times?

Similar to previous question, however certain areas may have better funding so they can afford more staffing and better equipment so they could possibly have better times. Also smaller fire departments are more efficient, easy to make changes when needed and problems are found. Depends upon the region. Old city of Louisville the opposite should be true. Areas with more volume should have better response time. Certain areas with greater tax and assets more funding should have better times. Some affluent areas have better fire department. The larger the department the decrease inability to have good management to have control in issues and pass down change. Consider merging but thought they would be less likely to respond. Small city mayors were worried about losing communication.

44. Would you say that in certain cities that fire districts with higher rates of property taxes have better response times?

You would think so if it resulted in greater funding you could have more staffing.

Current tax rate \$0.10 per \$100 of real property value (home, vehicle). Indianapolis → \$0.24-\$0.38 per \$100. Areas with lower taxing rates usually have to rely on volunteers. It takes volunteers several minutes to response to calls, if the district is very large then response times go up. In some instances Cities will annex areas to gain funding, but they will not add services. Ie Oxmoor.

Would be better with greater taxing. Other areas have higher revenues. Cincinnati 0.17 per \$100 of real property. Can better staff with more funding. Some areas staffed Mon-Fri. In evening volunteers, weekend volunteers. Takes while for people to come in. Had they had the money would have full time staff which is big difference.

45. It was found in this study it that in certain cities that lower income areas were disadvantaged with respect to response times, however this was not the case for all cities as reverse was found to be true. Would you have any possible explanations for this? You wouldn't think this should be the case.

Surprising and counterintuitive. Typically low income areas should have more volume better response times.

46. Similar to the previous question, in certain cities fire district's with higher cost housing had better response times, however once again this was not the case for all cities as reverse was found to be true. Would you have any possible explanations for this?

Could be some political explanations.

Is there political reasons? Don't have enough density, wealthy housing however, not enough of it to get good funding levels. 9th in income, but expensive housing. But density doesn't support having additional resources. Don't have population density to support better services.

47. In this study it was found that the higher the rate of property taxes, the worse the response time. Would you have any possible explanations for this?

Very expensive homes in hard to reach areas. Long narrow windy roads, isolated. Bridges. Tax rate is same. Louisville urban service district general fund about 0.22-0.25 per \$100.

Stations are placed in certain areas, however new growth occurs away from station. Poor areas might not be able to raise enough money, so need higher rates to compensate.

48. What do you think has the greatest influence on response times for a fire district (increases response time)?

22. Commuting Time

23. Vehicle Ownership

24. Population Density (Population per street mile)

25. Length of the Block → street network issues

26. Diversity of land use

27. Distance from the center of the city?

28. % of detached housing → problem

49. Commuting times within the fire district were found to be the most correlated with longer response times, would you agree with this and why do you think this would be the case? What would you recommend to deal with this?

Yes would agree with these. Traffic not an issue for suburban area. Finding the most efficient route. Add more infrastructure.

50. The length of the street block was found to be the (2nd most) correlated with longer response times, would you agree with this and why do you think this would be the case? What would you recommend to deal with this?

Would agree with this. How would deal with this? Less expensive to have more staff rather than to build roads. Have developers talk with fire people. Louisville annexed areas of Oxmoor but did not provide additional resources. So when send fire trucks to Oxmoor trucks go through 2 different fire protection districts to get there. Union contracts prevent suburban districts to response to urban district. Taxation without representation. Take tax money but don't provide additional services. Still like that. So increase response time.

51. Population density and congestion were found to be the correlated with longer response times, would you agree with this and why do you think this would be the case? What would you recommend to deal with this?

Yes, not really applicable to suburban area. But just add more resources.

52. Do issues with response times ever affect cities or fire department policies in any way?

Yes, policies for response. Response affects the type and number of apparatus that are sent. Water supplies in isolated areas no hydrants. Tankers need to come in. Roads more narrow, don't have weight capacity need smaller trucks. Affected by narrow roads. Some areas get in to because of private bridges, gates that block trucks. Have problems with big tree canopies. Trees grow up and out trucks get damaged.

Ambulance put in location in area with political pressure. Influential person died so ambulance placed in location for 6-7 area. If money is not there will do best with what you have.

Appendix 3 – IRB Documentation

For IRB Approval Stamp

Subject Informed Consent Document

Equity, Sprawl and Fire Department Response Times Across the U.S.

Investigator(s) name & address: David M. Simpson, Matin Katirai. 426 West Bloom St. Louisville, KY 40208.

Site(s) where study is to be conducted: Fire Stations in Jefferson County Kentucky.

Phone number for subjects to call for questions: 502-852-4735

Introduction and Background Information

You are invited to participate in a research study. The study is being conducted by **David M Simpson, PhD** and Matin Katirai, MPH, Student. The study is sponsored by the University of Louisville, Department of Urban and Public Affairs. The study will take place at **Fire station in Jefferson County Kentucky**. Approximately 3 subjects will be invited to participate.

Purpose

The purpose of this study is to understand the factors that influence fire department response times and offer possible explanations for most significant factors of this study. It is a follow up to the quantitative findings of the study.

Procedures

In this study, you will be asked to identify factors that influence response times and offer possible explanations for most significant factors that were found in this study through a survey. The surveys will be conducted in person. You may decline any

question that makes you uncomfortable. The survey should take less than fifteen minutes to complete.

Potential Risks

There are no foreseeable risks, although there may be unforeseen risks.

Benefits

The possible benefits of this study include improved understanding of factors that influence response times. The information collected may not benefit you directly. The information learned in this study may be helpful to others.

Compensation

You will not be compensated for your time, inconvenience, or expenses for your participation in this study

Confidentiality

Your identity as a subject in this study and the information you provide may be released and published only if you agree that the information may be made public. Data collected in this project will be kept in the principal investigator's computer under passwords secured protection

Voluntary Participation

Taking part in this study is voluntary. You may choose not to take part at all. If you decide to be in this study you may stop taking part at any time. If you decide not to be in this study or if you stop taking part at any time, you will not lose any benefits for which you may qualify.

Research Subject's Rights, Questions, Concerns, and Complaints

If you have any concerns or complaints about the study or the study staff, you have three options.

You may contact the principal investigator at 502-852-4735.

If you have any questions about your rights as a study subject, questions, concerns or complaints, you may call the Human Subjects Protection Program Office (HSPPO) (502) 852-5188. You may discuss any questions about your rights as a subject, in secret, with a member of the Institutional Review Board (IRB) or the HSPPO staff. The IRB is an independent committee composed of members of the University community, staff of the institutions, as well as lay members of the community not connected with these institutions. The IRB has reviewed this study.

If you want to speak to a person outside the University, you may call 1-877-852-1167. You will be given the chance to talk about any questions, concerns or complaints in secret. This is a 24 hour hot line answered by people who do not work at the University of Louisville.

This paper tells you what will happen during the study if you choose to take part. Your signature means that this study has been discussed with you, that your questions have been answered, and that you will take part in the study. This informed consent document is not a contract. You are not giving up any legal rights by signing this informed consent document. You will be given a signed copy of this paper to keep for your records.

Signature of Subject/Legal Representative

Date Signed

Signature of Person Explaining the Consent Form
(if other than the Investigator)

Date Signed

signature of Investigator

Date Signed

LIST OF INVESTIGATORS

PHONE NUMBERS

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Matin Katirai

502-852-8019
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For IRB Approval Stamp

The following IRB Protocol has been marked as Exempt.

Tracking #: 08.0626

PI: Simpson, David

Title: Equity, Sprawl, and Fire Department Response Times Across the
U.S.

CURRICULUM VITAE

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EDUCATION

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Geographic Information Systems Application Specialists Certificate

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September 1994 to December 1998

Technical Reports

“Malaria Early Warning Systems: Risk Assessment and Vulnerability Mapping for Nigeria.” Prepared by Project Engineering for the National Space Research and Development Agency (NASDRA) Garki, Abuja. February 2008. Ismaila Odogba & Martin Katirai

Publications

Now in Press: Large Scale Rooftop Search and Rescue: the experience of Hurricane Katrina. Martin Katirai and David M. Simpson. International Journal of Mass Emergencies and Disasters. 2009

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PROFESSIONAL EXPERIENCE

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Research Associate

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January 2005 – July 2005

Masters in Public Health Practicum – GIS Public Health Specialist

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January 2004 – January 2005

Graduate Assistant

University of Kentucky Prevention Research Center, Lexington, KY

August 2002 – August 2003

Geographic Information Systems Data Coordinator

Canadian Tire Real Estate, Canadian Tire Corporation, Toronto, Ontario Canada

July 2000 – August 2002

GIS Specialists

Akanda Innovation Inc, Thorn Hill, Ontario, Canada

January 2000 - July 2000

GIS Technician

Summit County Auditor, Akron, OH

Consulting

March 2008

Malaria Vulnerability Assessment of Nigeria

Client: National Space Research and Development Agency (NASDRA)

January 2007

Evaluation of Urban Sprawl and Agriculture in Clark County Indiana

Client: Center for Environmental Policy and Management