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LEVERAGING GEOSPATIAL INTELLIGENCE TO ENHANCE DALLAS FIRE DEPARTMENT PROGRAMS AND DATA ANALYSIS

by

Stephan J. Lopez Jr.

September 2021

Co-Advisors: Rudolph P. Darken
David W. Brannan (contractor)

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This research incorporates and enhances the use of geospatial intelligence, also known as a geographic information system (GIS), within the Dallas Fire Department bureaus, programs, and data analysis. Traditionally, fire departments have primarily leveraged GIS for its cartography (map) functions to produce large area wall maps of the city and first-up response areas, and for creating map books kept in fire apparatus units. While cartography is a useful tool for visualizing broad information, incorporating other aspects of GIS into additional areas of the department will provide heightened situational awareness and can become a primary tool used for decision support and resource allocation. Through practical quantitative measures, such as travel time measurements and calculating coverage area dimensions, this research specifically examines how GISs can provide data modeling, tracking, predictive analysis, and visualizations. This type of analysis can then be used for policy development and decision support in areas such as the resource allocation of fire apparatus and fire station placement. In addition, this research analyzes how GIS can be incorporated into strategic planning and budget analysis.

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LEVERAGING GEOSPATIAL INTELLIGENCE TO ENHANCE DALLAS FIRE DEPARTMENT PROGRAMS AND DATA ANALYSIS

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ABSTRACT

This research incorporates and enhances the use of geospatial intelligence, also known as a geographic information system (GIS), within the Dallas Fire Department bureaus, programs, and data analysis. Traditionally, fire departments have primarily leveraged GIS for its cartography (map) functions to produce large area wall maps of the city and first-up response areas, and for creating map books kept in fire apparatus units. While cartography is a useful tool for visualizing broad information, incorporating other aspects of GIS into additional areas of the department will provide heightened situational awareness and can become a primary tool used for decision support and resource allocation. Through practical quantitative measures, such as travel time measurements and calculating coverage area dimensions, this research specifically examines how GISs can provide data modeling, tracking, predictive analysis, and visualizations. This type of analysis can then be used for policy development and decision support in areas such as the resource allocation of fire apparatus and fire station placement. In addition, this research analyzes how GIS can be incorporated into strategic planning and budget analysis.

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LIST OF ACRONYMS AND ABBREVIATIONS

CAD	computer-aided dispatching
DFD	Dallas Fire Department
EMS	emergency medical services
EMT	emergency medical technician
ESRI	Environmental Systems Research Institute
FPE&I	Fire Prevention, Education, & Inspection
GIS	geographic information system
GPS	Global Positioning System
IT	information technology
MDC	mobile data computer
NFPA	National Fire Protection Association

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EXECUTIVE SUMMARY

Managing a large urban fire department is extremely difficult. Multiple decisions made every day will have ramifications and unintended consequences that can have lasting effects on a department. With this knowledge, fire chiefs and command staff level personnel need enhanced analysis to make appropriate, data-driven decisions for their department and their municipalities. GIS can assist that need by providing in-depth analysis of multiple datasets and stitch them together to provide a global overall view of the requisite data.

From its rudimentary beginnings in the 1960s, a GIS "has evolved from a concept to a science."[1] As these beginnings grew into a profession with various technical aspects, GIS began to pervade into other professions, such as city/urban planning, remote sensing, weather forecasts, telecom services, transportation planning, and industrial applications. As the prevalence of GIS continues to grow in other professions, the fire service has been slow to recognize and incorporate the benefits of this technology. Until recently, the Dallas Fire Department was one of those fire departments that had yet to realize the full potential of this powerful tool.

A GIS functions as more than a way in which to make visually appealing maps. Maps are indeed a perfect tool for visualizing single point data streams and representing real-world attributes on a smaller scale. Everything from demographic data, political boundaries, and even response times can be encompassed in a GIS digital map. Unfortunately, most people do not realize that digital maps contain vast amounts of data behind every feature; and it is that data in the background of the digital map that actually matters. In fact, terabytes of data are created every day by large metropolitan fire departments. Everything and everyone associated with a fire department from firefighters, apparatus, supplies, payroll, and even fire stations, create usable data. Innocuous things,

[1] "What is GIS?, History of GIS," ESRI, accessed April 16, 2021, https://www.esri.com/en-us/what-is-gis/history-of-gis.

such as apparatus movements, speeds, firefighter work locations, and reports also create data points; and GIS has the ability to capture all that data and make sense of it.

As this research illustrates, resource allocation of fire department apparatus and fire station placement is a fundamental use of GIS analysis. When seconds count, the placement of vital life safety resources cannot simply be left up to institutional knowledge or gut feelings. As such, when relocating or placing new units into service, coverage analysis, hot spot analysis, and travel time analysis play critical roles in the resource allocation process. At first glance, these processes may seem very similar, yet each is distinctly different and provides a different perspective of data.

This thesis was designed to answer the question: How can geospatial intelligence enhance Dallas Fire Department's bureaus, programs, and data analysis. Through this research, GIS analysis was leveraged to evaluate, and in some cases, incorporated into multiple programs and bureaus within the Dallas Fire Department. The incorporation of GIS technology has enhanced programs like Dallas' RIGHT Care Program by providing the requisite data necessary to make data-driven decisions. In addition, this research has demonstrated how GIS applications can be used to enhance pre-incident planning, fire hydrant maintenance, fleet maintenance, and special operations response.

Furthermore, this thesis demonstrates that GIS technology can and should be used for strategic planning and policy development processes. In each instance, key demographic data and social equity tools must be incorporated into the decision-making process, so that minority and historically underserved communities are represented fair and equitably.

Uniquely, during the research phase of this thesis as new approaches and applications were discovered, my team and I implemented many of them in near real-time. Several of the GIS applications discussed in this thesis were used as case studies for the Dallas Fire Department (Appendices A and B). The overarching goal was to provide the reader with authentic analysis and a possible template for future GIS analysis within the reader's own agency or jurisdiction. The contributions from this research have provided

my team and I with the opportunity to complete actual projects and transfer knowledge from academia into tangible real-world applications.

Finally, while the effects of GIS were only analyzed in a few programs within the Dallas Fire Department, additional research into every departmentally sponsored program or bureau should continue. Leveraging the power of GIS technology beyond maps will increase efficiency and provide the essential data necessary to make sound, well thought-out strategic and tactical decisions.

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I. INTRODUCTION

A. PROBLEM STATEMENT

Digital technology has pervaded nearly every occupation at an exponential pace for the last 20 years.[1] Whether the improved ergonomic design of tools or the incorporation of computers into first responder vehicles, most people could not fathom their current occupation without the use of digital technology. These advancements include the software and applications that operate on multiple platforms, which are used for data entry and data analysis needs.

Historically, the fire service has been slow to adopt these new types of technologies.[2] Indeed, one of the often-quoted fire service mantras is, "100 years of tradition unimpeded by progress."[3] As such, evolution and technological progression has traditionally been a low priority for the fire service. This resistance to advancing the fire service includes using technology at both the tactical and strategic levels. As geographic information system (GIS) technology and infrastructure have become more prevalent in numerous areas of local government, they have become part of the technological progression that the Dallas Fire Department has long resisted. This opposition to GIS technology has marginalized the data-driven decisions' concept, instead relying on the institutional knowledge and "gut feelings" of command staff personnel. While cartography is a useful tool for visualizing broad information, incorporating multiple aspects of GIS into additional areas of the fire service will provide heightened situational awareness and can become a primary tool used for decision support. At the tactical level, GIS can assist in the day-to-day emergency response operations of the frontline personnel in the fire service. At the strategic level, GIS can provide the information and data necessary for fire

[1] Reuters, "Technology Is Dramatically Invading Nearly All Us Jobs, Even Lower-Skilled Occupations," CNBC, November 15, 2017, https://www.cnbc.com/2017/11/15/technology-is-dramatically-invading-nearly-all-us-jobs-even-lower-skilled-occupations.html.

[2] Matt Gasior, "Technology in the Fire Service," *PowerDMS* (blog), April 4, 2018, https://www.powerdms.com/blog/technology-fire-service/.

[3] Mike Hendricks, "Fire Departments Fight a Culture That Saves—and Costs—Lives," *Kansas City Star*, December 7, 2016, https://www.kansascity.com/news/nation-world/national/article119120943.html.

department command staff personnel to manage their respective bureaus effectively. At the policy level, ensuring equitable strategic and tactical decisions for the public requires GIS. This thesis seeks to analyze the use of geospatial intelligence, also known as GIS, in the Dallas Fire Department, as well as the fire service as a whole.

B. RESEARCH QUESTION

How can geospatial intelligence enhance the Dallas Fire Department's bureaus, programs, and data analysis?

C. RESEARCH DESIGN

This research will examine to what extent GIS can provide data modeling, tracking, predictive analysis, and visualizations for different programs, divisions, and functions within a fire department. This research also attempts to determine whether:

- GIS can provide the data necessary for evidenced-based decision making.
- GIS can enhance fire station site selection.
- GIS can enhance apparatus allocation analysis.
- GIS can enhance strategic and policy development.

The literature on this topic is varied and dispersed among multiple sources in various fields. This author could not locate any one source that combines multiple elements of geospatial intelligence for fire department use across such a broad spectrum of programs and divisions. As such, this thesis cites scholarly articles that have some connection to the fire service and/or disaster response. In addition, this investigation evaluates sources that discuss data typing and management to determine which elements can be leveraged into fire service data streams. This thesis also researches commercially available trade documents and white papers for additional insight. These sources provide first-hand knowledge and expertise of the available software applications currently being used by GIS professionals in the world. Their inclusion offers legitimate uses and examples of GIS technology by subject matter experts currently working in the GIS field in both the professional and academic settings.

The research begins by looking at what geospatial intelligence is and how it has evolved over its history. Incorporating current research articles, white papers, and technical publications will provide the information necessary for the reader to grasp the current technical aspects of GIS technology and its uses. This thesis consults fire service trade magazines, scholarly literature, such as theses, informational texts, such as textbooks and standard operating procedures, and anecdotal evidence like often quoted fire service mottos.

Second, the research tests the hypothesis that GIS can enhance fire department analysis in resource allocation by demonstrating its uses in apparatus and fire station placement. The data for this consideration is produced through two case studies from the Dallas Fire Department specifically developed for this research. The first case study evaluates the use of GIS in the resource allocation of truck companies throughout the Dallas Fire Department's area of responsibility. The second case study demonstrates the use of GIS in the resource allocation of ambulances (referred to as rescues in Dallas) throughout the city.

Each case study walks the reader through the use and incorporation of travel time analysis, hot spot analysis, and coverage analysis, which are key to determining a proper and equitable placement of resources. In addition to resource allocation, this thesis exhibits for the reader how fire station site selection can be vastly enhanced using GIS technology. Additionally, this thesis analyzes the ways in which GIS can enhance fire station site selection through land acquisition (city owned land sites vs. privately owned land sites),[4] population demographic analysis,[5] new construction development, and access to highways and major arterial roadways.[6]

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[4] American Planning Association, *Fire House Location Planning*, Information Report No. 98 (Chicago: American Society of Planning Officials, 1957), https://www.planning.org/pas/reports/report98.htm.

[5] ESRI, *GIS for Fire Station Locations and Response Protocol* (Redlands, CA: Environmental Systems Research Institute, Inc., 2007), 9, https://www.esri.com/library/whitepapers/pdfs/gis-for-fire.pdf.

[6] ESRI, 22.

Third, this thesis analyzes possible unconventional uses of GIS in other areas of fire department divisions and/or programs. This analysis relies on evaluating current high-profile fire department programs and operations and determining the criteria needed to assist each program individually. By evaluating the data associated within each area and matching the proper source literature to the respective program, the research seeks to determine the viability of GIS incorporation into areas like pre-incident planning, fire hydrant maintenance, EMS program development, fleet maintenance, and special operations response. In essence, this research consults the available literature from various fire, GIS, and administrative sources and merges them into a real-world application using the Dallas Fire Department as an example.

Fourth, this thesis evaluates GIS used in the fields of policy development and strategic planning. The research will include an evaluation of budgetary and policy development for the City of Dallas and other Texas cities of similar size and population. After identifying the overriding priorities of these cities, this thesis provides recommendations on how GIS technology can be incorporated to meet and/or exceed the requirements identified for budget, policy development, and strategic planning for each city.

Finally, this thesis recognizes specific barriers to incorporating GIS into a fire department. Identifying resistance to change and technology in the fire service is the first step to overcoming it. Understanding the mindset and the roadblocks often created by blue-collar professions, such as the fire service must be identified, so that GIS technology may be incorporated carefully and systematically. The thesis demonstrates how little the technology and the job of firefighting have changed in the last 50 years by providing examples of only a handful of technological improvements that have affected it.

Ultimately, this thesis aspires to provide local fire department agencies with an "outside the box" approach to their application and use of geospatial intelligence and technology. Leveraging the power of GIS technology beyond maps may increase efficiency and provide the essential data necessary to make sound, well thought-out decisions.

D. LITERATURE REVIEW

Geospatial intelligence, also commonly referred to as GIS, has been around for nearly 60 years.[7] Its origins evolved from hand-drawn paper maps to printed-paper maps then to computer-based geographic systems in a remarkably short period of time. This literature review aims to examine the scholarly works in the field of GIS and to define how it can be leveraged within the Dallas Fire Department's response time analysis, which feeds directly into the department's strategic plans. Although GIS is currently used to develop cartography for station maps and special events like parades and marathons, the Dallas Fire Department has recently begun incorporating GIS into programs and other areas of the department that it had not considered in the past.

1. Strategic Planning

Strategic planning is more than just a dusty three-ring binder sitting in the Fire Chief's office. A strategic plan, "provides specific yet comprehensive information on the organization's current situation and circumstances and where the organization hopes to be or what it hopes to become over time."[8] Within the fire service, the largest areas of strategic planning primarily fall into the two categories of resource allocation and budget preparation. Although numerous other sub-categories exist, these two areas affect how a fire department completes its mission and how it pays for it.[9] Within each area, fire departments consistently ask fire department command staff personnel to do more with less.[10] As Glen Holder argues, the fire service, "calls for expanding interoperability between fire agencies over a large geographic region to increase service while decreasing

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[7] Jessica Camille Aguirre, "The Unlikely History of the Origins of Modern Maps," *Smithsonian Magazine*, June 2, 2014, https://www.smithsonianmag.com/history/unlikely-history-origins-modern-maps-180951617/.

[8] B. Keith Simerson, *Strategic Planning: A Practical Guide to Strategy Formulation and Execution* (Westport, CT: Praeger ABC-CLIO, 2011), 14.

[9] Eddie Burns, *Dallas Fire-Rescue 10 Year Strategic Plan* (Dallas, TX: Dallas Fire-Rescue Department, 2008), 3, http://dffa.org/DFD10YearPlan.pdf.

[10] Steven Knight, "Doing More with Less: Fire Department Budgets, Fiscal Responsibility," FireRescue1, August 2018, https://www.firerescue1.com/fire-chief/articles/doing-more-with-less-fire-department-budgets-fiscal-responsibility-GTj33j3axJ2tfshe/.

costs."[11] To do more with less successfully, fire department command staff personnel should be making decisions based on data rather than their organizational or institutional knowledge. According to Marie Patino, "data has become central to city hall, and a growing number of municipalities are now integrating it at every step of their decision-making process."[12] This data-driven decision-making process can then be leveraged to assist in evidenced-based policymaking. According to Urban.org, a non-profit organization dedicated to unbiased authoritative insights, evidence-based policymaking can enhance new or existing programs or policies, while also providing the data needed for analysis and research.[13] Geographic information systems have the ability to provide fire department command staff personnel with the data required for evidenced-based policymaking and strategic planning.

According to the Environmental Systems Research Institute (ESRI), no matter the size of a community, policy makers and managers have to consider spatial data like zoning restrictions, transportation networks, parcel size, land use, and housing restrictions in their decision-making process.[14] These elements not only affect the quality of life for the citizens and visitors to a city but also the planned growth and development of an area. Indeed, ESRI goes on to state, "Every day, planners use geographic information system (GIS) technology to research, develop, implement, and monitor the progress of their plans."[15] GIS has become the technological tool necessary to convert strategic planning into real-world, on-the-street action. The aforementioned zoning restrictions, transportation networks, land use, housing restrictions, and numerous others employ the geospatial intelligence information intimately tied to the strategic planning of future fire

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[11] Glen M. Holder, "Strategic Planning for the Fire Service" (master's thesis, Naval Postgraduate School, 2016), V, http://hdl.handle.net/10945/48535.

[12] Marie Patino, "The City Governments that Have Mastered Data," Bloomberg, July 15, 2021, https://www.bloomberg.com/news/articles/2021-07-15/how-city-governments-are-using-data.

[13] Evidenced-Based Policy Making Collaborative, *Principles of Evidence-Based Policymaking* (Washington, DC: Urban Institute, 2016), https://www.urban.org/sites/default/files/publication/99739/principles_of_evidence-based_policymaking.pdf.

[14] ESRI, *GIS Solutions for Urban and Regional Planning* (Redlands, CA: Environmental Systems Research Institute, 2006), https://www.esri.com/library/brochures/pdfs/gis-sols-for-urban-planning.pdf.

[15] ESRI, 2.

station locations and unit resource allocation. Members of fire department command staff personnel can leverage GIS resources to obtain this information in a logical and straightforward manner.

Cecilia Wong et al. agree and further note that GIS has the ability of "communicating complex planning issues in a 'language' that is easily understandable and effective at stimulating policy debate, critical thinking, and learning."[16] Their research "demonstrates the need for policy makers to think [and] act spatially when developing policies and programs."[17] With respect to evidence-based policy making and the fire service:

> GIS has the ability to retrieve large amounts of data maintained by agencies and organizations outside the fire service. GIS allows fire staff to access and integrate diverse datasets maintained by outside organizations. This enables personnel to access and fuse these datasets with existing preplanning, incident, and other fire data. Complex analysis and modeling can be performed to predict, monitor, and model service delivery based on call history.[18]

While conducting strategic planning, this type of complex analysis and modeling with external data streams provides the information needed to make decisions in the evidenced-based policymaking approach. Since a large portion of the fire department strategic planning model focuses on future needs and assessments, the placement of units and fire stations determines the future success of an organization. According to ESRI, "Because so much of the fire service mission is location dependent (emergencies always happen at a place or location), GIS has emerged as an important component of information platforms built to support fire service organizations."[19]

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[16] Cecilia Wong et al., "Mapping Policies and Programmes: The Use of GIS to Communicate Spatial Relationships in England," *Environment and Planning B: Planning and Design* 42, no. 6 (2015): 1020–39, https://doi.org/10.1068/b130099p.

[17] Wong et al.

[18] ESRI, *GIS for the Fire Service* (Redlands, CA: Environmental Systems Research Institute, Inc., 2010), 1, https://www.esri.com/library/whitepapers/pdfs/gis-for-fire-service.pdf.

[19] ESRI, 1.

In sum, this body of literature agrees that the strategic use of a technology like GIS provides decision makers (from fire department command staff personnel to local political leaders) with the research data and supporting evidence needed to make informed strategic planning and policy decisions. Finally, assimilating more data and its advanced analysis provides enhanced understanding, which leads to improved planning and more informed policy development.

2. Response Time Analysis

When your house is burning down or someone you love is dying before your eyes, seconds feel like minutes and minutes feel like hours. As part of a fire department's strategic planning process, the response time of fire apparatus draws critical scrutiny. As Robert Upson and Kathy Notarianni highlight, "A critical factor in the effectiveness of any emergency response agency is the ability to get personnel and equipment to the scene of the emergency in a timely manner."[20] Nancy Grant and David Hoover also echo that sentiment by stating, "The time of response and performance of fire fighters responding are important measures of adequate preparedness."[21] Indeed, as the literature reveals, if fire department personnel and equipment are not there when needed, what use is it to have a fire department in the first place? Lori Moore-Morrell et al. stress that response times establish a baseline performance standard for how well a fire department is performing its core missions of life safety and property conservation by measuring emergency, "response availability, capability, and operational performance."[22] Specifically, as the National Fire Protection Association (NFPA) reveals, this organization has established the benchmark

[20] Robert Upson and Kathy A. Notarianni, *Quantitative Evaluation of Fire and EMS Mobilization Times* (New York: Springer, 2012), 2.

[21] Nancy K. Grant and David H. Hoover, *Fire Service Administration* (Quincy, MA: National Fire Protection Association, 1994), 245.

[22] Lori Moore-Morrell et al., *Fire Department Response Capability, Performance and System Resilience* (Washington, DC: International Public Safety Data Institute, 2018), 3, https://i-psdi.org/assets/research/fire-department-response-capability-performance-and-system-resilience-2018.pdf.

standards for fire department turnout and travel times of fire apparatus.[23] These standards, while not binding, are considered as "best practices" for the fire service and are generally referred to by state fire commissions and accreditation agencies.[24] The NFPA itself admits its enforcement and policing limitation by stating it in its literature.[25] Although the organization does not have the ability to enforce its standards, as ESRI goes on to explain, some municipalities have chosen to implement various time standards for emergency responses.[26] The response time standards that ESRI is referring to have evolved from the turnout and travel time metrics within NFPA Standard 1710. According to NFPA 1710, fire apparatus should meet the following metrics for travel times:

- Travel time of 240 seconds or less for the arrival of the first arriving engine company at a fire suppression incident.
- Travel time of 480 seconds or less for the deployment of a full first alarm assignment at a fire suppression incident.
- Travel time of 240 seconds or less for the arrival of a unit with first responder or higher-level capability at an emergency medical incident.
- Travel time of 480 seconds or less for the arrival of an advanced life support unit at an emergency medical incident (where the service provided by the fire department).[27]

However, Todd Sheridan casts these standards as a myth by doubting that "NFPA 1710 response time standards are achievable in the real world."[28]

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[23] National Fire Protection Association, *NFPA 1710—Standard for the Organization and Deployment of Fire Suppression Operations, Emergency Medical Operations, and Special Operations to the Public by Career Fire Departments* (Quincy, MA: National Fire Protection Association, 2020), https://www.nfpa.org/codes-and-standards/all-codes-and-standards/list-of-codes-and-standards/detail?code=1710.

[24] "Government Code Chapter 419. Texas Commission on Fire Protection," 419 Commission Enforcement § Title 4. Executive Branch, Subtitle B. Law Enforcement and Public Protection (2001), https://statutes.capitol.texas.gov/Docs/GV/htm/GV.419.htm.

[25] "Notice and Disclaimer of Liability Concerning Use of NFPA Standards," National Fire Protection Association, accessed December 2, 2020, https://www.nfpa.org/Codes-and-Standards/Standards-development-process/Disclaimers.

[26] ESRI, *GIS for Fire Station Locations and Response Protocol*.

[27] National Fire Protection Association, *NFPA 1710*, 9.

[28] Todd Sheridan, "3 Fire Service Myths: Data, Response Times and Coverage Equity," FireRescue1, July 9, 2019, https://www.firerescue1.com/response-time/articles/3-fire-service-myths-data-response-times-and-coverage-equity-GaCh6wfeKUDFrmqr/.

The literature supports that GIS plays a vital role in the ability to provide the historical response times for units of a fire department. For example, ESRI argues that response times can be analyzed by GIS technology, since the data is included and tied to the different geospatial layers of a map.[29] In other literature, ESRI leverages response times standards through the resource allocation of fire apparatus and fire stations. With a high degree of accuracy, GIS technology can be leveraged to determine those site locations for fire stations, once the agencies response time metrics have been established.[30] Scholars and experts also argue that GIS improves the effectiveness of fire fighters beyond response times. As Dapeng Li et al. surmise in wildfire evacuation planning, a GIS framework enriches modeling, "by incorporating traffic simulation into trigger modeling."[31] Trigger modeling, in terms of wildfire risk perspective, could be thought of as a warning mechanism used for determining the proper time needed for the evacuation of people based on the current fire risk of an area.[32] This practice allows fire incident commanders to enhance their knowledge of when to evacuate an area based on the triggers within the trigger model.[33] In addition, according to Ronald T. Eguchi et al., GIS also contributes in other capacities of the response and recovery phase. After the initial disaster, GIS technology can be used to assist damage detection evaluation by prioritizing the relief efforts of an area and directing critical resources to the most severely damaged locations first, thus reducing the response times of first responders and ultimately saving the lives of victims.[34] Additionally, in ESRI's view, GIS also has the capability of revealing connections between multiple layers of data to uncover unseen and/or unrecognized

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[29] ESRI, *GIS for the Fire Service*.

[30] ESRI, *GIS for Fire Station Locations and Response Protocol*, 22.

[31] Dapeng Li, Thomas J. Cova, and Philip E. Dennison, "Setting Wildfire Evacuation Triggers by Coupling Fire and Traffic Simulation Models: A Spatiotemporal GIS Approach," *Fire Technology* 55, no. 2 (March 2019): 637, http://dx.doi.org.libproxy.nps.edu/10.1007/s10694-018-0771-6.

[32] Li, Cova, and Dennison, 622.

[33] Li, Cova, and Dennison, 637.

[34] Ronald T. Eguchi et al., "Utilizing New Technologies in Managing Hazards and Disasters," in *Geospatial Techniques in Urban Hazard and Disaster Analysis*, ed. Pamela S. Showalter and Yongmei Lu (Dordrecht: Springer Netherlands, 2010), 303–4, https://doi.org/10.1007/978-90-481-2238-7_15.

patterns.[35] Elvia Martínez Viveros and Fernando López Caloca also reiterate the point by stating that spatial trends and relationships can be visualized by merging different types of geospatial data together.[36] Those trends and relationships can then be visualized to assist in decision support. According to John Radke et al., GIS is a complex visualization system that provides viewers with the capability to make sense of vast amounts of data and the ability to create suitable mitigation strategies to remedy an issue discovered.[37] Harnessing the power of GIS technology along with fire department response time metrics builds an accurate picture of the day-to-day emergency response landscape of the fire department.

[35] ESRI, *GIS for the Fire Service*.

[36] Elvia Martínez Viveros and Fernando López Caloca, "A Cybercartographic Tool for Supporting Disaster Prevention Planning Processes and Emergency Management in Mexico City," in *Geospatial Techniques in Urban Hazard and Disaster Analysis*, ed. Pamela S. Showalter and Yongmei Lu (Dordrecht: Springer Netherlands, 2010), 270, https://doi.org/10.1007/978-90-481-2238-7_13.

[37] John Radke et al., *Challenges for GIS in Emergency Preparedness and Response* (Redlands, CA: Environmental Systems Research Institute, Inc., 2000), 17.

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II. GEOSPATIAL INTELLIGENCE IN RESOURCE ALLOCATION

A. OVERVIEW OF GEOSPATIAL INTELLIGENCE

Geospatial intelligence is the data that can be retrieved and analyzed from a using GIS. In my experience, generally one of the first questions asked in the fire service is, "what is GIS?." According to Professor Fernando Gibes Santaella of the University of Puerto Rico, GIS is a geographic information system that "integrates hardware, software, and data for capturing, managing, analyzing, and displaying all forms of geographically referenced information. Geographic information systems allow the user to view, understand, question, interpret, and visualize data in many ways that reveal relationships, patterns, and trends in the form of maps, globes, reports, and charts."[38] According to the United States Naval Academy, GIS is also a computer-based system that captures, stores, analyzes, and displays information (data) that is geographically (location) based.[39] Perhaps the best definition of GIS comes from the ESRI. As ESRI states, "A geographic information system (GIS) is a framework for gathering, managing, and analyzing data. Rooted in the science of geography, GIS integrates many types of data. It analyzes spatial location and organizes layers of information into visualizations using maps and 3D scenes."[40] Based on these definitions, GIS has the ability resolve spatial issues through an in-depth analysis of data in a manner that can be swiftly understood and clearly communicated to others.

To create, manage, and visualize data in the GIS environment, analysts take what is termed a "layer-centric approach." This approach visualizes different types of information by layering various types of data on top of one another like acetate sheets.[41] The data can consist

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[38] Fernando Santaella, "Geological Applications of Remote Sensing" (chapter summary for GEOL 4048, University of Puerto Rico at Mayaguez, n.d., accessed February 14, 2021, http://gers.uprm.edu/geol4048/pdfs/11_rs_gis.pdf.

[39] United States Geological Survey, "Define GIS," United States Naval Academy, May 19, 2020, https://www.usna.edu/Users/oceano/pguth/md_help/html/define_GIS.html.

[40] "What Is GIS? Overview," ESRI, accessed April 16, 2021, https://www.esri.com/en-us/what-is-gis/overview.

[41] ESRI, *GIS for the Fire Service*, 2.

of any information located on earth, such as streets and highways, topography, aerial imagery, fire response districts, and even fire station locations.[42] These layers of data come together to form an analytical framework that provides a complete and accurate representation of the data. While the "layer-centric approach" helps to visualize the data, spatial analysis is the process that defines at what the user is looking. According to the United States Geological Survey, spatial analysis is "the process of examining the locations, attributes, and relationships of features in spatial data through overlay and other analytical techniques, in order to address a question or gain useful knowledge. Spatial analysis extracts or creates new information from special data."[43] While the data is computed by computers, the parameters and interpretation of the data is conducted by GIS analysts. Similarly, Dartmouth University Library defines spatial analysis as "a type of geographical analysis which seeks to explain patterns of human behavior and its spatial expression in terms of mathematics and geometry, that is, locational analysis."[44]

Spatial analysis has derived the ability to integrate multiple forms of data, such as population densities, zoning types, demographics, and a host of others to solve real-world problems.[45] This data can then be visually represented and used for quantitative and qualitative analysis for decision support by stakeholders.[46] The true benefit of spatial analysis comes from the various ways in which analysis can be conducted and visualized. Incorporating those benefits, and that of GIS as a whole, into the fire service can occur at the tactical, strategic, and policy levels.[47] At the tactical level, GIS assists in the day-to-day

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[42] ESRI, 2.

[43] "Data Management, Analyze," United States Geological Survey, 2015, https://www.usgs.gov/products/data-and-tools/data-management/analyze?qt-science_support_page_related_con=0#qt-science_support_page_related_con.

[44] Lucinda M. Hall, "Geographic Information Systems/Science: Spatial Analysis & Modelling," Dartmouth Library Research Guides, June 12, 2021, https://researchguides.dartmouth.edu/gis/spatialanalysis.

[45] "GIS (Geographic Information System)," National Geographic Society, June 21, 2017, http://www.nationalgeographic.org/encyclopedia/geographic-information-system-gis/.

[46] Usman Ali et al., "A Data-Driven Approach for Multi-Scale GIS-Based Building Energy Modeling for Analysis, Planning and Support Decision Making," *Applied Energy* 279 (May 22, 2020): 2, https://doi.org/10.1016/j.apenergy.2020.115834.

[47] ESRI, *GIS for the Fire Service*, 1.

emergency response operations of frontline personnel in the fire service by providing large wall maps and station responsibility area map books.[48] In addition, GIS provides first responders with access to actionable intelligence that improves their ability to mitigate incidents and keep members safe.[49] At the strategic level, GIS can become a centralized repository for a variety of spatial data that provides the information and data necessary for fire department command staff personnel to manage their respective departments effectively based on empirical facts and not gut feelings.[50] At the policy level, GIS can incorporate the demographic data necessary to ensure that strategic and tactical decisions are based on quantitative evidence and are provided equitably to the public that they serve.

B. APPARATUS ALLOCATION

In the fire service, there are many varieties of emergency response apparatus; however, the three (3) primary types that will be the focus of this research are fire engines, fire trucks, and ambulance units. The first is what is termed as a fire engine or an "engine company," which carries an assortment of fire hoses and holds 500 to 1,000 gallons of water inside of them.[51] They are smaller in size and are located in nearly every firehouse in the country. The second is a fire truck (or "truck company" as they are often called) that does not carry any fire hoses or water, but instead is equipped with an assortment of ladders, hand tools, and rescue equipment like extrication tools (also known as the "jaws of life").[52] The personnel assigned to these apparatus types have different job functions on the incident scene. These separate, but equally important functions are conducted in concert with each other to produce

[48] ESRI, 2.

[49] Firefighter Nation Content Directors, "Using GIS to Visualize Risks and Hazards," Firefighter Nation, November 1, 2011, https://www.firefighternation.com/firerescue/using-gis-to-visualize-risks-and-hazards/.

[50] Labonno Islam and Kathy Matheson, "Exploring GIS and Tech at the Philadelphia Fire Department," City of Philadelphia, November 9, 2020, https://www.phila.gov/2020-11-09-exploring-gis-and-tech-at-the-philadelphia-fire-department/.

[51] "Know the Difference between Fire Trucks and Fire Engines?," City of Portland Oregon, accessed December 25, 2020, https://www.portlandoregon.gov/fire/article/275933.

[52] City of Portland, Oregon.

what is known as a "fire attack."[53] The third apparatus type that will be part of the focus of this research will be the ambulance units of a jurisdiction. For the unaware citizen, emergency medical services (EMS) are the medical services provided by paramedics and emergency medical technicians (EMTs) who generally staff an ambulance.[54] While firefighters on fire trucks and engines now provide some level of EMS care, the advanced level of treatment and transport required for higher acuity types of responses (cardiac arrests, seizures, strokes, etc.) are provided by the personnel that staff an ambulance.[55]

In general, placement for each of these unit types is dependent on the geographic locations of the fire stations within the municipality. Fire stations are the anchor points from which emergency responses are made; therefore, they limit the number of possible locations from which a unit can respond.[56] Since fire station locations are finite and stationary in nature, one important variable in emergency response becomes the quantities of each type of unit. According to a 2019 *Firehouse Magazine* profile of fire departments across the country, in nearly every instance, fire departments have more engine and truck companies than ambulances in their fire department fleet.[57] Because of this fact, engines are relatively simple to place, as they are located in essentially every firehouse in the country. Consequently, their placement is not quite as large of a concern as the placement of truck companies and ambulances within a jurisdiction.

In Dallas, truck companies play more of a specialized role in the fire department, and as such, make fewer emergency responses and are commonly the least active of all fire apparatus.[58] Their primary responsibilities are focused on the logistical support for victim

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53 James Angle et al., *Firefighting Strategies and Tactics*, 2nd ed. (Clifton Park, NY: Thomson Delmar Learning, 2008), 166–206.

54 Harry R. Carter, Erwin Rausch, and Arthur Kiamie, *Management in the Fire Service*, 3rd ed. (Quincy, MA: National Fire Protection Association, 1999), 445–50.

55 Carter, Rausch, and Kiamie, 445–46.

56 ESRI, *GIS for Fire Station Locations and Response Protocol*, 4.

57 "2019 National Run Survey," *Firehouse Magazine*, June 2020, https://cdn.baseplatform.io/files/base/cygnus/fhc/document/2020/06/NRS_profiles__part_1.5ed50dcd1c277.pdf.

58 Dominique Artis, "Dallas Fire-Rescue Fiscal Year 2020 Fleet Statistics," Dallas Fire-Rescue Department, October 9, 2020.

rescue and structure fire responses.[59] While personnel on truck companies do provide various levels of medical care, EMS response can be considered a tertiary responsibility to be conducted when an ambulance unit and engine company is not available. Because of the limited number of truck companies in most jurisdictions, the processes and procedures used to identify ambulance placement locations can also be used for truck company location placement.

Ambulance units play a vital role in the health and wellbeing of the public. With their sole focus being dedicated to EMS response, their exigency continues to grow every year. According to the NFPA, since 1980, the number of EMS responses (medical aid) outpaces all other types of emergency responses for fire departments (Table 1).[60] This can be observed in Table 1 as the number of "medical aid" responses for 1980 was 5,045,000 and it soared to 23,551,500 "medical aid" responses by 2018. This places an enormous amount of strain on all fire resources, especially the ambulance units. With this in mind, the placement of apparatus, especially ambulances, is critical to a community and becomes an ever-greater concern.

[59] John Mittendorf, *Truck Company Operations* (Tulsa, OK: PennWell, 2006), 3–12, http://site.ebrary.com/id/10344547.

[60] "Fire Department Calls," National Fire Protection Association, June 2021, https://www.nfpa.org/News-and-Research/Data-research-and-tools/Emergency-Responders/Fire-department-calls.

Table 1. Fire Department Emergency Response Counts since 1980.[61]

Year	Total	Fires	Medical Aid	False Alarms	Mutual Aid	Hazardous Materials	Other Hazardous Conditions	Other
1980	10,819,000	2,988,000	5,045,000	896,500	274,000	No Data	No Data	1,615,500*
1981	10,594,500	2,893,500	5,019,000	788,000	349,500	No Data	No Data	1,544,500*
1982	10,548,000	2,538,000	5,258,000	853,500	346,500	No Data	No Data	1,552,000*
1983	10,933,000	2,326,500	5,660,000	979,500	353,000	No Data	No Data	1,614,000*
1984	11,070,000	2,343,000	5,735,000	972,000	413,500	No Data	No Data	1,606,000*
1985	11,888,000	2,371,000	6,467,000	936,500	389,500	No Data	No Data	1,724,000*
1986	11,890,000	2,271,500	6,437,500	992,500	441,000	171,500	318,000	1,258,000
1987	12,237,500	2,330,000	6,405,000	1,238,500	428,000	193,000	315,000	1,328,000
1988	13,308,000	2,436,500	7,169,500	1,404,500	490,500	204,000	333,000	1,270,000
1989	13,409,500	2,115,000	7,337,000	1,467,000	500,000	207,000	381,500	1,402,000
1990	13,707,500	2,019,000	7,650,000	1,476,000	486,500	210,000	423,000	1,443,000
1991	14,556,500	2,041,500	8,176,000	1,578,500	494,000	221,000	428,500	1,617,000
1992	14,684,500	1,964,500	8,263,000	1,598,000	514,000	220,500	400,000	1,724,500
1993	15,318,500	1,952,500	8,743,500	1,646,500	542,000	245,000	432,500	1,756,500
1994	16,127,000	2,054,500	9,189,000	1,666,000	586,500	250,000	432,500	1,948,500
1995	16,391,500	1,965,500	9,381,000	1,672,500	615,500	254,500	469,500	2,033,000
1996	17,503,000	1,975,000	9,841,500	1,816,500	688,000	285,000	536,500	2,360,500
1997	17,957,500	1,795,000	10,483,000	1,814,500	705,500	271,500	498,500	2,389,500
1998	18,753,000	1,755,500	10,936,000	1,956,000	707,500	301,000	559,000	2,538,000
1999	19,667,000	1,823,000	11,484,000	2,039,000	824,000	297,500	560,000	2,639,500
2000	20,520,000	1,708,000	12,251,000	2,126,500	864,000	319,000	543,500	2,708,000
2001	20,965,500	1,734,500	12,331,000	2,157,500	838,500	381,500	605,000	2,917,500
2002	21,303,500	1,687,500	12,903,000	2,116,000	888,500	361,000	603,500	2,744,000
2003	22,406,000	1,584,500	13,631,500	2,189,500	987,000	349,500	660,500	3,003,500
2004	22,616,500	1,550,500	14,100,000	2,106,000	984,000	354,000	671,000	2,851,000
2005	23,251,500	1,602,000	14,375,000	2,134,000	1,091,000	375,000	667,000	3,009,000
2006	24,470,000	1,642,500	15,062,500	2,119,500	1,159,500	388,500	659,000	3,438,500
2007	25,334,500	1,557,500	15,784,000	2,208,500	1,109,500	395,500	686,500	3,593,000
2008	25,252,500	1,451,500	15,767,500	2,241,500	1,214,500	394,500	697,500	3,485,500
2009	26,534,500	1,348,500	17,104,000	2,177,000	1,296,000	397,000	625,500	3,586,500
2010	28,205,000	1,331,500	18,522,000	2,187,000	1,189,500	402,000	660,000	3,913,000
2011	30,098,000	1,389,500	19,803,000	2,383,000	1,252,000	379,000	720,000	4,171,500
2012	31,854,000	1,375,000	21,705,500	2,238,000	1,326,500	360,000	694,000	4,155,000
2013	31,644,500	1,240,000	21,372,000	2,343,000	1,298,000	366,500	678,000	4,347,000
2014	31,644,500	1,298,000	20,178,000	2,488,000	1,446,500	405,000	615,000	5,214,000
2015	33,635,500	1,345,500	21,500,000	2,566,500	1,492,500	442,000	643,000	5,646,000
2016	35,320,000	1,342,000	22,750,500	2,622,000	1,515,000	425,000	684,500	5,981,000
2017	34,683,500	1,319,500	22,341,000	2,547,000	1,353,000	423,500	693,000	6,006,000
2018	36,746,500	1,318,500	23,551,500	2,889,000	1,512,500	426,000	706,500	6,342,500

Despite the differing roles that these units play in emergency response, the placement of fire engines, trucks, and ambulances throughout a community is viewed as a strategic logistical priority.[62] GIS can assist the resource allocation process for effective and efficient use of limited resources by utilizing the following three (3) types of GIS analysis:

- coverage analysis
- hot spot analysis
- travel time analysis

[61] Source: National Fire Protection Association.

[62] ESRI, *GIS for the Fire Service*, 8.

Unit coverage analysis, hot spot analysis, and response time analysis all have varying functions that analyze different aspects of the emergency response cycle. While they do analyze different aspects of the emergency response cycle, when combined, they provide a universal view of each type of apparatus or variable being analyzed.

1. Coverage Analysis

Coverage analysis displays how much of an area that an apparatus can be projected to cover over a given period of time based on a municipality's street network. This type of visualization is extremely useful in determining gaps in emergency response coverage (Figure 1). Those gaps in coverage stem from areas of a jurisdiction that do not have a timely response for fire and/or medical units. Typically, gaps are determined by comparing the travel times for units against national response standards from the NFPA.[63] In a perfect world, there would be no gaps in coverage within a community. However, because of budget constraints and resource shortages, there will inevitably be coverage shortages in some areas of nearly every city. Command staff personnel should seek to reduce coverage gaps by relocating the necessary resources in an equitable fashion.[64]

[63] National Fire Protection Agency, *NFPA 1710.*

[64] Robert Policht, "Resource Allocation," *Fire Rescue Magazine*, February 19, 2018, https://firerescuemagazine.firefighternation.com/2018/02/19/resource-allocation/.

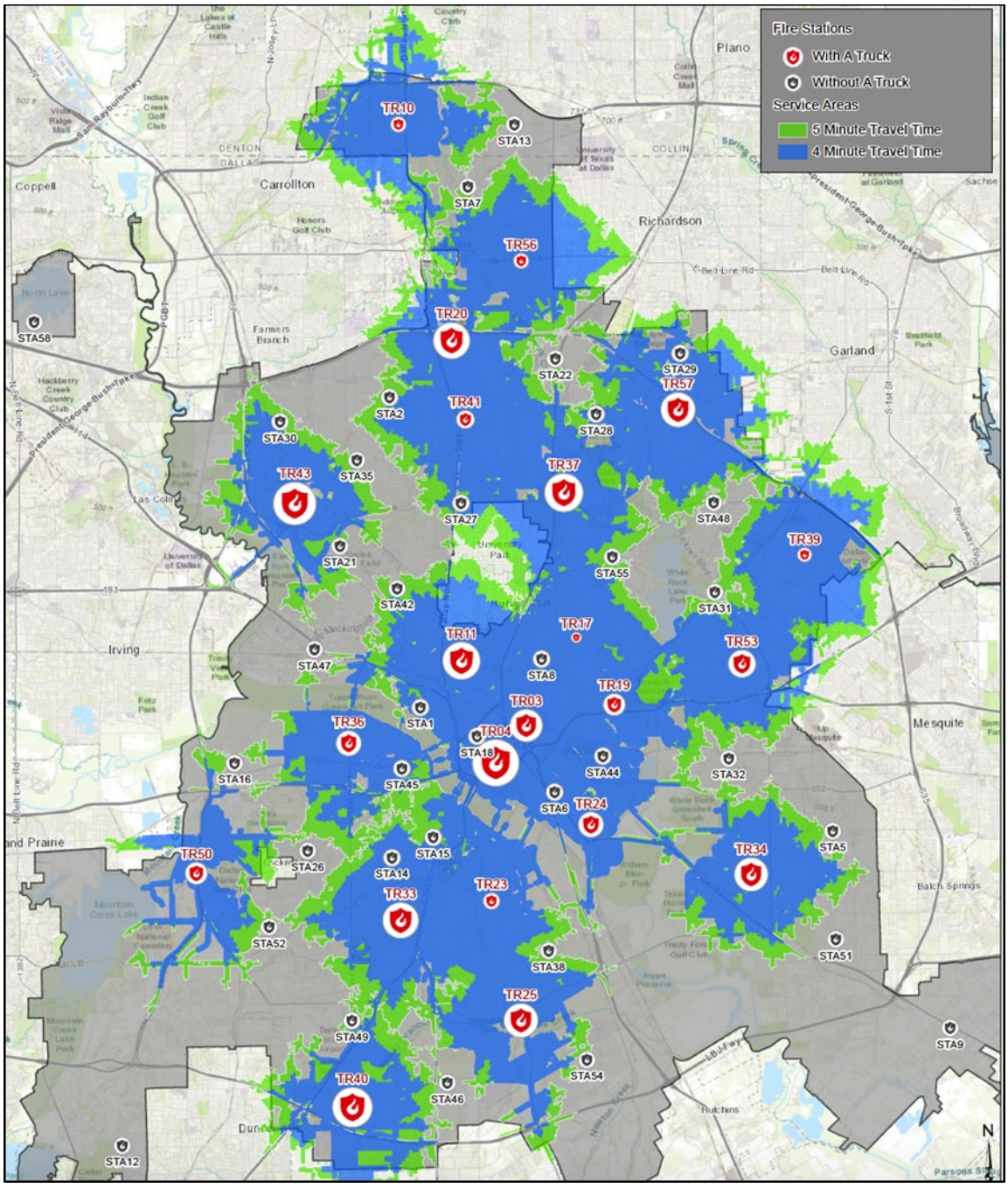

Figure 1. Coverage Analysis Map.[65]

As an added bonus, coverage analysis also has the inverse ability to determine areas of a jurisdiction that have "over-coverage" or too many resources assigned. Over coverage is

[65] Source: Information created using ArcGIS with Dallas Fire Department data.

considered an extensive overlapping of emergency response coverage by two (2) or more units. Over coverage can also be observed when analyzing the unit response times for an area. When response times are excessively low for the units that respond into a particular area, the most likely cause may be that the non-first due units into the area are located too close to the first due unit. In such cases, the most prudent course of action would be to relocate one (1) or more units to another area of the city. This would result in an increase of emergency response coverage, possibly citywide. Over coverage is an inefficient use of valuable resources and comes at the expense of other, underserved areas of a community.[66]

2. Hot Spot Analysis

Although coverage gap analysis visualizes the area that an apparatus can cover in a given period of time, hot spot analysis provides a visual representation of areas where the actual service demand is highest. GIS technology can map emergency response locations for a given time period and those points are then clustered together to form a centroid. That centroid produces geographic data that identifies the areas of high activity and quantifies those densities with a color gradient. Areas with more activity (higher densities of responses) are represented with deeper (darker) colors, while areas of low activity (less density) will be light in color. Areas with no activity will remain white or have no color gradient at all.

The points used to create hot spot analysis for this research were constructed from four (4) primary classifications or categorizations of the emergency response cycle. They consist of the "incident type" that provides a visualization of where a certain type of incident is occurring most frequently (i.e., structure fires, stabbings, heart attacks, motor vehicle accidents, etc.). The "apparatus type" provides a visualization of the responses for each type of apparatus (i.e., engines, trucks, ambulances, etc.). A "travel time metric" provides a visualization of where NFPA or other internal travel time metrics are (or are not) being achieved. Finally, a "boundary or area" classification was used to provide a visualization that

66 TriData, *Portland Fire and Rescue Service Delivery System Study* (Arlington, VA: TriData, A Division of System Planning Corporation, 2006), 73–75, https://www.portlandoregon.gov/fire/article/388478.

incorporates other classifications within a natural or manmade boundary or area (i.e., county lines, council districts, fire station responsibility areas, etc.).

These types of classifications are extremely beneficial for the fire service and can be merged so that multiple metrics can be analyzed in one visualization (Figure 2). For example, it is enormously valuable to visualize the locations of a city where ambulance responses are surpassing the 480-second NFPA standard for "arrival of an advanced life support unit at an emergency medical incident."[67] Once those areas are identified, decision makers can begin to strategize on the most appropriate method to resolve the issue.

[67] National Fire Protection Association, *NFPA 1710*, 12.

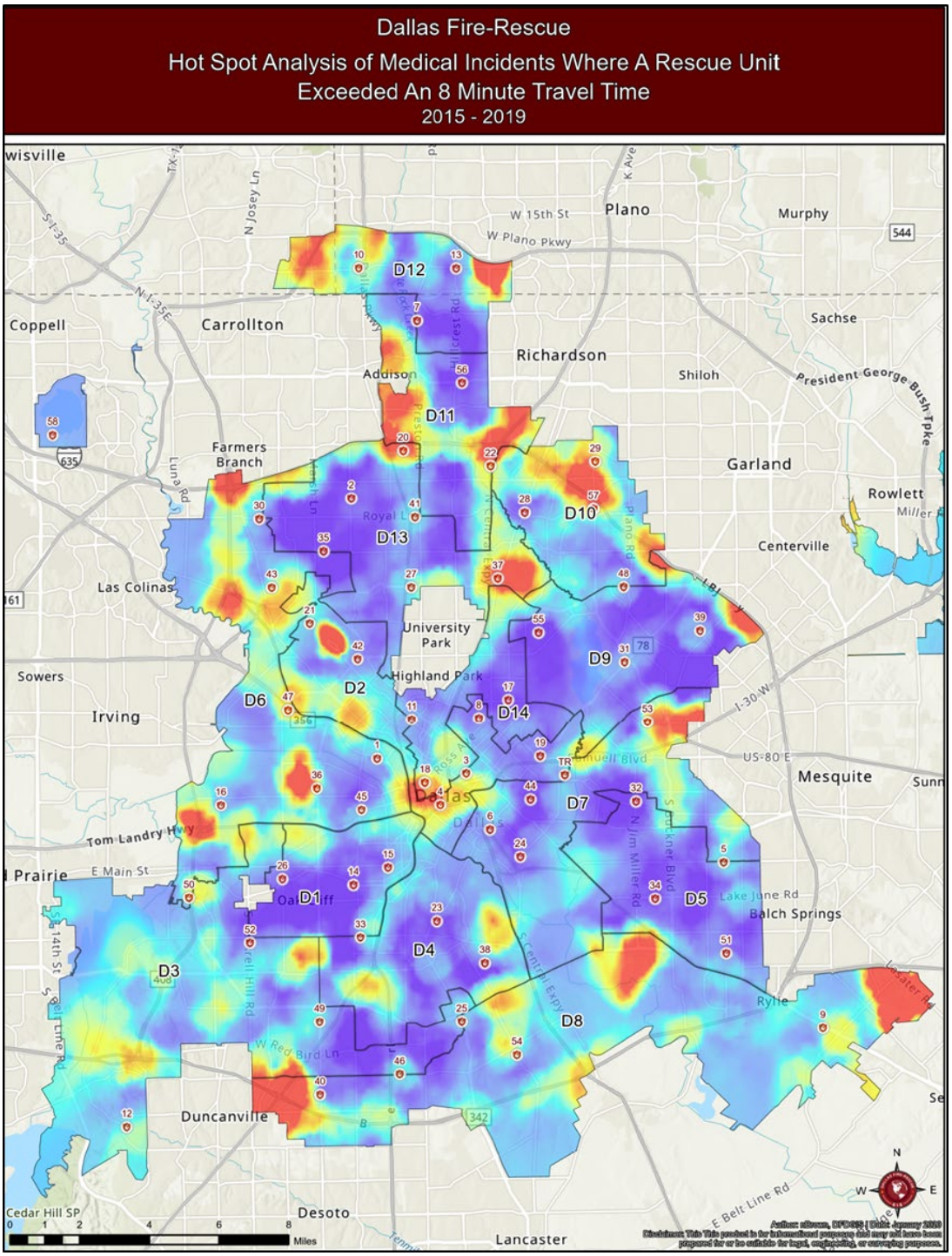

Figure 2. Hot Spot Analysis Map.[68]

68 Source: Information created using ArcGIS with Dallas Fire Department data.

It should be noted that hot spot analysis and heat maps are two very different processes that produce different visualizations. Heat maps measure the proximity/concentration of points on a map and can be skewed based on the scale or zoom factor of the map.[69] However, hot spot analysis is generated using a statistical analysis that visualizes areas statistically significant, which becomes less subjective than a common heat map.[70] The statistical confidence incorporated into hot spot analysis provides the quantitative confirmation needed for the research and decision-making process.

Raw data maps (points on a map) turn into simple population maps without greater insight and analysis. Leveraging hot spot analysis provides command staff personnel the ability to detect and quantify spatial trends and patterns over time. When used in conjunction with coverage analysis and travel time analysis, a clear picture of emergency response deficiencies becomes readily apparent.

3. Travel Time Analysis

Analysis of a unit's travel time consists of mostly tabular data extracted directly from a computer aided dispatch (CAD) server. However, GIS has the ability to leverage the tabular data into a dashboard for ease of viewing (Figure 3).

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[69] Environmental Systems Research Institute, "Heat Map vs. Hot Spot Map," ESRI ArcGIS, accessed May 5, 2021, https://www.arcgis.com/apps/MapJournal/index.html?appid=b89b59ef0ad14534aae4e5fc85fdb2eb.

[70] Caitlin Dempsey, "What Is the Difference between a Heat Map and a Hot Spot Map?," *GIS Lounge* (blog), August 10, 2014, https://www.gislounge.com/difference-heat-map-hot-spot-map/.

Figure 3. Travel Time Analysis Dashboard.[71]

While hot spot analysis displays "where" emergencies are occurring and coverage analysis projects the amount of coverage based on a specified time, travel time analysis provides detailed information regarding the actual historical travel times for a unit. As the timely response of fire and EMS apparatus are paramount to how a fire department serves its citizens and completes its core mission of protecting life and property, fire departments are normally measured by a set of NFPA standards that encompass time requirements for responding fire personnel. These time requirements set the standard against which all fire departments are measured.

The NFPA is a non-profit organization that creates fire service standards and is "devoted to eliminating death, injury, property and economic loss due to fire, electrical and related hazards."[72] Firefighters from across the nation sit on different working groups with the express purpose of developing, evaluating, and changing current and future fire service standards. These standards, while not binding, are considered as "best practices" for the fire service and are generally referred to by state fire commissions and accreditation entities.

[71] Source: Information created using ArcGIS with Dallas Fire Department data.

[72] "About NFPA," National Fire Protection Association, accessed July 12, 2020, https://www.nfpa.org/About-NFPA.

The particular NFPA standard that governs response times is NFPA 1710. This standard encompasses the time requirements that affect the delivery of fire and emergency medical services to a municipality. NFPA 1710 can be somewhat overwhelming to those individuals not accustomed to reading from the standard. As such, the most pertinent metrics regarding response times are:

- Travel time of 240 seconds or less for the arrival of the first arriving engine company at a fire suppression incident.
- Travel time of 480 seconds or less for the deployment of a full first alarm assignment at a fire suppression incident.
- Travel time of 240 seconds or less for the arrival of a unit with first responder or higher-level capability at an emergency medical incident.
- Travel time of 480 seconds or less for the arrival of an advanced life support unit at an emergency medical incident (where the service is provided by the fire department).[73]

NFPA standards do not preclude municipalities from developing additional metrics more suitable for their populace and municipality. For example, a city with numerous resources may choose to develop reduced travel time metrics, while a municipality with relatively few resources may decide that the NFPA standards cannot be reasonably attained for their jurisdictions. In those instances, the municipalities may choose to extend the metrics beyond the NFPA recommendations because they are not a realistic metric for their fire departments.[74]

The term "response time," when used concerning the fire service, is a bit of a misnomer. The average person would assume that the term refers to how long it takes an emergency unit to arrive on scene. While technically true, the term actually encompasses multiple segments from the receipt of the call until the unit arrives on location. Those segments include alarm receipt time, turnout time, and travel time. Alarm receipt time is the time it takes for the call taker to process and dispatch the emergency to a unit. Turnout time is the time it takes personnel to get enroute to the emergency. It begins at the receipt of the alarm and concludes when the apparatus gets in the enroute status on the mobile data

73 National Fire Protection Association, *NFPA 1710*.

74 TriData, *Portland Fire and Rescue Service Delivery System Study*, 62; Sheridan, "3 Fire Service Myths."

computer (MDC). Travel time is the time it takes for the unit to travel to the emergency scene. This time begins when the unit goes into an en route status and concludes when the unit updates its status to "at scene" on the MDC. Each of these segments are important when trying to reduce overall response time for a municipality, however, only the travel time segment is pertinent for GIS analysis. Both the alarm receipt time and turn out time are variables that do not have a bearing in the location of fire units, as they are too variable and inconsistent across agencies.

GIS technology can also be leveraged for travel time analysis by extracting the unit travel times for the responses that occur in the areas of the city under evaluation (Figure 4). In the following example, travel times were measured from one Dallas Fire Department firehouse and three mutual-aid fire stations from the neighboring City of Grand Prairie to the entrance of a subdivision in West Dallas.

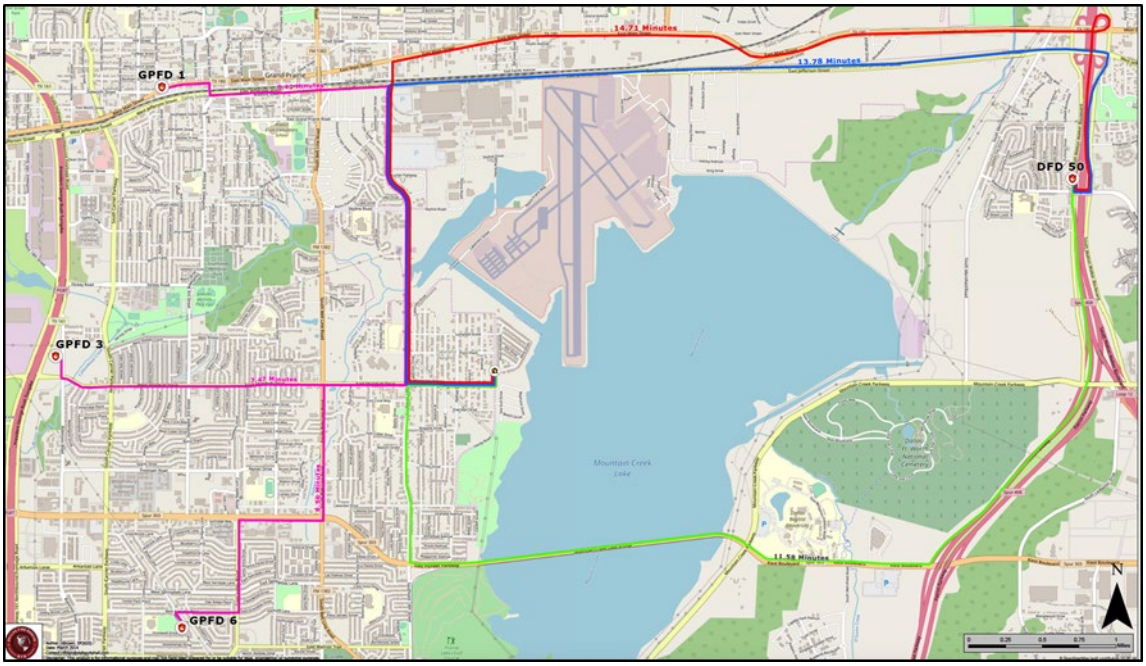

Figure 4. Travel Time Analysis Map.[75]

[75] Source: Information created using ArcGIS with Dallas Fire Department data.

GIS then has the ability to download the pertinent response data from a CAD server and upload it into a GIS application. That data is then post-processed and geo-coded into a digital map. Once plotted, a boundary can be placed around the area of study so that only the responses that occurred in that area are extracted. Once extracted, travel times can be calculated for each response and turned into an appropriate graph or chart that defines the analysis (Table 2). The incorporation of travel time analysis can be a time-consuming evaluation; however, it provides quantifiable evidence based on historic trends and responses.

Table 2. Travel Time Table.[76]

Travel Times by Route to West Dallas	
Designated Route	**Travel Time**
DFD Firehouse #50 Northern Route	13.78 minutes
DFD Firehouse #50 Southern Route	11.58 minutes
DFD Firehouse #50 Alternate Route	14.71 minutes
GPFD Station #3	7.47 minutes
GPFD Station #1	8.42 minutes
GPFD Station #6	8.56 minutes

C. FIRE STATION PLACEMENT

The terms fire station, station, fire hall, and firehouse are synonymous with each other and are the preferred nomenclature based on the traditions of each respective fire department. These facilities house anywhere from four to 16 personnel per work shift. In many cities, new firehouses are generically placed on a city owned lot at the outskirts of the jurisdiction, in an effort to save costs or reduce extended travel times to the peripheries of that city.[77] While reducing travel times are a strategic concern for fire command staff personnel and political decision makers, they should not come at the expense of a proper analysis that incorporates the current service demands of the public.

[76] Source: Information created using Microsoft Excel with Dallas Fire Department data derived from ArcGIS.

[77] American Planning Association, *Fire House Location Planning*.

Fire station placement is an extremely similar process to placing units within a jurisdiction. Decision makers must first determine what type of fire apparatus will be answering from the new fire station (engine, truck, and/or ambulance). Once that decision is made, GIS can be incorporated to determine the areas of the city where the service demands are high (hot spot analysis), the response coverages are low (coverage analysis), and the response times exceed the NFPA 1710 standard (response time analysis). Once those areas have been identified, additional factors should also be evaluated to ensure that the new fire station has the greatest response impact on the community. Those factors include land acquisition (city owned land sites vs. privately owned land sites),[78] population demographic analysis,[79] new construction development, and access to highways and major arterial roadways.[80]

1. Land Acquisition

One of the fundamental steps in finding site locations for placement of new fire stations occurs in the land acquisition phase.[81] Some cities have departments dedicated to the acquiring and selling of city owned property, while other cities rely on realty firms or an internal property list. Whatever the process, GIS has the ability to extract city owned parcel data from internal data sets and privately owned parcel data from public facing websites. These data sets can be post processed by GIS analysts to include only sites of the appropriate size, within the perspective coverage area, and within a stipulated price range.

All of the parcel tracts can then be visualized on a map and cross-referenced with pertinent data like price per square foot in the pre-determined areas of need (Figure 5). GIS would then have the ability to conduct the three (3) step analytical process of coverage analysis, hot spot analysis, and travel time analysis for each parcel identified. The results

78 American Planning Association.

79 ESRI, *GIS for Fire Station Locations and Response Protocol*, 9.

80 ESRI, 22.

81 Kerri Hatt, "Q&A: The No. 1 Issue in Building a Fire Station? Location," FireRescue1, November 29, 2017, https://www.firerescue1.com/station-design/articles/qa-the-no-1-issue-in-building-a-fire-station-location-ZotTqjRIGlsdOs1u/.

of the analysis can then be compared so that only the most statistically significant areas can be evaluated further.

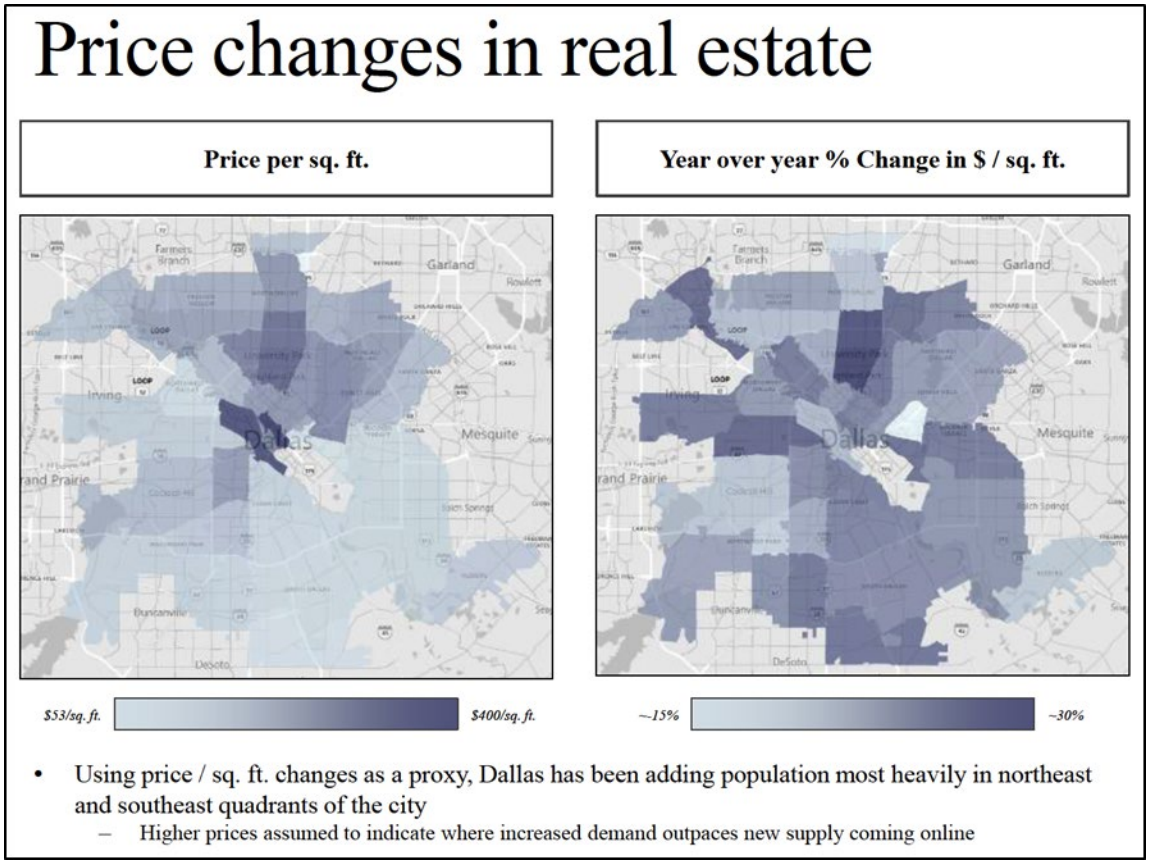

Figure 5. Real Estate Price Changes in Dallas, Texas (2012–2017).[82]

2. Demographic Data Analysis

A strategic priority for fire command staff personnel and political decision makers should be the inclusion of demographic data as part of the decision-making process. While not necessarily the most important variable in the site location process, demographic information should be incorporated to ensure that decisions are made equitably across all social fabrics of a community. In addition, this information is used to ensure that one area of a community is not being disproportionately affected over another area.

[82] Adapted from Dallas Fire Department project data in collaboration with Harvard Business School.

Demographic data can be extracted from multiple sources. Some cities have internal departments, like the City of Dallas' Office of Equity, which can provide the requisite data to be included in the analysis.[83]

Many public facing websites can also be accessed to extract demographic data. A few of those websites are:

- The United States Census Bureau[84]
- State demographic websites[85]
- County demographic websites[86]
- Private Research Firms like CDX Technologies[87]
- The University of Virginia's Demographics Research Group[88]

GIS has the tools to outline an area based on pre-defined boundaries, travel times, or response zones. Once those areas are delineated, the demographic data can then be isolated and extracted for decision analysis and support. In the following example, key demographic data was extracted using a five-minute travel time from Dallas Fire Station #24 (Figure 6). The same basic process and application can be leveraged on any parcel of land chosen as a possible location for the placement of a fire station.

83 "Equity Division," City of Dallas, accessed July 12, 2020, https://dallascityhall.com:443/departments/office-of-equity/Pages/default.aspx.

84 "Explore Census Data," United States Census Bureau, accessed July 12, 2020, https://data.census.gov/cedsci/.

85 "Descriptive Data Tables by Subject," Texas Demographic Center, accessed July 12, 2020, https://demographics.texas.gov/Data/Subject/.

86 "2020 Census Dallas County Counts," Dallas County, accessed July 12, 2020, https://www.dallascounty.org/government/comcrt/jenkins/census/.

87 "Free Demographic Data Reports by Zip Code," CDX Technologies, accessed July 12, 2020, https://www.cdxtech.com/tools/demographicdata/.

88 "Guide to Publicly Available Demographic Data, Overview," Demographics Research Group, accessed July 12, 2020, https://demographics.coopercenter.org/guide-to-publicly-available-demographic-data.

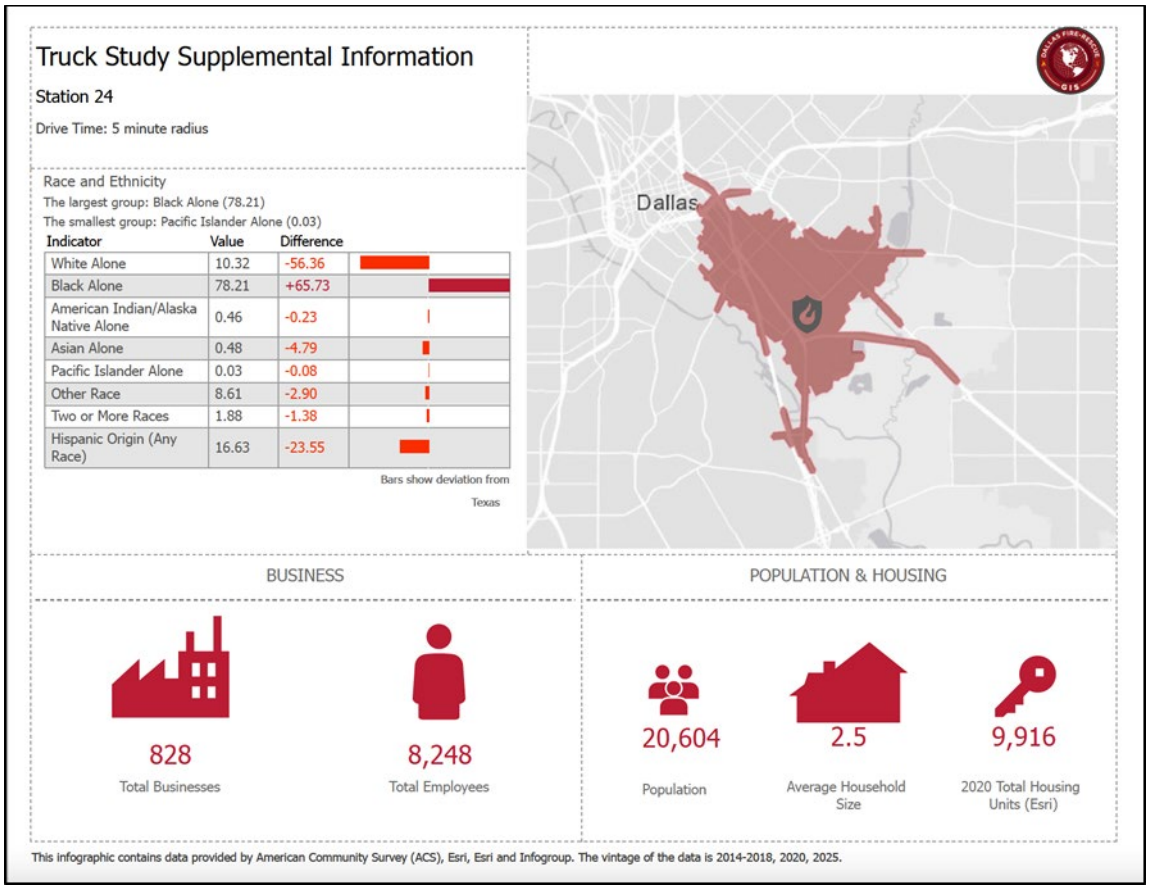

Figure 6. Demographic Data by Response Area.[89]

Incorporating demographic data has the ability to show where resources are being positioned in a community with respect to age, race, gender, income, and educational levels. These variables will assist decision makers in determining the most equitable placement of fire resources based on city policy initiatives.

3. New Construction Development

New construction development within a city is an extremely important variable in determining site locations for the planned construction of new fire stations. Zoning restrictions will determine if an area has high occupancy residential developments like apartments or if the area will be zoned for commercial business for bars and restaurants.

[89] Source: Information created using ArcGIS Community Analyst with Dallas Fire Department data.

Each of these zoning areas has different fire service needs when compared to other zoned construction areas. For example, commercial office buildings may have a high daytime occupancy that drops off severely after 5:00 pm. This may necessitate the need to have a fire station constructed with an additional bay, so that an ambulance unit can be stationed there during regular business hours and then relocated to another area of the city after business hours. As an additional example, there may be a new construction development for an industrial refinery within an area of the city. This type of construction development would necessitate the need for a nearby fire station to provide a quick response to an industrial fire or accident. In another scenario, an area may be designated as a park or nature preserve and may require wildland firefighting units to be in close proximity.[90]

To retrieve pertinent data regarding new construction developments within a city, GIS analysts can use various sources and even contact the local permitting office or department. Any major construction that will be of notable concern for a fire department will inevitably have to receive building permits to begin the construction process. If the number of possible site locations for a new fire station is relatively few, an additional way to retrieve new construction intel will be to simply drive around and observe the perspective areas. This would provide a street level view of the areas surrounding the perspective sites, while also providing intel on traffic patterns and roadway congestion.

Similar to the land acquisition phase, GIS can provide analysis and visuals of the new construction developments surrounding the site locations being considered (Figures 7 and 8). The data can then be cross-referenced with the pre-determined areas of need, so that a determination as to the station size and unit types that need to respond from the proposed station can be made.

[90] Howard E. Moore, *Protecting Residences from Wildfires*, General Technical Report PSW-50 (Berkeley: Pacific Southwest Forest and Range Experiment Station, 1981), 11–12.

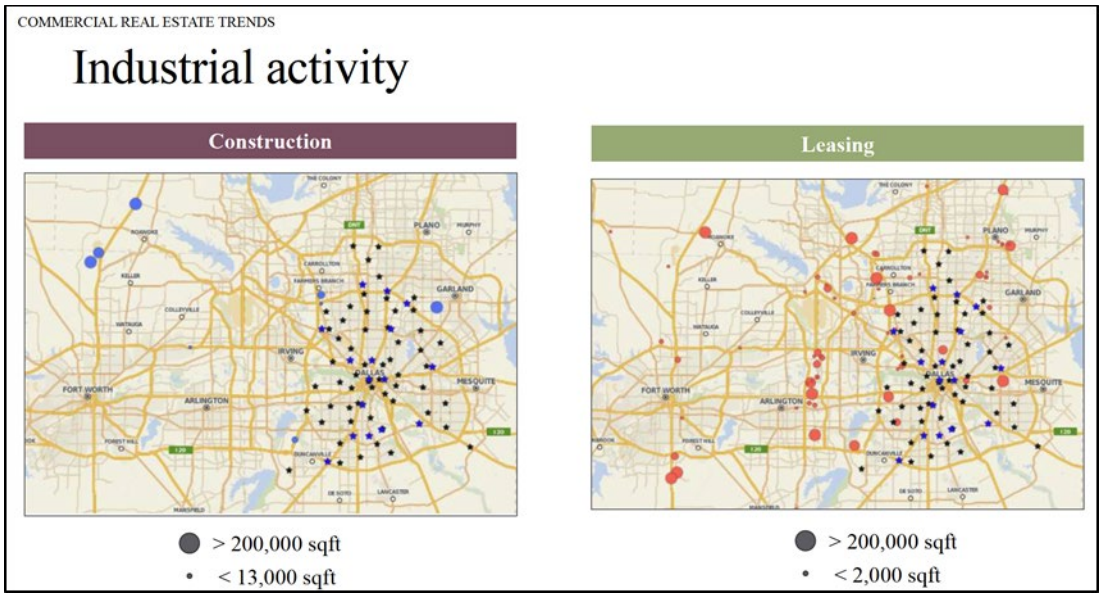

Figure 7. Industrial Construction in Dallas, Texas.[91]

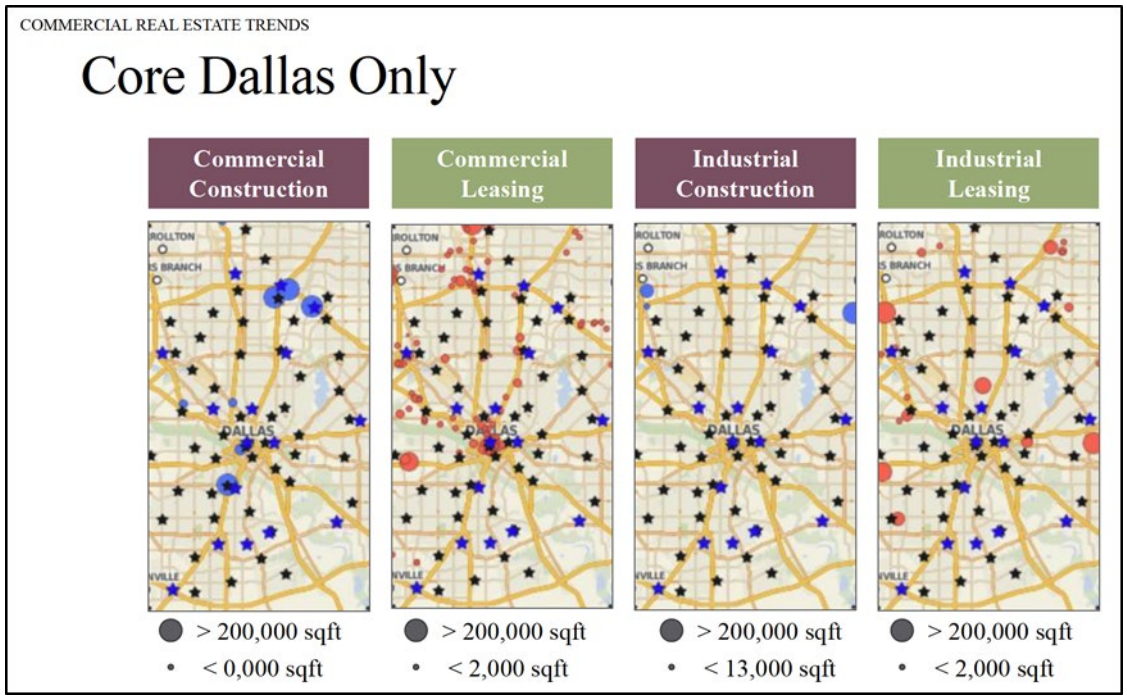

Figure 8. Commercial Real Estate Trends in Dallas, Texas.[92]

[91] Adapted from Dallas Fire Department project data in collaboration with Harvard Business School.

[92] Adapted from Dallas Fire Department project data in collaboration with Harvard Business School.

4. Access to Highways and Major Arterial Roadways

As something that affects both response coverage and travel time, access to highways and major arterial roadways are key when trying to increase response coverage and reduce travel time. According to the U.S. Department of Transportation's Federal Highway Administration, roads are generally classified into four (4) categories:

- Interstate Arterials—The interstate system is the highest classification of roadways in the United States. These arterial roads provide the highest level of mobility and the highest speeds over the longest uninterrupted distance. Interstates nationwide usually have posted speeds between 55 and 75 mi/h.[93]
- Other Arterials—Other arterials include freeways, multilane highways, and other important roadways that supplement the interstate system. They connect, as directly as practicable, the nation's principal urbanized areas, cities, and industrial centers. Land access is limited. Posted speed limits on arterials usually range between 50 and 70 mi/h.[94]
- Collector Roads—Collector roads are major and minor roads that connect local roads and streets with arterials. Collectors provide less mobility than arterials at lower speeds and for shorter distances. They balance mobility with land access. The posted speed limit on collectors is usually between 35 and 55 mi/h.[95]
- Local Roads—Local roads provide limited mobility and are the primary access to residential areas, businesses, farms, and other local areas. Local roads, with posted speed limits usually between 20 and 45 mi/h, are the majority of roads in the United States.[96]

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[93] Federal Highway Administration, *Road Function Classifications* (Washington, DC: U.S. Department of Transportation, 2000), https://safety.fhwa.dot.gov/speedmgt/data_facts/docs/rd_func_class_1_42.pdf.

[94] Federal Highway Administration.

[95] Federal Highway Administration.

[96] Federal Highway Administration.

GIS has the ability to analyze the distance of a proposed fire station location to the nearest interstate highway or other arterial. Although access to highways and arterials are important, they should not override analytical decisions based on coverage analysis, travel time analysis, response time analysis, land acquisition, demographic makeup, or new construction development. Roadway speeds and coverage are already included in the coverage analysis process.

When analyzing all possible fire station sites, if all other variables are equal, the research suggests choosing the site with the best access to an interstate or major arterial.[97] The ability to travel on larger roadways at faster speeds translates to increased coverage areas and reduced travel times, which reduces overall response times.

As previously stated, fire stations are the anchor points from which emergency responses are made. Their presence within a jurisdiction signifies a municipality's dedication to public safety as a priority to its citizens. To ensure public safety is delivered equally to all citizens, the site placement of future fire stations must be thoroughly examined to ensure that the units responding out of the station will meet the service demands and response time metrics of the locale.

[97] John Norquist, *Traditional Streets Are Safer*, CNU Report (Chicago: The Congress for the New Urbanism, 2009), 5, http://www.portoforcas.com/dev/wp-content/uploads/2017/10/236-Attachment-Evelyn-Fuchser-EmergencyResponseandStreetDesign.pdf.

III. GEOSPATIAL INTELLIGENCE IN BUREAU SUPPORT

A. PRE-FIRE INCIDENT PLANNING

Pre-incident fire planning is a fire department program within most fire prevention divisions or bureaus for collecting pertinent safety information for commercial buildings prior to a fire or other incident occurring at a particular address. Commercial structures include businesses, churches, apartment complexes, sports arenas, and even healthcare facilities. These plans are created and retained for structures that may pose a potential fire or rescue hazard for responding firefighters. The hazards can be anything from hazardous materials on location to unique floorplans that will hamper interior firefighting efforts or the escape of trapped firefighters. GIS can provide a unique planning capability by digitizing floor plans and creating site maps that list various tactical information needs, such as electrical shutoffs, gas shutoffs, key boxes, hydrant locations, entry/exit locations, stairwell designations, alarm control panels, invalid patient locations, roof construction, fire department standpipe connections, and fire department sprinkler connections.

Historically, this type of information would be kept on paper forms located in the first-due apparatus or the first-due responding battalion chief vehicle.[98] This system has become extremely problematic as the regular first-in units may be assigned to a different emergency and never get assigned to the actual emergency. In those instances, none of the on-scene units has access to the pertinent information needed for tactical decision making. Furthermore, GIS can be leveraged so that pre-incident planning information can be accessed digitally from a tablet, the MDCs located in fire units, or even on smart phones (Figure 9).[99] This has the advantage of providing the most recent up-to-date information to the incident commander's fingertips.

[98] Carter, Rausch, and Kiamie, *Management in the Fire Service*, 238.

[99] Carter, Rausch, and Kiamie, 238.

Figure 9. Pre-Incident Plan on a Tablet.[100]

Incorporating GIS into the pre-incident planning program of the fire department will also provide the department's command staff with the ability to track and monitor the progress of the overall program within the jurisdiction.[101] GIS has the capability of creating real-time dashboards that are updated simultaneously as pre-incident plans are completed (Figure 10).

[100] Source: Environmental Systems Research Institute, "Pre-Incident Plan Field Inventory," ArcGIS Solutions, accessed July 23, 2021, https://solutions.arcgis.com/local-government/help/pre-incident-plan-field-inventory/.

[101] Environmental Systems Research Institute, "Pre-Incident Plan Dashboard," ArcGIS Solutions, accessed July 23, 2021, https://solutions.arcgis.com/local-government/help/pre-incident-plan-dashboard/.

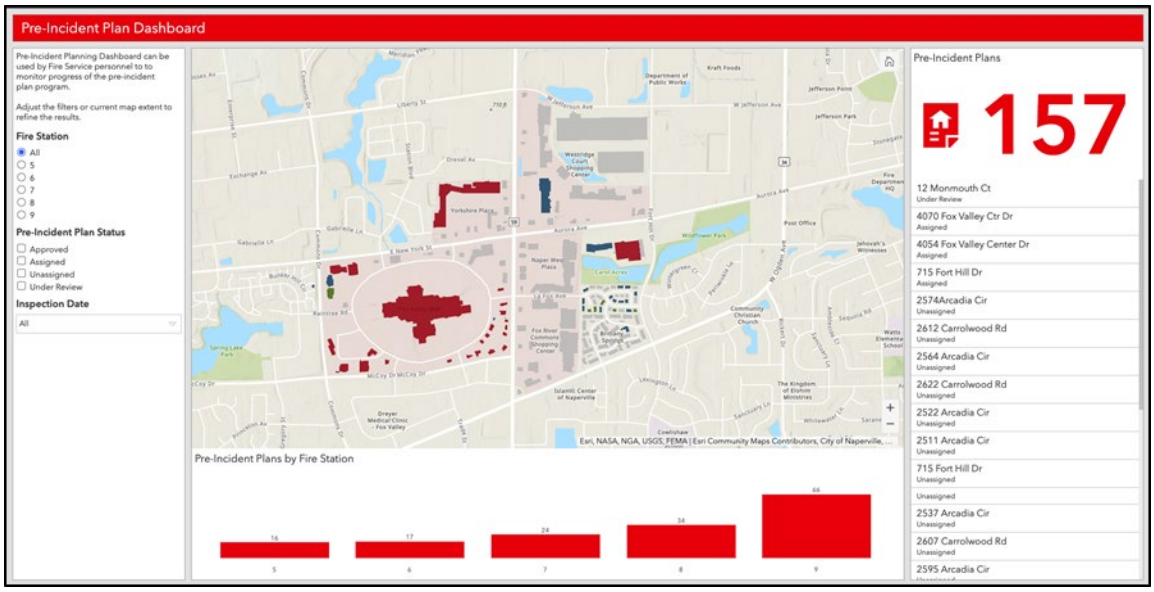

Figure 10. Pre-Incident Planning Digital Dashboard.[102]

Dashboards also allow the user to sort pre-incident plans by multiple variables, such as address, station responsibility area, pre-incident plan status (approved, assigned, unassigned, under review), city council districts, date, year, or overall pre-incident plan counts.[103] Additionally, depending on the required detail of the pre-incident plan, floorplans and layouts may be digitally overlaid on top of a picture of the structure.[104] This would allow the users visually to "see" the inside of the structure from their chosen devices. This could potentially provide key tactical intelligence during a structure fire or even during a non-fire event like an active shooter. As evidenced by the preceding, GIS technology has now evolved into a tool that can be useful in non-emergency field applications, as well as in emergency response duties.

[102] Source: Environmental Systems Research Institute.

[103] Environmental Systems Research Institute.

[104] Chris Rogers, *Tips and Tricks for Using ArcGIS for Fire Pre-Incident Planning* (Kirkland, WA: Kirkland Fire Department, 2010), 8.

B. FIRE HYDRANT MAINTENANCE

The fire hydrant maintenance program is an important function for every fire department.[105] The water supplied by the fire hydrants is the literal lifeline for every firefighter who enters a burning structure. Maintaining and testing a fire hydrant consists of flowing water through the hydrant, testing the flow pressure, ensuring that the stem turns, lubricating the various parts, and also ensuring that vegetation around the hydrant is kept to a minimum.[106] Once the hydrant is tested, flowed, and maintained, the record of such maintenance needs to be documented.[107] In legacy or traditional systems, a paper form for each hydrant is forwarded to a central point person within the department who records the entries and then forwards any repairs or changes to a contact point in the Water Department.[108] This process relies on all links of the chain to be present and completing their portion of the program in a timely manner.

Currently, the Dallas Fire Department conducts a very similar process except that the paper form has been replaced with a digital form.[109] Obviously, this process is a great improvement over paper forms; however, accurate maintenance and testing counts are not readily available to fire station officers responsible for completing hydrant maintenance in their station responsibility areas. This process also makes it very difficult for fire department command staff personnel to observe visually how many hydrants have actually been maintained in a given time frame.

For hydrant maintenance and records management, GIS can provide deliverables and services very similar to those provided for pre-incident planning.[110] For instance, GIS staff can create editable forms and apps that can be used on a tablet, the MDCs located in

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105 Carter, Rausch, and Kiamie, *Management in the Fire Service*, 239.

106 Robert W. Klinoff, *Introduction to Fire Protection* (Clifton Park, NY: Thomson Delmar Learning, 2007), 359–60.

107 Klinoff, 363–64.

108 Klinoff, 363.

109 Charles Hampton, *Dallas Fire-Rescue Hydrant Training Plan* (Dallas: Dallas Fire-Rescue Department, 2013), 4.

110 Rogers, *Tips and Tricks for Using ArcGIS for Fire Pre-Incident Planning*, 3.

fire units, or on smart phones.[111] These devices can be formatted to feed pertinent maintenance and testing data directly to a database. This would negate the manual process of having to come back to the fire station and complete multiple forms and entering data into a second system for tracking and monitoring purposes. The number of hours used for data entry can be greatly reduced as fire personnel are not having to duplicate effort.[112] Fire personnel would simply open the app, hit a couple of dropdown options for each hydrant, and then move to the next hydrant.

Similar to pre-incident plans, GIS also has the capability to create multi-user dashboards that have the power to query a database by hydrant ID number, hydrant manufacturer type, hydrant flow rate, hydrant physical address, fire station responsibility area, hydrant inspection/maintenance date, hydrant inspection/maintenance history, hydrant color (if applicable), or hydrant status (in-service, out-of-service, needs repair). GIS dashboards typically provide a quick, easy to use visual aid for all users (Figure 11).

111 Environmental Systems Research Institute, "Fire Hydrant Inspection Dashboard," ArcGIS Dashboards, accessed July 23, 2021, https://www.arcgis.com/apps/dashboards/523d702da7734e71973273d08035a126.

112 Rogers, *Tips and Tricks for Using ArcGIS for Fire Pre-Incident Planning*, 2.

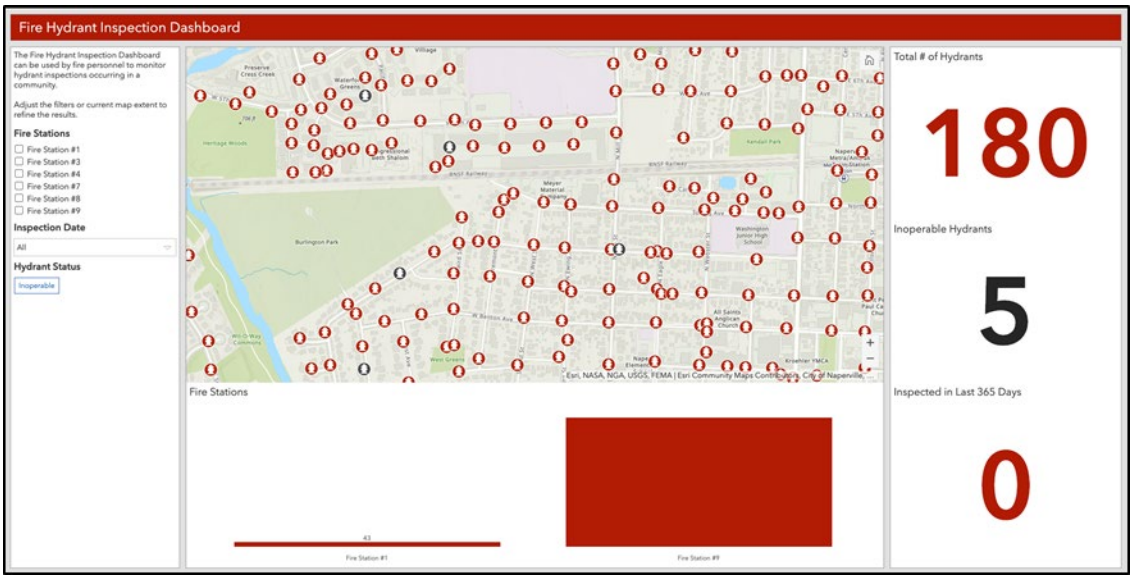

Figure 11. Fire Hydrant Dashboard.[113]

It takes very little technological expertise to open, filter, and extrapolate the data that a user may need. In addition, accurate maintenance and flow records can be kept for the life of a fire hydrant, which will enhance safety and assist with determining if a fire hydrant has a trend of mechanical issues.[114] This could lead to early replacement or removal of the fire hydrant altogether.

C. EMS PROGRAM DEVELOPMENT

Within the Division of EMS, GIS has proven to be an asset not only in response, but also in new program development. One new program of consequence was derived for the City of Dallas' response to mental health emergencies. Mental health emergencies often consist of agitated patients who have substance abuse issues or undiagnosed mental illness.[115] That analysis, coupled with the identified need to provide other social services, can spur on changes in response protocols. As an example, the cities of Colorado Springs

[113] Source: Environmental Systems Research Institute, "Fire Hydrant Inspection Dashboard."

[114] Klinoff, *Introduction to Fire Protection*, 363–64.

[115] "RIGHT Care Team Responds to Mental Health Crisis Calls," Parkland Health & Hospital System, February 18, 2019, https://www.parklandhospital.com/news-and-updates/right-care-team-responds-to-mental-health-crisis-c-1488.

and Dallas have developed innovative programs in response to mental health disorders. These programs, called The Community Response Team and RIGHT Care, respectively, team up a mental health physician, a paramedic, and a police officer to respond to mental health emergencies within certain areas of their cities.[116] Their goal "is to divert mental health patients from area emergency rooms and jails by stabilizing them on the scene and getting them to the appropriate preventive and intervention services that can meet their healthcare needs."[117]

In Dallas' program, GIS was initially integrated to determine where the pilot program would begin. Because of the limited funding and staffing, the pilot program was restricted to operating 112 hours per week between the hours of 7:00 am and 11:00 pm.[118] To receive the largest return on investment, GIS had to define the response boundaries through geospatial analysis. GIS began by analyzing the number and locations of fire department emergency responses coded as "mental health" emergencies across the city. This list was then cross referenced with police department responses coded as "46A-mental health" emergencies. GIS then went a step further and incorporated an analysis of areas with relatively low median household income, with the belief being that many citizens in those areas cannot afford mental health treatment or have been undiagnosed due to lack of insurance coverage. Once all data was quantified and evaluated, the decision was made to begin the pilot program within the Dallas Police Department's South Central Patrol Division.[119] This area marked the boundary for responses to ensure that the highest number of emergencies could be captured within the designated hours of operation and that response times were within the 480-second NFPA standard for advanced life support (ALS) responses.[120]

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[116] Harvard Kennedy School, "The Community Response Team," Government Innovators Network, accessed July 20, 2021, https://www.innovations.harvard.edu/community-response-team.

[117] Parkland Health & Hospital System, "RIGHT Care Team Responds to Mental Health Crisis Calls."

[118] Daniel Salazar, *Dallas Fire-Rescue RIGHT Care Program Launch* (Dallas: Dallas Fire-Rescue Department, 2018).

[119] Salazar.

[120] National Fire Protection Association, *NFPA 1710*, 9.

Once an EMS program has been developed and implemented, GIS can also be leveraged for reporting the status of the program on a regularly scheduled basis. This information can then be used to determine if a program is meeting, exceeding, or underperforming expectations. With enhanced visualizations and data analytics, GIS can assist decision makers in altering response plans or areas of coverage by providing one-page primers or other deliverables (Figure 12).

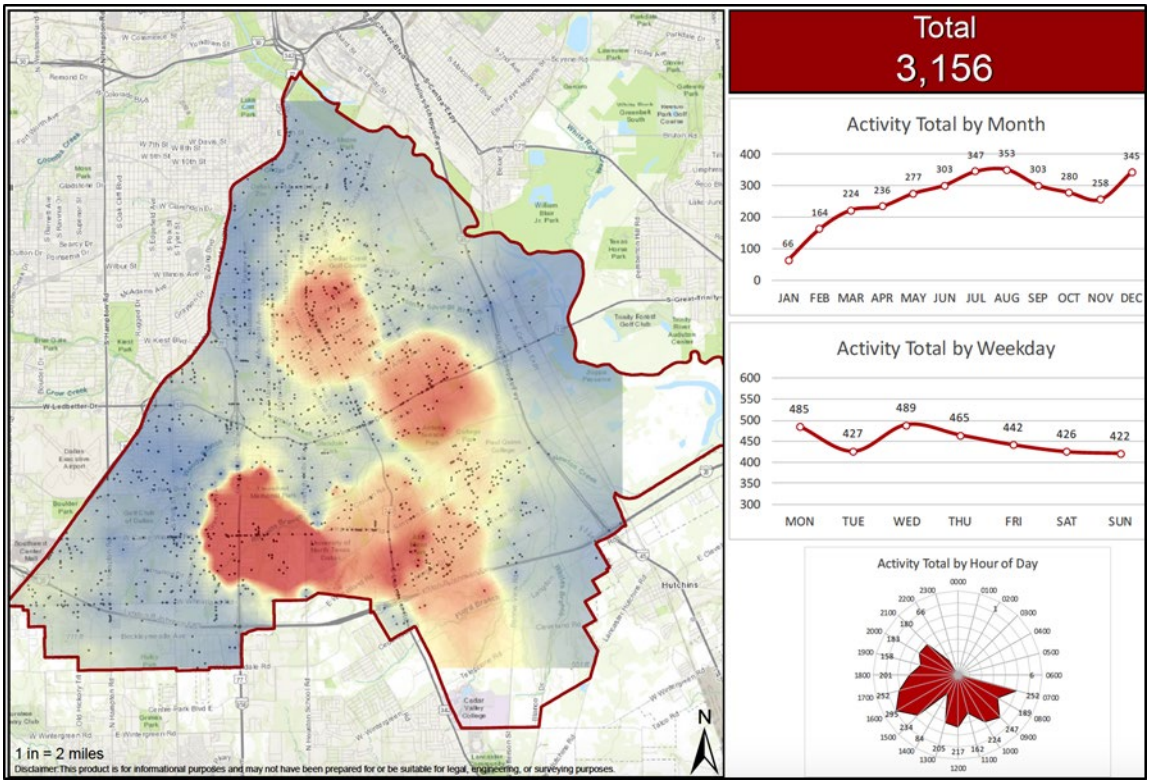

Figure 12. GIS Deliverable for Status Update and Decision Support.[121]

D. FIRE PREVENTION, EDUCATION, AND INSPECTION

Fire prevention, education, and inspection have a different yet important mission in the fire service. While fire operations personnel typically focus on the emergency after it has already occurred, fire prevention efforts are focused on preventing the fire or

[121] Source: Information created using ArcGIS with Dallas Fire Department data.

emergency from actually occurring in the first place.[122] A department's fire inspection division assists in the prevention efforts by ensuring that all applicable fire codes and standards are followed for commercial structures and multi-family residences.[123] GIS can be used in the fire prevention and inspection areas by providing readily identifiable data concerning commercial buildings and multi-family dwellings within the jurisdiction.[124] GIS can also assist by identifying areas with high rates of fire fatalities, so that unique fire prevention programs can be implemented in those areas in an attempt to reduce preventable emergencies.[125] Such measures could include the dispersal of fire safety pamphlets, voluntary home inspections, and the instillation of free smoke detectors in areas with high rates of structure fires and/or fire deaths.

As an additional example, Dallas Fire Department recently teamed up with the Massachusetts Institute of Technology (MIT) to develop a fire predictive modeling report that integrated GIS technology with machine learning, fuzzy matching algorithms, and random forest modeling (Figure 13).

[122] Klinoff, *Introduction to Fire Protection*, 294–96.

[123] Carter, Rausch, and Kiamie, *Management in the Fire Service*, 131–32.

[124] ESRI, *GIS for Fire Station Locations and Response Protocol*, 12.

[125] ESRI, *GIS for the Fire Service*, 5.

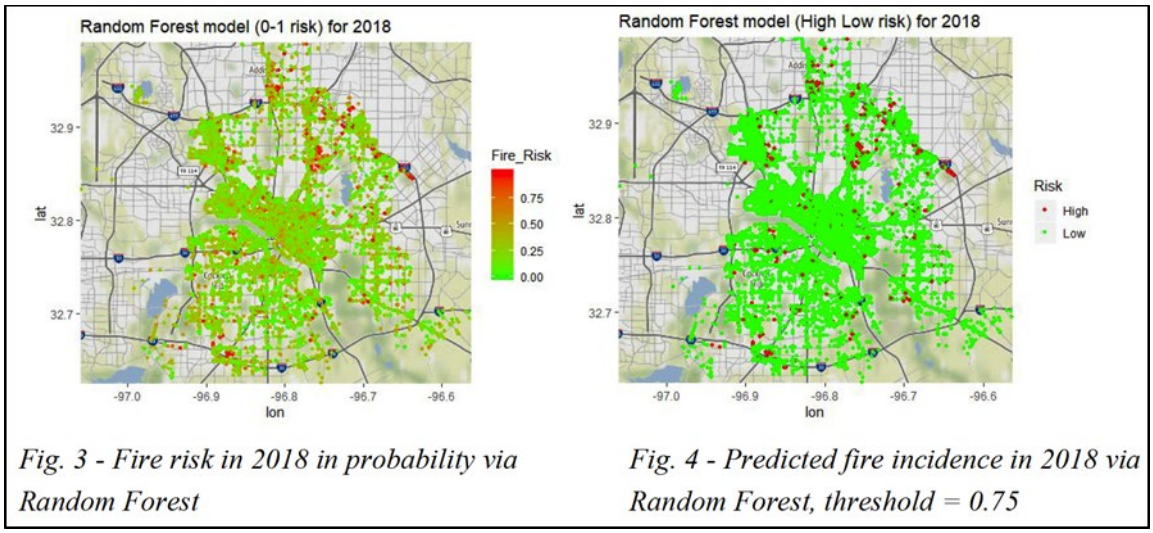

Fig. 3 - Fire risk in 2018 in probability via Random Forest

Fig. 4 - Predicted fire incidence in 2018 via Random Forest, threshold = 0.75

Figure 13. Fire Risk Predictive Modeling Report.[126]

These efforts produced a fire predictive modeling data set currently being used to prioritize commercial property inspections within the City of Dallas. The report incorporated numerous variables like fire incident data, building age, construction type, historical code violations, and others to provide a fire risk score for each structure. This score was then leveraged by Dallas Fire Department's Fire Prevention, Education, and Inspection (FPE&I) Division to prioritize its fire inspection activities in Dallas' 56,000 commercial and multi-family residential properties.

The current goal is to provide one dashboard capable of three (3) data visualization deliverables, so that the fire department can integrate fire risk scores into its existing decision-making practices. The three deliverables consist of an overview and descriptive statistics dashboard page to display current and historical fire incidence rate trends easily by citywide fire districts over time. The second deliverable consisted of an interactive dashboard page that allows fire prevention inspectors the ability to display and compare risk levels easily based on property type, station responsibility areas, zip code, and fire district. The final deliverable is an interactive map to visualize spatially the high-risk properties with associated fire risk based on its location. Incorporating GIS and machine

[126] Adapted from Dallas Fire Department project data in collaboration with the Massachusetts Institute of Technology (MIT).

learning into the FPE&I Division of the Dallas Fire Department was an idiosyncratic use of multiple technologies and skills that produced unique results to enhance departmental operations for years to come.

E. FLEET MAINTENANCE

Many firefighters and most outsiders can overlook the Fleet Maintenance Division of a fire department. This division, under the supervision of a Fleet Manager, is responsible for the maintenance and performance of every vehicle in the fire department fleet.[127] Unbeknownst to most, the Fleet Maintenance Division is a vital part of the emergency response cycle. If fire department apparatus are not roadworthy, the fire departments cannot respond and perform their life saving duties.[128]

The use of GIS in fleet maintenance operations is not a customary use. However, GIS has the ability to analyze the most highly traveled response routes for units. When the response route data is combined with apparatus repair data, the result could be used to prioritize road repair requests. For instance, if a particular apparatus continues to need multiple repairs to suspension components (i.e., struts), GIS could be used to analyze the company's response routes and provide quantitative proof that the fire company does indeed travel frequently on a road that needs repair. While asking the crews which roads need repair will provide qualitative data, the use of GIS in this instance would provide the quantitative proof needed to justify repairs to the road. With response route data and the records of repair costs to the apparatus, command staff personnel have the proof needed to request expedient repairs to the road. GIS could then be used to pull all data from all apparatus that respond on that particular section of road and compare if those fire companies have inordinately high repair requests. While a proof of concept for this type of analysis is beyond the scope of this research, the framework for the analysis is attainable.

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[127] Christian Koop, "Fleet Management Reports," *Fire Apparatus & Emergency Equipment Magazine*, August 1, 2018, https://www.fireapparatusmagazine.com/fire-apparatus/fleet-management-reports/.

[128] Koop.

A supplementary use of GIS related to the fleet division comes in the area of apparatus construction specification requirements. With building permit data, GIS can be used to determine trends in municipal infrastructure and building codes.[129] These trends may necessitate modifications to future fire apparatus. Effects, such as the narrowing of city streets due to the instillation of bike paths in historically narrow streets, may require that fire apparatus in that area be constructed with a reduced overall width (Figure 14).[130]

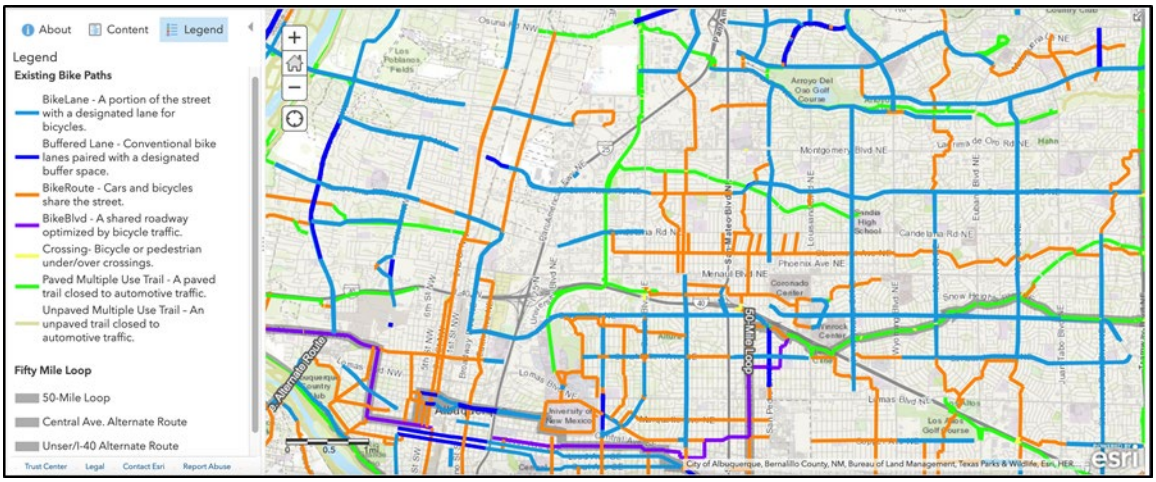

Figure 14. Bike Paths in Albuquerque, New Mexico.[131]

In addition, the construction of mid-rise (four to eight stories) residential apartments place residents out of the reach of the longest fire service ground ladders.[132] This may necessitate the need to purchase a truck company rather than an engine company for a particular area

[129] Kathy Cappelli, "Visualize Regional Growth with Building Permits," *ArcGIS Blog* (blog), March 1, 2019, https://www.esri.com/arcgis-blog/products/api-python/analytics/visualize-regional-growth-with-building-permits/.

[130] Klaus Philipsen, "Do Protected Bike-Lanes Really Kill Fire Access?," *Community Architect Daily* (blog), February 20, 2018, https://communityarchitectdaily.blogspot.com/2018/02/do-protected-bike-lanes-really-kill.html.

[131] Environmental Systems Research Institute, "Bike Paths," ArcGIS Online, accessed July 23, 2021, https://www.arcgis.com/home/webmap/viewer.html?webmap=2734725f1a894ee49a0834a30cf49e43&extent=-106.7106,35.0796,-106.5083,35.1657.

[132] Mittendorf, *Truck Company Operations*, 25.

due to the aerial ladder rescue capabilities. GIS has the capability of extracting this type of commercial construction data and visualizing it for analysis and decision support.[133]

Using GIS in the fleet maintenance division provides an alternative use for a technology not typically associated with this area of the fire service. While the information for road conditions, street width, and new construction height can be attained from various other sources, incorporating GIS allows each data set to be combined and evaluated for the enhancement of apparatus maintenance and construction.

F. SPECIAL OPERATIONS RESPONSE

Special operations consist of the types of responses outside the norm of standard fire and medical emergency responses.[134] During these types of events, communication and situational awareness become increasingly important.[135] None more so than during a disaster response. Disaster responses can stem from earthquakes, hurricanes, tornadoes, industrial accidents, and a number of other sources. Special operations teams within a fire department are specially trained to combat the unique rescues required in these types of emergency environments.[136]

During a disaster, emergency response zones typically cover large areas that cannot be easily encompassed.[137] GIS can be used to provide a common operating platform for all emergency responders, city, county, and state officials. This platform provides a collective operating picture for all parties involved (interoperability), so that to the most up-to-date situational awareness can be maintained.[138] As an example, if a tornado were to strike a heavily populated area of a city, 9–1-1 calls for service would immediately begin to inundate the first responders of the affected area and cause them to become quickly

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[133] Cappelli, "Visualize Regional Growth with Building Permits."

[134] John Norman, *Fire Department Special Operations* (Tulsa, OK: PennWell, 2009), 6.

[135] Norman, 310.

[136] Norman, 8–9.

[137] Sisi Zlatanova and Jonathan Li, eds., *Geospatial Information Technology for Emergency Response*, International Society for Photogrammetry and Remote Sensing (ISPRS) (London, UK: Taylor & Francis, 2008), 12.

[138] Zlatanova and Li, 14–17.

overwhelmed.[139] Traditionally within Dallas Fire Department, there has not been an accurate or efficient way of tracking true victim counts, downed power lines, or damaged structures that need to be searched. Usually, this kind of tracking occurs on a dry-erase board at the back of command vehicle, completely siloed from every other entity needing real-time information.[140] To remedy this issue, GIS has the ability to produce an easy to access digital tracking form that includes the requisite information needed to be tracked during a disaster. This digital form uses a QR code that can be accessed from an apparatus mobile data computer (MDC), tablet, smart phone, text message, or email. Once the QR code is accessed, it takes the users to an easy-to-use digital survey form, where they can input pertinent rescue information like victim counts and locations, damage assessments to structures, and hazards, such as downed power lines. Information from the digital survey form is fed directly into a special operations disaster dashboard that can be used for tactical decision support and can be accessed from any location with internet access (i.e., emergency management offices, command vehicles, or political officials' offices or homes) (Figure 15). In addition, GIS technology can provide an avenue to track damage assessments for federal disaster declaration status and reimbursement.[141] At the conclusion of the event, all information gathered can later be used to create accurate intelligence reports for after action reviews and tabletop training exercises.

Obviously, prior planning, training, vulnerability analysis, and hazard identification would have to be incorporated into the jurisdiction's emergency response plan.[142] In reality, a GIS system can be pre-built, trained on, and implemented before an actual emergency occurs. Since internal GIS staff create the system, it allows the forms to be adaptable and able to make customized changes swiftly and in-house.

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[139] Don Jorgensen, "911 Centers Overwhelmed during Disasters," *KELOLAND News*, 2017, https://www.keloland.com/news/911-centers-overwhelmed-during-disasters/.

[140] Louie Bright, *Dallas Fire-Rescue Manual of Procedures: Emergency Response Procedures (600)* (Dallas: Dallas Fire-Rescue Department, 2012), 12.

[141] ESRI, *GIS for the Fire Service*, 6–8.

[142] ESRI, 4–5.

Incorporating GIS into special operations allows city departments and other response entities that typically do not work together the opportunity to synthesize a response and recovery plan that meets the needs of the community that they serve.[143]

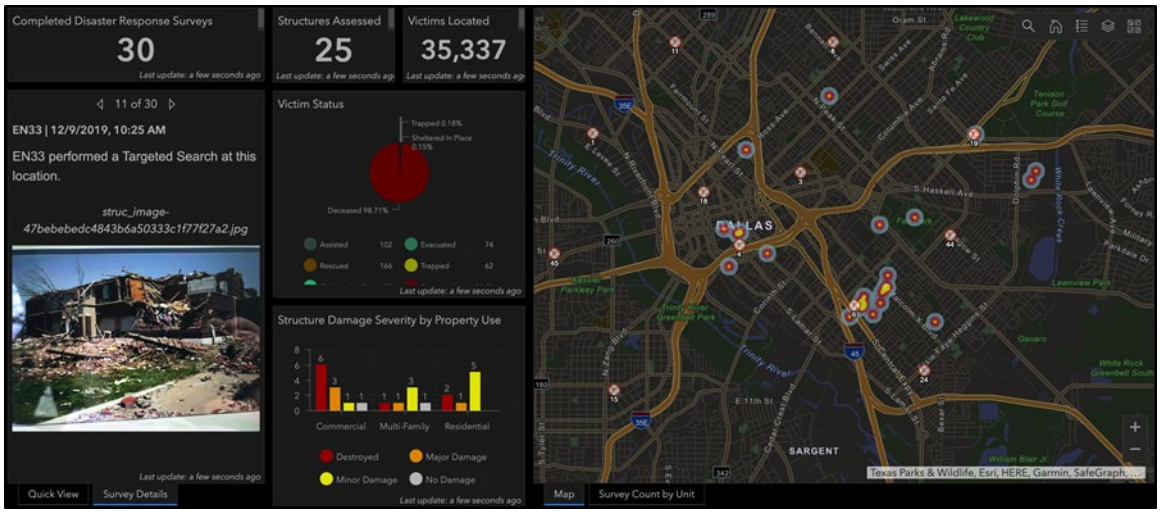

Figure 15. Special Operations Disaster Dashboard.[144]

[143] Natasha Manick, Ashvin Appigadoo, and Zarine Cadersaib, "ERP and GIS Relevance for Fire Rescue Services," in *2019 Amity International Conference on Artificial Intelligence (AICAI)*, ed. Sunil Kumar4 Khatri, Ajay Rana, and P. K. Kapur (Dubai: IEEE, 2019), 927, https://doi.org/10.1109/AICAI.2019.8701261.

[144] Source: Information created using ArcGIS with Dallas Fire Department data.

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IV. GEOSPATIAL INTELLIGENCE IN STRATEGIC PLANNING AND POLICY DEVELOPMENT

Fire department planning and jurisdictional policy development go hand in hand. As the fire department is one of the three primary elements of public safety (along with the police department and emergency management office), its resources and strategic considerations must be incorporated, so that it can contribute to the overall policy course of a community. As evidenced in previous sections of this research, GIS can provide fire department command staff personnel with the ability to plan for the future needs of the public and allocate resources efficiently and effectively. These plans feed directly into a jurisdiction's policy focus. Reports have shown that, "city governments that use data also are able to identify the needs of residents more efficiently, and deploy policies where they can have the greatest impact."[145] If public safety is a high priority in a city's policy agenda, things, such as fire station placement, population shifts, demands for service, evolution of emergency response types, and fire prevention/education programs for low-income areas, become important parts of the city's overall policy direction. The goal should be that the strategy and resource allocation of all city departments should aim to accomplish the jurisdiction's overall policy goals.

Political leaders want to ensure that the needs of its citizens are met and that enhancements are provided fairly and equitably to all demographics of a city. As stated previously, questions like "where should a new fire station be placed" and "where should a new ambulance be located" are inquiries that can be resolved by incorporating geographic information systems technologies. Once the "where" question is answered, then strategies can be created and implemented to remedy the various issues that plague a jurisdiction. As examined previously with demographic data, fire resource allocation of units, as well as new fire station construction must be administered accordingly through some sort of equity

[145] Patino, "The City Governments that Have Mastered Data."

policy process. In the Texas cities of Dallas and San Antonio, that policy process is called "budgeting for equity."[146]

A. BUDGETING FOR EQUITY

Budgeting for equity is a policy process that asks a set of very specific internal questions, to ensure that city services are provided equitably across all socioeconomic and demographic classes. In San Antonio, Texas, the budgeting for equity tool is designed to:

- Identify whether budget requests advance equitable outcomes for residents.
- Assess the equity impacts of budget decisions for potential burdens and benefits for communities of color and low-income communities.
- Ensure that programs, projects, plans, and investments help to reduce disparities.
- Increase community engagement in improvements, reductions and overall budget development.[147]

San Antonio's budgeting for equity tool includes three strategies and nine questions. Those strategies include:

- Strategy One: Apply an equity lens to assess equity impact—This section is intended to assess if departmental budget decisions considered potential benefits and burdens to communities of color and low-income communities.
- Strategy Two: Be equity data driven—This section is intended to assess how equity data indicators informed departmental budget decisions.
- Strategy Three: Equitable community engagement and access—This section is intended to assess community engagement in the budget process, whether there was equitable representation and input, and whether the budget supports departments in authentically engaging with and adequately servicing communities of color and low-income communities.[148]

To ensure that an equity policy is incorporated into the resource allocation and decision making of the fire department, GIS can be used to extract and combine multiple

[146] "Fiscal Year 2022 Budget Equity Tool," City of San Antonio, accessed July 12, 2020, https://www.sanantonio.gov/Equity/Initiatives/BudgetEquityTool.

[147] City of San Antonio.

[148] City of San Antonio.

demographic data streams for decision-making purposes.[149] Specifically, GIS can provide the analysis for "strategy two: be equity data driven" and can become a function of the underlying equity practice. Any data extracted can be in the form of simple tabular data as in an Excel spreadsheet or can be produced as a graphic representation with charts and figures. In either case, the data must be clear, concise, and understandable for fire command staff personnel.

In Figure 16, GIS can be used to quantify the demographic data within a four (4) minute drive time from Dallas Fire Station #41. In this instance, the demographic data (median household income) could be used as decision support to locate an ambulance to another area of the city with a lower median household income as an equity measure.

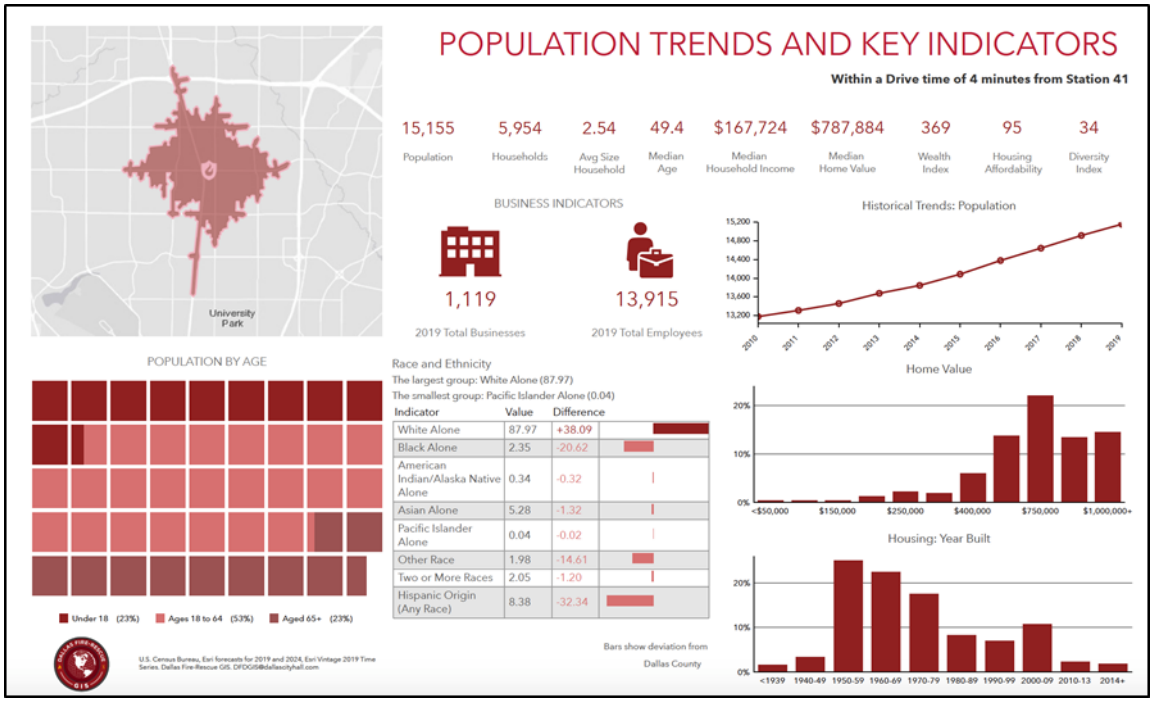

Figure 16. Demographic Data by Response Area.[150]

[149] ESRI, *GIS for the Fire Service*, 6–7.

[150] Source: Information created using ArcGIS Community Analyst with Dallas Fire Department data.

Whether the Budgeting for Equity Tool or another equity instrument is used, fire department strategic placement of resources must incorporate city policy considerations.

B. EVIDENCED-BASED POLICY MAKING

Policy makers are now discovering that governing necessitates enhanced strategic use of technology to overcome problems and challenges effectively within their jurisdictions. Gone are the days when policy decisions were made based on a perceived need or simple speculation. Instead, political leaders now rely on an evidenced-based policy making approach to create and implement policy. The methods of evidenced-based policy making can consist of research for new policy implementation or data collection and evaluation to improve and increase efficiency of current programs.[151]

No matter the size of a community, policy makers and planners have to consider spatial data like zoning restrictions, transportation networks, parcel size, land use, and housing restrictions in their decision-making processes. These elements not only affect the quality of life for the citizens and visitors to a city, but they also affect the planned growth and development of an area. Planners use GIS every day to study, design, develop, implement, and monitor their plans.[152] GIS also offers planners the tools they need to plan and develop neighborhood and city layouts.[153] Planners leverage GIS to assist the decision-making process, so that their technical knowledge, political understanding, and fiscal awareness can convert a vision into a strategic action plan.[154]

According to Baker et al., GIS has the ability of, "communicating complex planning issues in a 'language' that is easily understandable and effective at stimulating policy debate, critical thinking, and learning."[155] Their research demonstrates that there is a need

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[151] Evidenced-Based Policy Making Collaborative, *Principles of Evidence-Based Policymaking*.

[152] Evidenced-Based Policy Making Collaborative.

[153] Evidenced-Based Policy Making Collaborative.

[154] Evidenced-Based Policy Making Collaborative.

[155] Wong et al., "Mapping Policies and Programmes," 1020.

for policy makers to, "think spatially and act spatially" when developing policies and programs.[156]

> In respect to evidence-based policymaking and the fire service:
>
> > GIS has the ability to retrieve large amounts of data maintained by agencies and organizations outside the fire service. GIS allows fire staff personnel the ability to access and integrate diverse datasets maintained by outside organizations. This enables personnel to access and fuse these datasets with existing preplanning, incident, and other fire data. Complex analysis and modeling can be performed to predict, monitor, and model service delivery based on call history.[157]

This type of complex analysis and modeling with external data streams provides the evidence needed to make decisions in the evidenced-based policy making approach.

The strategic use of a technology like GIS provides decision makers (from fire department command staff personnel to political leaders) with the research data and supporting evidence needed to make informed policy decisions. As Parrish et al. states, "decisions based on improved understanding will be better than ones based on ignorance."[158] At the end of the day, the assimilation of additional data coupled with advanced analysis, provides enhanced understanding, which leads to improved planning and greater policy development.

C. BUDGET POLICY

According to a fiscal tracker managed by the United States Conference of Mayors, COVID-19 will have a detrimental financial effect on local economies. In many cities across the country, more workers will become unemployed and critical services provided during the national crisis will be curtailed.[159]

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156 Wong et al., 1020.

157 ESRI, *GIS for the Fire Service*, 5.

158 Shane Parrish and Rhiannon Beaubien, *The Great Mental Models: General Thinking Concepts*, vol. 1 (Ottawa, Ontario: Latticework Publishing, 2019), 17.

159 David W. Burns, "Fiscal Pain Tracker," United States Conference of Mayors, April 30, 2020, https://www.usmayors.org/issues/covid-19/fiscal-pain-tracker/.

Public policy in every jurisdiction is affected by budgetary restraints and limits. When enacting public policy, fiscal impact is always a consideration and may even become the deciding factor as to whether a policy is implemented or not. As an example, due to the negative fiscal effects that the COVID-19 epidemic has already had on city and fire department budgets, policy makers may consider drastic cost cutting measures, such as fire company brownouts. Brownouts occur when "companies are shut down to save money, stretch resources, and compensate for budget shortfalls. An entire firehouse does not close—just certain engines or ladder companies rotating on a daily basis."[160]

These brownouts save money as the companies in the brownout status, do not have to be filled with on-duty personnel since they are out-of-service.[161] Depending on the fire departments' staffing models, this program saves the expenditures spent on the salaries of the firefighters who would have been encumbered to staff that particular apparatus. In these cases, GIS could be used to determine the most appropriate fire companies to be placed out-of-service. The overall goal would be to ensure that the brownouts would have the least negative impact on emergency response coverage and travel times. In this scenario, GIS would be used to analyze the inverse of three (3) step analytical process by choosing the companies that would least affect response coverage, have a low service demand, and only slightly raise surrounding apparatus response times.

If the policies of fire company brownouts are deliberated in cities across America, GIS can be incorporated to provide the research and quantifiable data necessary to refute this policy. As in any department, if resources are diverted away from a department's mission, policy makers must decide whether the effects of such a decision are an acceptable risk.[162] If GIS analysis demonstrates that there will be significant increases in fire department travel times, policy makers must determine if that increase is an acceptable risk factor for their constituencies. If it is not a risk that policy makers are willing to take, they

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[160] Kara Foxx, "What Is a 'Brownout'? The Answer Impacts Residents' Safety," Fox 19 Now, February 10, 2014, https://www.fox19.com/story/24676706/brownouts-can-impact-community-safety.

[161] Anthony Kontji, "Fire Department Considers 'Brown Outs' to Save Money," Action News 5, July 2013, https://www.wmcactionnews5.com/story/22904512/fire-department-considers-brown-outs-to-save-money/.

[162] ESRI, *GIS for the Fire Service*, 5.

may seek cuts from unaffected departments or seek additional cuts from departments already affected. In this instance, GIS data and analysis could provide the information necessary to prevent such a drastic measure from occurring.

Another budgetary effect that GIS has a substantial role in comes in the form of the decision-making process for the resource allocation of fire stations. As discussed previously, GIS plays a crucial role in determining the actual placement of a new fire station by compiling and analyzing the vast amounts of data needed to ensure proper and equitable placement. As a budgetary tool, however, GIS could be used to determine if rebuilding a current fire station in a different location is more advantageous than simply building a brand-new fire station in an area of need.[163]

The decision to construct a brand-new station or to rebuild an existing station in a different location is complex.[164] Yet, it is a decision that can be quantifiably answered with GIS technology. For instance, GIS will conduct the three (3) step analytical process of coverage analysis, hot spot analysis, and travel time analysis to determine what quantifiable deficiencies are present in the community. If analysis demonstrates that there are multiple deficiencies in coverage and response times across the city, the inclusion of a brand-new fire station may be shown to be the most advantageous. It would add additional resources (units and responders) to the overall size of the department, while lessening the workload on multiple units. This most likely would have a positive effect on response times and response coverage.

However, the building of a brand-new fire station will require additional expenses that must be accounted for in future budgets. Those additional expenditures include, but are not limited to:

- Salaries for additional fulltime personnel[165]

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163 TriData, *Portland Fire and Rescue Service Delivery System Study*, 70.

164 TriData, 73.

165 Mark Wallace, "Fire Department Budget Strategies," *Fire Engineering*, March 2, 2018, https://www.fireengineering.com/2018/03/02/290700/fire-department-budget-strategies/.

- New fire apparatus[166]
- New personal protective equipment for each new fulltime position[167]
- Additional station supply costs

On the other hand, GIS analysis may demonstrate that response times for all units are meeting an acceptable metric and that there are relatively few gaps in overall coverage. If that is the case, GIS can conduct multiple site location studies by moving a current station to another area and analyzing the effects. This process would then be repeated for each proposed station move. Once all the studies are complete, all the data would be evaluated and compared to determine the most feasible site. Once the most feasible site is chosen, that data could then be compared to the original metrics for current alignment. If there are only negligible changes to response times and coverage across the community, the decision to rebuild a current fire station at a different location may be more fiscally responsible. It would have the advantage of not having to incur the additional costs of personnel salaries, equipment, or apparatus. It would also provide an avenue that would replace one of the older, more dilapidated fire stations in the city.

While GIS can provide the quantifiable data and analysis necessary to justify either decision, political intervention or jurisdictional trends may provide qualitative information for which it cannot be accounted.

166 Wallace.

167 Wallace.

V. BARRIERS TO INCORPORATING GIS

This research would not be complete if it did not explore the barriers to integrating GIS technology into the fire service. While GIS can demonstrate its value in multiple areas of fire department operations, as well as in traditional city government, it is not without its own set of impediments.

A. FIRE SERVICE RESISTANCE TO EMBRACE TECHNOLOGY

The first barrier to GIS incorporation is the fire service's reluctance to embrace technology. In the blue-collar world of firefighting, technology and information systems are often viewed as an unnecessary hindrance, rather than an asset to accomplish the mission. Experience and gut-feelings are often followed on the incident scene and is sometimes transferred into the administrative positions in which some fire officers find themselves. While strategic administrative decision making is evolving into an evidence-based approach, some fire chiefs in senior leadership may still resort to making decisions based on experience rather than data analysis and quantitative measures.[168]

B. TECHNICAL COMPLEXITY

The second barrier to incorporating GIS into the fire service is the high technical complexity of the technology itself. Multiple products, software applications, and companies are available on the current market. Some of those companies include Coord (New York, New York),[169] ESRI (Redlands, California),[170] Spatial AI (Cincinnati, Ohio),[171] and Ordinance Survey (Southampton, United Kingdom).[172]

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168 Lori Moore-Morrell, "Using Fire Department Operational Data to Demonstrate Value," *Lexipol* (blog), May 3, 2019, https://www.lexipol.com/resources/blog/using-fire-department-operational-data-to-demonstrate-community-value/.

169 Muthukumar Kumar, "2019 Top 100 Geospatial Companies and Startups List," *Geoawesomeness* (blog), January 13, 2019, https://geoawesomeness.com/2019-top-100-geospatial-companies-startups/.

170 Kumar.

171 Kumar.

172 Kumar.

As with any software application, a learning curve must take place if a person is to use the technology effectively. College courses and training, both in person and remotely, are readily available for those wishing to learn. Unfortunately, however, the processing and analysis of vast amounts of data are also skillsets that have to be acquired. These skillsets are so complex that a number of college degree programs in data analytics, computer information systems (CIS), and data science are dedicated to them.[173] To produce the type of analysis and deliverables described within this research, that level of technical expertise is needed.

C. FINANCIAL EXPENDITURES

The third barrier to incorporating GIS into the fire service can be the financial costs incurred for the hardware, software licensing, and training. These costs could range anywhere from a few thousand dollars up into the million-dollar range.[174] As costs are so customized based on agency and jurisdictional requirements, it would be beyond the scope of this research to provide even an approximate dollar figure. However, depending on the overall use of GIS within a city, an enterprise agreement with a GIS software vendor may be a cost-effective solution.[175] Vendors typically offer reduced pricing based on the number and types of licenses purchased in a contract. These vendors may also provide basic and advanced training as part of their contract services in an enterprise agreement.

D. DATA GOVERNANCE

A fourth barrier to incorporating GIS into the fire service is the actual data itself. Not only does the fire department create and maintain multiple data sets, so do other

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[173] "60 Bachelor Degrees in Data Science for 2020," Master's in Data Science, accessed July 18, 2020, https://www.mastersindatascience.org/specialties/bachelor-degrees-in-data-science/.

[174] GIS Consultants, *Estimating GIS Return on Investment the Empirical Way, Computing the Costs, Benefits, and ROI of GIS Products and Services* (New Orleans, LA: National States Geographic Information Council, n.d.), accessed July 18, 2020, https://nsgic.memberclicks.net/assets/docs/Library/Estimating-GIS-Return-on-Investment-the-Empirical-Way.pdf.

[175] "Enterprise Agreement (EA)," Environmental Systems Research Institute, accessed July 18, 2020, https://www.esri.com/en-us/industries/enterprise-agreement/overview.

municipal and county agencies.[176] These data sets are often joined together to create a true picture of the decision environment. While spatial analysis and data visualization are key components for decision makers, it is the data behind the points on a map where true justification for decisions lie. Data purity, data integrity, and data governance are the most essential part of the entire GIS process.[177] The data is what is actually collected and interpreted on which to base all decisions. As the old adage regarding data states, "trash in, trash out." If the data is not post processed appropriately to remove statistical outliers, false positives, and erroneous entries, decisions made on false information and analysis could have a negative impact on both budgetary and safety requirements. Data integrity and the management of authoritative data sets are beyond the scope of this research; however, it should be noted that any GIS analysis would only be as dependable as the data used to derive such analysis. If key strategic decisions are made on inaccurate data, the results may not have the desired effect or outcome.[178]

176 "A Catalog of Civic Data Use Cases: How Can Data and Analytics Be Used to Enhance City Operations?," Data-Smart City Solutions, March 30, 2020, https://datasmart.ash.harvard.edu/news/article/how-can-data-and-analytics-be-used-to-enhance-city-operations-723.

177 Muhammad Raza, "Data Integrity vs Data Quality: An Introduction," *Machine Learning & Big Data Blog* (blog), July 3, 2018, https://www.bmc.com/blogs/data-integrity-vs-data-quality/.

178 Terry Brown, "Garbage In, Garbage Out—How Bad Data Leads to Bad Reporting and Bad Decision-Making," *ITChronicles* (blog), May 6, 2019, https://itchronicles.com/big-data/garbage-in-garbage-out-how-bad-data-leads-to-bad-reporting-and-bad-decision-making/.

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VI. RECOMMENDATIONS AND CONCLUSION

Because fire departments across the country are so diverse, a magical formula cannot be used to determine the depth of a geographic information system that is optimal for an agency. In each case, fire department command staff personnel must make decisions based on budget, other departmental needs, and innovative programs and technology. If a fire department is relatively static without much change or transformation within its bureaus or divisions, then the answer can lie in sharing GIS resources amongst other city departments. In this scenario, unit locations (resource allocation) are generally static with little expansion of the fire department's fleet (budget policy). In addition, innovative programs like Dallas' RIGHT Care Program and advanced analysis for decision support (evidenced-based policymaking) are requested infrequently and sporadically. On the other hand, if a department is continually striving to increase efficiency and operates in a city government that is persistently evolving, the answer should come in the form of developing an entire team of GIS professionals in a formal GIS section within the department.

A. SHARING OF GIS RESOURCES

As this research has shown, GIS are highly technical in nature and require true GIS professionals to maximize its capabilities. While it is true that a technologically savvy firefighter can learn the technology, this option could take multiple months, if not years, to acquire enough expertise for a robust working knowledge of GIS. A viable option to remedy this issue is to collaborate across multiple departments within the jurisdiction to employ a GIS analyst and share GIS resources. In essence, each contributing department would fund a portion of the position and the salary of a GIS analyst. The hardware and IT data infrastructure (servers) costs would also be shared amongst the participating departments, so that the expenditures were divided equally. Optimally, fire and police departments would be the most likely place to begin, as each department's data structures are typically the same since they are dispatched from the same computer aided dispatch (CAD) system and server. Furthermore, police and fire resources often respond to the same incident types (i.e., shootings, stabbings, motor vehicle collisions, etc.), which lends itself

to cross collaboration between the departments. In this scenario, there is a potential of having competing interests for the GIS analyst's time, which may possibly result in delayed project results for one department or another. However, with a well-established plan based on city priorities, there is no reason to believe that multiple agencies cannot work together and share the same GIS resources.

B. FORMAL GIS SECTION

The sharing of a GIS analyst position and other GIS resources is a viable option for many cities that have reduced call volumes and small fire departments. However, large metropolitan fire departments that have extensive data analysis needs should establish a formal GIS section comprised of multiple GIS analysts. Having multiple analysts prevents a single point of failure in the case of a single analyst being on long-term sick leave or discontinuing employment with the department. Fire department decisions and policy implementation are simply too important to rely on one singular analyst for all the data and geospatial needs of a department. In addition, having multiple analysts evenly distributes the workload, which provides greater efficiency and enhances the turnaround time for project completion.

This research initially began with the idea that the creation or inclusion of a formal GIS position within the Dallas Fire Department was based on a single resource, the firefighter. However, after extensive research and an analysis of the knowledge, skills, and abilities necessary for GIS analysts, the persons occupying the position must be adequately equipped and have the aptitude and skillsets necessary to learn a new application and analyze complex data.[179] In a perfect world, the persons filling the positions would be firefighters who possessed the GIS technical expertise before assignment into these positions. However, since most firefighters join the fire service to answer emergency responses and not compute data, this scenario will most likely not occur frequently. It is my recommendation that a department hire multiple GIS professionals who already possess the technical proficiency in geographic information systems necessary to produce and

[179] Elmhurst University, "What Skills Does a GIS Analyst Require?," *Elmhurst University* (blog), March 3, 2020, https://www.elmhurst.edu/blog/gis-analyst/.

analyze data. While there may be some hesitation with hiring civilian employees in a uniform department, the benefit of having true GIS professionals in these positions trumps any other factor when compared to the learning curve and time delay of training firefighters for these positions. At the end of the day, the GIS positions are data analysts with a geospatial technical component added.

C. CONCLUSION

As demonstrated throughout this research, GIS has the ability to determine optimum placement of fire resources, such as apparatus and fire stations. It also has the ability to provide the evidence necessary for fire department decision makers to meet and/ or exceed municipal policy requirements. Perhaps GIS' biggest advantage stems from its ability to incorporate multiple data streams into one cohesive, easy to understand data set capable of being visualized and interpreted. When incorporated with the resource allocation planning of the fire service, a well thought out plan can take effect.

Furthermore, as exhibited, geographic information systems can and should be incorporated into numerous functions of fire service agencies. These functions include, but are not limited to:

- Pre-incident fire planning
- Fire hydrants maintenance and records management
- EMS program development
- Fire prevention, education, and inspection
- Fleet maintenance
- Special operations response

GIS is an information systems technology, much like information technology (IT) and can provide a pivotal tool for decision makers. Similar to the use of IT in the fire service 20 years ago, GIS is setup up to become the wave of the future for insight into the vast amount of data currently being generated by the Dallas Fire Department and the fire service as a whole.

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APPENDIX A. DFD TRUCK ALLOCATION CASE STUDY

APPENDIX A. TRUCK ALLOCATION CASE STUDY

Dallas Fire-Rescue Department

Geospatial Intelligence & Analytics

In an effort to ensure that truck company response times throughout the City of Dallas are minimized and truck coverage is maximized, the following options for relocation have been analyzed and developed for the following truck companies. The below options are numbered sequentially and are not listed in order of priority, due to the multiple variables that DFD Command Staff must evaluate. All options listed will result in an increase in the number of truck responses for each truck, while also maximizing geographic coverage, thereby reducing truck company response times.

- Trucks Considered for Relocation:

  1) Truck 17
  2) Truck 23
  3) Truck 41

- Stations to be Considered for Placement of a Truck:

  1) Station 02
  2) Station 05
  3) Station 22
  4) Station 32
  5) Station 42
  6) Station 47
  7) Station 54

The above options are based on extensive research and statistical analysis using CAD response data, ESRI, and Deccan's Apparatus Deployment Analysis Modeling (ADAM) platform; which analyzed the following:

- Truck Company Incident Assignments & Arrivals (Historical Analysis)
- Truck Company Coverage Comparisons (Predictive Analysis)
- Truck Company Incident Percentage Comparisons (Predictive Analysis)
- Estimated Time Target Response Comparisons (Predictive Analysis)

All statistical data evaluated for predictive and historical analysis were derived from 259,840 truck assignments during the calendar years of 2013-2019. It should also be noted that NFPA 1710 does not have specific recommendations for the travel times of truck companies. As such, GIS incorporated multiple metrics, including "first truck dispatch to on scene" for Deccan's scenario modeling.

According to geospatial analysis, it is expected that the above listed relocation options will result in an increase in the number of responses and a decrease in travel times to areas that have been historically underserved by truck companies.

Justification Analysis

The suggestions for the preceding relocation scenarios are based on the following parameters:

- Truck 17 Relocation Option
  - Excessively Low Call Volume for Truck 17
  - Excessively Low Call Volume for Trucks in Station 17's Response Area
  - Inordinately Low Travel Time for Truck 17 in Station 17's Response Area
  - Truck Coverage Overlap with Truck 19
  - Net Increase of Incident Percentage in Nearly Every Scenario
  - Net Increase of Incident Average in Every Scenario
  - Net Increase of Coverage Percentage in Every Scenario

- Truck 23 Relocation Option
  - Excessively Low Call Volume for Truck 23
  - Excessively Low Call Volume for Trucks in Station 23's Response Area
  - Inordinately Low Travel Time for Truck 23 in Station 23's Response Area
  - Excessively Small Response Area
  - Less Densely Populated Response Area
  - Cedar Crest Golf Course, Wastewater Treatment Plant, and Robert Orden Park
  - Excessive Truck Coverage Overlap with Truck 04, Truck 33, and Truck 25
  - Net Increase of Incident Percentage in Nearly Every Scenario
  - Net Increase of Incident Average in Every Scenario
  - Net Increase of Coverage Percentage in Every Scenario

- Truck 41 Relocation Option
  - Excessively Low Call Volume for Truck 41
  - Excessively Low Call Volume for Trucks in Station 41's Response Area
  - Low Travel Time for Truck 41 in Station 41's Response Area
  - Net Increase of Incident Percentage in Every Scenario
  - Net Increase of Incident Average in Every Scenario
  - Net Increase of Coverage Percentage in Every Scenario

Truck Companies Not Considered for Relocation

At the direction of the DFD Command Staff, the below truck companies were not considered for relocation as they either serve the Central Business District, high occupancy highrise structures, and/or are part of a Special Operations Program.

- Truck 03 (Haz Mat Program)
- Truck 04 (Central Business District)
- Truck 11 (High Occupancy Highrises)
- Truck 18 (High Occupancy Highrises)
- Truck 19 (US&R Program)
- Truck 33 (US&R Program)
- Truck 34 (Swift Water Program)
- Truck 39 (Marine 1 Program)
- Truck 40 (ARFF Program)

It should also be noted that Truck 18 was placed in service at Station 18 in August of 2020 and that Truck 34 will be relocated to Station 59 upon completion (approximately July 2021). **These factors were accounted for and included when the analysis for this project was conducted**.

Computer Aided Dispatch (CAD) Data Analysis

❖ **Total Truck Assignments (2013-2019)**

Since the last truck realignment occurred on December 5th, 2012 (2012 Departmental Directive #56), CAD emergency response data was analyzed from January 1, 2013 to December 31st, 2019 which resulted in seven (7) full calendar years of emergency response data.

Total Truck Emergency Assignments (2013-2019)									
Rank	Unit	2013	2014	2015	2016	2017	2018	2019	Grand Total
1	**TR04**	2,236	2,432	2,799	2,741	2,754	2,752	3,072	18,786
2	**TR43**	2,028	2,150	2,368	2,457	2,643	2,845	2,857	17,348
3	**TR40**	1,941	2,022	2,344	2,290	2,456	2,669	2,453	16,175
4	**TR37**	1,917	2,089	2,255	2,285	2,276	2,405	2,445	15,672
5	**TR11**	1,823	2,001	2,479	2,133	2,106	2,268	2,473	15,283
6	**TR20**	1,944	1,790	2,083	2,004	2,146	2,492	2,465	14,924
7	**TR33**	1,619	1,810	2,060	2,126	2,250	2,417	2,355	14,637
8	**TR57**	1,757	1,859	2,054	2,105	2,141	2,089	2,148	14,153
9	**TR25**	1,459	1,673	1,947	2,012	2,136	2,424	2,325	13,976
10	**TR34**	1,755	1,788	2,001	2,010	2,021	1,999	2,202	13,776
11	**TR03**	1,518	1,671	2,062	1,962	1,969	2,221	1,982	13,385
12	**TR53**	1,346	1,499	1,663	1,710	1,553	1,739	1,954	11,464
13	**TR24**	1,243	1,315	1,435	1,518	1,597	1,803	1,735	10,646
14	**TR36**	1,092	1,349	1,556	1,445	1,666	1,681	1,783	10,572
15	**TR50**	1,202	1,130	1,345	1,316	1,385	1,486	1,552	9,416
16	**TR19**	972	1,143	1,300	1,441	1,487	1,559	1,464	9,366
17	**TR41**	949	968	1,192	1,107	1,187	1,253	1,261	7,917
18	**TR23**	810	901	923	1,022	1,215	1,189	1,229	7,289
19	**TR10**	927	905	964	951	972	1,060	1,122	6,901
20	**TR56**	893	776	898	969	1,018	1,134	1,113	6,801
21	**TR39**	847	946	971	795	841	990	1,017	6,407
22	**TR17**	615	674	671	689	671	706	920	4,946
Grand Total		**30,893**	**32,891**	**37,370**	**37,088**	**38,490**	**41,181**	**41,927**	**259,840**

After analyzing all truck assignments from 2013 to 2019, it can be observed that Truck 17, Truck 23, and Truck 41 were assigned to far fewer emergencies than rest of the truck companies in the city respectively. This typically occurs because of two (2) reasons:

1) There are relatively few requests for service in the area.
2) There is "over coverage" from another truck company in the area.

Note: Truck 10 and Truck 56 are termed "coverage trucks" due to the lack of truck coverage in the far North Dallas area. While their overall number of responses are also excessively low, relocating either truck would result in excessively large areas of reduced service coverage.

❖ **Average Number of Assignments Per Year**

Upon further analsis of the emergency response assignments, GIS found it necessary to present comparative statistical data for each truck based on the average number of assignments for each year. As overall yearly totals may not necessarily provide a complete picture, conducting this analysis provided the opportunity to compare each truck company within the perspective of the time that these responses were being made.

Average Number of Assignments Per Year (2013-2019)							
Unit	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
TR04	2,236	2,432	2,799	2,741	2,754	2,752	3,072
TR43	2,028	2,150	2,368	2,457	2,643	2,845	2,857
TR40	1,941	2,022	2,344	2,290	2,456	2,669	2,453
TR37	1,917	2,089	2,255	2,285	2,276	2,405	2,445
TR11	1,823	2,001	2,479	2,133	2,106	2,268	2,473
TR20	1,944	1,790	2,083	2,004	2,146	2,492	2,465
TR33	1,619	1,810	2,060	2,126	2,250	2,417	2,355
TR57	1,757	1,859	2,054	2,105	2,141	2,089	2,148
TR25	1,459	1,673	1,947	2,012	2,136	2,424	2,325
TR34	1,755	1,788	2,001	2,010	2,021	1,999	2,202
TR03	1,518	1,671	2,062	1,962	1,969	2,221	1,982
TR53	1,346	1,499	1,663	1,710	1,553	1,739	1,954
TR24	1,243	1,315	1,435	1,518	1,597	1,803	1,735
TR36	1,092	1,349	1,556	1,445	1,666	1,681	1,783
TR50	1,202	1,130	1,345	1,316	1,385	1,486	1,552
TR19	972	1,143	1,300	1,441	1,487	1,559	1,464
TR41	949	968	1,192	1,107	1,187	1,253	1,261
TR23	810	901	923	1,022	1,215	1,189	1,229
TR10	927	905	964	951	972	1,060	1,122
TR56	893	776	898	969	1,018	1,134	1,113
TR39	847	946	971	795	841	990	1,017
TR17	615	674	671	689	671	706	920
Yearly Avg.	**1,404**	**1,495**	**1,699**	**1,686**	**1,750**	**1,872**	**1,906**

Response counts highlighted in grey are below the average number of responses for that year

After comparing the yearly average of truck assignments to each truck's average number of assignments, it can be observed that Truck 17, Truck 23, and Truck 41 remained far below the average number of responses for each of the seven (7) years analyzed.

❖ **Truck Company Travel Times (2013-2019)**

Based on truck company data from 2013 to 2019, the below travel times have been parsed by truck company and response category (excluding Non-Emergency, Special Operations, and Uncategorized responses). Travel times were then calculated from only the emergency response assignments where the unit actually "arrived" on scene. As in all statistical analysis provided by GIS, all responses over twenty (20) minutes were also excluded from this analysis as they are considered statistical outliers by the department.

Average Travel Times by Response Category			
Unit	Fire (Other)	Med. Emergency	Structure Fire
TR03	04:23	05:26	05:57
TR04	04:04	05:14	05:49
TR10	05:51	05:57	06:47
TR11	04:14	05:10	06:06
TR17	04:47	05:28	05:44
TR19	04:59	04:40	07:02
TR20	05:37	06:51	08:08
TR23	04:27	04:05	05:16
TR24	04:23	04:32	05:36
TR25	04:39	04:38	05:01
TR33	04:48	04:36	05:54
TR34	05:26	04:55	06:19
TR36	05:22	05:25	06:30
TR37	04:52	05:02	06:32
TR39	05:18	05:20	06:06
TR40	05:16	05:19	05:58
TR41	05:41	06:01	07:32
TR43	05:25	06:08	05:28
TR50	06:07	06:15	06:53
TR53	04:10	04:23	06:07
TR56	05:48	07:12	07:33
TR57	05:11	05:18	05:47

Chart based on 152,240 emergency response arrivals for Truck Companies

At first glance, travel times for "Structure Fire" responses may appear to be high or even inaccurate, but it should be noted that this analysis includes the structure fire responses that occur outside of a truck company's first due area (two trucks assigned to every reported structure fire). These responses typically add (on average) an additional 60-120 seconds to the travel time of a truck's overall structure fire response time.

❖ **Total Truck Responses into First Due Areas**

In addition to analyzing the travel times and the overall number of assignments for truck companies, it is also necessary to analyze where truck responses are occurring. In doing so, all truck response arrivals from 2013 to 2019 have been parsed by the first due area of all 58 fire stations.

Truck Responses in First Due Areas				
First Due Area	Fire Other	Medical Emergency	Structure Fire	Grand Total
01	853	2,165	90	3,108
02	226	337	86	649
03	1,074	2,734	113	3,921
04	831	3,364	102	4,297
05	310	295	252	857
06	556	1,514	280	2,350
07	365	740	82	1,187
08	836	1,046	298	2,180
09	72	157	134	363
10	936	2,673	221	3,830
11	2,343	2,532	219	5,094
12	341	1,024	101	1,466
13	278	309	92	679
14	215	59	135	409
15	416	1,813	213	2,442
16	381	1,528	109	2,018
17	449	332	97	878
18	3,205	3,993	293	7,491
19	748	3,711	290	4,749
20	1,315	4,488	209	6,012
21	190	420	45	655
22	1,446	4,028	291	5,765
23	560	1,906	409	2,875
24	428	2,073	289	2,790
25	640	3,121	325	4,086
26	523	551	190	1,264
27	502	819	106	1,427
28	717	935	116	1,768
29	312	228	188	728

Truck Responses in First Due Areas				
First Due Area	Fire Other	Medical Emergency	Structure Fire	Grand Total
30	556	3,273	219	4,048
31	229	190	100	519
32	428	1,166	258	1,852
33	745	4,006	291	5,042
34	709	3,346	364	4,419
35	158	87	115	360
36	476	1,416	139	2,031
37	2,371	5,317	399	8,087
38	487	1,123	388	1,998
39	663	1,961	244	2,868
40	1,063	4,702	264	6,029
41	420	686	79	1,185
42	659	477	164	1,300
43	892	3,767	311	4,970
44	240	234	234	708
45	238	829	119	1,186
46	499	2,218	207	2,924
47	921	2,990	175	4,086
48	435	980	146	1,561
49	473	1,335	205	2,013
50	584	2,130	99	2,813
51	252	1,084	149	1,485
52	502	413	216	1,131
53	1,105	3,508	264	4,877
54	349	1,287	183	1,819
55	324	251	107	682
56	441	548	103	1,092
57	1,211	4,265	335	5,811
58	1	0	5	6

Chart based on 152,240 emergency response arrivals for Truck Companies

After comparative analysis of truck arrivals into the first due areas of each station responsibility area, it can be observed that number of arrivals for the first due areas of Station 17, Station 23, and Station 41 are among the lowest in the city and demonstrate a lesser need for a truck company.

❖ **Average Truck Company Travel Times into First Due Areas**

Because unit travel times only represent a portion of the analytical picture, an additional metric that was analyzed was the average travel time for truck companies into the first due areas of all 58 fire stations. This analysis identified two (2) factors relating to travel times that needed further research.

1) Average truck travel times into the first due areas for the suggested relocation stations.
2) Average truck travel times into first due areas with excessively low travel times.

1) First Due Areas Exceeding Seven (7) Minutes

Average travel times that exceed seven (7) minutes identifies areas of the city that require an additional truck in the first due area (or neighboring first due area) in order to reduce truck company responses times. According to the previous seven (7) years of CAD data, the travel times into the first due areas of the suggested relocation stations are as follows:

- Truck Travel Times into **Station 05**'s First Due Area (**9 min 52 seconds**)
- Truck Travel Times into **Station 54**'s First Due Area (**9 min 09 seconds**)
- Truck Travel Times into **Station 02**'s First Due Area (**8 min 28 seconds**)
- Truck Travel Times into **Station 47**'s First Due Area (**8 min 20 seconds**)
- Truck Travel Times into **Station 42**'s First Due Area (**7 min 33 seconds**)
- Truck Travel Times into **Station 22**'s First Due Area (**7 min 11 seconds**)
- Truck Travel Times into **Station 32**'s Frist Due Area (**6 min 35 seconds**)

2) First Due Areas Less than Four (4) Minutes

On a global perspective, low unit travel times are a metric that our units should be striving to achieve. However, when the average travel time for truck companies into their own first due areas are extremely low (less than four (4) minutes), it indicates that either the first due area is too small to justify a truck company or there is an excessive amount of "over coverage" for trucks in that area. Ordinarily, this should not cause a problem, except when resources are limited and it comes at the expense of travel times into other first due areas (including the citizens of those areas). According to the seven (7) previous years of data, the trucks with inordinately low travel times into their first due areas are as follows:

- **Truck 25** into Station 25's First Due Area (**3 minutes 15 seconds**)
- **Truck 23** into Station 23's First Due Area **(3 minutes 19 seconds)**
- **Truck 17** into Station 17's First Due Area (**3 minutes 20 seconds**)
- **Truck 24** into Station 24's First Due Area (**3 minutes 31 seconds**)
- **Truck 36** into Station 36's First Due Area (**3 minutes 37 seconds**)
- **Truck 53** into Station 53's First Due Area (**3 minutes 49 seconds**)
- **Truck 03** into Station 03's First Due Area (**3 minutes 51 seconds**)
- **Truck 11** into Station 11's First Due Area (**3 minutes 55 seconds**)
- **Truck 41** into Station 41's First Due Area (**4 minutes 04 seconds**)

Note: For the comprehensive list of truck travel times into all first due areas, see the chart titled "Average Truck Company Travel Times into First Due Areas (2013-2019)".

Deccan Apparatus Deployment & Analysis Modeling

❖ **Incident Percentage**

The incident percentage category approximates the percentage of responses that will meet the six (6) minute time target for trucks into a particular response area. It compares the "base scenario" (truck at its current location) and the "comparison scenario" (recommended station location) to determine if a statistical difference exists. According to Deccan scenario analysis, the following recommendations resulted in the greatest statistical significance:

- **If a Truck is relocated to Station 47**, the 6-minute time target into Station 47's response area will be met **93.50%** of the time. This would result in an increase of **90.55%** from our current base deployment (base scenario).
- **If a Truck is relocated to Station 05**, the 6-minute time target into Station 05's response area will be met **85.05%** of the time. This would result in an increase of **85.05%** from our current base deployment (base scenario).
- **If a Truck is relocated to Station 42,** the 6-minute time target into Station 42's response area will be met **90.52%** of the time. This would result in an increase of **71.09%** from our current base deployment (base scenario).
- **If a Truck is relocated to Station 54,** the 6-minute time target into Station 54's response area will be met **82.78%** of the time. This would result in an increase of **74.05%** from our current base deployment (base scenario).
- **If a Truck is relocated to Station 22,** the 6-minute time target into Station 22's response area will be met **69.32%** of the time. This would result in an increase of **54.85%** from our current base deployment (base scenario).
- **If a Truck is relocated to Station 02,** the 6-minute time target into Station 02's response area will be met **67.48%** of the time. This would result in an increase of **62.91%** from our current base deployment (base scenario).
- **If a Truck is relocated to Station 32,** the 6-minute time target into Station 32's response area will be met **48.12%** of the time. This would result in an increase of **47.54%** from our current base deployment (base scenario).

It should be noted that if a truck is moved from its current location, there will be a corresponding decrease in meeting the six (6) minute time target for that station's response area. While at first glance, it may appear to somewhat negate the relocation, however, the effects are minimal due to the relatively low number of emergency responses that occur in the below response areas.

- **If the Truck is relocated from Station 17,** the 6-minute time target into Station 17's response area will be met **30.77%** of the time. This would result in a decrease of **58.54%** from our current base deployment (base scenario).
- **If the Truck is relocated from Station 23,** the 6-minute time target into Station 23's response area will be met **32.08%** of the time. This would result in a decrease of **58.31%** from our current base deployment (base scenario).
- **If the Truck is relocated from Station 41,** the 6-minute time target into Station 41's response area will be met **53.36%** of the time. This would result in a decrease of **7.32%** from our current base deployment (base scenario).

❖ **Incident Average**

The incident average category averages historical incident response times, in order to predict future response times for all truck emergency responses occurring in a particular response area. It compares the "base scenario" (all trucks at their current location) and the "comparison scenario" (a truck at the suggested location) to determine if a response time difference exists.

- **If a Truck is relocated to Station 05**, the average response time for the first truck to all incidents occurring in Station 05's response area will be **4 minutes 22 seconds**. This would result in a decrease of **6 minutes 44 seconds** in truck response times when compared to the base scenario.
- **If a Truck is relocated to Station 47**, the average response time for the first truck to all incidents occurring in Station 47's response area will be **4 minutes 37 seconds**. This would result in a decrease of **3 minutes 00 seconds** in truck response times when compared to the base scenario.
- **If a Truck is relocated to Station 42**, the average response time for the first truck to all incidents occurring in Station 42's response area will be **4 minutes 33 seconds**. This would result in a decrease of **2 minutes 28 seconds** in truck response times when compared to the base scenario.
- **If a Truck is relocated to Station 54**, the average response time for the first truck to all incidents occurring in Station 54's response area will be **4 minutes 46 seconds**. This would result in a decrease of **3 minutes 15 seconds** in truck response times when compared to the base scenario.
- **If a Truck is relocated to Station 22**, the average response time for the first truck to all incidents occurring in Station 22's response area will be **5 minutes 39 seconds**. This would result in a decrease of **1 minutes 35 seconds** in truck response times when compared to the base scenario.
- **If a Truck is relocated to Station 02**, the average response time for the first truck to all incidents occurring in Station 02's response area will be **5 minutes 28 seconds**. This would result in a decrease of **2 minutes 23 seconds** in truck response times when compared to the base scenario.
- **If a Truck is relocated to Station 32**, the average response time for the first truck to all incidents occurring in Station 47's response area will be **6 minutes 02 seconds**. This would result in a decrease of **3 minutes 03 seconds** in truck response times when compared to the base scenario.

It should be noted that if a truck is moved from its current location, there will be a corresponding decrease in truck response times for that station's response area. While at first glance, it may appear to somewhat negate the relocation, however, the effects are minimal due to the relatively low number of emergency responses that occur in the below response areas.

- **If the Truck is relocated from Station 17,** the average response time for a truck into Station 17's response area will be **6 minutes and 44 seconds**. This would result in an increase of **2 minutes 19 seconds** from our current base deployment (base scenario).
- **If the Truck is relocated from Station 23,** the average response time for a truck into Station 23's response area will be **6 minutes and 41 seconds**. This would result in an increase of **1 minute 52 seconds** from our current base deployment (base scenario).
- **If the Truck is relocated from Station 41,** the average response time for a truck into Station 41's response area will be **6 minutes and 08 seconds**. This would result in an increase of **18 seconds** from our current base deployment (base scenario).

❖ **Coverage Percentage**

The coverage percentage category estimates the percentage of the geographic response area that will meet the six (6) minute time target. It compares the "base scenario" (all trucks at their current location) and the "comparison scenario" (a truck at the suggested location) to determine if a statistical difference exists.

- **If a Truck is relocated to Station 05**, approximately **79.37%** of Station 05's geographic response area will meet the six (6) minute time target. This would result in an increase of **79.26%** from the base scenario.
- **If a Truck is relocated to Station 47**, approximately **63.59%** of Station 47's geographic response area will meet the six (6) minute time target. This would result in an increase of **60.10%** from the base scenario.
- **If a Truck is relocated to Station 42**, approximately **85.86%** of Station 42's geographic response area will meet the six (6) minute time target. This would result in an increase of **71.31%** from the base scenario.
- **If a Truck is relocated to Station 54**, approximately **29.94%** of Station 54's geographic response area will meet the six (6) minute time target. This would result in an increase of **23.31%** from the base scenario.
- **If a Truck is relocated to Station 22**, approximately **78.68%** of Station 22's geographic response area will meet the six (6) minute time target. This would result in an increase of **52.19%** from the base scenario.
- **If a Truck is relocated to Station 02**, approximately **71.13%** of Station 02's geographic response area will meet the six (6) minute time target. This would result in an increase of **62.26%** from the base scenario.
- **If a Truck is relocated to Station 32**, approximately **63.39%** of Station 32's geographic response area will meet the six (6) minute time target. This would result in an increase of **57.71%** from the base scenario.

It should be noted that if a truck is moved from its current location, there will be a corresponding decrease in the geographical coverage percentage for that station's response area. While at first glance, it may appear to somewhat negate the relocation, however, the effects are minimal due to the relatively low number of emergency responses that occur in the below response areas.

- **If the Truck is relocated from Station 17**, the geographical coverage for the six (6) minute time target for Station 17's response area will be met **17.84%** of the time. This would result in a decrease of **56.71%** from our current base deployment (base scenario).
- **If the Truck is relocated from Station 23**, the geographical coverage for the six (6) minute time target for Station 23's response area will be met **24.63%** of the time. This would result in a decrease of **50.74%** from our current base deployment (base scenario).
- **If the Truck is relocated from Station 41**, the geographical coverage for the six (6) minute time target for Station 41's response area will be met **42.10%** of the time. This would result in a decrease of **34.89%** from our current base deployment (base scenario).

❖ **Response & Availability Predictions**

The Deccan Apparatus Deployment & Analysis Modeling (ADAM) platform also allows for responses per day and truck availability to be estimated based on historic data (trend analysis). As a result, Deccan has provided the following responses per day and availability estimates for our current deployment of trucks (base scenario) and the suggested relocation sites (comparison scenarios).

Base Scenario		
Unit	Responses/Day	Availability
Truck 17	1.79	98.20
Truck 23	2.95	97.32
Truck 41	2.94	97.05

Comparison Scenarios		
Station Resp. Area	Responses/Day	Availability
Sta. 47	4.64	95.33
Sta. 05	2.20	97.67
Sta. 42	3.67	96.41
Sta. 54	3.00	97.06
Sta. 22	6.61	93.25
Sta. 02	3.32	96.52
Sta. 32	3.19	96.69

In nearly every scenario, relocating any/all the suggested truck companies will result in an increase of daily responses and a corresponding decrease in availability.

ESRI Geographic Coverage Analysis

As the old adage states, "a picture is worth a thousand words". As such, GIS has created multiple maps to provide a visual representation of the current deployment of truck company locations and the three (3) most statistically significant station location recommendations. Within each map, the response areas are clearly delineated with 5- and 6-minute travel times. These travel times are based on the City of Dallas road network and are leveraged for all of the GIS Division's analysis. The cartographic representations include to following:

- Map of Current Truck Deployment Locations
- Map of Truck 23 at Station 05
- Map of Truck 41 at Station 02
- Map of Truck 17 at Station 47

These maps will provide the Command Staff with visual representations of coverage and coverage gaps based on the 5- and 6-minute travel time metric. Each recommendation map is meant to be compared to the "Current Truck Deployment" map, so that the travel time coverage gaps and enhancements can be observed.

ESRI Demographic Analysis

In addition, GIS has also included the demographic information for all current and perspective truck location sites. The "Truck Study Supplemental Information" sheets provided herein, provides multiple variables for consideration based on a 5-minute travel time from each station. However, in an effort to condense this study, GIS has identified and listed the most pertinent variables for truck company response. They are as follows:

- Population
- Number of Housing Units
- Number of Businesses

Truck Study Supplemental Information			
Location	Population	Housing Units	Businesses
Sta. 02	23,169	9,385	689
Sta. 05	54,427	16,366	717
Sta. 17	68,198	36,221	2,226
Sta. 22	46,269	22,995	3,908
Sta. 23	29,632	10,822	662
Sta. 32	45,068	14,255	1,009
Sta. 41	30,987	13,637	2,197
Sta. 42	42,615	20,020	1,972
Sta. 47	2,846	1,174	2,598
Sta. 54	18,052	7,078	258
Sta. 59	25,838	7,865	372

**It should be noted that Station 47 has low population count, however, their daytime population increases to approximately 41,925 due to the hospital and commercial business districts.

While these statistics frequently fluctuate throughout the year, they are provided by the *American Community Survey (ACS)*, which is a nationally recognized source of demographic data.

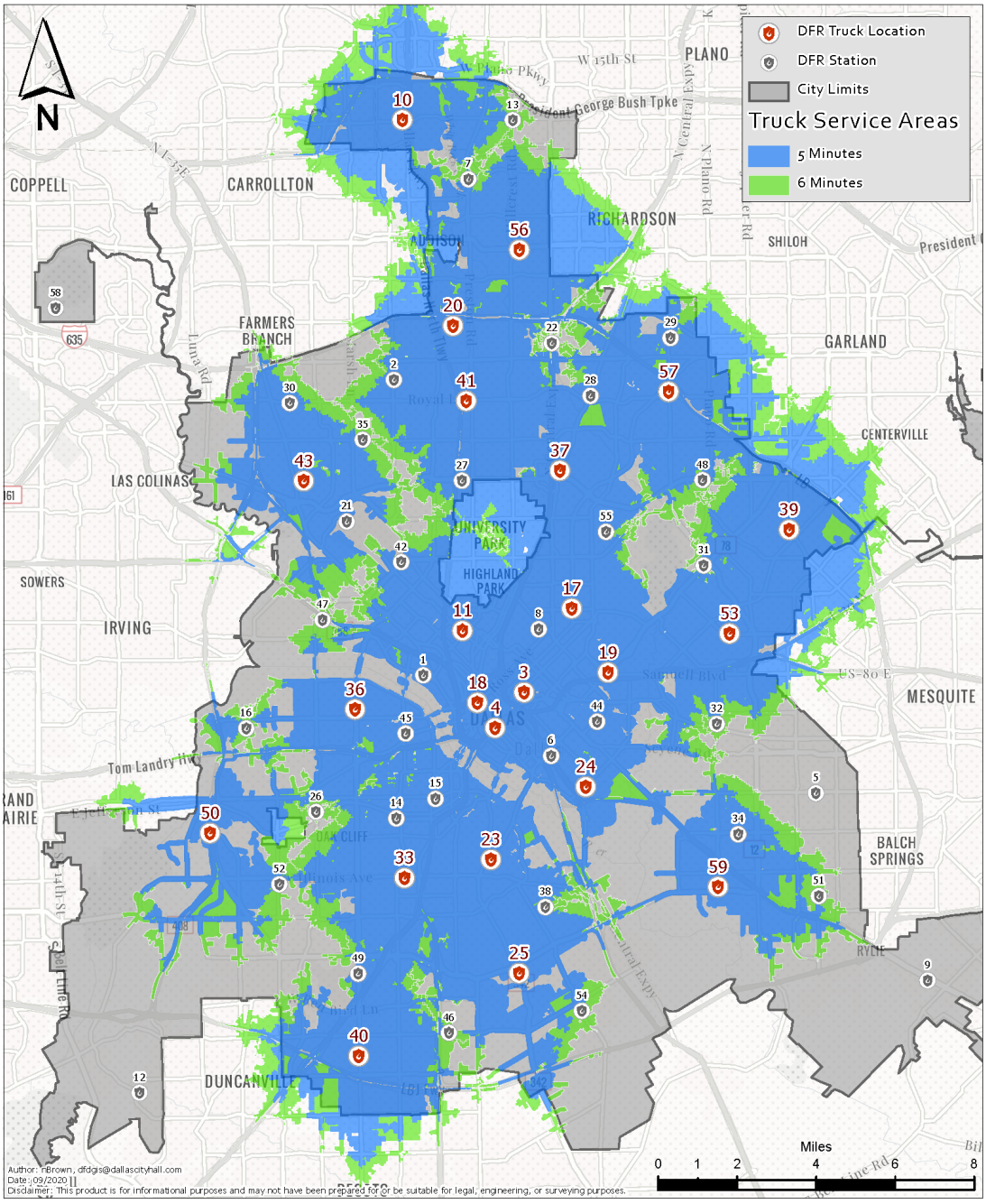
Conclusion

During the initial planning sessions for this study, there was an effort to restrain the analysis so that each fire district would have approximately the same number of truck companies. While great in theory, in order to provide true analysis based on response variables, GIS simply could not accommodate that request. Confining truck companies to battalion districts creates arbitrary constraints that fail to meet the mission objective of increasing response efficiency and reducing response times.

As such, the above recommendations are the most statistically significant and are expected to provide an increase in truck response coverage and reduce overall response times.

Dallas Fire-Rescue

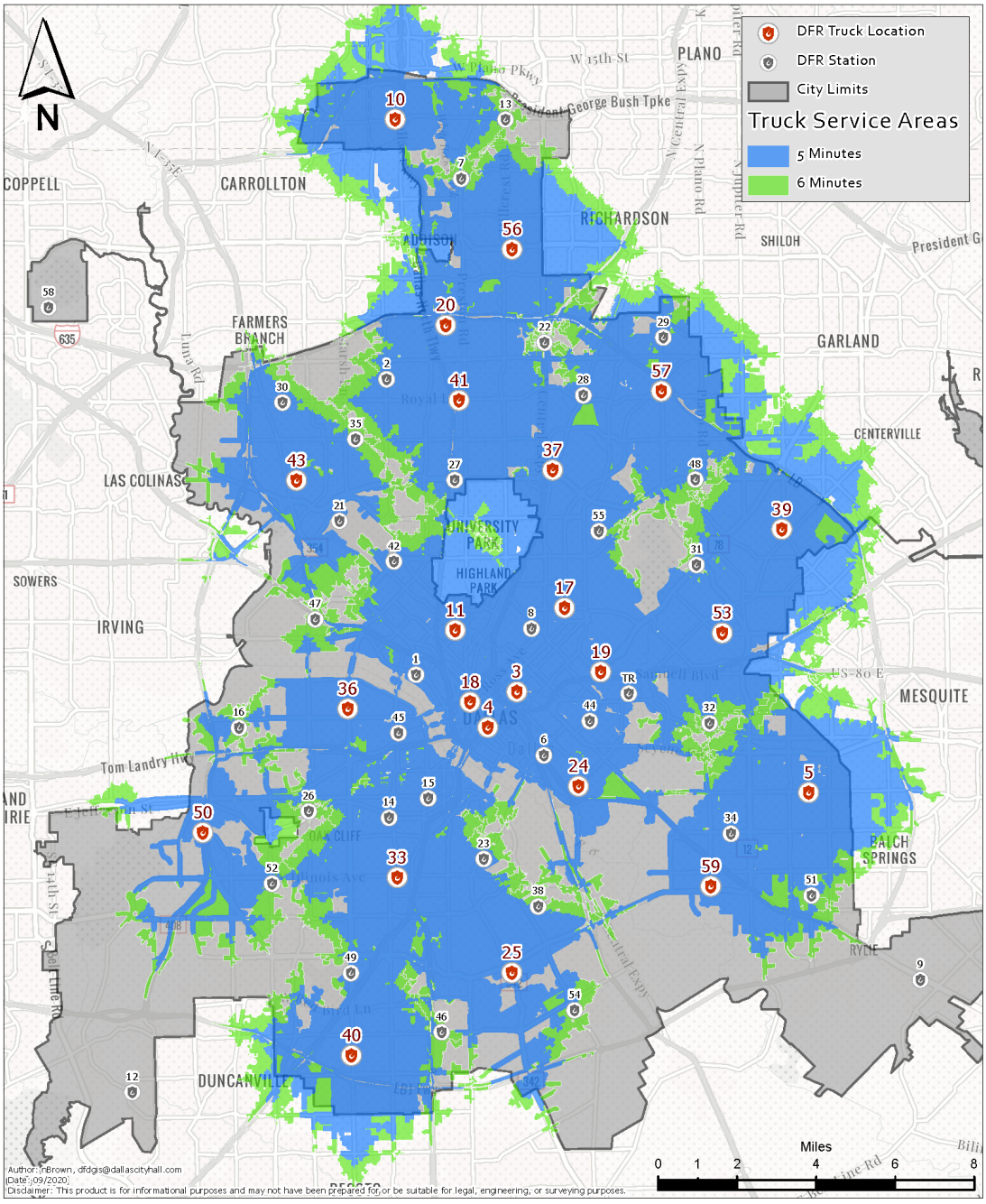
Current Truck Deployment



Author: nBrown, dfdgis@dallascityhall.com
Date: 09/2020
Disclaimer: This product is for informational purposes and may not have been prepared for or be suitable for legal, engineering, or surveying purposes.

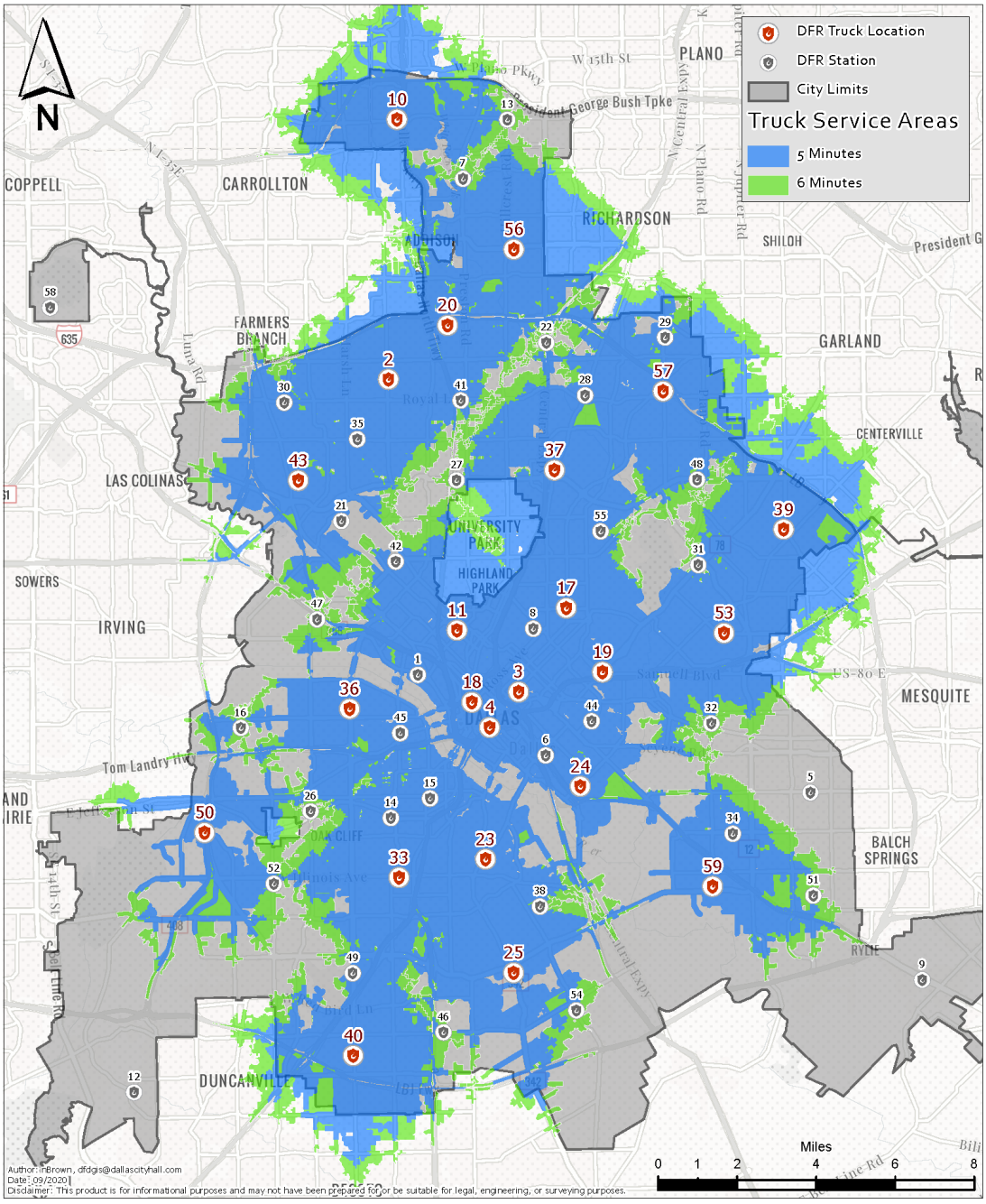
Dallas Fire-Rescue

Truck 23 to Station 05 Deployment



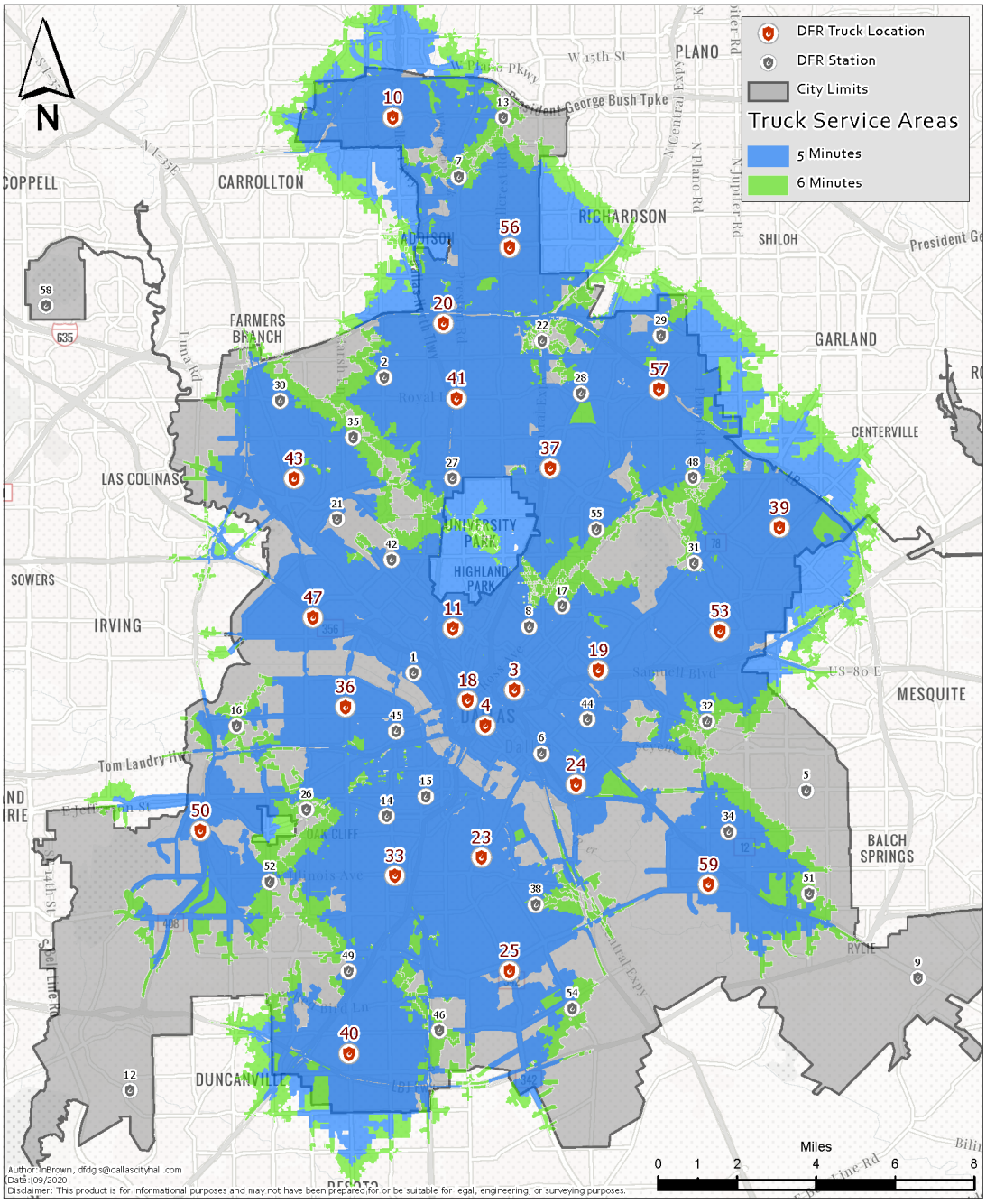
Dallas Fire-Rescue

Truck 41 to Station 02 Deployment



Dallas Fire-Rescue

Truck 17 to Station 47 Deployment



Truck Study Supplemental Information

Station 2

Drive Time: 5 minute radius

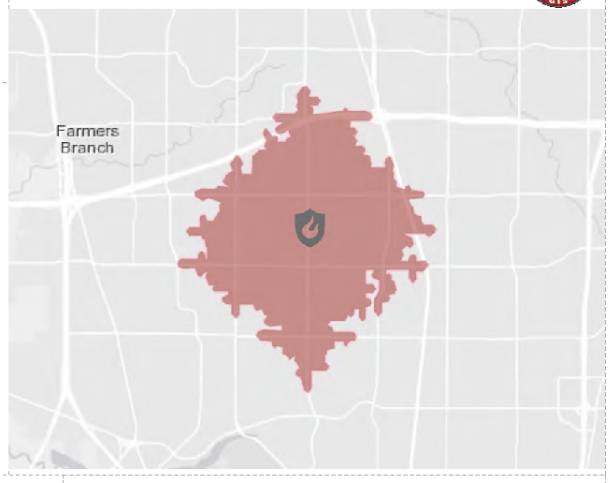
Race and Ethnicity

The largest group: White Alone (80.88)

The smallest group: Pacific Islander Alone (0.04)

Indicator	Value	Difference
White Alone	80.88	+14.20
Black Alone	4.31	-8.17
American Indian/Alaska Native Alone	0.50	-0.19
Asian Alone	4.55	-0.72
Pacific Islander Alone	0.04	-0.07
Other Race	6.89	-4.62
Two or More Races	2.83	-0.43
Hispanic Origin (Any Race)	21.68	-18.50

Bars show deviation from Texas



BUSINESS

689
Total Businesses

6,112
Total Employees

POPULATION & HOUSING

23,169
Population

2.6
Average Household Size

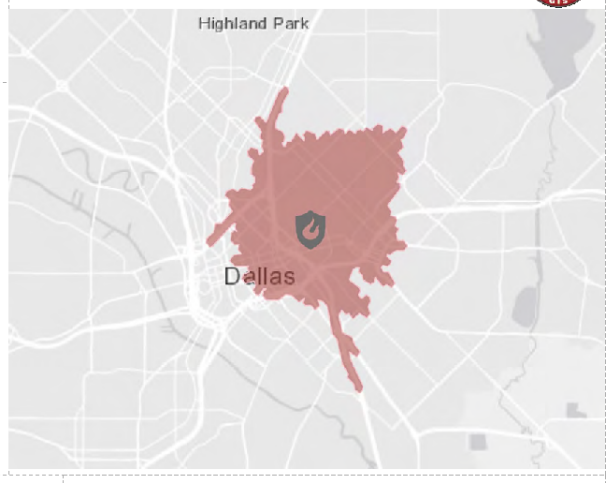
9,385
2020 Total Housing Units (Esri)

This infographic contains data provided by American Community Survey (ACS), Esri, Esri and Infogroup. The vintage of the data is 2014-2018, 2020, 2025.

Truck Study Supplemental Information

Station 3

Drive Time: 5 minute radius



Race and Ethnicity

The largest group: White Alone (51.79)

The smallest group: Pacific Islander Alone (0.06)

Indicator	Value	Difference
White Alone	51.79	-14.89
Black Alone	24.15	+11.67
American Indian/Alaska Native Alone	0.63	-0.06
Asian Alone	5.89	+0.62
Pacific Islander Alone	0.06	-0.05
Other Race	13.97	+2.46
Two or More Races	3.51	+0.25
Hispanic Origin (Any Race)	32.95	-7.23

Bars show deviation from Texas

BUSINESS

5,047
Total Businesses

80,397
Total Employees

POPULATION & HOUSING

44,564
Population

1.9
Average Household Size

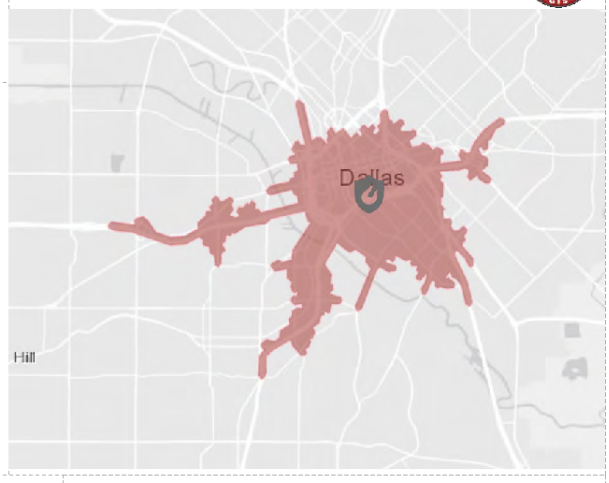
26,570
2020 Total Housing Units (Esri)

This infographic contains data provided by American Community Survey (ACS), Esri, Esri and Infogroup. The vintage of the data is 2014-2018, 2020, 2025.

Truck Study Supplemental Information

Station 4

Drive Time: 5 minute radius



Race and Ethnicity

The largest group: White Alone (50.13)

The smallest group: Pacific Islander Alone (0.09)

Indicator	Value	Difference
White Alone	50.13	-16.55
Black Alone	29.47	+16.99
American Indian/Alaska Native Alone	0.85	+0.16
Asian Alone	3.55	-1.72
Pacific Islander Alone	0.09	-0.02
Other Race	12.49	+0.98
Two or More Races	3.41	+0.15
Hispanic Origin (Any Race)	31.87	-8.31

Bars show deviation from Texas

BUSINESS

4,982
Total Businesses

79,157
Total Employees

POPULATION & HOUSING

27,840
Population

1.8
Average Household Size

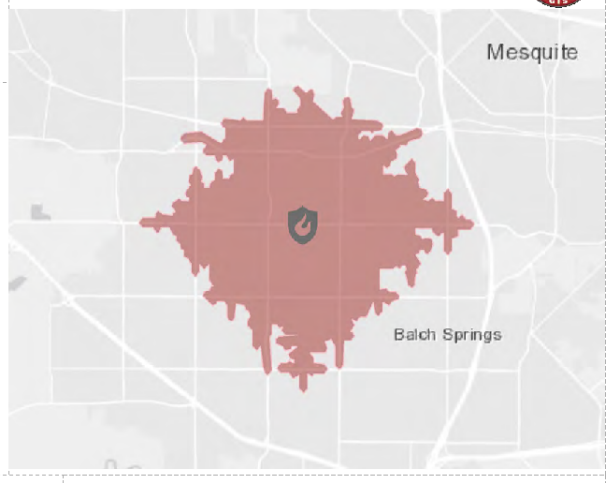
15,453
2020 Total Housing Units (Esri)

This infographic contains data provided by American Community Survey (ACS), Esri, Esri and Infogroup. The vintage of the data is 2014-2018, 2020, 2025.

Truck Study Supplemental Information

Station 5

Drive Time: 5 minute radius



Race and Ethnicity

The largest group: Hispanic Origin (Any Race) (60.71)

The smallest group: Pacific Islander Alone (0.01)

Indicator	Value	Difference
White Alone	37.05	-29.63
Black Alone	32.12	+19.64
American Indian/Alaska Native Alone	0.63	-0.06
Asian Alone	0.61	-4.66
Pacific Islander Alone	0.01	-0.10
Other Race	26.81	+15.30
Two or More Races	2.78	-0.48
Hispanic Origin (Any Race)	60.71	+20.53

Bars show deviation from Texas

BUSINESS

717
Total Businesses

7,554
Total Employees

POPULATION & HOUSING

54,427
Population

3.6
Average Household Size

16,366
2020 Total Housing Units (Esri)

This infographic contains data provided by American Community Survey (ACS), Esri, Esri and Infogroup. The vintage of the data is 2014-2018, 2020, 2025.

Truck Study Supplemental Information

Station 10

Drive Time: 5 minute radius

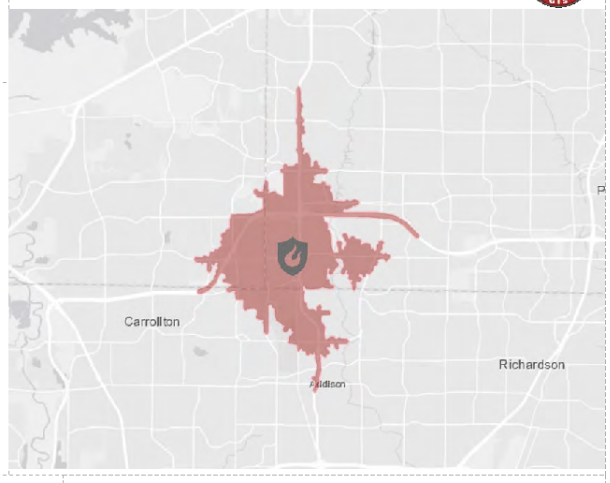
Race and Ethnicity

The largest group: White Alone (50.70)

The smallest group: Pacific Islander Alone (0.05)

Indicator	Value	Difference
White Alone	50.70	-15.98
Black Alone	24.56	+12.08
American Indian/Alaska Native Alone	0.45	-0.24
Asian Alone	11.70	+6.43
Pacific Islander Alone	0.05	-0.06
Other Race	8.71	-2.80
Two or More Races	3.83	+0.57
Hispanic Origin (Any Race)	19.16	-21.02

Bars show deviation from Texas



BUSINESS

3,774
Total Businesses

40,096
Total Employees

POPULATION & HOUSING

65,322
Population

1.9
Average Household Size

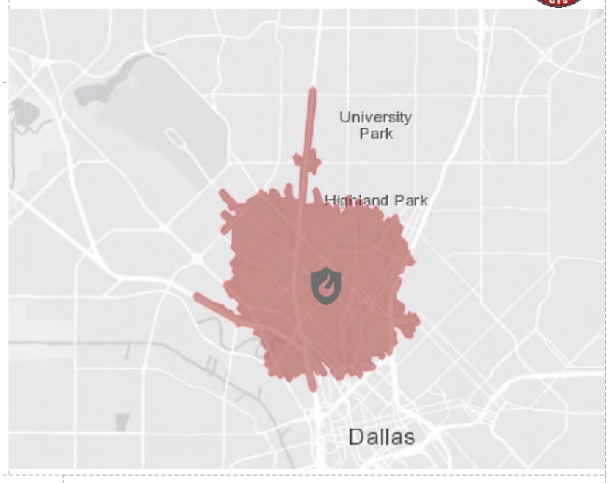
39,058
2020 Total Housing Units (Esri)

This infographic contains data provided by American Community Survey (ACS), Esri, Esri and Infogroup. The vintage of the data is 2014-2018, 2020, 2025.

Truck Study Supplemental Information

Station 11

Drive Time: 5 minute radius



Race and Ethnicity

The largest group: White Alone (68.57)

The smallest group: Pacific Islander Alone (0.06)

Indicator	Value	Difference
White Alone	68.57	+1.89
Black Alone	9.82	-2.66
American Indian/Alaska Native Alone	0.47	-0.22
Asian Alone	7.34	+2.07
Pacific Islander Alone	0.06	-0.05
Other Race	10.80	-0.71
Two or More Races	2.94	-0.32
Hispanic Origin (Any Race)	29.87	-10.31

Bars show deviation from Texas

BUSINESS

6,168
Total Businesses

73,538
Total Employees

POPULATION & HOUSING

72,369
Population

1.7
Average Household Size

47,139
2020 Total Housing Units (Esri)

This infographic contains data provided by American Community Survey (ACS), Esri, Esri and Infogroup. The vintage of the data is 2014-2018, 2020, 2025.

Truck Study Supplemental Information

Station 17

Drive Time: 5 minute radius

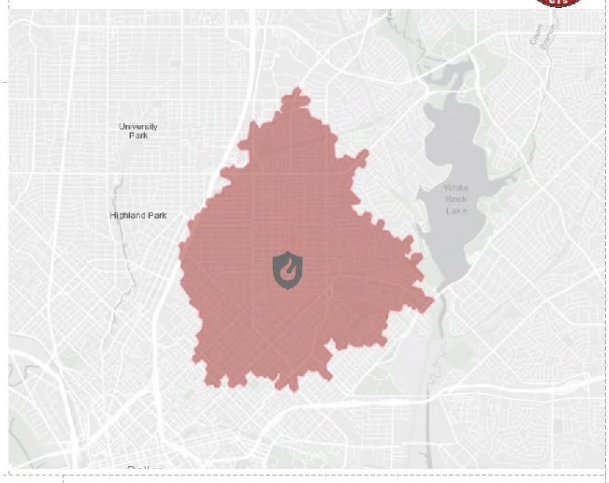
Race and Ethnicity

The largest group: White Alone (68.91)

The smallest group: Pacific Islander Alone (0.07)

Indicator	Value	Difference
White Alone	68.91	+2.23
Black Alone	6.87	-5.61
American Indian/Alaska Native Alone	0.71	+0.02
Asian Alone	3.98	-1.29
Pacific Islander Alone	0.07	-0.04
Other Race	16.17	+4.66
Two or More Races	3.29	+0.03
Hispanic Origin (Any Race)	37.72	-2.46

Bars show deviation from Texas



BUSINESS

2,226
Total Businesses

17,603
Total Employees

POPULATION & HOUSING

68,198
Population

2.1
Average Household Size

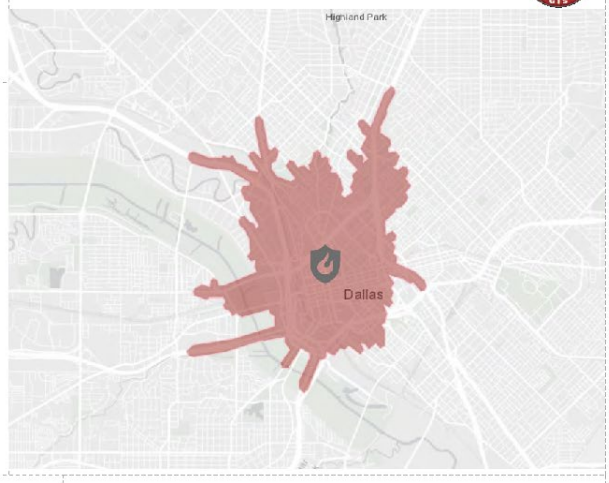
36,221
2020 Total Housing Units (Esri)

This infographic contains data provided by American Community Survey (ACS), Esri, Esri and Infogroup. The vintage of the data is 2014-2018, 2020, 2025.

Truck Study Supplemental Information

Station 18

Drive Time: 5 minute radius



Race and Ethnicity

The largest group: White Alone (60.85)

The smallest group: Pacific Islander Alone (0.09)

Indicator	Value	Difference
White Alone	60.85	-5.83
Black Alone	27.23	+14.75
American Indian/Alaska Native Alone	0.46	-0.23
Asian Alone	5.08	-0.19
Pacific Islander Alone	0.09	-0.02
Other Race	3.90	-7.61
Two or More Races	2.39	-0.87
Hispanic Origin (Any Race)	17.33	-22.85

Bars show deviation from Texas

BUSINESS

6,892
Total Businesses

116,189
Total Employees

POPULATION & HOUSING

47,880
Population

1.7
Average Household Size

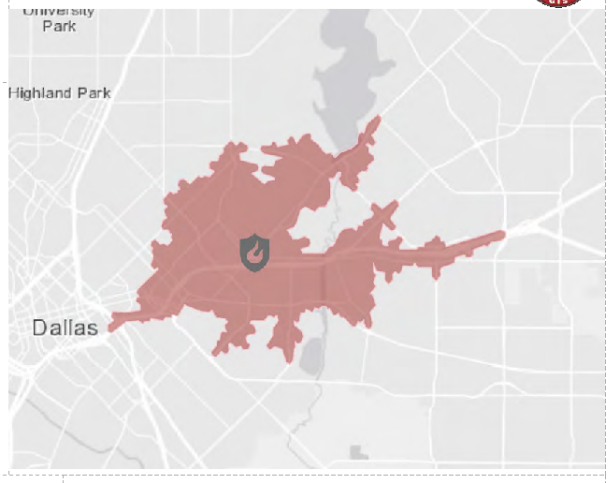
26,631
2020 Total Housing Units (Esri)

This infographic contains data provided by American Community Survey (ACS), Esri, Esri and Infogroup. The vintage of the data is 2014-2018, 2020, 2025.

Truck Study Supplemental Information

Station 19

Drive Time: 5 minute radius



Race and Ethnicity

The largest group: Hispanic Origin (Any Race) (55.83)

The smallest group: Pacific Islander Alone (0.05)

Indicator	Value	Difference
White Alone	48.20	-18.48
Black Alone	18.23	+5.75
American Indian/Alaska Native Alone	0.75	+0.06
Asian Alone	1.75	-3.52
Pacific Islander Alone	0.05	-0.06
Other Race	27.46	+15.95
Two or More Races	3.55	+0.29
Hispanic Origin (Any Race)	55.83	+15.65

Bars show deviation from Texas

BUSINESS

1,544
Total Businesses

13,691
Total Employees

POPULATION & HOUSING

41,845
Population

2.7
Average Household Size

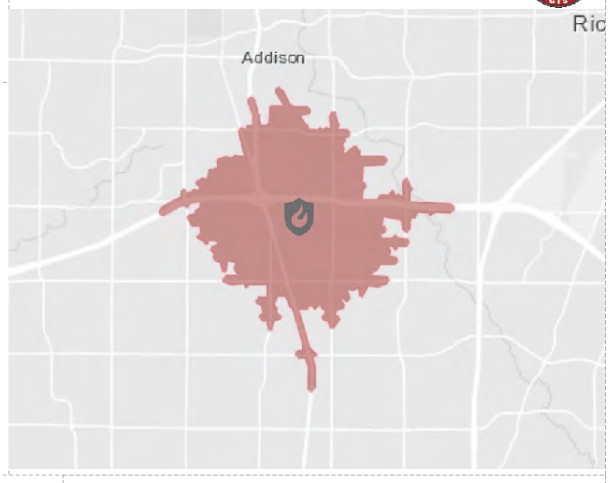
17,737
2020 Total Housing Units (Esri)

This infographic contains data provided by American Community Survey (ACS), Esri, Esri and Infogroup. The vintage of the data is 2014-2018, 2020, 2025.

Truck Study Supplemental Information

Station 20

Drive Time: 5 minute radius



Race and Ethnicity

The largest group: White Alone (59.92)

The smallest group: Pacific Islander Alone (0.09)

Indicator	Value	Difference
White Alone	59.92	-6.76
Black Alone	12.82	+0.34
American Indian/Alaska Native Alone	0.52	-0.17
Asian Alone	6.21	+0.94
Pacific Islander Alone	0.09	-0.02
Other Race	17.52	+6.01
Two or More Races	2.92	-0.34
Hispanic Origin (Any Race)	37.55	-2.63

Bars show deviation from Texas

BUSINESS

3,294
Total Businesses

42,537
Total Employees

POPULATION & HOUSING

28,889
Population

2.2
Average Household Size

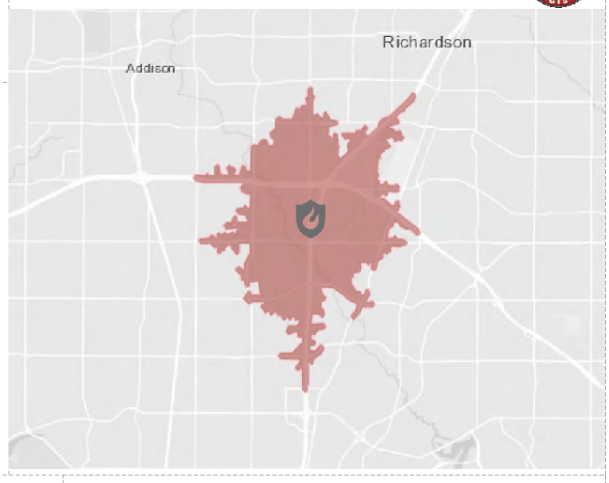
14,584
2020 Total Housing Units (Esri)

This infographic contains data provided by American Community Survey (ACS), Esri, Esri and Infogroup. The vintage of the data is 2014-2018, 2020, 2025.

Truck Study Supplemental Information

Station 22

Drive Time: 5 minute radius



Race and Ethnicity

The largest group: White Alone (51.63)

The smallest group: Pacific Islander Alone (0.07)

Indicator	Value	Difference
White Alone	51.63	-15.05
Black Alone	21.60	+9.12
American Indian/Alaska Native Alone	0.79	+0.10
Asian Alone	5.58	+0.31
Pacific Islander Alone	0.07	-0.04
Other Race	16.61	+5.10
Two or More Races	3.71	+0.45
Hispanic Origin (Any Race)	37.44	-2.74

Bars show deviation from Texas

BUSINESS

3,908
Total Businesses

58,410
Total Employees

POPULATION & HOUSING

46,269
Population

2.3
Average Household Size

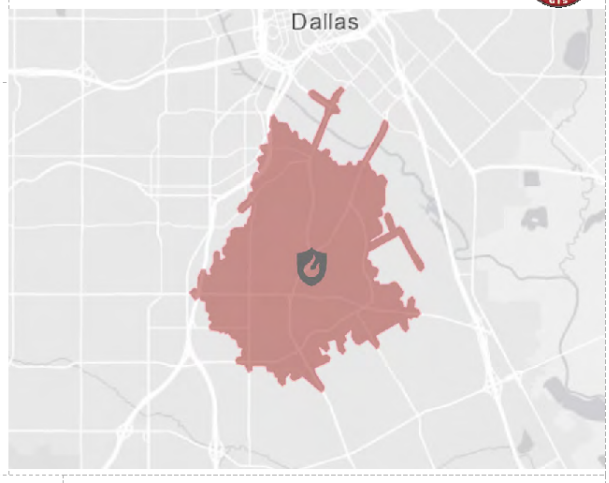
22,995
2020 Total Housing Units (Esri)

This infographic contains data provided by American Community Survey (ACS), Esri, Esri and Infogroup. The vintage of the data is 2014-2018, 2020, 2025.

Truck Study Supplemental Information

Station 23

Drive Time: 5 minute radius



Race and Ethnicity

The largest group: Black Alone (52.35)

The smallest group: Pacific Islander Alone (0.05)

Indicator	Value	Difference
White Alone	19.63	-47.05
Black Alone	52.35	+39.87
American Indian/Alaska Native Alone	0.42	-0.27
Asian Alone	0.21	-5.06
Pacific Islander Alone	0.05	-0.06
Other Race	25.04	+13.53
Two or More Races	2.30	-0.96
Hispanic Origin (Any Race)	45.70	+5.52

Bars show deviation from Texas

BUSINESS

662
Total Businesses

5,041
Total Employees

POPULATION & HOUSING

29,632
Population

3.1
Average Household Size

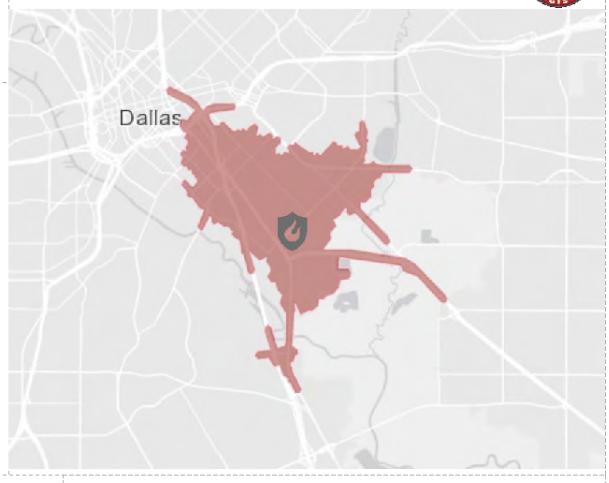
10,822
2020 Total Housing Units (Esri)

This infographic contains data provided by American Community Survey (ACS), Esri, Esri and Infogroup. The vintage of the data is 2014-2018, 2020, 2025.

Truck Study Supplemental Information

Station 24

Drive Time: 5 minute radius



Race and Ethnicity

The largest group: Black Alone (78.21)

The smallest group: Pacific Islander Alone (0.03)

Indicator	Value	Difference
White Alone	10.32	-56.36
Black Alone	78.21	+65.73
American Indian/Alaska Native Alone	0.46	-0.23
Asian Alone	0.48	-4.79
Pacific Islander Alone	0.03	-0.08
Other Race	8.61	-2.90
Two or More Races	1.88	-1.38
Hispanic Origin (Any Race)	16.63	-23.55

Bars show deviation from Texas

BUSINESS

828
Total Businesses

8,248
Total Employees

POPULATION & HOUSING

20,604
Population

2.5
Average Household Size

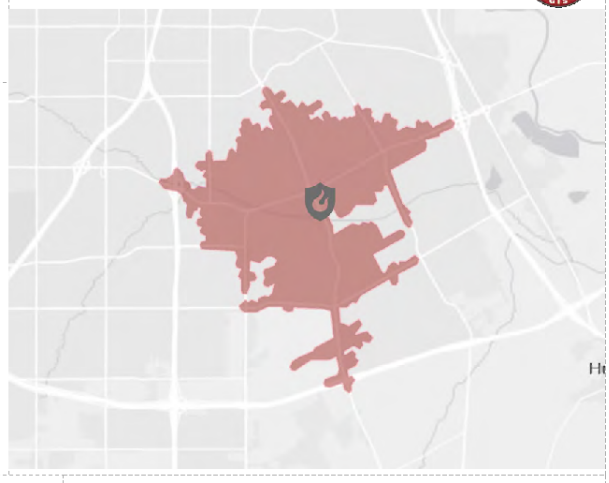
9,916
2020 Total Housing Units (Esri)

This infographic contains data provided by American Community Survey (ACS), Esri, Esri and Infogroup. The vintage of the data is 2014-2018, 2020, 2025.

Truck Study Supplemental Information

Station 25

Drive Time: 5 minute radius



Race and Ethnicity

The largest group: Black Alone (80.85)

The smallest group: Pacific Islander Alone (0.07)

Indicator	Value	Difference
White Alone	7.62	-59.06
Black Alone	80.85	+68.37
American Indian/Alaska Native Alone	0.26	-0.43
Asian Alone	0.08	-5.19
Pacific Islander Alone	0.07	-0.04
Other Race	9.57	-1.94
Two or More Races	1.55	-1.71
Hispanic Origin (Any Race)	17.05	-23.13

Bars show deviation from Texas

BUSINESS

486
Total Businesses

3,786
Total Employees

POPULATION & HOUSING

21,126
Population

2.9
Average Household Size

8,199
2020 Total Housing Units (Esri)

This infographic contains data provided by American Community Survey (ACS), Esri, Esri and Infogroup. The vintage of the data is 2014-2018, 2020, 2025.

Truck Study Supplemental Information

Station 32

Drive Time: 5 minute radius

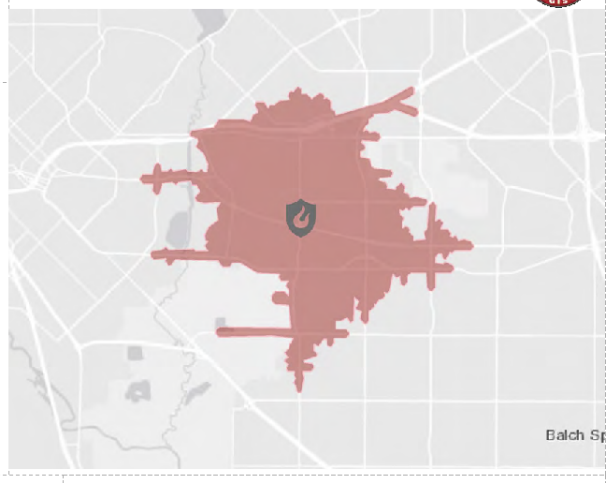
Race and Ethnicity

The largest group: Hispanic Origin (Any Race) (62.40)

The smallest group: Pacific Islander Alone (0.01)

Indicator	Value	Difference
White Alone	38.30	-28.38
Black Alone	27.23	+14.75
American Indian/Alaska Native Alone	0.65	-0.04
Asian Alone	1.06	-4.21
Pacific Islander Alone	0.01	-0.10
Other Race	29.53	+18.02
Two or More Races	3.22	-0.04
Hispanic Origin (Any Race)	62.40	+22.22

Bars show deviation from Texas



BUSINESS

1,009
Total Businesses

13,481
Total Employees

POPULATION & HOUSING

45,068
Population

3.4
Average Household Size

14,255
2020 Total Housing Units (Esri)

This infographic contains data provided by American Community Survey (ACS), Esri, Esri and Infogroup. The vintage of the data is 2014-2018, 2020, 2025.

Truck Study Supplemental Information

Station 33

Drive Time: 5 minute radius

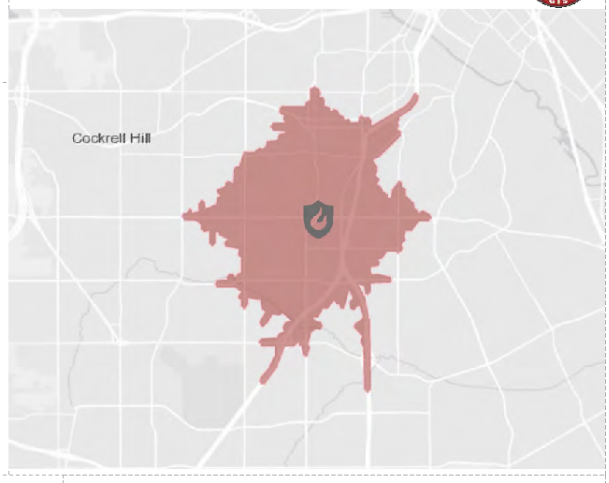
Race and Ethnicity

The largest group: Hispanic Origin (Any Race) (74.73)

The smallest group: Pacific Islander Alone (0.01)

Indicator	Value	Difference
White Alone	47.04	-19.64
Black Alone	18.00	+5.52
American Indian/Alaska Native Alone	0.65	-0.04
Asian Alone	0.88	-4.39
Pacific Islander Alone	0.01	-0.10
Other Race	30.57	+19.06
Two or More Races	2.85	-0.41
Hispanic Origin (Any Race)	74.73	+34.55

Bars show deviation from Texas



BUSINESS

1,256
Total Businesses

9,004
Total Employees

POPULATION & HOUSING

52,802
Population

3.6
Average Household Size

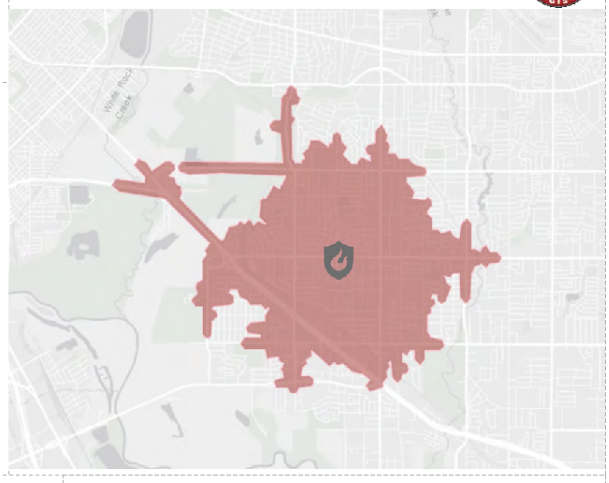
16,055
2020 Total Housing Units (Esri)

This infographic contains data provided by American Community Survey (ACS), Esri, Esri and Infogroup. The vintage of the data is 2014-2018, 2020, 2025.

Truck Study Supplemental Information

Station 34

Drive Time: 5 minute radius



Race and Ethnicity

The largest group: Hispanic Origin (Any Race) (73.70)

The smallest group: Pacific Islander Alone (0.00)

Indicator	Value	Difference
White Alone	38.44	-28.24
Black Alone	21.09	+8.61
American Indian/Alaska Native Alone	1.00	+0.31
Asian Alone	0.28	-4.99
Pacific Islander Alone	0.00	-0.11
Other Race	36.20	+24.69
Two or More Races	2.99	-0.27
Hispanic Origin (Any Race)	73.70	+33.52

Bars show deviation from Texas

BUSINESS

658
Total Businesses

5,585
Total Employees

POPULATION & HOUSING

31,935
Population

4.0
Average Household Size

8,603
2020 Total Housing Units (Esri)

This infographic contains data provided by American Community Survey (ACS), Esri, Esri and Infogroup. The vintage of the data is 2014-2018, 2020, 2025.

Truck Study Supplemental Information

Station 36

Drive Time: 5 minute radius

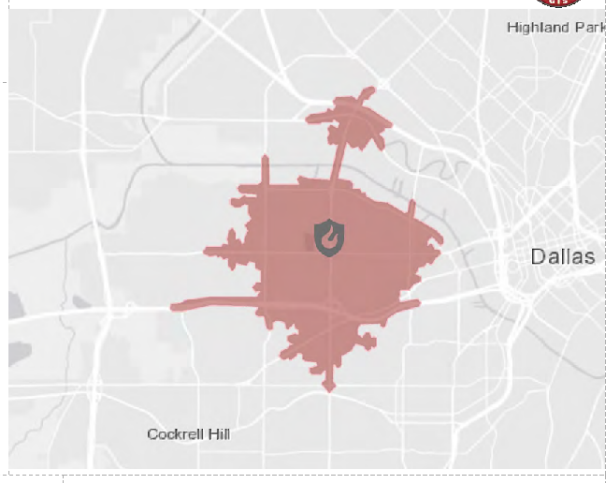
Race and Ethnicity

The largest group: Hispanic Origin (Any Race) (61.61)

The smallest group: Pacific Islander Alone (0.09)

Indicator	Value	Difference
White Alone	39.06	-27.62
Black Alone	30.75	+18.27
American Indian/Alaska Native Alone	0.79	+0.10
Asian Alone	1.41	-3.86
Pacific Islander Alone	0.09	-0.02
Other Race	25.18	+13.67
Two or More Races	2.73	-0.53
Hispanic Origin (Any Race)	61.61	+21.43

Bars show deviation from Texas



BUSINESS

1,056
Total Businesses

15,424
Total Employees

POPULATION & HOUSING

27,627
Population

3.2
Average Household Size

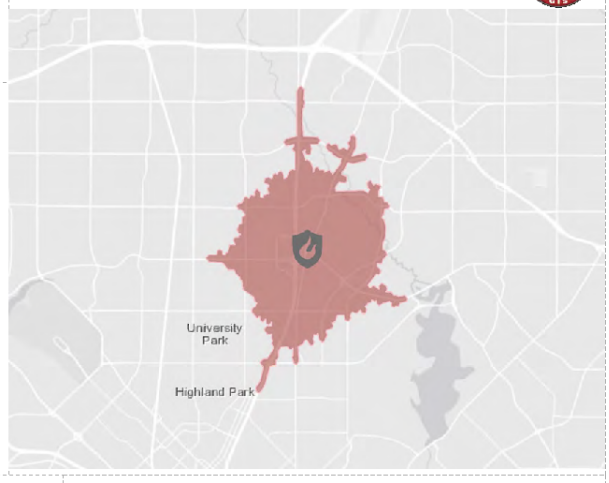
9,586
2020 Total Housing Units (Esri)

This infographic contains data provided by American Community Survey (ACS), Esri, Esri and Infogroup. The vintage of the data is 2014-2018, 2020, 2025.

Truck Study Supplemental Information

Station 37

Drive Time: 5 minute radius



Race and Ethnicity

The largest group: White Alone (58.44)

The smallest group: Pacific Islander Alone (0.03)

Indicator	Value	Difference
White Alone	58.44	-8.24
Black Alone	13.22	+0.74
American Indian/Alaska Native Alone	0.60	-0.09
Asian Alone	8.57	+3.30
Pacific Islander Alone	0.03	-0.08
Other Race	15.88	+4.37
Two or More Races	3.26	0
Hispanic Origin (Any Race)	35.19	-4.99

Bars show deviation from Texas

BUSINESS

4,347
Total Businesses

52,003
Total Employees

POPULATION & HOUSING

70,435
Population

2.2
Average Household Size

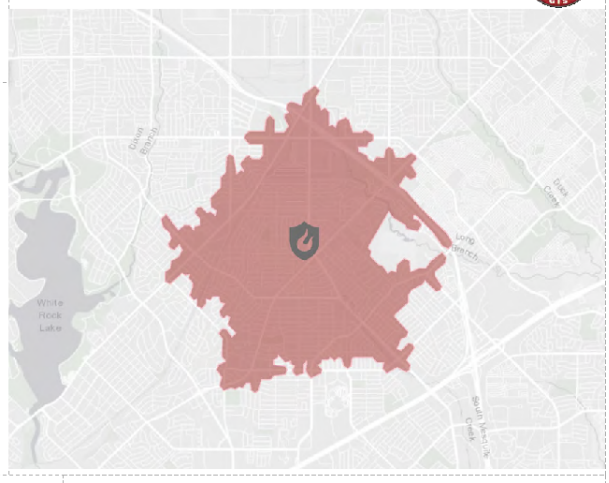
36,879
2020 Total Housing Units (Esri)

This infographic contains data provided by American Community Survey (ACS), Esri, Esri and Infogroup. The vintage of the data is 2014-2018, 2020, 2025.

Truck Study Supplemental Information

Station 39

Drive Time: 5 minute radius



Race and Ethnicity

The largest group: Hispanic Origin (Any Race) (61.00)

The smallest group: Pacific Islander Alone (0.09)

Indicator	Value	Difference
White Alone	52.48	-14.20
Black Alone	13.13	+0.65
American Indian/Alaska Native Alone	0.79	+0.10
Asian Alone	3.89	-1.38
Pacific Islander Alone	0.09	-0.02
Other Race	25.83	+14.32
Two or More Races	3.79	+0.53
Hispanic Origin (Any Race)	61.00	+20.82

Bars show deviation from Texas

BUSINESS

1,036
Total Businesses

8,752
Total Employees

POPULATION & HOUSING

42,803
Population

3.1
Average Household Size

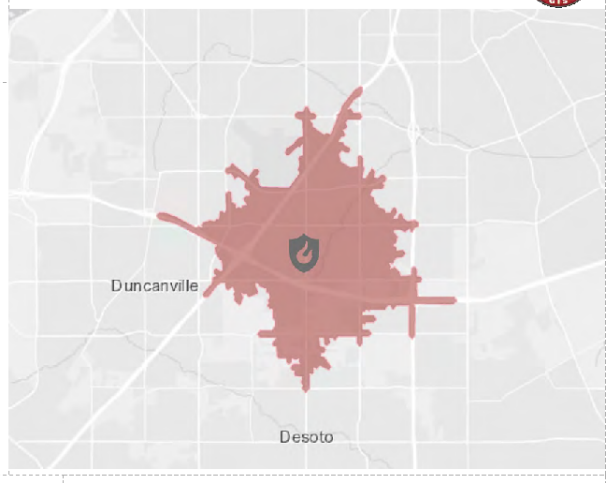
15,176
2020 Total Housing Units (Esri)

This infographic contains data provided by American Community Survey (ACS), Esri, Esri and Infogroup. The vintage of the data is 2014-2018, 2020, 2025.

Truck Study Supplemental Information

Station 40

Drive Time: 5 minute radius



Race and Ethnicity

The largest group: Black Alone (79.54)

The smallest group: Pacific Islander Alone (0.07)

Indicator	Value	Difference
White Alone	9.24	-57.44
Black Alone	79.54	+67.06
American Indian/Alaska Native Alone	0.28	-0.41
Asian Alone	0.25	-5.02
Pacific Islander Alone	0.07	-0.04
Other Race	8.47	-3.04
Two or More Races	2.14	-1.12
Hispanic Origin (Any Race)	16.48	-23.70

Bars show deviation from Texas

BUSINESS

1,073
Total Businesses

13,246
Total Employees

POPULATION & HOUSING

29,173
Population

2.6
Average Household Size

12,429
2020 Total Housing Units (Esri)

This infographic contains data provided by American Community Survey (ACS), Esri, Esri and Infogroup. The vintage of the data is 2014-2018, 2020, 2025.

Truck Study Supplemental Information

Station 41

Drive Time: 5 minute radius

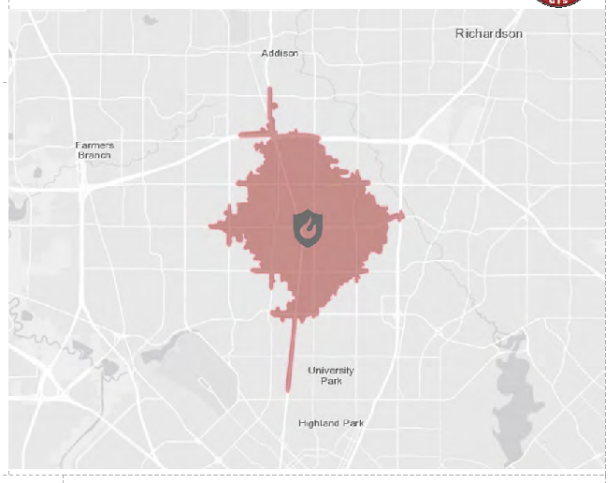
Race and Ethnicity

The largest group: White Alone (83.80)

The smallest group: Pacific Islander Alone (0.07)

Indicator	Value	Difference
White Alone	83.80	+17.12
Black Alone	4.25	-8.23
American Indian/Alaska Native Alone	0.39	-0.30
Asian Alone	5.18	-0.09
Pacific Islander Alone	0.07	-0.04
Other Race	3.95	-7.56
Two or More Races	2.35	-0.91
Hispanic Origin (Any Race)	13.42	-26.76

Bars show deviation from Texas



BUSINESS

2,197
Total Businesses

25,225
Total Employees

POPULATION & HOUSING

30,987
Population

2.4
Average Household Size

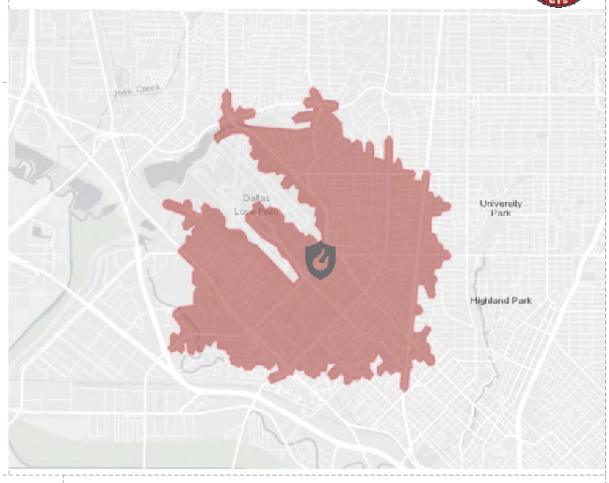
13,637
2020 Total Housing Units (Esri)

This infographic contains data provided by American Community Survey (ACS), Esri, Esri and Infogroup. The vintage of the data is 2014-2018, 2020, 2025.

Truck Study Supplemental Information

Station 42

Drive Time: 5 minute radius



Race and Ethnicity

The largest group: White Alone (60.26)

The smallest group: Pacific Islander Alone (0.04)

Indicator	Value	Difference
White Alone	60.26	-6.42
Black Alone	11.31	-1.17
American Indian/Alaska Native Alone	0.45	-0.24
Asian Alone	8.17	+2.90
Pacific Islander Alone	0.04	-0.07
Other Race	16.70	+5.19
Two or More Races	3.07	-0.19
Hispanic Origin (Any Race)	47.04	+6.86

Bars show deviation from Texas

BUSINESS

1,972
Total Businesses

30,777
Total Employees

POPULATION & HOUSING

42,615
Population

2.3
Average Household Size

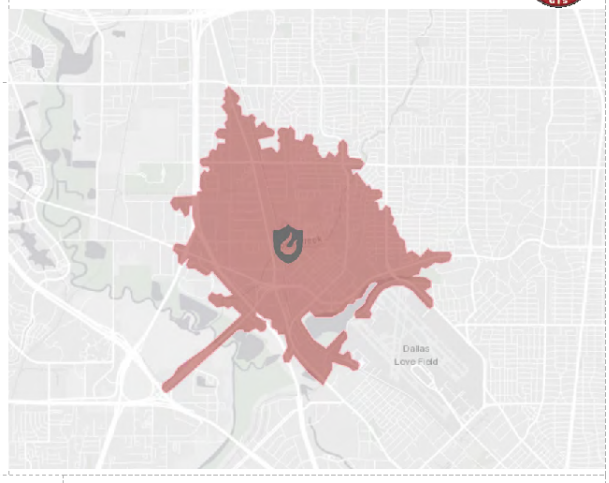
20,020
2020 Total Housing Units (Esri)

This infographic contains data provided by American Community Survey (ACS), Esri, Esri and Infogroup. The vintage of the data is 2014-2018, 2020, 2025.

Truck Study Supplemental Information

Station 43

Drive Time: 5 minute radius



Race and Ethnicity

The largest group: Hispanic Origin (Any Race) (91.34)

The smallest group: Pacific Islander Alone (0.03)

Indicator	Value	Difference
White Alone	49.17	-17.51
Black Alone	3.50	-8.98
American Indian/Alaska Native Alone	0.91	+0.22
Asian Alone	0.45	-4.82
Pacific Islander Alone	0.03	-0.08
Other Race	42.74	+31.23
Two or More Races	3.19	-0.07
Hispanic Origin (Any Race)	91.34	+51.16

Bars show deviation from Texas

BUSINESS

2,086
Total Businesses

20,396
Total Employees

POPULATION & HOUSING

35,874
Population

3.4
Average Household Size

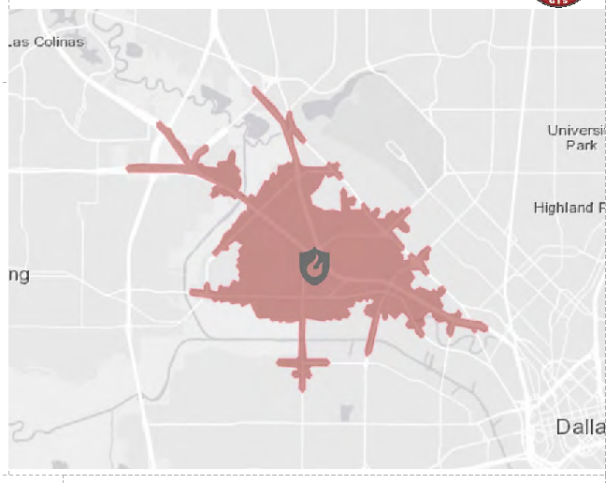
12,113
2020 Total Housing Units (Esri)

This infographic contains data provided by American Community Survey (ACS), Esri, Esri and Infogroup. The vintage of the data is 2014-2018, 2020, 2025.

Truck Study Supplemental Information

Station 47

Drive Time: 5 minute radius



Race and Ethnicity

The largest group: Black Alone (48.44)

The smallest group: Pacific Islander Alone (0.04)

Indicator	Value	Difference
White Alone	30.93	-35.75
Black Alone	48.44	+35.96
American Indian/Alaska Native Alone	0.74	+0.05
Asian Alone	1.97	-3.30
Pacific Islander Alone	0.04	-0.07
Other Race	14.94	+3.43
Two or More Races	2.95	-0.31
Hispanic Origin (Any Race)	40.13	-0.05

Bars show deviation from Texas

BUSINESS

2,598
Total Businesses

41,925
Total Employees

POPULATION & HOUSING

2,846
Population

2.5
Average Household Size

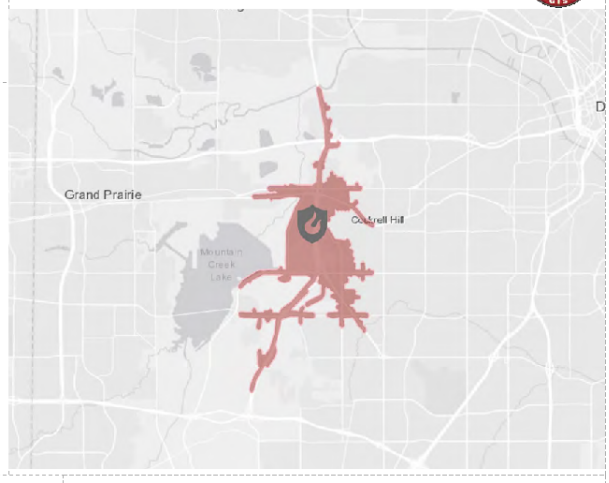
1,174
2020 Total Housing Units (Esri)

This infographic contains data provided by American Community Survey (ACS), Esri, Esri and Infogroup. The vintage of the data is 2014-2018, 2020, 2025.

Truck Study Supplemental Information

Station 50

Drive Time: 5 minute radius



Race and Ethnicity

The largest group: Hispanic Origin (Any Race) (74.86)

The smallest group: Pacific Islander Alone (0.13)

Indicator	Value	Difference
White Alone	47.75	-18.93
Black Alone	16.70	+4.22
American Indian/Alaska Native Alone	0.83	+0.14
Asian Alone	2.17	-3.10
Pacific Islander Alone	0.13	+0.02
Other Race	29.48	+17.97
Two or More Races	2.94	-0.32
Hispanic Origin (Any Race)	74.86	+34.68

Bars show deviation from Texas

BUSINESS

165
Total Businesses

3,566
Total Employees

POPULATION & HOUSING

12,904
Population

3.8
Average Household Size

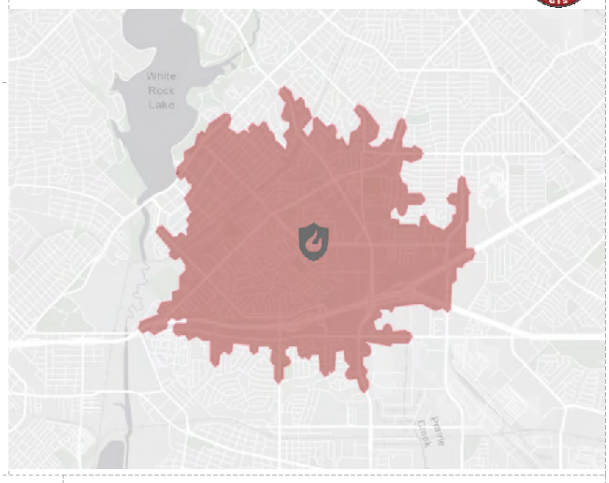
3,550
2020 Total Housing Units (Esri)

This infographic contains data provided by American Community Survey (ACS), Esri, Esri and Infogroup. The vintage of the data is 2014-2018, 2020, 2025.

Truck Study Supplemental Information

Station 53

Drive Time: 5 minute radius



Race and Ethnicity

The largest group: White Alone (46.21)

The smallest group: Pacific Islander Alone (0.04)

Indicator	Value	Difference
White Alone	46.21	-20.47
Black Alone	29.39	+16.91
American Indian/Alaska Native Alone	0.67	-0.02
Asian Alone	2.24	-3.03
Pacific Islander Alone	0.04	-0.07
Other Race	18.46	+6.95
Two or More Races	3.00	-0.26
Hispanic Origin (Any Race)	40.89	+0.71

Bars show deviation from Texas

BUSINESS

906
Total Businesses

7,578
Total Employees

POPULATION & HOUSING

31,323
Population

2.6
Average Household Size

13,604
2020 Total Housing Units (Esri)

This infographic contains data provided by American Community Survey (ACS), Esri, Esri and Infogroup. The vintage of the data is 2014-2018, 2020, 2025.

Truck Study Supplemental Information

Station 54

Drive Time: 5 minute radius

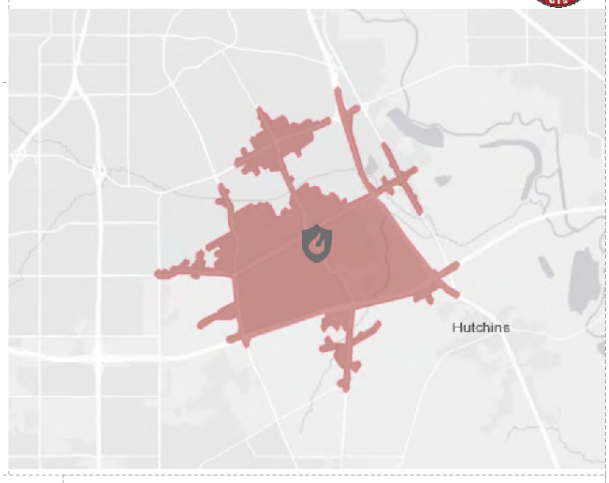
Race and Ethnicity

The largest group: Black Alone (90.33)

The smallest group: Pacific Islander Alone (0.04)

Indicator	Value	Difference
White Alone	3.54	-63.14
Black Alone	90.33	+77.85
American Indian/Alaska Native Alone	0.30	-0.39
Asian Alone	0.19	-5.08
Pacific Islander Alone	0.04	-0.07
Other Race	4.51	-7.00
Two or More Races	1.08	-2.18
Hispanic Origin (Any Race)	8.09	-32.09

Bars show deviation from Texas



BUSINESS

258
Total Businesses

3,376
Total Employees

POPULATION & HOUSING

18,052
Population

2.9
Average Household Size

7,078
2020 Total Housing Units (Esri)

This infographic contains data provided by American Community Survey (ACS), Esri, Esri and Infogroup. The vintage of the data is 2014-2018, 2020, 2025.

Truck Study Supplemental Information

Station 56

Drive Time: 5 minute radius

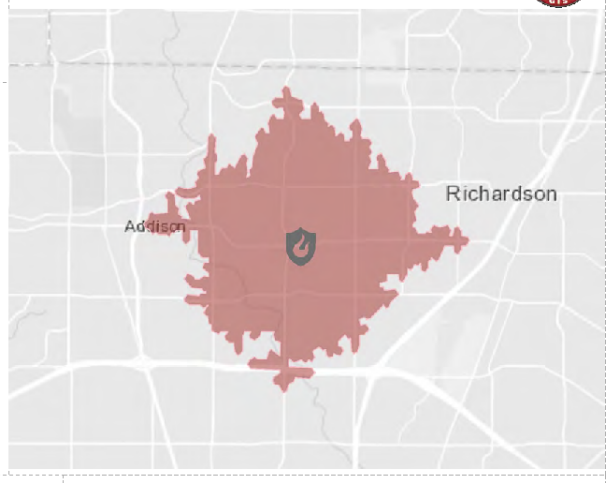
Race and Ethnicity

The largest group: White Alone (66.06)

The smallest group: Pacific Islander Alone (0.05)

Indicator	Value	Difference
White Alone	66.06	-0.62
Black Alone	10.67	-1.81
American Indian/Alaska Native Alone	0.77	+0.08
Asian Alone	5.07	-0.20
Pacific Islander Alone	0.05	-0.06
Other Race	13.78	+2.27
Two or More Races	3.60	+0.34
Hispanic Origin (Any Race)	33.01	-7.17

Bars show deviation from Texas



BUSINESS

1,490
Total Businesses

11,075
Total Employees

POPULATION & HOUSING

44,120
Population

2.6
Average Household Size

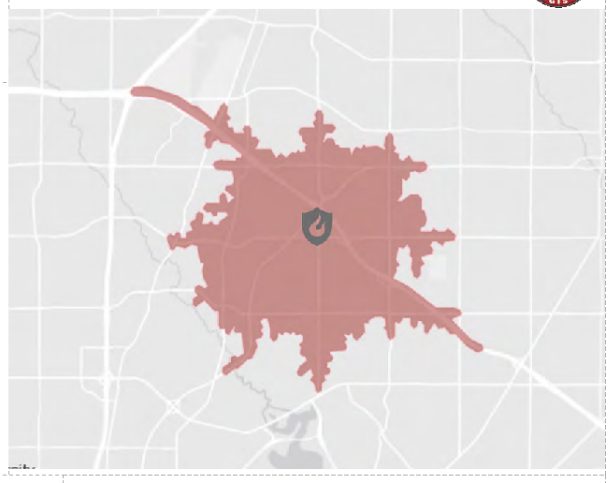
18,222
2020 Total Housing Units (Esri)

This infographic contains data provided by American Community Survey (ACS), Esri, Esri and Infogroup. The vintage of the data is 2014-2018, 2020, 2025.

Truck Study Supplemental Information

Station 57

Drive Time: 5 minute radius



Race and Ethnicity

The largest group: White Alone (44.11)

The smallest group: Pacific Islander Alone (0.04)

Indicator	Value	Difference
White Alone	44.11	-22.57
Black Alone	33.66	+21.18
American Indian/Alaska Native Alone	0.44	-0.25
Asian Alone	4.61	-0.66
Pacific Islander Alone	0.04	-0.07
Other Race	13.83	+2.32
Two or More Races	3.30	+0.04
Hispanic Origin (Any Race)	30.68	-9.50

Bars show deviation from Texas

BUSINESS

2,281
Total Businesses

21,297
Total Employees

POPULATION & HOUSING

61,367
Population

2.5
Average Household Size

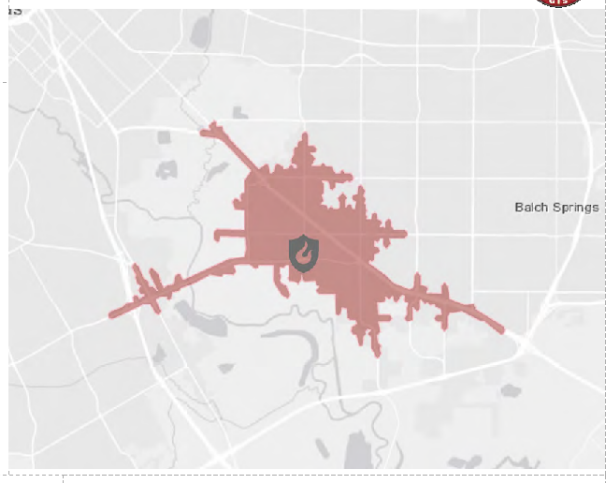
28,835
2020 Total Housing Units (Esri)

This infographic contains data provided by American Community Survey (ACS), Esri, Esri and Infogroup. The vintage of the data is 2014-2018, 2020, 2025.

Truck Study Supplemental Information

Station 59

Drive Time: 5 minute radius



Race and Ethnicity

The largest group: Hispanic Origin (Any Race) (61.29)

The smallest group: Pacific Islander Alone (0.00)

Indicator	Value	Difference
White Alone	30.51	-36.17
Black Alone	34.78	+22.30
American Indian/Alaska Native Alone	0.73	+0.04
Asian Alone	0.22	-5.05
Pacific Islander Alone	0.00	-0.11
Other Race	31.39	+19.88
Two or More Races	2.36	-0.90
Hispanic Origin (Any Race)	61.29	+21.11

Bars show deviation from Texas

BUSINESS

372
Total Businesses

4,450
Total Employees

POPULATION & HOUSING

25,838
Population

3.7
Average Household Size

7,865
2020 Total Housing Units (Esri)

This infographic contains data provided by American Community Survey (ACS), Esri, Esri and Infogroup. The vintage of the data is 2014-2018, 2020, 2025.

Average Truck Company Travel Times into First Due Areas (2013-2019)

First Due Area	TR03	TR04	TR10	TR11	TR17	TR19	TR20	TR23	TR24	TR25	TR33	TR34	TR36	TR37	TR39	TR40	TR41	TR43	TR50	TR53	TR56	TR57	Grand Total
01	06:56	05:25		05:10	12:09	09:03		07:45	09:12		08:14		05:28	09:12			08:56	05:57	10:49	09:45			08:09
02			12:13	05:46	03:55	13:51	07:47						05:30	12:10			06:01	08:41			08:50		08:28
03	03:51	05:13	04:41	05:57	05:20	04:34	02:47	05:50	05:00	07:12	07:58	07:36	05:15	08:43		19:51	01:45	03:34	03:46	06:15			06:04
04	05:53	04:15		07:12	07:20	06:12	05:57	05:59	05:33	06:32	05:20	03:30	07:11	07:21	02:24	05:46	05:53	04:09	07:40	05:03	16:02		06:16
05	09:37	13:13				10:04		04:13	08:58	17:37		05:38			10:56					08:30			09:52
06	05:09	04:40		06:29	06:40	05:57	04:17	05:27	04:13	06:04	09:05	08:45	09:26	03:33				04:35		04:17			05:55
07			06:27			09:50	07:29						10:38				06:38				06:03		07:51
08	04:38	05:22		05:49	04:37	04:28	04:08	10:57	03:57	05:13	10:32	06:26	06:51	06:30			06:15	04:40	02:28	02:02	02:17	10:10	05:39
09	12:08					16:24			11:02	12:01		09:50	10:37						06:38	16:01			11:50
10			05:41	05:19	11:01	16:18	10:14							07:44			10:57	10:03		10:43	10:26	09:57	09:51
11	05:47	05:53		03:35	07:17	06:34	04:48	07:25	04:48	02:36	04:58		06:20	06:33	07:38		07:40	06:09		06:08	03:52		05:46
12								17:27		14:31	12:05					08:34			09:02			17:38	13:13
13			06:53				10:56										12:27	05:02			07:29	11:34	09:04
14	13:32	06:14		05:50		14:21		07:21			04:24		05:46						06:44				08:01
15	08:21	05:27		07:01	06:19	06:16	03:26	04:57	06:03	04:29	04:52		06:16			05:58		08:06	02:55	03:14		19:29	06:27
16	10:06	08:47		11:33	07:56			14:49		06:31	07:14	11:03	06:45					08:21	06:30	19:27			09:55
17	05:17	08:58		06:28	03:20	04:54		05:12	08:44	10:33	19:39	04:24	06:01	05:12			07:42			08:30		09:01	07:36
18	05:07	04:32	05:29	05:08	06:51	06:33	10:42	06:51	05:28	02:21	06:56	08:39	07:05	08:54			08:33	05:12	04:43	05:37		12:02	06:40
19	06:41	05:31		05:36	05:42	04:12	01:09	06:26	05:20	02:16	06:48	04:21	05:02	08:43	08:50		03:38	04:44	02:31	05:37	09:44	02:19	05:16
20			09:04	10:07	06:20	10:32	05:39	12:59	03:34					07:11	09:03		06:38	09:01	04:37		07:32	07:47	07:52
21	10:36	10:11		07:31		04:26	05:49						08:07	09:28			06:52	04:30			04:54		07:14
22	05:04		14:25	09:54	08:07	14:26	06:57	06:29	02:28	06:35		03:16	05:39	06:32	08:54	02:11	06:49	10:34	05:52	04:46	07:42	06:48	07:11
23	09:21	04:58		05:29	04:12	13:18		03:19	05:23	03:55	04:44		11:02			04:45				07:39			06:30
24	06:34	05:13		05:10	03:21	06:11		07:02	03:31	06:27	06:26	06:18	02:22					07:54		06:43			05:38
25	08:38	06:21		14:05		08:49		05:08	06:28	03:15	06:32	09:43				07:06	08:48		04:31				07:27
26	09:58	06:44		07:12	12:02	17:34		09:35	09:46		05:58		05:50			04:15		12:01	06:49				08:59
27	05:50	09:58	10:23	07:19	08:32	03:54	07:52	15:03	17:40	18:49	10:01		10:19	05:40		09:19	05:25	05:16		18:35	11:47	10:31	10:07
28	16:19		10:44	09:46	06:53	15:27	07:43			09:19	19:29		03:15	04:57	08:37		06:40	09:27		04:57	07:29	05:26	09:09
29		18:46	04:31	07:09	07:55	15:44	09:50		05:41					08:56	08:14		05:15			06:07	09:54	05:00	08:42
30	05:50	06:28	09:23	10:43	12:07	14:46	09:23	18:52	13:31	11:39	10:35		09:30	13:31		06:06	08:55	07:30	04:30		10:47	07:23	10:05
31		04:27			06:43	06:00		16:38	06:43		19:46	13:26		07:03	05:28					05:04		06:21	08:53
32	09:05	05:52		07:04	05:30	05:52		09:15	06:14	05:47	13:23	05:12	04:03		08:56	03:55	04:25			05:20		05:33	06:35
33	07:04	06:28		06:56	03:20	07:41		05:07	05:24	04:56	04:07	04:57	08:35	05:11		05:45			08:27				06:00
34	09:43	05:19			07:27	11:22		06:07	06:10	05:31	14:02	04:09		18:28		14:27		08:27		06:17			09:02
35	19:49	14:43		08:03	05:24	10:09	08:56					06:32	10:07	08:45			06:49	05:10					09:30
36	11:23	06:27		08:03			03:22		12:54		07:59		03:37	04:02			07:51	07:27	07:00				07:17
37	06:16	07:15	05:21	07:39	06:26	08:37	07:56	05:09	06:36		15:47	09:05	07:01	04:30	04:24		06:48	05:37		03:58	07:58	06:14	06:59
38	09:31	07:01			08:09	10:30		04:56	05:51	04:42	07:10	05:37				08:24	08:37			18:04			08:13
39					12:41	10:34	02:43		10:34		11:01			13:31	04:42		05:34		01:08	06:39		07:15	07:51
40	10:28	09:30				17:19		08:39	07:11	07:44	07:38		01:43			04:47			09:15				08:25
41	13:45		06:10	08:31	05:54	08:38	05:47			08:03			10:44	06:26			04:04	06:51		11:14	08:34	09:19	08:09
42	08:54	06:40		05:43	08:46	07:37	06:41	11:39	08:31	03:18			06:36	08:49			06:53	06:32			08:59		07:33
43	10:58	13:45	16:02	10:03	15:18	11:04	10:43	11:16	11:15		13:30		08:20	06:21	03:47		08:34	04:39	10:56		08:33		10:18
44	05:56	05:30			09:03	04:26		07:03	04:01	06:25		06:18	05:44			04:06	01:43	05:22	02:34	02:37			05:04
45	07:30	06:16		05:24	02:32	06:55		05:47	07:52		07:14		05:38	03:53			08:48		07:10				06:15
46	05:53	07:41		18:34				06:12	04:01	05:42	05:19			05:24		06:02		07:25	05:13				07:02
47	07:54	06:29	02:32	06:30	07:55	11:17	09:55	12:55	07:47		12:45		06:05	09:11			10:55	06:43	09:15			05:16	08:20
48	06:01		15:53		06:12	09:49	09:49	09:07	05:14				01:58	07:39	06:30		18:24	04:58		09:26	09:14	05:31	08:23
49		09:33		17:39		14:48		06:30	17:10	05:28	04:50					04:55			06:33				09:43
50	01:41	09:26		07:15		13:09		09:01		02:31	08:16		07:07			09:20		10:36	05:11				07:36
51	10:13					15:52	12:46	11:38	08:19	08:31		06:32				09:11				08:25			10:10
52		05:07		18:29	17:16	16:29		09:03		07:01	05:52		08:17			07:37			05:29				10:04
53	07:01	06:15		11:07	08:22	05:39			06:24	05:01	13:20	06:49		04:30	06:42			07:32		03:49		06:53	07:06
54	04:06	09:47				14:28		08:43	08:17	06:25	09:56	11:20				09:05	13:26	07:17	08:43		07:25		09:09
55	07:38	07:33		06:57	05:02	09:14			04:30		13:27	08:41		05:06	09:06		05:30	03:53		05:46		06:32	07:04
56	08:20		08:32	10:31	07:24	11:31	06:19							09:15	07:59	08:46	08:08	07:22			04:15	05:25	07:59
57	09:37		16:12	07:31	08:13	13:54	08:39		18:10	09:32	19:57			07:45	08:55		08:10	05:12	02:45	08:24	09:30	04:43	09:50
58			18:45				16:43										14:17	11:44					15:22

Travel times for trucks in their first due areas.

* All Travel Times Include the 1st & 2nd Truck to Structure Fires and People Pinned Responses

Percentage of Total Truck Responses into First Due Areas

First Due Ar	TR03	TR04	TR10	TR11	TR17	TR19	TR20	TR23	TR24	TR25	TR33	TR34	TR36	TR37	TR39	TR40	TR41	TR43	TR50	TR53	TR56	TR57	Grand Total
01	1.84%	6.28%	0.06%	18.81%	0.30%	0.45%	0.05%	0.29%	0.12%	0.01%	0.05%	0.01%	5.42%	0.01%	0.00%	0.00%	0.15%	0.26%	0.05%	0.04%	0.01%	0.00%	1.95%
02	0.19%	0.00%	0.12%	0.03%	0.04%	0.16%	4.98%	0.00%	0.01%	0.00%	0.02%	0.00%	0.01%	0.04%	0.00%	0.01%	5.29%	0.64%	0.00%	0.02%	0.46%	0.01%	0.53%
03	25.18%	6.89%	0.04%	1.67%	2.31%	7.29%	0.01%	0.30%	3.18%	0.03%	0.10%	0.01%	0.11%	0.04%	0.02%	0.01%	0.05%	0.02%	0.03%	0.13%	0.00%	0.02%	2.37%
04	11.66%	20.70%	0.01%	0.69%	0.45%	2.67%	0.03%	2.13%	3.40%	0.08%	1.70%	0.05%	0.58%	0.02%	0.05%	0.02%	0.09%	0.06%	0.11%	0.08%	0.03%	0.01%	2.59%
05	0.26%	0.03%	0.00%	0.00%	0.00%	0.43%	0.00%	0.01%	1.44%	0.02%	0.05%	9.28%	0.01%	0.00%	0.16%	0.00%	0.00%	0.00%	0.01%	4.46%	0.00%	0.01%	0.79%
06	7.34%	4.43%	0.00%	0.33%	0.49%	1.58%	0.01%	0.77%	18.32%	0.12%	0.10%	0.12%	0.03%	0.03%	0.00%	0.00%	0.03%	0.02%	0.02%	0.03%	0.00%	0.02%	1.58%
07	0.24%	0.01%	11.59%	0.01%	0.02%	0.18%	3.06%	0.00%	0.00%	0.01%	0.04%	0.01%	0.02%	0.01%	0.00%	0.01%	0.84%	0.02%	0.00%	0.01%	8.79%	0.04%	0.77%
08	4.75%	0.83%	0.00%	7.63%	21.85%	2.25%	0.01%	0.04%	0.54%	0.02%	0.05%	0.01%	0.09%	2.07%	0.00%	0.00%	0.10%	0.02%	0.01%	0.02%	0.03%	0.04%	1.42%
09	0.28%	0.02%	0.00%	0.00%	0.00%	0.15%	0.01%	0.01%	3.91%	0.21%	0.01%	11.43%	0.01%	0.00%	0.06%	0.01%	0.00%	0.01%	0.02%	0.25%	0.03%	0.01%	0.82%
10	0.23%	0.01%	72.82%	0.05%	0.06%	0.32%	3.23%	0.00%	0.01%	0.01%	0.02%	0.01%	0.01%	0.04%	0.00%	0.01%	0.48%	0.05%	0.02%	0.04%	4.38%	0.04%	2.29%
11	7.09%	3.06%	0.01%	36.29%	4.59%	1.19%	0.02%	0.12%	0.56%	0.01%	0.10%	0.02%	0.79%	0.33%	0.03%	0.00%	0.37%	0.05%	0.00%	0.01%	0.01%	0.00%	2.95%
12	0.11%	0.02%	0.00%	0.00%	0.00%	0.02%	0.00%	0.08%	0.00%	0.04%	0.50%	0.04%	0.05%	0.00%	0.00%	6.29%	0.00%	0.00%	15.68%	0.01%	0.00%	0.01%	1.00%
13	0.17%	0.00%	12.32%	0.01%	0.02%	0.09%	0.26%	0.00%	0.00%	0.00%	0.01%	0.00%	0.00%	0.02%	0.00%	0.01%	0.15%	0.01%	0.00%	0.00%	7.28%	0.04%	0.56%
14	0.14%	0.43%	0.00%	0.01%	0.00%	0.06%	0.00%	0.88%	0.03%	0.01%	3.56%	0.00%	1.62%	0.00%	0.00%	0.01%	0.01%	0.00%	0.13%	0.00%	0.00%	0.00%	0.34%
15	1.22%	7.61%	0.00%	0.21%	0.06%	0.25%	0.01%	7.97%	0.15%	0.13%	13.14%	0.07%	0.61%	0.01%	0.00%	0.07%	0.01%	0.04%	0.05%	0.01%	0.00%	0.01%	1.65%
16	0.34%	0.34%	0.00%	0.05%	0.02%	0.06%	0.01%	0.04%	0.04%	0.03%	0.25%	0.06%	8.72%	0.00%	0.00%	0.01%	0.00%	0.14%	22.31%	0.04%	0.00%	0.00%	1.24%
17	0.45%	0.04%	0.00%	0.14%	19.64%	1.43%	0.00%	0.03%	0.03%	0.01%	0.01%	0.04%	0.02%	0.49%	0.00%	0.00%	0.01%	0.00%	0.01%	0.05%	0.00%	0.01%	0.50%
18	16.89%	36.07%	0.04%	13.68%	1.70%	3.05%	0.06%	0.76%	1.58%	0.01%	0.36%	0.03%	2.42%	0.08%	0.02%	0.01%	0.15%	0.09%	0.02%	0.05%	0.03%	0.01%	4.65%
19	5.83%	0.79%	0.01%	0.12%	11.14%	46.55%	0.01%	0.15%	0.87%	0.03%	0.15%	0.13%	0.06%	0.02%	0.20%	0.01%	0.06%	0.03%	0.01%	7.84%	0.03%	0.05%	2.67%
20	0.14%	0.01%	1.45%	0.07%	0.16%	0.50%	43.92%	0.04%	0.02%	0.00%	0.03%	0.01%	0.03%	0.30%	0.14%	0.01%	16.50%	1.60%	0.02%	0.02%	13.93%	1.04%	3.65%
21	0.05%	0.01%	0.00%	0.33%	0.06%	0.19%	0.03%	0.01%	0.02%	0.00%	0.03%	0.03%	0.23%	0.06%	0.00%	0.00%	1.71%	4.80%	0.00%	0.00%	0.01%	0.00%	0.42%
22	0.33%	0.02%	0.28%	0.09%	0.51%	0.50%	22.84%	0.05%	0.02%	0.10%	0.05%	0.07%	0.03%	13.52%	0.34%	0.01%	7.52%	0.22%	0.05%	0.03%	40.56%	11.87%	4.17%
23	0.24%	0.48%	0.01%	0.02%	0.04%	0.12%	0.00%	42.24%	0.38%	2.90%	2.89%	0.02%	0.02%	0.01%	0.00%	0.03%	0.01%	0.00%	0.00%	0.01%	0.00%	0.01%	1.58%
24	3.52%	0.87%	0.00%	0.06%	0.04%	1.02%	0.01%	0.93%	31.44%	0.41%	0.08%	2.36%	0.02%	0.01%	0.02%	0.01%	0.00%	0.01%	0.00%	0.03%	0.00%	0.00%	1.75%
25	0.28%	0.07%	0.00%	0.01%	0.04%	0.06%	0.01%	7.00%	0.35%	37.15%	1.76%	0.04%	0.01%	0.00%	0.00%	1.11%	0.01%	0.01%	0.01%	0.00%	0.00%	0.00%	2.41%
26	0.25%	1.11%	0.00%	0.02%	0.02%	0.05%	0.01%	0.37%	0.03%	0.01%	2.01%	0.00%	10.64%	0.00%	0.00%	0.05%	0.00%	0.01%	5.67%	0.00%	0.00%	0.00%	0.86%
27	0.20%	0.06%	0.10%	2.08%	0.39%	0.79%	0.40%	0.07%	0.06%	0.02%	0.03%	0.01%	0.09%	2.61%	0.03%	0.01%	17.26%	0.56%	0.02%	0.04%	0.07%	0.06%	0.94%
28	0.13%	0.00%	0.01%	0.04%	0.43%	0.20%	1.76%	0.01%	0.00%	0.01%	0.07%	0.01%	0.03%	4.98%	0.33%	0.00%	1.54%	0.02%	0.00%	0.03%	0.90%	11.42%	1.14%
29	0.11%	0.01%	0.01%	0.01%	0.12%	0.16%	0.77%	0.01%	0.02%	0.01%	0.01%	0.02%	0.00%	1.59%	0.23%	0.00%	0.09%	0.02%	0.02%	0.08%	0.74%	5.38%	0.49%
30	0.43%	0.09%	0.38%	0.22%	0.08%	0.45%	10.46%	0.04%	0.03%	0.01%	0.08%	0.07%	0.75%	0.05%	0.00%	0.06%	7.66%	27.72%	0.06%	0.01%	1.39%	0.28%	2.86%
31	0.20%	0.02%	0.01%	0.00%	0.61%	1.22%	0.00%	0.01%	0.01%	0.00%	0.01%	0.12%	0.00%	0.02%	7.34%	0.00%	0.01%	0.00%	0.00%	5.15%	0.01%	0.35%	0.51%
32	0.55%	0.04%	0.00%	0.01%	0.39%	8.57%	0.00%	0.01%	1.50%	0.03%	0.08%	7.71%	0.03%	0.01%	0.45%	0.02%	0.04%	0.02%	0.00%	17.55%	0.00%	0.03%	1.62%
33	0.35%	0.66%	0.00%	0.06%	0.06%	0.06%	0.00%	14.88%	0.06%	3.89%	40.18%	0.03%	0.20%	0.01%	0.00%	1.52%	0.03%	0.01%	0.10%	0.00%	0.00%	0.00%	3.08%
34	0.47%	0.07%	0.00%	0.02%	0.04%	0.60%	0.00%	0.11%	10.49%	0.77%	0.05%	42.76%	0.01%	0.01%	0.02%	0.01%	0.00%	0.01%	0.01%	1.17%	0.00%	0.01%	2.85%
35	0.12%	0.02%	0.03%	0.06%	0.08%	0.21%	0.19%	0.05%	0.02%	0.02%	0.01%	0.01%	0.08%	0.08%	0.02%	0.01%	3.18%	1.94%	0.01%	0.03%	0.04%	0.02%	0.28%
36	0.25%	1.36%	0.01%	0.32%	0.02%	0.04%	0.01%	0.05%	0.01%	0.00%	0.24%	0.04%	22.58%	0.02%	0.02%	0.00%	0.03%	0.05%	0.79%	0.00%	0.03%	0.00%	1.10%
37	0.91%	0.19%	0.07%	1.14%	23.64%	1.52%	0.36%	0.08%	0.24%	0.00%	0.08%	0.03%	0.07%	60.63%	0.14%	0.00%	9.39%	0.06%	0.02%	0.03%	0.38%	3.33%	4.82%
38	0.44%	0.13%	0.01%	0.00%	0.02%	0.11%	0.00%	10.88%	7.27%	11.52%	0.64%	0.41%	0.01%	0.02%	0.00%	0.06%	0.03%	0.00%	0.00%	0.01%	0.01%	0.00%	1.32%
39	0.24%	0.00%	0.00%	0.01%	0.16%	0.51%	0.01%	0.01%	0.04%	0.02%	0.04%	0.10%	0.00%	0.04%	57.63%	0.01%	0.03%	0.01%	0.01%	3.67%	0.01%	2.87%	1.79%
40	0.28%	0.07%	0.00%	0.01%	0.04%	0.14%	0.01%	1.29%	0.07%	2.35%	6.23%	0.03%	0.05%	0.00%	0.00%	57.16%	0.01%	0.01%	1.46%	0.00%	0.01%	0.01%	4.16%
41	0.20%	0.01%	0.06%	0.39%	0.14%	0.30%	1.91%	0.00%	0.00%	0.04%	0.01%	0.00%	0.03%	0.50%	0.03%	0.01%	16.23%	0.05%	0.02%	0.02%	0.34%	0.08%	0.71%
42	0.59%	0.29%	0.00%	8.02%	0.28%	0.57%	0.07%	0.04%	0.04%	0.01%	0.02%	0.01%	2.43%	0.17%	0.00%	0.00%	3.72%	1.97%	0.00%	0.01%	0.01%	0.00%	0.91%
43	0.39%	0.07%	0.04%	1.29%	0.04%	0.70%	1.07%	0.04%	0.05%	0.00%	0.10%	0.20%	5.04%	0.10%	0.03%	0.01%	4.99%	36.68%	0.32%	0.01%	0.15%	0.00%	3.04%
44	1.14%	0.18%	0.00%	0.03%	0.22%	4.45%	0.01%	0.04%	4.18%	0.04%	0.02%	0.09%	0.04%	0.01%	0.00%	0.02%	0.03%	0.02%	0.01%	0.04%	0.00%	0.01%	0.43%
45	0.77%	5.44%	0.00%	0.30%	0.02%	0.19%	0.00%	0.22%	0.05%	0.00%	0.38%	0.01%	6.84%	0.01%	0.00%	0.02%	0.01%	0.00%	0.13%	0.00%	0.00%	0.01%	0.77%
46	0.23%	0.11%	0.00%	0.01%	0.02%	0.11%	0.03%	2.23%	0.06%	13.06%	7.62%	0.02%	0.01%	0.02%	0.00%	16.44%	0.01%	0.09%	0.04%	0.02%	0.00%	0.00%	2.26%
47	0.52%	0.60%	0.01%	5.40%	0.24%	0.45%	0.56%	0.03%	0.08%	0.00%	0.09%	0.02%	24.72%	0.04%	0.00%	0.01%	0.76%	22.42%	0.20%	0.01%	0.03%	0.02%	2.99%
48	0.20%	0.00%	0.01%	0.01%	0.51%	0.31%	0.09%	0.01%	0.01%	0.00%	0.00%	0.15%	0.01%	1.17%	15.33%	0.00%	0.04%	0.02%	0.00%	0.57%	0.12%	12.86%	1.23%
49	0.20%	0.04%	0.00%	0.02%	0.06%	0.04%	0.00%	1.59%	0.03%	1.37%	11.88%	0.04%	0.01%	0.00%	0.00%	12.99%	0.00%	0.01%	0.83%	0.00%	0.00%	0.00%	1.65%
50	0.20%	0.22%	0.00%	0.03%	0.00%	0.09%	0.00%	0.22%	0.01%	0.04%	1.38%	0.23%	5.04%	0.01%	0.00%	0.78%	0.00%	0.02%	37.10%	0.01%	0.00%	0.01%	1.73%
51	0.34%	0.04%	0.00%	0.01%	0.02%	0.36%	0.03%	0.11%	6.47%	3.87%	0.04%	22.47%	0.00%	0.01%	0.05%	0.12%	0.00%	0.00%	0.00%	0.33%	0.01%	0.00%	1.73%
52	0.23%	0.02%	0.00%	0.02%	0.06%	0.05%	0.02%	0.34%	0.00%	0.10%	3.21%	0.01%	0.32%	0.01%	0.00%	1.46%	0.01%	0.00%	14.50%	0.01%	0.00%	0.00%	0.85%
53	0.46%	0.08%	0.00%	0.03%	0.99%	5.99%	0.00%	0.03%	0.11%	0.01%	0.10%	0.42%	0.02%	0.03%	8.65%	0.00%	0.03%	0.01%	0.00%	57.56%	0.00%	0.11%	3.06%
54	0.32%	0.04%	0.00%	0.00%	0.02%	0.02%	0.01%	3.22%	2.66%	21.42%	0.16%	0.91%	0.01%	0.01%	0.00%	1.56%	0.04%	0.01%	0.03%	0.03%	0.03%	0.01%	1.53%
55	0.12%	0.02%	0.03%	0.07%	6.88%	0.34%	0.01%	0.01%	0.02%	0.00%	0.03%	0.18%	0.02%	4.42%	0.11%	0.01%	0.13%	0.01%	0.00%	0.07%	0.00%	0.45%	0.47%
56	0.14%	0.00%	0.33%	0.01%	0.02%	0.20%	1.78%	0.00%	0.00%	0.00%	0.03%	0.01%	0.00%	0.06%	0.03%	0.01%	0.37%	0.02%	0.00%	0.02%	18.91%	0.13%	0.65%
57	0.28%	0.02%	0.06%	0.05%	0.81%	0.57%	1.87%	0.08%	0.03%	0.05%	0.06%	0.03%	0.04%	6.27%	8.53%	0.03%	0.81%	0.12%	0.06%	0.39%	1.19%	49.31%	3.54%
58	0.00%	0.00%	0.01%	0.00%	0.00%	0.01%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%	0.00%	0.00%	0.01%	0.03%	0.00%	0.00%	0.00%	0.00%	0.00%
Grand Total	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**

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APPENDIX B. DFD RESCUE LOCATION ANALYSIS CASE STUDY

APPENDIX B. RESCUE LOCATION ANALYSIS CASE STUDY

Dallas Fire-Rescue Department

Geospatial Intelligence & Analytics

In an effort to provide Dallas Fire-Rescue's Command Staff with multiple options for the placement of a new rescue unit, the GIS Section has conducted extensive research and analysis into compiling the following list of recommended locations. Because the needs of the City of Dallas are so diverse, the recommended locations were split between stations without a rescue and stations currently with a rescue.

Placement of a rescue at a station without a rescue currently assigned provides greater coverage, however, the number of overall responses that the new unit will respond to will be relatively low.

Stations Without a Rescue

- **Station 09** – Council District #08
- **Station 12** – Council District #03
- **Station 16** – Council District #06
- **Station 27** – Council District #13
- **Station 35** – Council District #13
- **Station 36** – Council District #06

Placement of a rescue at a station that currently has another rescue assigned will respond to a greater number of emergencies, while also reducing response times for second due rescues into that area (i.e. the Rescue 218 concept).

Stations With a Rescue

- **Station 20** – Council District #13
- **Station 37** – Council District #12
- **Station 40** – Council District #08

The above recommendations were derived through an analysis of the following:

- Coverage Gaps Surpassing NFPA 1710 Recommendations
- Emerging Rescue Assignment Hot Spots
- Estimated Emergency Response Comparison (Predictive Analysis)
- Estimated Rescue Availability Comparison (Predictive Analysis)
- Estimated Time Target Responses (Predictive Analysis)

All statistical information evaluated for predictive and historical analysis were derived from Deccan's Apparatus Deployment Analysis Module (ADAM).

Stations Currently Without A Rescue

Rescue Deployment Comparison to Base Deployment

(with RE13 & RE59 In Service)

Addition of Rescue at STA 09		Performance Target	Incident Percentage			Incident Average		
Station	Response Criteria		Base Scenario	Rescue @ STA09	Difference	Base Scenario	Rescue @ STA 09	Difference
5	1710 First Rescue ALS (Disp to OnScene)	9:00	88.59%	92.76%	4.17%	6:22	6:03	0:19
9	1710 First Rescue ALS (Disp to OnScene)	9:00	5.72%	76.22%	70.50%	12:48	7:25	5:23
34	1710 First Rescue ALS (Disp to OnScene)	9:00	85.53%	97.78%	12.25%	7:13	5:56	1:17
51	1710 First Rescue ALS (Disp to OnScene)	9:00	75.60%	91.28%	15.68%	7:25	6:32	0:53

Addition of Rescue at STA 12		Performance Target	Incident Percentage			Incident Average		
Station	Response Criteria		Base Scenario	Rescue @ STA12	Difference	Base Scenario	Rescue @ STA 12	Difference
12	1710 First Rescue ALS (Disp to OnScene)	9:00	0.55%	83.19%	82.64%	13:47	7:04	6:43
40	1710 First Rescue ALS (Disp to OnScene)	9:00	83.22%	84.04%	0.82%	7:09	7:06	0:03
50	1710 First Rescue ALS (Disp to OnScene)	9:00	90.27%	92.48%	2.21%	6:21	6:11	0:10
52	1710 First Rescue ALS (Disp to OnScene)	9:00	84.93%	86.05%	1.12%	6:59	6:54	0:05

Addition of Rescue at STA 16		Performance Target	Incident Percentage			Incident Average		
Station	Response Criteria		Base Scenario	Rescue @ STA16	Difference	Base Scenario	Rescue @ STA 16	Difference
16	1710 First Rescue ALS (Disp to OnScene)	9:00	55.46%	93.17%	37.71%	12:06	9:23	2:43
26	1710 First Rescue ALS (Disp to OnScene)	9:00	97.37%	98.49%	1.12%	6:16	6:07	0:09
36	1710 First Rescue ALS (Disp to OnScene)	9:00	84.25%	91.14%	6.89%	8:58	8:44	0:14
50	1710 First Rescue ALS (Disp to OnScene)	9:00	90.27%	92.13%	1.86%	6:21	6:14	0:07

Addition of Rescue at STA 27		Performance Target	Incident Percentage			Incident Average		
Station	Response Criteria		Base Scenario	Rescue @ STA27	Difference	Base Scenario	Rescue @ STA 27	Difference
27	1710 First Rescue ALS (Disp to OnScene)	9:00	63.78%	98.06%	-34.28%	8:24	5:43	2:41
35	1710 First Rescue ALS (Disp to OnScene)	9:00	74.27%	81.67%	-7.40%	7:59	7:44	0:15
37	1710 First Rescue ALS (Disp to OnScene)	9:00	97.92%	98.63%	-0.71%	5:59	5:55	0:04
41	1710 First Rescue ALS (Disp to OnScene)	9:00	89.52%	94.76%	-5.24%	7:03	6:50	0:13
42	1710 First Rescue ALS (Disp to OnScene)	9:00	94.21%	97.48%	-3.27%	6:32	6:24	0:08

Addition of Rescue at STA 35		Performance Target	Incident Percentage			Incident Average		
Station	Response Criteria		Base Scenario	Rescue @ STA35	Difference	Base Scenario	Rescue @ STA 35	Difference
2	1710 First Rescue ALS (Disp to OnScene)	9:00	69.69%	89.23%	19.54%	8:00	7:19	0:41
30	1710 First Rescue ALS (Disp to OnScene)	9:00	88.29%	94.66%	6.37%	6:21	5:53	0:28
35	1710 First Rescue ALS (Disp to OnScene)	9:00	74.27%	93.14%	18.87%	7:59	6:16	1:43
41	1710 First Rescue ALS (Disp to OnScene)	9:00	89.52%	90.93%	1.41%	7:03	7:00	0:03
43	1710 First Rescue ALS (Disp to OnScene)	9:00	88.44%	94.92%	6.48%	6:41	6:19	0:22

Addition of Rescue at STA 36		Performance Target	Incident Percentage			Incident Average		
Station	Response Criteria		Base Scenario	Rescue @ STA36	Difference	Base Scenario	Rescue @ STA 36	Difference
1	1710 First Rescue ALS (Disp to OnScene)	9:00	99.32%	99.34%	0.02%	5:58	5:56	0:02
16	1710 First Rescue ALS (Disp to OnScene)	9:00	55.46%	62.38%	6.92%	12:06	11:50	0:16
36	1710 First Rescue ALS (Disp to OnScene)	9:00	84.25%	97.12%	12.87%	8:58	7:09	1:49
45	1710 First Rescue ALS (Disp to OnScene)	9:00	94.49%	94.80%	0.31%	7:01	6:39	0:22
47	1710 First Rescue ALS (Disp to OnScene)	9:00	93.40%	95.64%	2.24%	6:17	6:07	0:10

Addition of Rescue at STA 41		Performance Target	Incident Percentage			Incident Average		
Station	Response Criteria		Base Scenario	Rescue @ STA41	Difference	Base Scenario	Rescue @ STA 41	Difference
2	1710 First Rescue ALS (Disp to OnScene)	9:00	69.69%	74.34%	4.65%	8:00	7:49	0:11
20	1710 First Rescue ALS (Disp to OnScene)	9:00	84.29%	94.77%	10.48%	6:47	6:21	0:26
27	1710 First Rescue ALS (Disp to OnScene)	9:00	63.78%	91.23%	27.45%	8:24	7:24	1:00
35	1710 First Rescue ALS (Disp to OnScene)	9:00	74.27%	80.37%	6.10%	7:59	7:46	0:13
41	1710 First Rescue ALS (Disp to OnScene)	9:00	89.52%	96.47%	6.95%	7:03	6:13	0:50

Stations Currently With A Rescue

Rescue Deployment Comparison to Base Deployment

Addition of Rescue at STA 20			Incident Percentage			Incident Average		
Station	Response Criteria	Performance Target	Rescue at Sta. 20	Base Scenario	Difference	Rescue at Sta. 20	Base Scenario	Difference
2	1710 First Rescue ALS (Disp to OnScene)	9:00	72.59%	69.94%	2.65%	7:54	8:00	-0:06
7	1710 First Rescue ALS (Disp to OnScene)	9:00	98.42%	95.53%	2.89%	5:56	6:21	-0:25
20	1710 First Rescue ALS (Disp to OnScene)	9:00	96.95%	86.67%	10.28%	6:00	6:40	-0:40
22	1710 First Rescue ALS (Disp to OnScene)	9:00	92.14%	91.39%	0.75%	6:31	6:37	-0:06
41	1710 First Rescue ALS (Disp to OnScene)	9:00	95.66%	91.09%	4.57%	6:45	6:57	-0:12
56	1710 First Rescue ALS (Disp to OnScene)	9:00	97.40%	94.77%	2.63%	6:24	6:39	-0:15
Addition of Rescue at STA 37			Incident Percentage			Incident Average		
Station	Response Criteria	Performance Target	Rescue at Sta. 37	Base Scenario	Difference	Rescue at Sta. 37	Base Scenario	Difference
27	1710 First Rescue ALS (Disp to OnScene)	9:00	79.50%	65.28%	14.22%	7:55	8:22	-0:27
28	1710 First Rescue ALS (Disp to OnScene)	9:00	98.32%	98.21%	0.11%	5:59	6:01	-0:02
37	1710 First Rescue ALS (Disp to OnScene)	9:00	99.88%	99.23%	0.65%	5:25	5:52	-0:27
55	1710 First Rescue ALS (Disp to OnScene)	9:00	99.23%	98.93%	0.30%	6:05	6:15	-0:10
Addition of Rescue at STA 40			Incident Percentage			Incident Average		
Station	Response Criteria	Performance Target	Rescue at Sta. 40	Base Scenario	Difference	Rescue at Sta. 40	Base Scenario	Difference
40	1710 First Rescue ALS (Disp to OnScene)	9:00	98.08%	85.21%	12.87%	6:14	7:02	-0:48
46	1710 First Rescue ALS (Disp to OnScene)	9:00	96.73%	91.58%	5.15%	6:21	6:37	-0:16
49	1710 First Rescue ALS (Disp to OnScene)	9:00	97.09%	92%	5.09%	6:38	6:54	-0:16

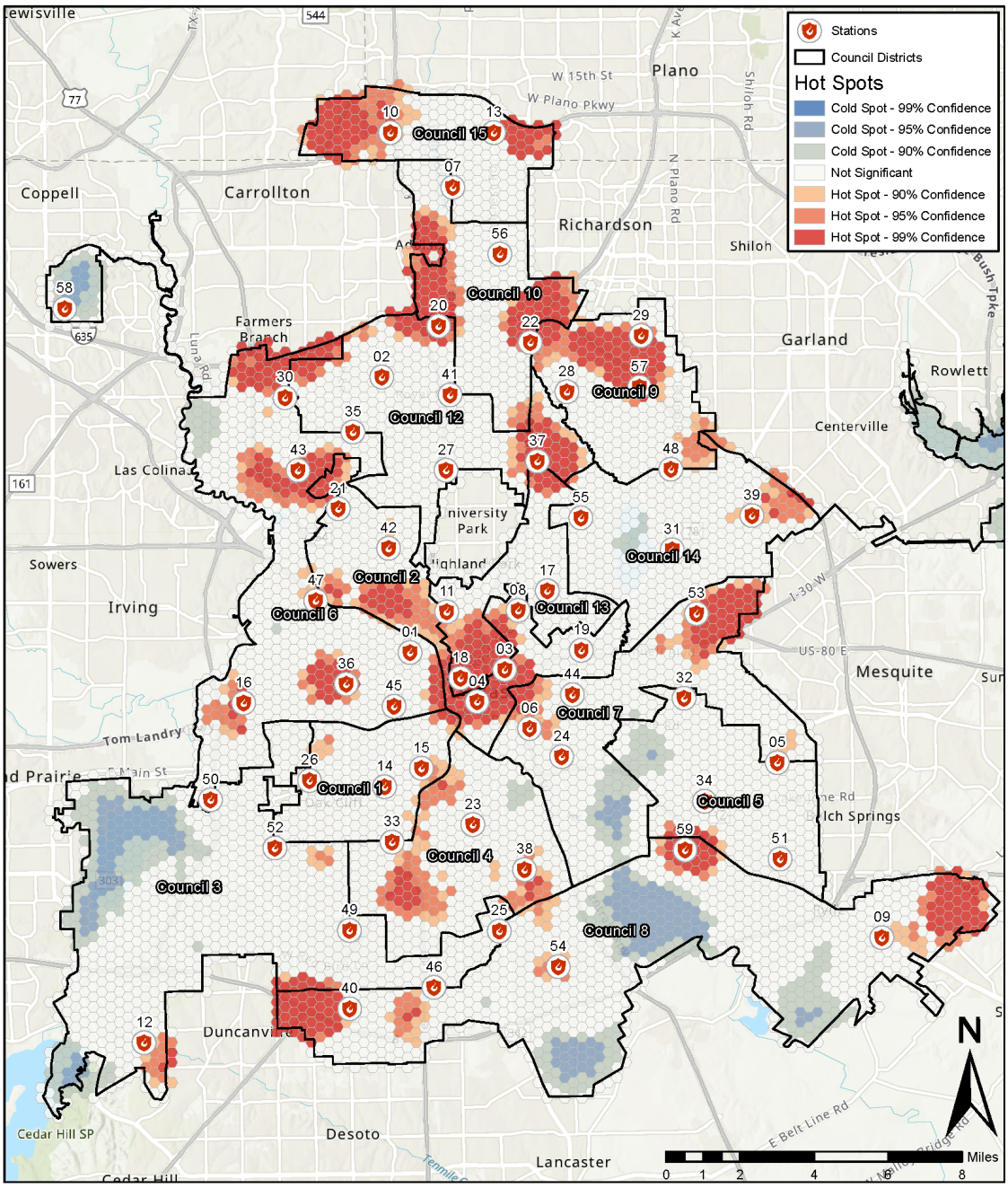
Note: Due to staffing constraints, only stations that have a truck company assigned were considered for "double stacking" of rescues. Stations 23, 25, and 57 are other possible locations that can be analyzed if additional locations need to be considered.

Rescue Availability Percentage									
Unit	Base Deployment	RE59	RE59 & RE09	RE59 & RE12	RE59 & RE16	RE59 & RE27	RE59 & RE35	RE59 & RE36	RE59 & RE41
RE01	73.90	73.93	73.94	73.97	74.63	74.83	74.77	76.68	74.32
RE03	62.83	63.09	63.12	63.12	63.14	63.15	63.13	63.21	63.13
RE04	62.79	62.93	62.95	62.99	63.14	62.98	62.97	63.41	62.96
RE05	60.87	65.40	67.21	65.41	65.41	65.41	65.41	65.41	65.41
RE06	60.43	61.33	61.39	61.36	61.37	61.36	61.35	61.39	61.35
RE08	69.62	69.70	69.72	69.71	69.73	69.95	69.74	69.74	69.83
RE09	-	-	85.72	-	-	-	-	-	-
RE10	77.07	77.09	77.09	77.09	77.09	77.29	77.18	77.10	77.55
RE11	68.15	68.18	68.19	68.19	68.30	69.39	68.90	68.76	68.66
RE12	-	-	-	90.23	-	-	-	-	-
RE13	80.93	80.94	80.95	80.95	80.95	81.07	81.02	80.95	81.35
RE15	61.22	61.28	61.29	61.49	61.98	61.31	61.31	62.11	61.30
RE16	-	-	-	-	83.79	-	-	-	-
RE18	60.19	60.23	60.25	60.30	60.34	60.32	60.35	60.77	60.27
RE218	60.19	60.23	60.25	60.30	60.34	60.32	60.35	60.77	60.27
RE19	65.84	66.29	66.36	66.30	66.30	66.34	66.30	66.31	66.33
RE20	70.28	70.31	70.31	70.32	70.33	71.54	72.74	70.36	73.74
RE22	62.40	62.43	62.44	62.44	62.45	63.49	63.05	62.45	65.68
RE23	56.40	56.57	56.59	56.64	56.64	56.59	56.58	56.66	56.59
RE24	61.81	64.04	64.27	64.06	64.05	64.05	64.05	64.06	64.05
RE25	51.98	52.17	52.20	52.29	52.21	52.20	52.19	52.21	52.19
RE26	66.55	66.58	66.59	67.08	70.96	66.62	66.68	69.02	66.62
RE27	-	-	-	-	-	84.08	-	-	-
RE28	64.58	64.62	64.63	64.63	64.64	65.96	64.84	64.64	66.27
RE29	73.69	73.72	73.73	73.73	73.74	73.92	73.77	73.74	74.05
RE30	69.51	69.53	69.54	69.54	69.57	70.27	75.42	69.64	70.77
RE32	62.41	65.22	65.65	65.23	65.23	65.24	65.23	65.24	65.24
RE33	53.26	53.34	53.36	53.85	53.66	53.37	53.36	53.62	53.37
RE34	62.32	71.83	73.47	71.85	71.85	71.85	71.84	71.85	71.85
RE35	-	-	-	-	-	-	77.52	-	-
RE36	-	-	-	-	-	-	-	73.99	-
RE37	65.08	65.11	65.12	65.12	65.12	67.32	65.39	65.13	66.64
RE38	56.20	56.55	56.58	56.60	56.58	56.57	56.56	56.58	56.57
RE39	67.77	67.90	67.92	67.91	67.91	67.94	67.91	67.91	67.94
RE40	58.16	58.21	58.22	59.40	58.34	58.23	58.22	58.27	58.23
RE41	-	-	-	-	-	-	-	-	80.27
RE42	68.69	68.72	68.73	68.74	68.97	71.21	72.04	69.59	70.15
RE43	64.81	64.83	64.84	64.84	64.93	65.63	69.16	65.07	65.63
RE44	63.42	64.11	64.18	64.12	64.13	64.13	64.12	64.14	64.13
RE45	73.65	73.68	73.69	73.82	75.74	73.73	73.78	83.24	73.72
RE46	59.85	60.00	60.02	60.39	60.09	60.02	60.01	60.06	60.02
RE47	67.39	67.42	67.43	67.47	68.89	68.07	69.85	71.72	67.95
RE49	57.49	57.55	57.57	58.31	57.78	57.58	57.57	57.69	57.58
RE50	74.83	74.85	74.86	78.71	78.66	74.87	74.88	75.89	74.87
RE51	62.66	67.85	73.66	67.86	67.86	67.86	67.86	67.86	67.86
RE52	68.80	68.84	68.85	70.26	69.80	68.86	68.86	69.44	68.86
RE53	61.65	62.24	62.33	62.26	62.26	62.27	62.26	62.26	62.27
RE54	66.33	67.14	67.29	67.19	67.16	67.16	67.15	67.16	67.15
RE55	78.00	78.04	78.05	78.05	78.05	78.90	78.11	78.05	78.59
RE56	75.55	75.57	75.58	75.58	75.59	76.10	76.04	75.59	77.69
RE57	60.30	60.35	60.36	60.36	60.36	60.74	60.41	60.37	60.90
RE59	-	70.18	73.78	70.19	70.19	70.19	70.18	70.19	70.19

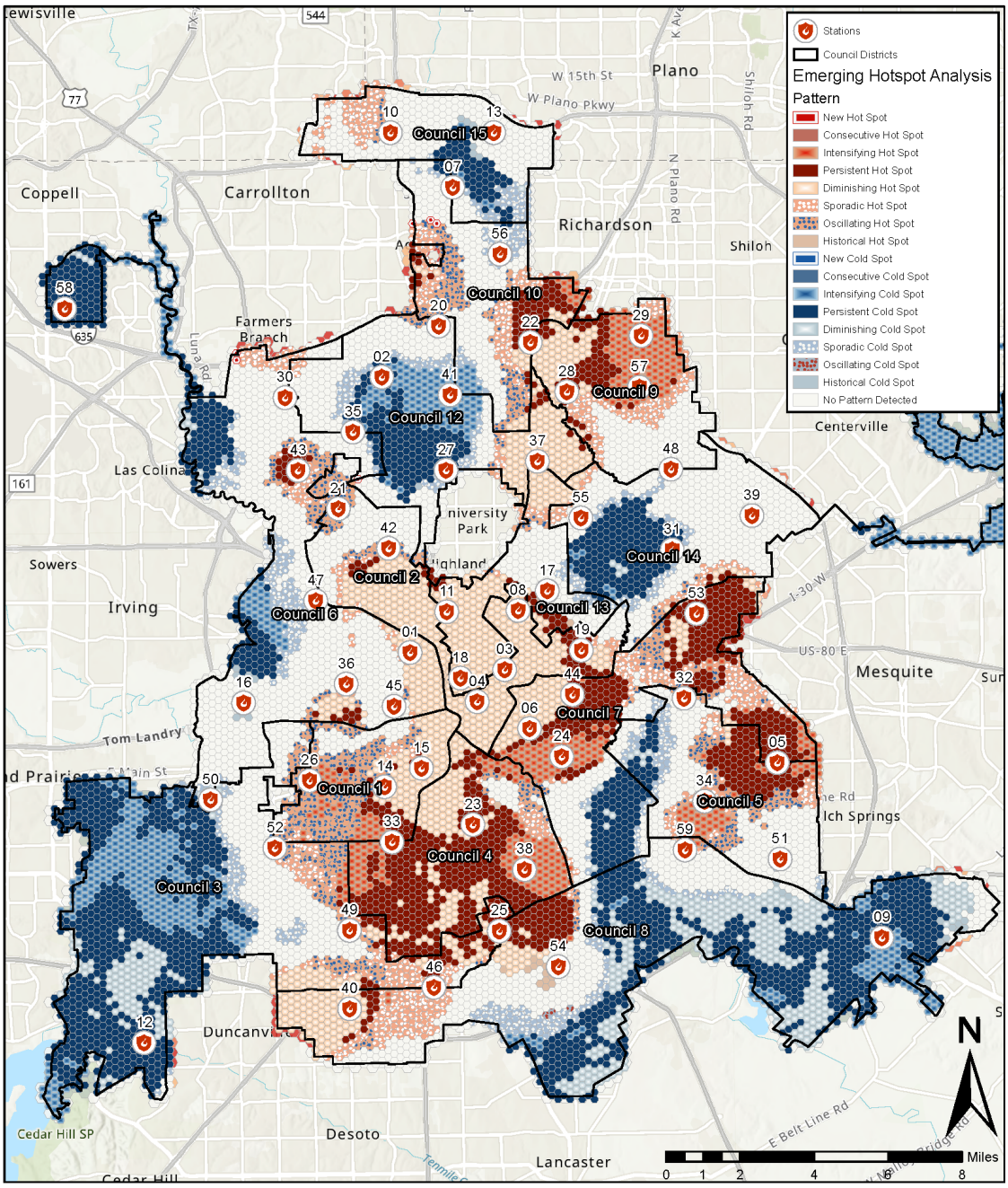
Note: **Rescue Availability Percentage** provides the percentage of time that a rescue unit is available for assignment. The lower the percentage, the "busier" the unit is considered.

Estimated Emergency Responses Per Day									
Unit	Base Deployment	RE59	RE59 & RE09	RE59 & RE12	RE59 & RE16	RE59 & RE27	RE59 & RE35	RE59 & RE36	RE59 & RE41
RE01	10.22	10.22	10.22	10.21	9.95	9.86	9.88	9.18	10.06
RE03	14.16	14.07	14.06	14.07	14.06	14.05	14.06	14.03	14.06
RE04	14.22	14.17	14.17	14.15	14.09	14.16	14.16	13.97	14.17
RE05	14.67	12.87	12.17	12.87	12.87	12.87	12.87	12.87	12.87
RE06	14.89	14.55	14.53	14.55	14.54	14.55	14.55	14.53	14.55
RE08	11.65	11.63	11.62	11.63	11.62	11.53	11.61	11.61	11.58
RE09	-	-	5.40	-	-	-	-	-	-
RE10	8.83	8.83	8.83	8.83	8.83	8.74	8.79	8.83	8.64
RE11	12.30	12.30	12.30	12.30	12.25	11.82	12.02	12.06	12.11
RE12	-	-	-	4.16	-	-	-	-	-
RE13	7.27	7.27	7.27	7.27	7.27	7.22	7.24	7.27	7.11
RE15	14.89	14.88	14.88	14.80	14.61	14.88	14.88	14.54	14.88
RE16	-	-	-	-	6.32	-	-	-	-
RE18	15.23	15.21	15.21	15.21	15.16	15.15	15.17	15.02	15.18
RE218	15.23	15.21	15.21	15.21	15.16	15.15	15.17	15.02	15.18
RE19	13.25	13.09	13.06	13.09	13.09	13.07	13.09	13.08	13.08
RE20	11.99	11.99	11.99	11.99	11.98	11.49	10.98	11.97	10.65
RE22	14.81	14.81	14.81	14.81	14.81	14.40	14.55	14.81	13.49
RE23	16.15	16.09	16.08	16.06	16.06	16.09	16.09	16.05	16.09
RE24	14.43	13.58	13.50	13.58	13.58	13.59	13.58	13.58	13.59
RE25	17.80	17.73	17.72	17.68	17.72	17.73	17.73	17.72	17.73
RE26	12.76	12.76	12.76	12.56	11.01	12.75	12.72	11.82	12.75
RE27	-	-	-	-	-	6.25	-	-	-
RE28	13.61	13.61	13.61	13.61	13.61	13.09	13.52	13.61	12.96
RE29	10.08	10.07	10.07	10.07	10.07	9.99	10.05	10.07	9.94
RE30	12.40	12.40	12.40	12.40	12.39	12.11	10.17	12.35	11.91
RE32	14.31	13.25	13.08	13.25	13.25	13.25	13.25	13.25	13.25
RE33	17.81	17.80	17.80	17.60	17.67	17.80	17.80	17.68	17.80
RE34	14.22	10.64	10.00	10.64	10.64	10.64	10.64	10.64	10.64
RE35	-	-	-	-	-	-	8.80	-	-
RE36	-	-	-	-	-	-	-	9.78	-
RE37	13.28	13.28	13.28	13.28	13.28	12.41	13.16	13.28	12.66
RE38	16.23	16.08	16.07	16.07	16.07	16.08	16.08	16.07	16.08
RE39	12.09	12.04	12.04	12.04	12.04	12.03	12.04	12.04	12.03
RE40	15.98	15.97	15.97	15.39	15.91	15.97	15.97	15.95	15.97
RE41	-	-	-	-	-	-	-	-	7.89
RE42	11.96	11.96	11.96	11.96	11.86	10.93	10.66	11.60	11.36
RE43	13.88	13.88	13.88	13.88	13.84	13.57	12.23	13.78	13.55
RE44	13.83	13.57	13.54	13.57	13.56	13.56	13.57	13.56	13.56
RE45	10.10	10.10	10.10	10.04	9.30	10.08	10.06	6.52	10.09
RE46	15.41	15.37	15.36	15.19	15.33	15.36	15.36	15.35	15.36
RE47	12.70	12.70	12.70	12.69	12.17	12.45	11.71	11.19	12.50
RE49	16.20	16.19	16.19	15.83	16.09	16.19	16.19	16.14	16.19
RE50	10.10	10.10	10.10	8.35	8.61	10.10	10.09	9.71	10.10
RE51	14.15	12.18	10.03	12.18	12.18	12.18	12.18	12.18	12.18
RE52	11.77	11.76	11.76	11.18	11.35	11.76	11.76	11.51	11.76
RE53	14.43	14.19	14.16	14.20	14.20	14.19	14.19	14.20	14.19
RE54	12.68	12.35	12.28	12.33	12.34	12.35	12.35	12.34	12.35
RE55	8.37	8.36	8.36	8.36	8.36	8.02	8.33	8.36	8.14
RE56	9.39	9.38	9.38	9.38	9.38	9.18	9.19	9.38	8.51
RE57	15.37	15.36	15.36	15.36	15.36	15.21	15.34	15.36	15.14
RE59	-	11.26	9.85	11.26	11.26	11.26	11.26	11.26	11.26

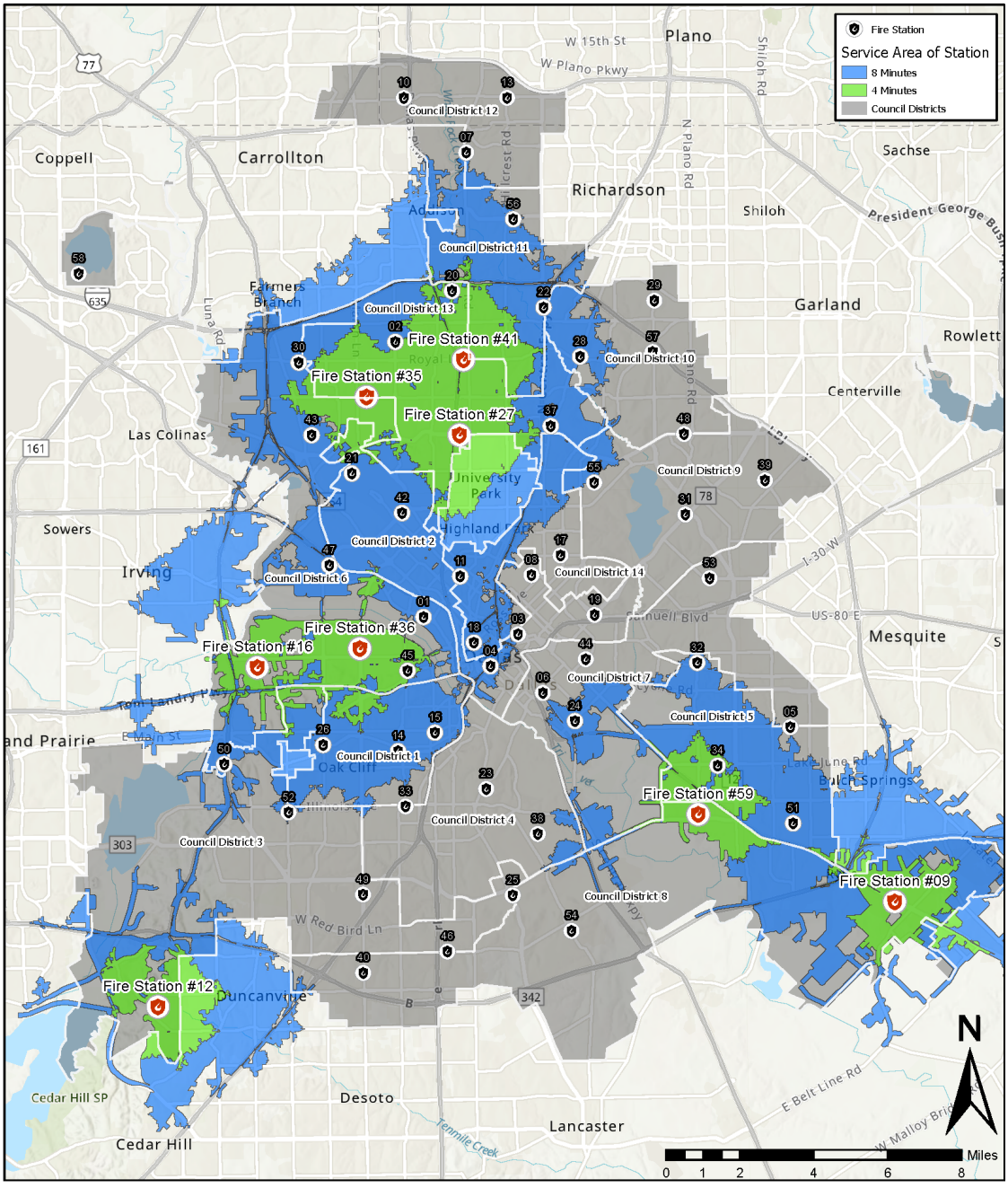
Dallas Fire-Rescue
Hot Spots of Medical Incidents that Exceeded 8 Minute Travel Time
2015 - 2020



Dallas Fire-Rescue
Emerging Hot Spots of Medical Incidents that Exceeded 8 Minute Travel Time
2019 - 2020



Dallas Fire-Rescue
Estimated 4 and 8 Minute Service Areas



Emerging Hot Spot Report

The space time cube has aggregated 331,518 points into 28,917 hexagon grid locations over 105 time step intervals. Each location has a height of 1,000 feet, a width of 1,154.7 feet, sides of 577.35 feet, and an area of 866,025.4 square feet. The entire space time cube spans an area 163,967.48 feet west to east and 153,000 feet north to south. Each of the time step intervals is 1 week in duration so the entire time period covered by the space time cube is 105 weeks. Of the 28,917 total locations, 8505 (29.41%) contain at least one point for at least one time step interval. These 8,505 locations comprise 893,025 space time bins of which 196,922 (22.05%) have point counts greater than zero. There is a statistically significant decrease in point counts over time.

---------- Space Time Cube Characteristics ----------
Input feature time extent
2019-01-01 00:02:48 to 2020-12-31 23:59:34
Number of time steps 105
Time step interval 1 week
Time step alignment End
---------- Input Space Time Cube Details ----------
Distance interval 1,000 feet
Time step interval 1 week
Aggregation Shape Type Hexagon Grid
First time step temporal bias 57.17%
First time step interval after
2018-12-27 23:59:34
to on or before
2019-01-03 23:59:34
Last time step temporal bias 0.00%
Last time step interval after
2020-12-24 23:59:34
to on or before
2020-12-31 23:59:34
Number of time steps 105
Number of locations analyzed 13,353
Number of space time bins analyzed 1,402,065
% non-zero 14.02%

Emerging Hot Spot Report

---------- Analysis Details ----------
Neighborhood distance 7,235.029046 feet
Neighborhood time step intervals 1
(spanning 1 week)

---------- Summary of Results ---------
HOT COLD
New 6 0
Consecutive 0 0
Intensifying 496 2,054
Persistent 1,152 2,210
Diminishing 1,381 529
Sporadic 742 517
Oscillating 620 3
Historical 18 34

All locations with hot or cold spot trends: 9,762 of 13,353
Category Definitions

Last time step is hot:
- New: the most recent time step interval is hot for the first time
- Consecutive: a single uninterrupted run of hot time step intervals, comprised of less than 90% of all intervals
- Intensifying: at least 90% of the time step intervals are hot, and becoming hotter over time
- Persistent: at least 90% of the time step intervals are hot, with no trend up or down
- Diminishing: at least 90% of the time step intervals are hot, and becoming less hot over time
- Sporadic: some of the time step intervals are hot
- Oscillating: some of the time step intervals are hot, some are cold
Last time step is not hot:
- Historical: at least 90% of the time step intervals are hot, but the most recent time step interval is not
---
Last time step is cold:
- New: the most recent time step interval is cold for the first time
- Consecutive: a single uninterrupted run of cold time step intervals, comprised of less than 90% of all
- Intensifying: at least 90% of the time step intervals are cold, and becoming colder over time
- Persistent: at least 90% of the time step intervals are cold, with no trend up or down
- Diminishing: at least 90% of the time step intervals are cold, and becoming less cold over time intervals
- Sporadic: some of the time step intervals are cold
- Oscillating: some of the time step intervals are cold, some are hot
Last time step is not cold:
- Historical: at least 90% of the time step intervals are cold, but the most recent time step interval is not

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