GEOGRAPHIC INFORMATION SYSTEM EMERGENCY SERVICES RESPONSE CAPABILITIES ANALYSIS

Final Report

International Association of Fire Fighters
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PADUCAH FIRE DEPARTMENT

PADUCAH, KENTUCKY

APRIL 2019

Dedication

This Report is Dedicated to the Citizens of Paducah, Kentucky who Deserve the Most Efficient and Effective Fire, Rescue, and Emergency Medical Services Available.

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Executive Summary

The International Association of Fire Fighters (IAFF) Headquarters was engaged by the Paducah Professional Firefighters, IAFF Local 168, to provide information to decision makers in Paducah regarding current emergency response resources that are understaffed.

Currently, fire suppression apparatus in the Paducah Fire Department (PFD) are not staffed to meet industry standards. Staffing apparatus below the minimum set by industry standards has been shown to result in crews being less efficient in completing critical fireground tasks. An individual on a smaller crew size must perform more fireground tasks, which takes more time and contributes to a reduced efficiency in stopping fire loss. Larger crews can perform fireground tasks more quickly and are more efficient at stopping fire loss. Inadequate staffing also drains the emergency response system, because more apparatus and personnel must travel greater distances to mitigate the incident, which results in increased response times. That leads to fewer apparatus and personnel available to respond to other emergencies that may occur simultaneously within the jurisdiction. Staffing below industry standards on fire suppression apparatus increases the risk to civilians, firefighters, and economic loss of property.

Background

The members of the PFD provide fire suppression, emergency medical services (EMS) first response at the BLS (basic life support) level, disaster incident mitigation, hazardous materials response, and technical rescue to the citizens of Paducah 24 hours per day, 7 days per week from five fire stations. The department typically staffs 15 firefighters and one assistant chief per shift. In total, the Paducah Fire Department supports 59 firefighters within the Suppression Division. The Prevention Division has 2 deputy fire marshals, a building inspector, a deputy building inspector, and an electrical inspector. Administration staff consists of the fire chief, deputy chief of prevention, deputy chief of operations, and one clerical position.

Engine and ladder companies in the PFD are staffed with three personnel, less than what is required by industry standards as outlined in the National Fire Protection Association (NFPA®) Standard 1710: *Standard for the Organization and Deployment of Fire Suppression Operations, Emergency Medical Operations, and Special Operations to the Public by Career Fire Departments*. In addition to suppression apparatus being staffed with three firefighters, Engine 5 and Ladder 7 are cross-staffed by one crew. Cross-staffing is a practice whereby firefighters must select the apparatus with which to respond based on the nature of the call. This practice can create delays in response, especially when firefighters are out of the station on one apparatus and must respond back to the station to board the appropriate apparatus for the call.

Ladder 7 is a quint which is a hybrid vehicle, capable of operating as either an engine **or** ladder company.[1] Ladder 7 is typically assigned to operate as a ladder truck, has a 500-gallon tank, and a 105-foot aerial ladder. On a fire scene, the primary function of engine companies is the delivery of water to suppress the fire. Ladders are principally designed to give firefighters access to heights and are usually tasked with rescue and ventilation operations.

This report examines the department's current response capabilities in comparison to recommended scenarios when all fire suppression apparatus are in service and staffed with four personnel. This report also assesses the workload of primary suppression apparatus in order to provide necessary context for the analysis of the PFD's staffing and deployment configuration and response capabilities, and as a utility to decision makers tasked with maintaining the services that mitigate emergencies in the community.

Analysis and Methods

Using Geographic Information Systems (GIS), analysis was performed to evaluate how different staffing and deployment configurations impact the department's response capabilities. Using historical traffic patterns,[2] analysis was performed to examine the department's ability to meet industry standard response requirements such as 4-minute initial unit arrival, the establishment of a minimum of four personnel on scene within 4 minutes, and the assembly of the required numbers of personnel for response to low-hazard structure fires.[3]

Analysis was also performed to examine the department's past workload and response performance. PFD provided computer-aided dispatch (CAD) data for all emergencies responded to from January 1, 2015 through June 11, 2018. The CAD data contain, but are not limited to, information about the type of the emergency incident, the responding apparatus, time the call was received, dispatch time, respond time, time of arrival on scene, and the clear time. The PFD uses first-due response areas tied to the CAD to dispatch units to an emergency that falls within a pre-determined boundary around each fire station.

The CAD data provided did not include call volume for the entire year of 2018; therefore, some analyses (number of incidents, apparatus responses per year, and apparatus responses to structure

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[1] NFPA Standard 1710 states that quint companies operating as an engine or ladder shall be staffed with a minimum of four personnel. If the vehicle is expected to perform multiple roles simultaneously, it must be staffed above that level. Section 5.2.3.4. (NFPA 1710, 2016).

[2] Historical traffic data contained in ESRI's StreetMap Premium, version 18.1.

[3] NFPA defines a typical structure fire as a fire occurring in a 2,000 sq. ft. single-family home with no basement or exposures.

fires) used a forecast model to determine estimated values for the entire year of 2018 to allow for a year-to-year comparison. An exponential smoothing model was used to forecast future values. The exponential smoothing model evaluated historical data to predict future results. The model assigned recent observations (2018 and 2017) a relatively greater importance than older observations (2015 and 2016) when predicting future trends. The model captured the evolving trends and/or patterns of the data and predicted future values. [4]

It should be noted that the current CAD system is outdated[5] and contains errors such as listing apparatus as responding to an incident when these units were not staffed and did not respond. These false records must be manually erased; however, not all false records are identified and removed, as the process is quite labor intensive and time consuming. Further examination of the CAD found some incident records had travel times of over 35 minutes. Statistical analysis determined that travel times above 35 minutes have a 0.3% probability of occurring. Therefore, these records were removed as they were considered erroneous. The removed data comprised 1.54% of the total data used for this analysis.[6]

The workload analysis examined the CAD data to evaluate the department's historical response capabilities and determine the possible need for additional resources. The department's workload was assessed using several parameters, including the total number of incidents[7] and apparatus responses[8] per year, the average and 90th percentile[9] travel times of the first arriving PFD apparatus, the number of back-to-back responses[10], responses made by units into other

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[4] Exponential smoothing models iteratively forecast future values of a regular time series of values from weighted averages of past values of the series. Exponential smoothing computes the next level or smoothed value from a weighted average of the last actual value and the last level value. The level value refers to the predicted value calculated using the exponential smoothing model. The level values are estimated values used to forecast future values in the time interval that does not have actual values. The method is exponential because the value of each level is influenced by every preceding actual value to an exponentially decreasing degree—more recent values are given greater weight.

[5] A new CAD system has been purchased and will soon replace the current system. It is expected that this new system will fix errors and allow the department to perform accurate data analyses in the future.

[6] https://docs.oracle.com/cd/E40248_01/epm.1112/cb_statistical/frameset.htm?ch07s02s10s01.html
Mean and Standard Deviation Method. The Mean and Standard Deviation method was used to statistically remove outliers in the CAD data. In this method, if a value is a certain number of standard deviations away from the mean, that data point is considered an outlier.

[7] An incident is an emergency to which individual or multiple fire department mobile and personnel resources are dispatched to intervene and mitigate. An incident may require single or multiple apparatus.

[8] A response refers to an individual unit being dispatched and traveling to an incident.

[9] In statistics, percentile measurements refer to the values below which a specified percentage of observations fall.

[10] Back-to-back responses refer to occurrences where units have been dispatched within 10 minutes of becoming available from a previous emergency.

stations' first-due areas, and cover incidents[11]. These factors were examined to determine how changes in staffing and deployment have affected PFD's response capabilities and how performance may be improved through the implementation of recommended staffing and deployment enhancements.

Key Findings

- Fire suppression apparatus are only staffed with three firefighters, and do not meet the minimum staffing objectives as outlined in NFPA 1710.
- NFPA 1710 states that the first arriving apparatus should be on scene within 4 minutes of travel to 90% of incidents. Based on this GIS assessment of areas within the Paducah city limits, PFD was able to respond on 55.7% of roads[12] and to 61% of historical CAD incident locations from January 1, 2015 through June 11, 2018 within 4 minutes 90% of the time, which did not meet this response objective.
- Based on this GIS assessment of areas within the Paducah city limits, PFD is able to assemble a minimum of four personnel within 4 minutes on 14% of roads and 29.5% of historical incident locations, assuming at least two PFD units respond and arrive together. The arrival of the first arriving apparatus within 4 minutes is considered to be the standard for safe, effective, and efficient operations.
    - If all primary suppression apparatus were to be staffed with a minimum of four personnel, the department would likely be able to assemble 4 firefighters within 4 minutes on 55.7% of roads and at 79.4% of historical incident locations. This equates to *a 297% **increase** in road coverage and a 169% **increase** in incident coverage above current capabilities.*
- According to NFPA 1710, a minimum of 15 firefighters arriving within 8 minutes is considered the standard for safe, effective, and efficient operations at a typical residential structure fire. Currently, the department can assemble 15 firefighters within 8 minutes on 2.1% of roads and at 7.1% of historical incident scenes within an 8-minute travel time. This assumes all units are available upon dispatch.
    - If all primary suppression apparatus were to be staffed with a minimum of four personnel, the department would likely be able to assemble 15 firefighters within 8 minutes on 56.4% of roads and at 71.7% of historical incident scenes within an 8-

[11] A cover incident refers to an incident to whereby units must travel to another first-due area when the primary first-due unit is responding to another incident at the same time.

[12] Percentages of roads covered given in this document are based on a desire to cover one hundred percent of all road segments within a fire department's total response area.

minute travel time, assuming all units are available upon dispatch. This equates to *a 2,601%* ***increase*** *in road coverage and an 897%* ***increase*** *in incident coverage above current capabilities.*

- Incident call volume remained steady in the full years of data from 2015-2017 and was not predicted to statistically change in 2018. Unit responses remained steady or increased in the full years of data from 2015-2017. There was a projected increase in unit responses from 2017 to 2018.
- 90th percentile travel times increased for primary suppression apparatus from January 1, 2015 through December 31, 2017. There were not any primary suppression units that were able to respond within 4 minutes 90% of the time from January 1, 2015 through June 11, 2018.
- 90th percentile travel times increased for primary suppression apparatus from January 1, 2015 through December 31, 2017 to structure fires. There were not any primary suppression units that were able to respond within 4 minutes 90% of the time from January 1, 2015 through June 11, 2018 to structure fires.
- The highest number of back-to-back responses occurred within 2 minutes of the previous incident for all primary suppression apparatus from January 1, 2015 through June 11, 2018.
- The vacant housing percentage in Paducah is higher than the national average. Vacant homes have an increased risk of fires and spreading beyond the structure of origin. Most vacant homes are located on the eastern side of Paducah.
- Paducah has a high Social Vulnerability Index based on the Center of Disease Control 2014 vulnerability score. The social vulnerability index is determined by socio-economics, housing composition, residents with disabilities, minority status, languages spoken, and housing and transportation. These factors determine areas with higher risk to fires. The eastern side of Paducah has the highest Social Vulnerability Index.

Recommendations

- The department should increase staffing on all fire suppression apparatus to a minimum of four firefighters. It is recommended that the department and city plan and budget for these positions over time. Staffing fire suppression apparatus with a minimum of four firefighters would meet the minimum staffing objectives in NFPA 1710 and enhance safety and operational effectiveness and efficiency.
- The department should not reduce resources or eliminate staffing. The department already has insufficient staffing and further reductions would have a negative impact on the ability of the department to assemble adequate and efficient staffing to emergencies and meet increasing demand on resources.
- Engine 5 and Ladder 7 should each be staffed with a minimum of 4 firefighters at all times, ending the cross-staffing of these units.
- The department should routinely perform risk and hazard assessments, along with a review of system demand, to identify the potential threats to the community so that stakeholders and decision makers can make informed decisions on how to best mitigate, or at least minimize, any emergency incidents that arise.
- Operational costs associated with system improvements can be partly offset in some ways. If not already doing so, the city and department should:
    - Establish fees and fines for fire inspections and violations
    - Establish fees for building plan reviews
    - Establish fees for fire-safety permits for fireworks, open burns, etc.
    - Work cooperatively with law enforcement to establish a means of ticketing fire lane violators with revenue being directed to the city to disperse to the fire department
    - Establish processing fees for requested reports and other paperwork
    - Seek government and private grants and funding to support operations

Executive Summary Conclusion

This analysis assessed the existing staffing and deployment of the PFD, as well as an alternate scenario whereby cross-staffing was discontinued, and all primary fire suppression apparatus were staffed with a minimum of four personnel at all times. In addition, the analysis assessed the workload on current apparatus.

Following a series of analyses of the current staffing and deployment practices, the department can assemble a minimum of 4 firefighters within 4 minutes on only 14% of roads and 29.4% of historical incident locations. The department can assemble 15 firefighters with 8 minutes to only 2.1% of roads and 7.1% of historical incident locations. If staffing is increased, the department would have a 297% increase in road coverage and a 169% increase in incident coverage when assembling 4 firefighters within 4 minutes. The department would have a 2,601% increase in road coverage and an 897% increase in incident coverage assembling a minimum of 15 firefighters within 8 minutes to a structure fire. The workload assessed Engine 4 is the busiest unit and responded the most often in its first-due area. Engine 2 responded to other first-due areas the most often resulting in the second highest percentage of travel times compared to other units. In addition, units have seen an increase in responses to incidents.

Increasing daily staffing levels on all engine and ladder companies will likely have a positive impact on the ability to effectively and efficiently respond to emergency incidents. If staff on fire apparatus is increased, the fire department can mitigate all hazards in a quicker amount of time and reduce the risk of injury to firefighters and civilians.

Fire departments should be adequately resourced to respond to emergencies within the initial response times as outlined in NFPA 1710, and to emergencies occurring simultaneously. This is necessary to minimize the loss of life and the loss of property that the fire department is charged to protect. By deploying apparatus staffed in accordance with industry standards, fire and rescue services provided by the Paducah Fire Department will likely improve.

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Risk Factors

A significant part of planning for future fire department strategies is identifying the risk areas, hazards, and vulnerabilities in the community so that emergency responders and resources are adequately positioned to respond when and where emergencies occur. As such, risk characteristics within the City of Paducah were examined for this report.

Population Characteristics

The Paducah Fire Department is located in Paducah, Kentucky. The city is within McCraken County in southwestern Kentucky along the Ohio River that borders Illinois. The fire department's response jurisdiction consists of approximately 20.7 square miles of land. As of July 2017, the city had an approximate population of 24,941, which is a 0.3% decrease from the year 2000.[13]

An assessment of the U.S. Census data sets from 2016 revealed that 26.2% of the population was in a vulnerable category. A vulnerable population is defined as a group of people who are unable to anticipate, cope with, resist and recover from the impacts of disaster.[14] [15] This category consists of persons under the age of 5 (6.4%) and persons 65 years of age and older (19.8%).[16] These populations typically place an increased demand on public safety resources because these groups are at higher risk of hazard-related injury and death as a result of their inability, or reduced ability, to evacuate in an emergency situation. These groups may be either unable to care for themselves without assistance or may have multiple health issues. In addition, 24.3% of the Paducah population was living below the poverty level (2016).[17] These are people who typically lack the means to properly maintain their residences which can contribute to an increased risk for fire.

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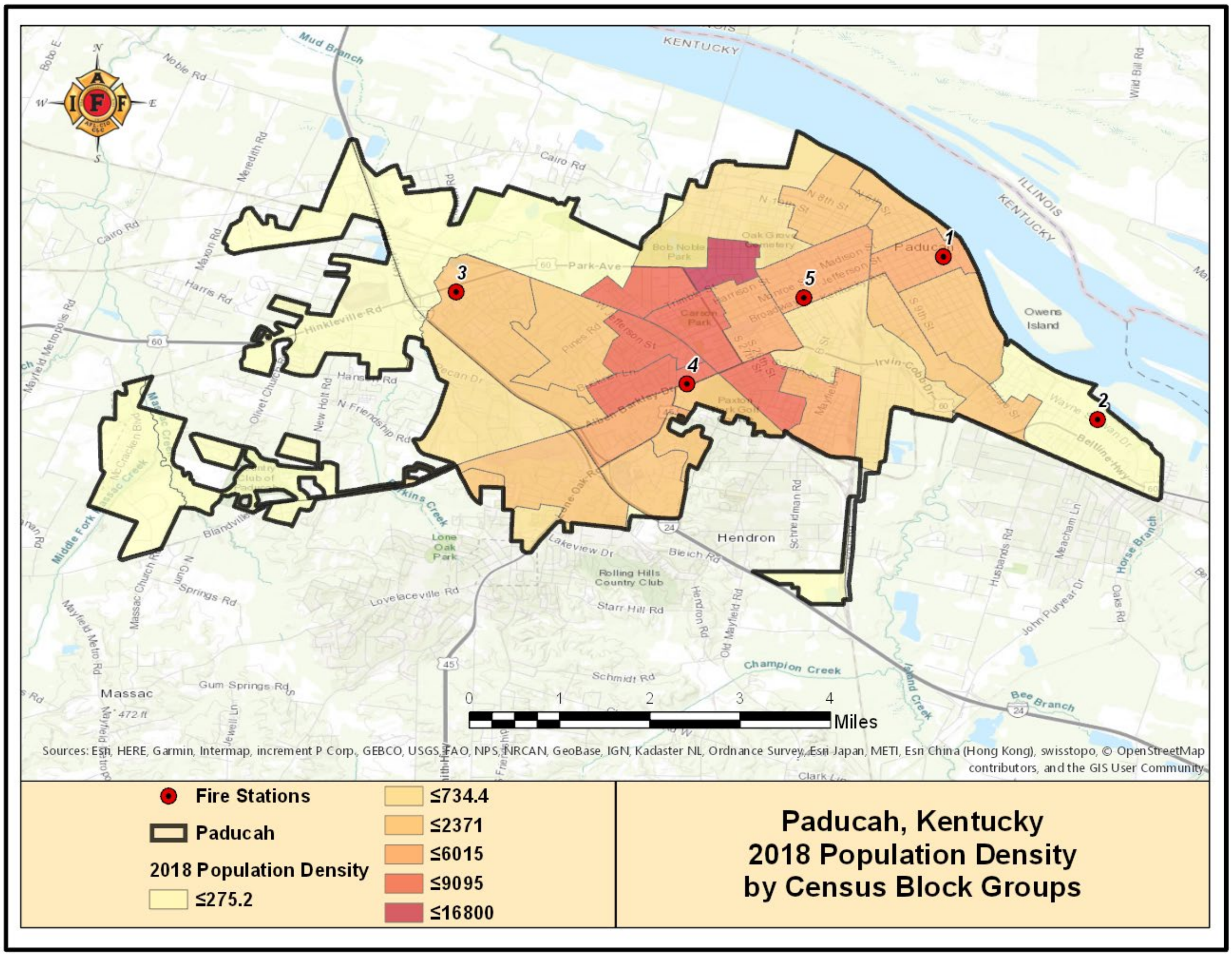
[13] United States Census Bureau. American Fact Finder Community Facts. Annual Estimates of the Resident Population: April 1, 2010 to July 1, 2017. https://www.census.gov/quickfacts/paducahcitykentucky

[14] http://www.who.int/environmental_health_emergencies/vulnerable_groups/en/

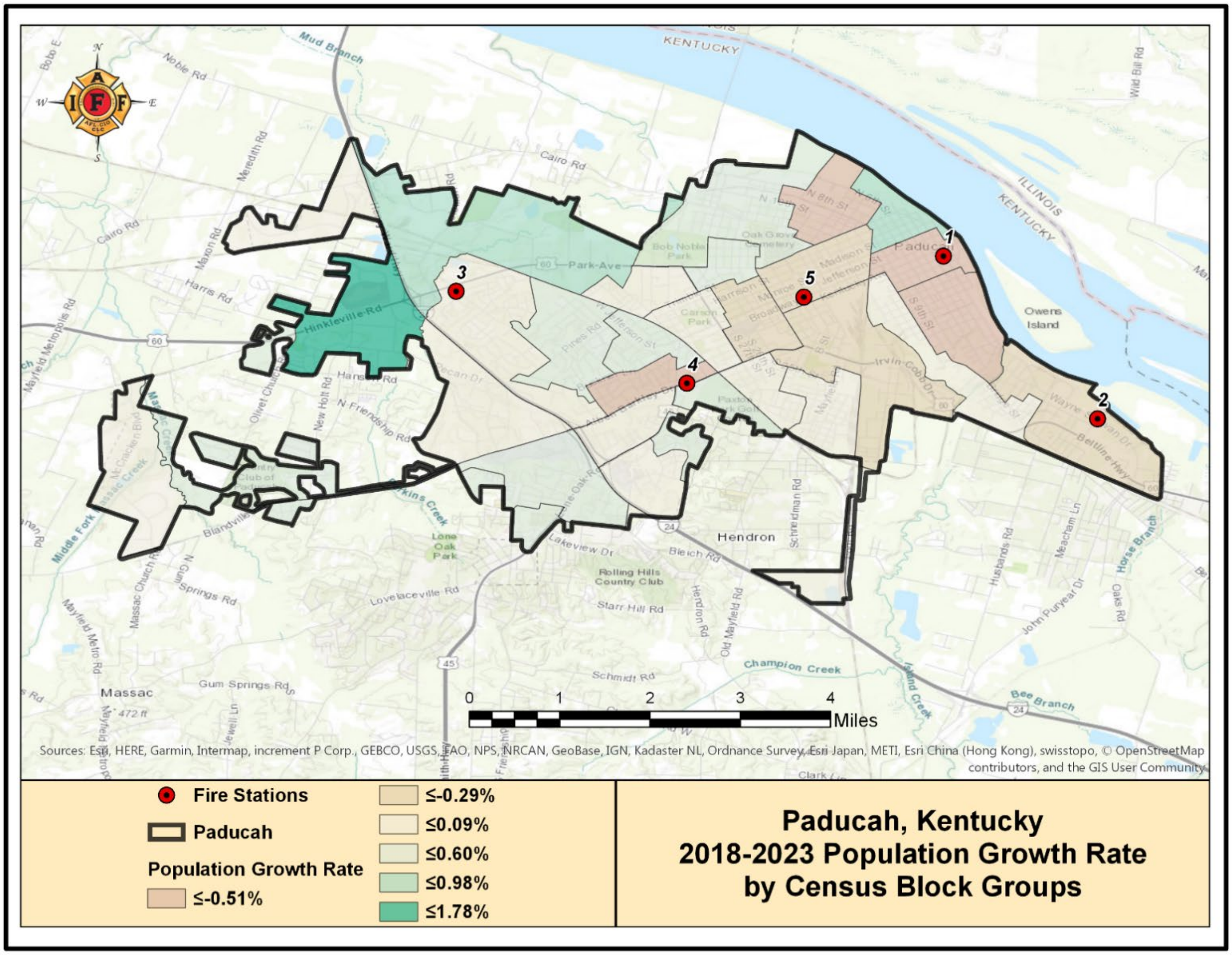
[15] Vulnerable populations include the economically disadvantaged, racial and ethnic minorities, the uninsured, low-income children, the elderly, homeless, and those with chronic health conditions, which includes people with mental illness. The American Journal of Managed Care. Vulnerable Populations: Who are They? Nov 1, 2006. http://www.ajmc.com/journals/supplement/2006/2006-11-vol12-n13suppl/nov06-2390ps348-s352?p=2

[16] U.S. Census American Fact Finder. Age and Sex 2012-2016 American Community Survey 5 Year Estimates: 2016 Demographic Profile. Paducah City Kentucky. https://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?src=CF

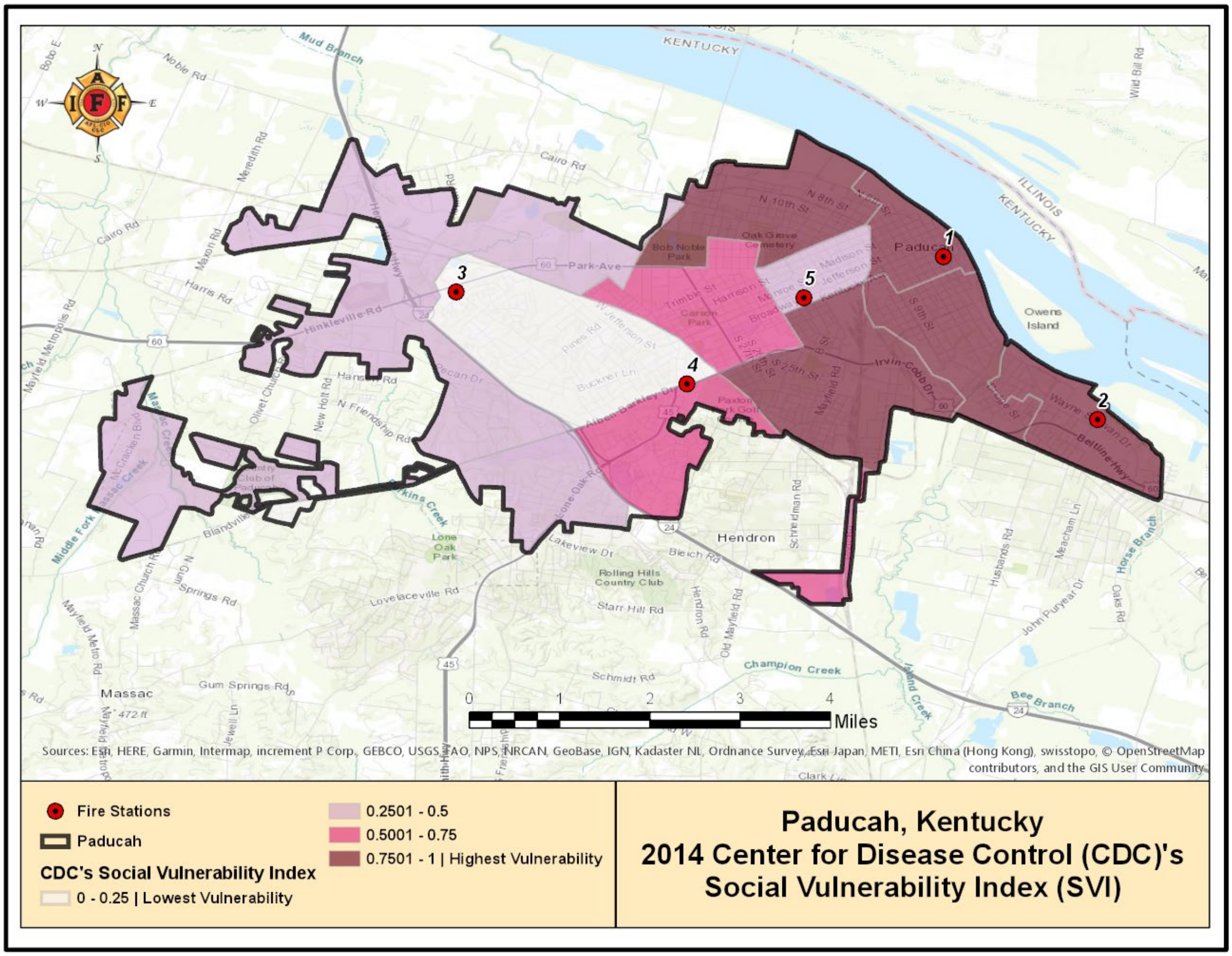
[17] U.S. Census American Fact Finder. Poverty Status in the Past 12 Months. 2011-2016 American Community Survey 5-year estimates. Paducah City Kentucky. https://factfinder.census.gov/faces/nav/jsf/pages/community_facts.xhtml



Map 1: 2018 Population Density by Census Block Groups. Map 1 identifies the 2018 population density broken down by census block groups for the city of Paducah. The highest population density is centered northwest of Station 5 and north of Station 4. The higher the population density within a city results in an increased demand for emergency services.



Map 2: 2018-2023 Population Growth Rate by Census Block Groups. Map 2 identifies the 2018-2023 population growth rate broken down by census block groups for the city of Paducah. The highest population growth rate is projected to be west and north of Station 3.



Map 3: 2014 Center for Disease Control (CDC)'s Social Vulnerability Index (SVI). Map 3 depicts the social vulnerability index score per census tract in the City of Paducah. An SVI score is determined by examining factors such as socio-economics, housing composition, residents with disabilities, minority status, languages spoken, and housing and transportation. An SVI score assists in identifying areas in the community that will most likely need assistance before, during, and after a hazardous event. The closer the SVI score is to 1, the higher the vulnerability. The highest SVI scores occur on the eastern side of Paducah.

Building Characteristics

There were 13,357 housing units in Paducah, with the majority being single-family residences (65.6%) and the remainder being multifamily (31.8%) and mobile homes (2.6%). Of these structures, 59.8% were of pre-1970 construction. Typically, when there are high numbers of older buildings constructed before many current fire codes were developed, there is an increased demand on emergency services. The risk of fires is greater in older buildings with outdated building codes which may have building construction, type of materials, or wiring that increases the risk and spread of fire.

In addition, 13.9% of housing units were vacant.[18] The U.S. average vacancy rate is 12.2%. Based on a January 2018 NFPA study,[19] over 50% of all structure fires in vacant buildings are intentionally set. Structure fires in vacant structures are approximately three times more likely to spread beyond the structure of origin compared to overall structure fires. Between 2011 and 2015, 3,310 (13%) of firefighter injuries occurred at the scene of a structure fire at a vacant building.

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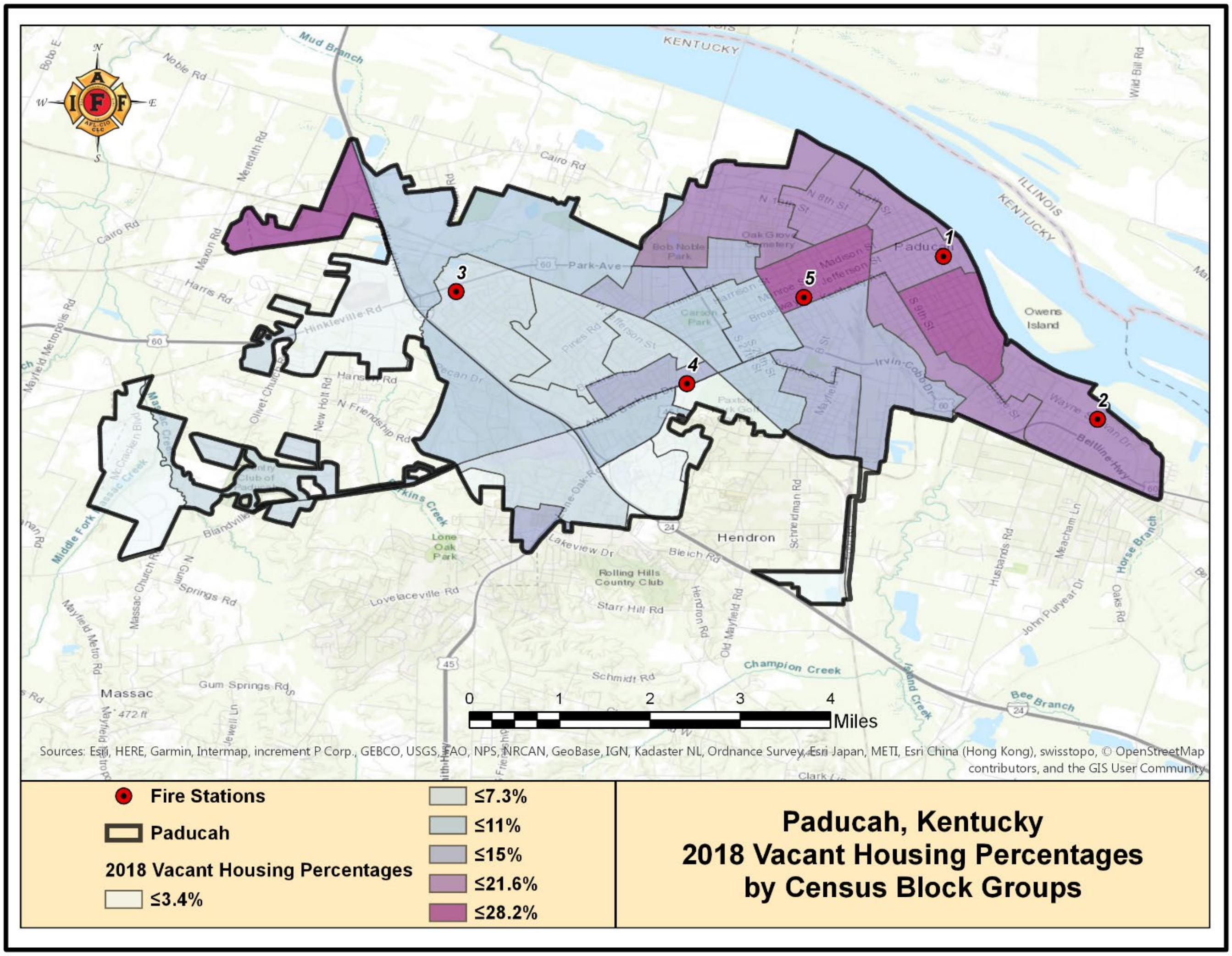
[18] U.S. Census American Fact Finder. Selected Housing Characteristics. 2012-2016 American Community Survey 5-year estimates. Paducah City Kentucky. https://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?src=CF

[19] https://www.nfpa.org/-/media/Files/News-and-Research/Fire-statistics/Occupancies/osvacantbuildings.pdf



Map 4: 2018 Vacant Housing Percentages by Census Block Groups. Map 4 identifies the 2018 vacant housing percentages broken down by census block groups for the City of Paducah. The highest vacancies are on the eastern side of the city, surrounding Station 5 and between Stations 1 and 2.

Fire Suppression Operations

The business of providing emergency services has always been labor intensive and remains so today. Although new technology has improved firefighting equipment and protective gear and has led to advances in modern medicine, it is the firefighters who still perform the time-critical tasks necessary to contain and extinguish fires, rescue trapped occupants from a burning structure, and provide emergency medical and rescue services.

A small flame can quickly burn out of control and become a major fire in a short period of time. This is because fire grows and expands exponentially as time passes. In the time frame of fire growth, the temperature of a fire rises to above 1,000º Fahrenheit. It is generally accepted in the fire service that for a medium growth rate fire,[20] flashover-the very rapid spreading of the fire due to super heating of room contents and other combustibles-can occur. Assuming an immediate discovery of a fire, followed by an un-delayed call to 9-1-1, and dispatch of emergency responders, flashover is likely to occur within 8 minutes of fire ignition. However, studies conducted by the Underwriters Laboratory (UL) and the National Institute of Standards and Technology (NIST) have proved that, due to modern construction materials and room contents that act as fuel, flashover may occur much sooner.

At the point of flashover, the odds of survival for unprotected individuals inside the affected area are virtually non-existent. The rapid response of an appropriate number of firefighters is therefore essential to initiating effective fire suppression and rescue operations that seek to minimize fire spread and maximize the odds of preserving both life and property.

This section will explain fire growth and the importance of a fire department response to a low-hazard structure fire. A low-hazard structure fire is defined as a fire that occurs in a typical, 2000 square foot single-family residential home with no basement or exposures.[21]

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[20] As defined in the *Handbook of the Society of Fire Protection Engineers*, a fast fire grows exponentially to 1.0 MW in 150 seconds. A medium fire grows exponentially to 1 MW in 300 seconds. A slow fire grows exponentially to 1 MW in 600 seconds. A 1 MW fire can be thought-of as a typical upholstered chair burning at its peak. A large sofa might be 2 to 3 MWs.

[21]NFPA 1710, 2016 ed.

Fire Growth

The Incipient Phase

The first stage of any fire is the incipient stage. In this stage, a high heat source is applied to a combustible material. The heat source causes chemical changes to the material's surface which converts from a solid and begins to release combustible gases. If enough combustible gases are released, the material will burn freely.

This process is exothermic, which means it produces heat. The generated heat raises the temperature of surrounding materials, which in turn begin to release more combustible gases into the environment and begins a chemical chain reaction of heat release and burning. At this point, the fire may go out if the first object completely burns before another fire begins or the fire can progress to the next stage, which is called the Free Burning Phase.

The Free Burning Phase

The second stage of fire growth is the "free" or "open burning" stage. When an object in a room starts to burn, (such as the armchair in Figure 1, following page), it burns in much the same way it would in an open area. In this phase of a fire, oxygen in the air is drawn into the flame and combustible gases rise to the ceiling and spread out laterally. Simultaneously, the materials that are burning continue to release more heat, which heats nearby objects and materials to their ignition temperature, and they begin to burn as well. Inside a room, unlike in an open area, after a short period of time confinement begins to influence fire development. The combustible gases that have collected on the ceiling will eventually begin to support fire and will begin to burn. Thermal radiation from this hot layer will begin to heat the ceiling, upper walls, and all the objects in the lower part of the room which will augment both the rate of burning of the original object and the rate of flame spread over its surface.

When this occurs, the structure fire reaches a critical point: either it has sufficient oxygen available to move onto the next stage or the fire does not have sufficient oxygen and progresses back to the incipient phase. However, since structures are not airtight, there is a low likelihood of the fire depleting the available oxygen. During this stage of fire growth, toxic chemicals released by the fire and high heat are enough to burn people in the immediate area and disorient and/or incapacitate people in the structure. Without rapid response and intervention by an adequately staffed fire department, the fire will likely spread to the rest of the structure.

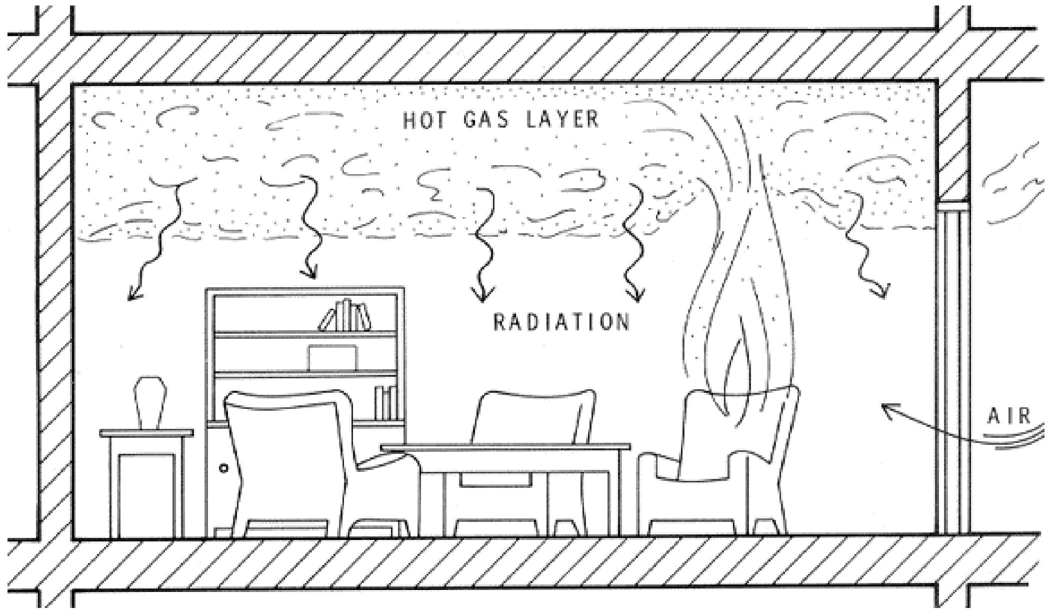

Figure 1: Fire Growth in a Compartment.[22] The above figure depicts the growth of fire in a compartment, which is an enclosed space or room in a building. In a compartment the walls, ceiling, floors, and objects absorb radiant heat produced by the fire. Unabsorbed heat is reflected back to the initial fuel source, which is depicted by the armchair above. This reflected heat continues to increase the temperature of the fuel source and therefore the rate of combustion. Hot smoke, combustible gases, and super-heated air will then rise to the ceiling and spread at first laterally across the ceiling, but later downward towards other fuel sources and the floor of the compartment. As this toxic, super-heated cloud touches cooler materials, the heat is conducted to them, thus increasing their temperature and eventually leading to pyrolysis, which is the process where a fuel source begins to release flammable vapor. This release of flammable vapor leads to further fire growth and eventually flashover. Flashover is the point at which all exposed fuel sources in a compartment ignite.

If there is sufficient oxygen, then the fire will continue to grow and the heating of the other combustibles in the room will continue to the point where they reach their ignition temperatures more or less simultaneously. If this occurs, all combustible materials in the room will spontaneously ignite. This transition from the burning of one or two objects to full room involvement is referred to as flashover.[23]

Flashover

Flashover, when it occurs, is the most significant event during a structure fire. As combustible gases are produced by the two previous stages they are not entirely consumed and are therefore available fuels. These available fuels rise and form a superheated gas layer at the ceiling that continues to increase, until it begins to bank down to the floor, heating all combustible objects

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[22] Image courtesy of University of California at Davis Fire Department

[23] J.R. Mehaffey, Ph.D., Flammability of Building Materials and Fire Growth, Institute for Research in Construction, 1987.

regardless of their proximity to the burning object. In a typical structure fire, the gas layer at the ceiling can quickly reach temperatures of 1,200º F and higher. With enough existing oxygen at the floor level, flashover occurs, which is when everything in the room ignites at once. The instantaneous eruption into flame generates a tremendous amount of heat, smoke, and pressure. The pressure generated from this explosion has enough force to push beyond the room of origin and into the rest of the structure, as well as through doors and windows.

As has been noted, at the time of flashover, windows in the room will break. When these windows break, as a result of the increased pressure in the room, a fresh supply of air from outside of the building is available to help the fire grow and spread. Based on the dynamics of fire behavior in an unprotected structure fire, any decrease in emergency unit response capabilities will correlate directly with an increase in expected life, property, and economic loss.

The Importance of Adequate Staffing: Concentration

NFPA 1500 and 1710 both recommend that a minimum acceptable fire company staffing level should be four firefighters responding on, or arriving with, each fire suppression apparatus responding to any type of fire.

A prime objective of fire service agencies is to maintain enough strategically located personnel and equipment so that the minimum effective response force can reach a reasonable number of fire scenes before flashover occurs.[24] Of utmost importance in limiting fire spread is the quick arrival of sufficient numbers of personnel and equipment to attack and extinguish the fire, as well as rescue any trapped occupants and care for the injured. Sub-optimal staffing of arriving units may delay these activities, thus allowing the fire to progress to more dangerous conditions for firefighters and civilians.

Staffing deficiencies on primary fire suppression apparatus negatively affects the ability of the fire department to safely and effectively mitigate emergencies and therefore correlates directly with higher risks and increased losses, both physically and economically. Continued fire growth beyond the time of firefighter on scene arrival is directly linked to the time it takes to initiate fire suppression operations. As indicated in Table 1, following page, responding companies staffed with four firefighters are capable of initiating critical fire ground operational tasks more efficiently than those with crew sizes below industry standards.

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[24] University of California at Davis Fire Department website; site visited June 7, 2004.
< http://fire.ucdavis.edu/ucdfire/UCDFDoperations.htm >

Engine Company Duties					Ladder Company Duties			
Fireground Tasks	**Advance Attack Line**	**% Change**	**Water on Fire**	**% Change**	**Primary Search**	**% Change**	**Venting Time**	**% Change**
4 Firefighters	0:03:27		0:08:41		0:08:47		0:04:42	
3 Firefighters	0:03:56	12% Less Efficient	0:09:15	6% Less Efficient	0:09:10	4% Less Efficient	0:07:01	32% Less Efficient
2 Firefighters	0:04:53	29% Less Efficient	0:10:16	15% Less Efficient	0:12:16	28% Less Efficient	0:07:36	38% Less Efficient

Table 1: Impact of Crew Size on a Low-Hazard Residential Fire.[25] The above table compares and contrasts the efficiencies of suppression companies in the completion of critical tasks for fire control and extinguishment. The smaller the crew size, the more tasks an individual must complete as a team member, which contributes to the delay in initiating fire attack and contributes to diminished efficiency in stopping fire loss. The Paducah Fire Department staffs suppression apparatus with 3 firefighters.

First-arriving companies staffed with four firefighters are more efficient in all aspects of initial fire suppression and search and rescue operations compared to two- or three-person companies. There is a significant increase in time for all the tasks if a company arrives on scene staffed with only three firefighters compared to four firefighters. According to the NIST Report on Residential Fireground Field Experiments, four-person crews are able to complete time critical fireground tasks 5.1 minutes (nearly 25%) faster than three-person crews. The increase in time to task completion corresponds with an increase in risk to both firefighters and trapped occupants.

With four-person crews, the effectiveness of first-arriving engine company interior attack operations *increases* by 12% to 29% efficiency compared to three- and two-person crews, respectively. The efficacy of search and rescue operations also *increases* by 4% to 28% with four-person crews compared to three- and two-person crews. Moreover, with a four-person crew, because the first-in unit is staffed with a sufficient number of personnel to accomplish its assigned duties, the second-in company does not need to support first-in company operations and is therefore capable of performing other critical fireground tasks that are likely to improve safety and outcomes.

At the scene of a structure fire, the driver/operator of the first engine company on the scene must remain with the apparatus to operate the pump. This leaves one firefighter to assist the operator in securing a water source from a hydrant and two firefighters to deploy a hoseline and stretch it to the fire. After assisting the operator, the third firefighter should begin to assist the other two firefighters with advancing the hoseline into the building and to the location of the fire. Before initiating fire suppression, the supervising officer of the first-arriving engine company is also

[25] Averill, J.D. et al. (2010). Report on Residential Fireground Field Experiments. NIST Technical Note 1661. National Institute of Standards and Technology; Gaithersburg, MD, April 2010.

responsible for walking around the building to assess the situation, determine the extent of the emergency, and request any additional resources necessary to mitigate the fire.

Similarly, the driver/operator of the first arriving ladder company must remain with the apparatus to safely position and operate the aerial device while the other three firefighters also perform critical fireground tasks such as ventilation and search and rescue. Due to the demands of fireground activities, a fire attack initiated by companies with only three or fewer firefighters is not capable of effecting a safe and effective fire suppression and/or rescue operation until additional personnel arrive.

Insufficient numbers of emergency response units, or inadequate staffing levels on those units, exposes civilians and firefighters to increased risk. It also further drains already limited fire department resources and stresses the emergency response system by requiring additional apparatus to respond from further distances. Failing to assemble sufficient resources on the scene of a fire in time to stop the spread and extinguish the fire, conduct a search, and rescue any trapped occupants puts responding firefighters and occupants in a dangerous environment with exponential risk escalation such that it is difficult to catch up and mitigate the event to a positive outcome.

The Importance of Crew Size to Overall Scene Time

Studies have shown that the more personnel that arrive on engine and ladder truck companies to the scene of a fire, the less time it takes to complete all tasks associated with fire suppression, search and rescue, and other critical fireground activities. As dispatched units arrive with sufficient numbers of firefighters, the overall time on the scene of the emergency decreases since critical fireground tasks can be completed simultaneously rather than in sequence. This also results in in the decrease of on-scene risk levels. In other words, the more firefighters available to respond and arrive early to a structure fire, the less time it takes to extinguish the fire and perform search and rescue activities, thus reducing the risk of injury and death to both firefighters and trapped occupants and reducing the economic loss to the property.

Overall Scene Time Breakdown by Crew Size		
Scenario	**Total Time**	**Efficiency**
4-Person Close Stagger	0:15:44	
3-Person Close Stagger	0:20:30	23% Less Efficient
2-Person Close Stagger	0:22:16	29% Less Efficient
4-Person Far Stagger	0:15:48	
3-Person Far Stagger	0:21:17	26% Less Efficient
2-Person Far Stagger	0:22:52	31% Less Efficient

Table 2: The Relationship between Crew Size and Scene Time. The above table displays how companies staffed with larger crew sizes will be on the scene of an emergency for a shorter time than smaller sized companies. This lag on scene could be translated to mean that emergency resources will be unavailable longer to address other emergencies that may arise.

As Table 2 shows, units that arrive with only two firefighters on an engine or ladder truck are on the scene of a fire almost 7 minutes longer than units that arrive with four firefighters on each crew. Responding units arriving with only three firefighters on an apparatus are on the scene of a fire 5 to 6 minutes longer than units that arrive with four firefighters on each apparatus. In addition to crew size, the time between the arriving crews matters to overall effectiveness and total on scene time.

In the NIST study on the low-hazard residential fire, close stagger was defined as a 1-minute time difference in the arrival of each responding crew. Far stagger was defined as a 2-minute time difference in the arrival of each responding crew.[26] [27] The results show a consistent pattern of units arriving with four firefighters in a close stagger or far stagger will decrease the overall time at the scene of the emergency compared to units that arrive with two or three firefighters, and are more efficient in fire suppression tasks as well.

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[26] Ibid.

[27] One-minute and two-minute arrival stagger times were determined from analysis of deployment data from more than 300 U.S. fire departments responding to a survey on fire department operations conducted by the International Association of Fire Chiefs and the International Association of Fire Fighters.

Physiological Strain on Smaller Crew Sizes

The same NIST study also examined the relationship between crew size and physiological strain. Two important conclusions were drawn from this part of the experiments.

- Average heart rates were higher for members of small crews.
- These higher heart rates were maintained for longer durations.[28]

In 2017 alone, 53% of all firefighter fatalities were related to overexertion.[29] There is strong epidemiological evidence that heavy physical exertion can trigger sudden cardiac events.[30] Smaller crews are responsible for performing a number of task that are designed to be performed by multiple people and frequently in teams of two. This means that firefighters on smaller crews are required to work harder than larger crews to accomplish multiple tasks. Additionally, as discussed earlier, firefighters on smaller crews will also be working longer than larger sized crews. Working harder and longer in high heat and dangerous, stressful environments increases the likelihood of firefighters suffering an injury, or worse dying, as a result of overexertion.

Charts 1 and 2, on the following pages, highlight the cardiovascular impact on firefighters based on crew size for the first arriving engine and ladder company. The heart rates of firefighters of crew sizes ranging from 2 to 5 firefighters were measured as they participated in the NIST study. The study was able to conclude that not only do smaller crews work harder and longer than larger crews, their heart rates are also more elevated for longer periods of time as well. This increases the risk of firefighters suffering an injury or death from overexertion. A firefighter suffering a medical emergency on the scene of a working fire, EMS, or rescue incident negatively impacts outcomes and increases the risk to the community, the citizen requiring assistance, and the firefighter.

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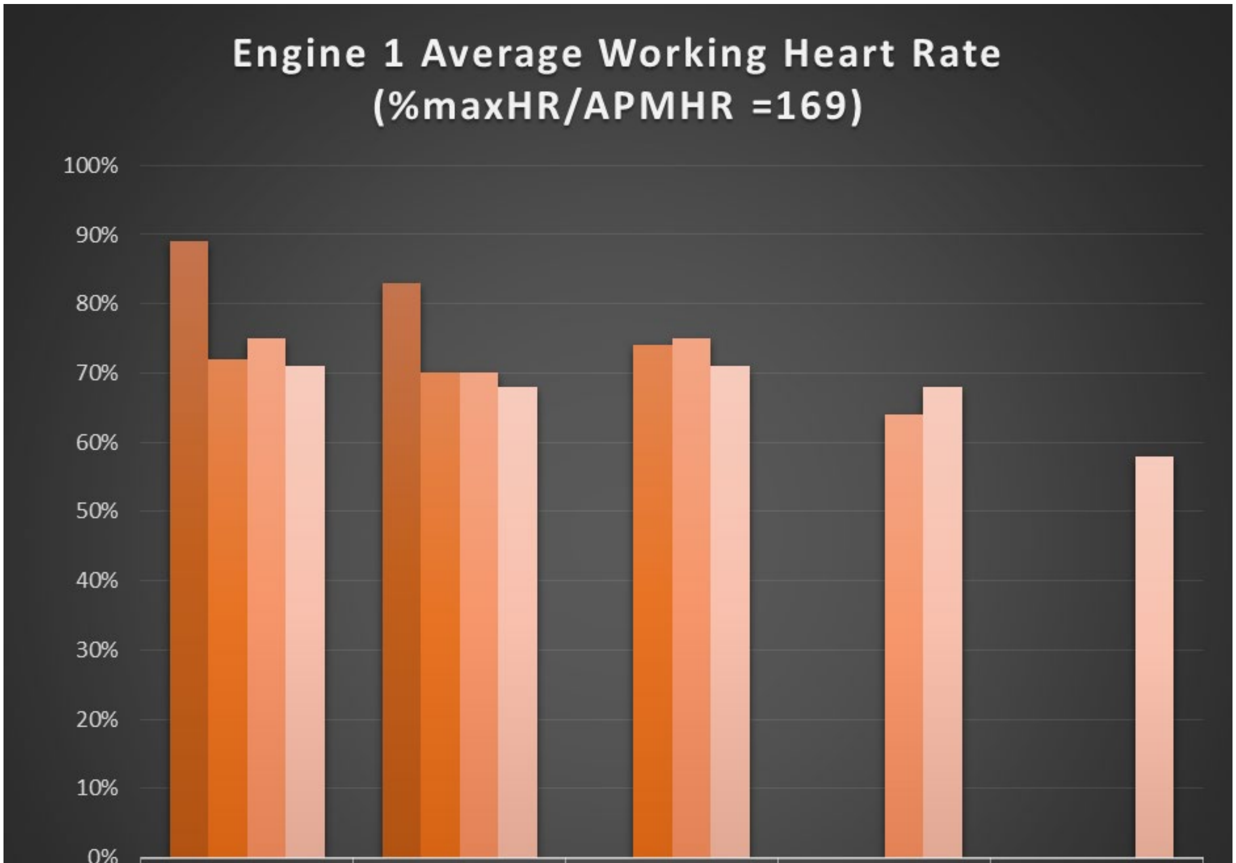
[28] Averill, J.D., et al. Report on Residential Fireground Field Experiments. NIST Technical Note 1661. National Institute of Standards and Technology; Gaithersburg, MD, April 2010.
[29] Fahy, R.F., LeBlanc, P.R., Molis, J.L. (June, 2018) Firefighter Fatalities in the United States-2017. NFPA.
[30] Albert, C.A., Mittleman, M.A., Chae C.U., Lee, I.M., Hennekens, C.H., Manson, J.E. (2000) Triggering Sudden Death from Cardiac Causes by Vigorous Exertion. N Engl J Med 343(19):1355-1361



	Driver	Officer	FF1 (RB)	FF2 (LB)	FF3 (CB)
2 FF's	89%	83%			
3 FF's	72%	70%	74%		
4 FF's	75%	70%	75%	64%	
5 FF's	71%	68%	71%	68%	58%

Chart 1: Average Peak Heart Rate of First Engine (E1) with Different Crew Sizes by Riding Position.[31] *In Chart 1, heart rates are expressed as a percent of maximal age-predicted maximal HR.* The average heart rates for firefighters on the first engine company were above 80% of age-predicted maximum values when only 2 firefighters were working. When staffing was at 2 firefighters, the driver of the apparatus had an average peak heart rate of nearly 90% of the age-predicted maximum. This is largely due to the number of additional tasks the driver must perform to prepare the engine to pump water to the fire and then join the officer to stretch hose to the fire. As can be seen, the larger the crew size, the lower the heart rate.[32] Decision makers could potentially reduce their liability for firefighter injury and death by ensuring staffing is compliant with the minimum recommended industry standards of four firefighters per apparatus.

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[31] Riding position for Chart 1 are as follows: Driver, Officer, Firefighter 1-Right Bucket (RB) seat, Firefighter 2-Left Bucket (LB) seat, Firefighter 3- Center Bucket (CB) seat. A fire company that is staffed with 2 will consist of a Driver and an "Officer."

[32] Smith, D.L., Benedict, R. Effect of Deployment of Resources on Cardiovascular Strain of Firefighters. April, 2010. Pp 5-7

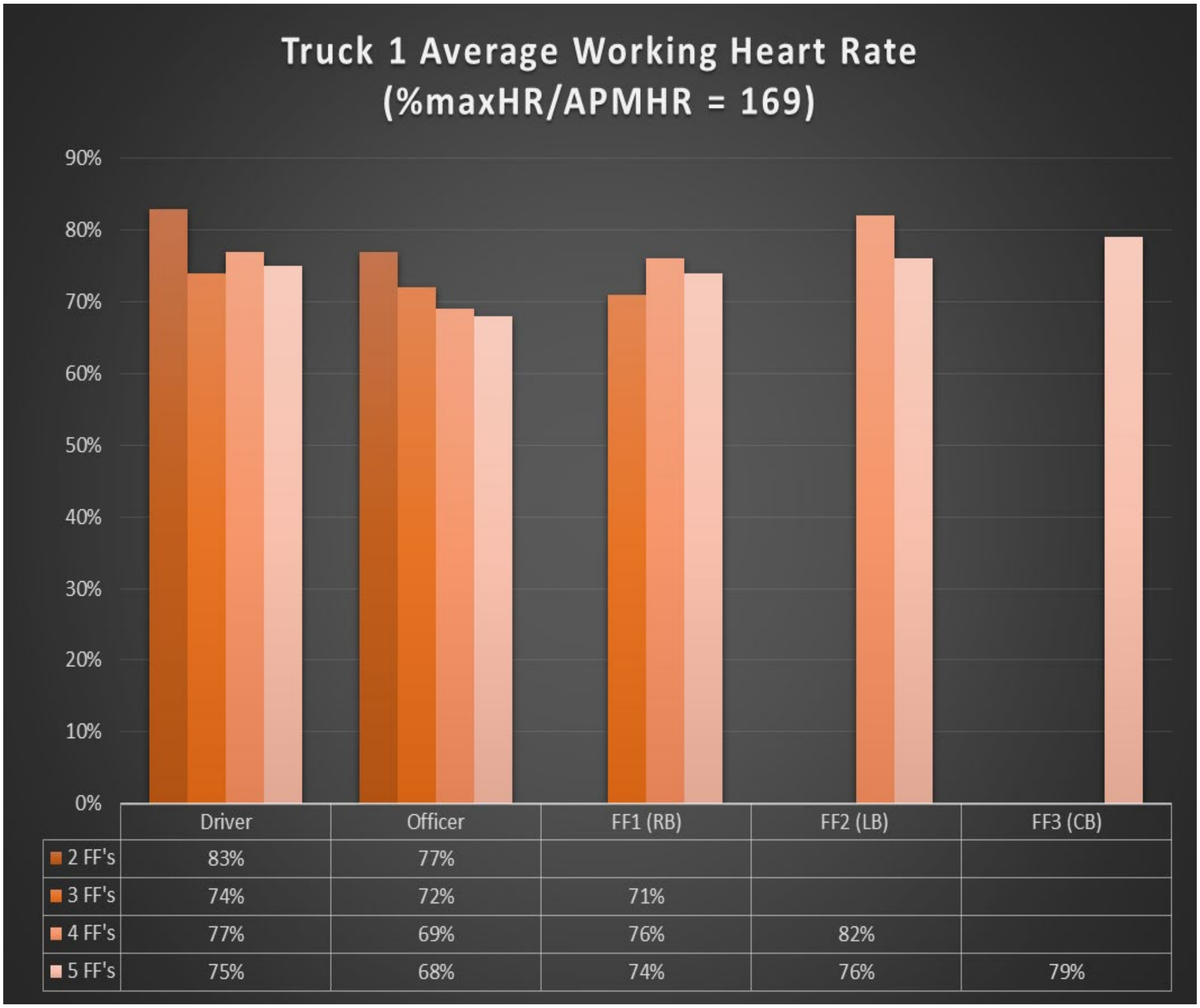

Chart 2: Average Peak Heart Rate of First Ladder (L1) with Different Crew Sizes by Riding Position.[33] *In Chart 2, heart rates are expressed as a percent of maximal age-predicted maximal HR.* The average heart rates for firefighters on the first ladder company were above 80% of age-predicted maximum values when only 2 firefighters were working.[34] Decision makers could potentially reduce their liability for firefighter injury and death by ensuring staffing is compliant with the minimum recommended industry standards of four firefighters per apparatus.

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[33] Riding position for Chart 2 are as follows: Driver, Officer, Firefighter 1-Right Bucket (RB) seat, Firefighter 2-Left Bucket (LB) seat, Firefighter 3- Center Bucket (CB) seat. A fire company that is staffed with 2 will consist of a Driver and an "Officer."

[34] Smith, D.L., Benedict, R. Effect of Deployment of Resources on Cardiovascular Strain of Firefighters. April, 2010. Pp 5-7

The Importance of a Rapid Response

Uncontained fire in a structure grows exponentially, growing in size with every passing minute. Any delay in the initiation of fire suppression and rescue operations, such as the 5- to 7- minute delay that results from smaller sized crews of firefighters, translates directly into a proportional *increase* in expected property, life, and economic losses as is shown in Table 3, following page. It warrants emphasizing that if a structure has no automatic suppression or detection system, a more advanced fire may exist by the time the fire department is notified of the emergency and is able to respond. Fires of an extended duration weaken structural support members, compromising the structural integrity of a building and forcing operations to shift from an offensive to defensive mode.[35] As with inadequate staffing, this type of operation will continue until enough resources can be amassed to mitigate the event.

In the NIST study on the low-hazard residential fire, researchers also used fire modeling to mark the degree of the toxicity of the environment for a range of growth fires (slow, medium, and fast). Occupant exposures were calculated both when firefighters arrive earlier to the scene, and when arriving later. The modeling provided that the longer it takes for firefighters to rescue trapped occupants, the greater the risk posed to both the firefighters and occupants by increasing atmospheric toxicity in the structure.

[35] According to the NFPA, "it's important to realize that every 946.3 LPM (250 GPM) stream applied to the building can add up to one ton per minute to the load the weakened structure is carrying."

Rate Per 1,000 Fires			
Fire Extension in Residential Structures:	Civilian Deaths	Civilian Injuries	Average Property Damage
Confined fires (identified by incident type)	0.00	10.29	$212.00
Confined to object of origin	0.65	13.53	$1,565.00
Confined to room of origin, including confined fires by incident type[36]	1.91	23.32	$2,993.00
Beyond the room, but confined to floor of origin	22.73	64.13	$7,168.00
Beyond floor of origin	24.63	60.41	$58,431.00

Table 3: The Relationship between Fire Extension and Fire Loss.[37] The above table displays the rates of civilian injuries and deaths per 1,000 fires, as well as the average property damage. Following the far-left column from top to bottom, each row represents a more advanced level of fire involvement in a residence. Typically, the more advanced the fire, the larger the delay in suppression. Assuming an early discovery of a fire, companies staffed with larger crew sizes help to minimize deaths, injuries, and property loss. This highlights why a 5- to 7- minute delay in suppression activities by smaller sized crews results in higher economic losses to a residence.

OSHA's "2 In/2 Out" Regulation

The "2 In/2 Out" Regulation is part of paragraph (g)(4) of the United States Occupational Safety and Health Administration's (OSHA) revised respiratory protection standard, 29 CFR 1910.134. The focus of this important section is the safety of fire fighters engaged in interior structural firefighting. OSHA's requirements for the number of firefighters required to be present when conducting operations in atmospheres that are immediately dangerous to life and health (IDLH) also covers the number of persons who must be on the scene before firefighting personnel may initiate an interior attack on a structural fire.

An interior structural fire (*an advanced fire that has spread inside of the building where high temperatures, heat and dense smoke are normally occurring*) would present an IDLH

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[36] NFIRS 5.0 has six categories of confined structure fires including cooking fires confined to the cooking vessel, confined chimney or flue fire, confined incinerator fire, confined fuel burner or boiler fire or delayed ignition, confined commercial compactor fire, and trash or rubbish fire in a structure with no flame damage to the structure or its contents. Although causal information is not required for these incidents, it is provided in some cases. In this analysis (NFPA Fire Extension in Residential Structures 2002-2005), all confirmed fires were assumed to be confined to the room of origin.

[37] National Fire Protection Association, NFPA 1710 (2016), Table A.5.2.2.2.1(b) Fire Extension in Residential Structures, 2006-2010.

atmosphere and, therefore, require the use of respirators. In those cases, at least two standby persons, in addition to the minimum of two persons inside needed to fight the fire, must be present before firefighters may enter the building.[38] [39] This requirement is mirrored in NFPA 1500, which states that "a rapid intervention team shall consist of at least two members and shall be available for rescue of a member or a team if the need arises. Once a second team is assigned or operating in the hazardous area, the incident shall no longer be considered in the 'initial stage,' and at least one rapid intervention crew shall be required."

NFPA Standard 1710 also supports the OSHA Regulation by requiring a minimum of four personnel on all suppression apparatus. Portions of the 1710 Standard recommend that "fire companies whose primary functions are to pump and deliver water and perform basic firefighting at fires, including search and rescue… shall be staffed with **a minimum of four on-duty members**,"[40] while "fire companies whose primary functions are to perform the variety of services associated with truck work, such as forcible entry, ventilation, search and rescue, aerial operations for water delivery and rescue, utility control, illumination, overhaul and salvage work… shall [also] be staffed with **a minimum of four on-duty members**."[41] For either fire suppression company, NFPA 1710 states that "In jurisdictions with a high number of incidents or geographical restrictions, as identified by the AHJ,[42] these companies shall be staffed with a minimum of five on-duty members" and "In jurisdictions with tactical hazards, high-hazard occupancies, or dense urban areas, as identified by the AHJ, these companies shall be staffed with a minimum of six on-duty members."[43]

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[38] According to NFPA standards relating to fire fighter safety and health, the incident commander may make exceptions to these rules if necessary to save lives. The Standard does not prohibit fire fighters from entering a burning structure to perform rescue operations when there is a "reasonable" belief that victims may be inside.

[39] Paula O. White, letter to Thomas N. Cooper, 1 November 1995 (OSHA)

[40] NFPA 1710, § 5.2.3.1 and § 5.2.3.1.1.

[41] NFPA 1710, § 5.2.3.2 and § 5.2.3.2.1.

[42] Authority Having Jurisdiction.

[43] NFPA 1710, §5.2.3.1.2, § 5.2.3.1.2.1, § 5.2.3.2.2, and § 5.2.3.2.2.1.

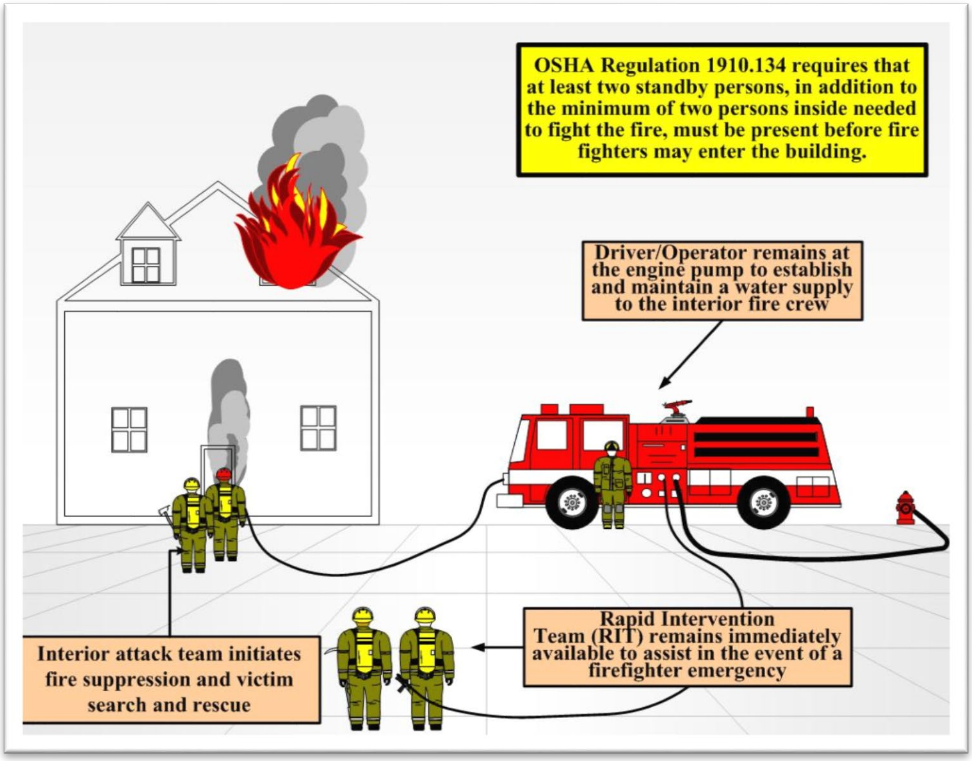

Figure 2: The OSHA "2 IN/2 Out" Regulation. The above figure depicts the number of firefighters required to meet OSHA Regulation 1910.134, which demands one firefighter outside for every firefighter inside. In this sense, the firefighters outside can support a secondary attack line and facilitate the rescue of trapped or disabled firefighters should the need arise. In this scenario, the driver/operator of the apparatus is not counted towards the total number of firefighters.

A number of incidents exists in which the failure to follow the "2 In/2 Out" Regulation have contributed to firefighter casualties. For example, in Bridgeport, Connecticut in July 2010, two firefighters died following a fire where the National Institute of Occupational Safety and Health (NIOSH) later found that although a "Mayday" was called by the firefighters, it wasn't responded to promptly as there was no incident safety officer or rapid intervention team (RIT) readily available on scene. In a second case, two firefighters were killed in a fire in San Francisco, California in June 2011. The initial RIT was re-assigned to firefighting duties, and the back-up RIT did not arrive on scene until after the victims were removed.

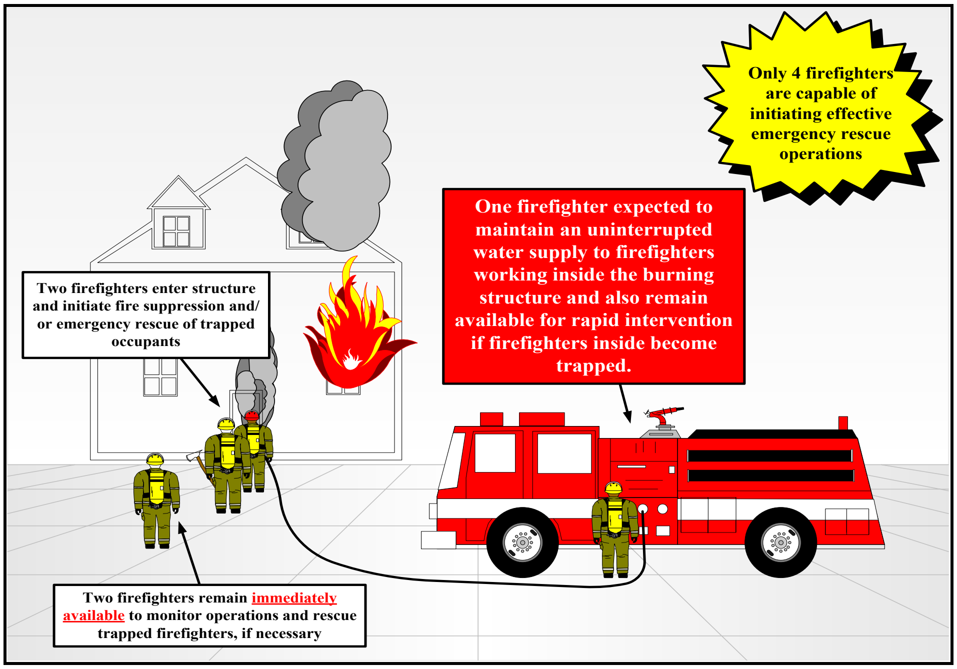

Figure 3: Emergency "2 In/2 Out" Operations. In the emergency model depicted above, the arriving fire apparatus is staffed with a crew of 4 personnel and operates under emergency conditions. In this case the driver/operator of the fire apparatus is also counted as a firefighter, which means that firefighter must be dressed in personal protective equipment (PPE) and be ready to participate in rescue if the need should arise.

When confronted with occupants trapped in a burning structure and a single fire company is on scene, only a company staffed with four firefighters is able to initiate emergency search and rescue operations in compliance with the "2 In/2 Out" Regulation. As indicated in the previous graphic, this requires the complete engagement of every firefighter from the first-in fire company, staffed with four, to participate in the effort, and means that the driver-operator of the apparatus must tend to the pump to ensure the delivery of water to the firefighters performing the initial attack and search and rescue operations and be prepared to make entry with the remaining firefighter should the crew operating inside become trapped.

Regardless, when there exists an immediate threat to life, only a company of four firefighters can initiate fire suppression and rescue operations in compliance with the "2 In/2 Out" Regulation, and in a manner that minimizes the threat of personal injury. In crews with fewer than 4 firefighters, the first-in company must wait until the arrival of the second-in unit to initiate safe and effective fire suppression and rescue operations. This condition underlines the importance and desirability of fire companies to be staffed with four firefighters and stresses the benefit of four-person companies and their ability to save lives without having to wait for the second-in company to arrive.

Initial Full Alarm Assignment

Single-Family Dwelling Initial Full Alarm Assignment Capability, as outlined in NFPA Standard 1710, recommends that the "fire department shall have the capability to deploy an initial full alarm assignment within a 480-second travel time to 90 percent of the incidents… [and that the] initial full alarm shall provide for the following:

Assignment	*Required Personnel*
Incident Command	1 Officer
Uninterrupted Water Supply	1 Pump Operator
Water Flow from Two Handlines	4 Firefighters (2 for each line)
Support for Handlines	2 Firefighters (1 for each line)
Victim Search and Rescue Team	2 Firefighters
Ventilation Team	2 Firefighters
Aerial Operator	1 Firefighter
Initial Rapid Intervention Crew (IRIC)	2 Firefighters
Required Minimum Personnel for Full Alarm	**14 Firefighters & 1 Scene Commander**

Table 4: NFPA 1710, §5.2.4.1.1. This breakdown of the expected capabilities of a full alarm assignment, in compliance with NFPA 1710, requires a minimum contingent of 15 fire suppression personnel. NFPA 1710 also requires that supervisory chief officers shall be assisted by a staff aide[44] which will increase on-scene staffing to 16 personnel required to arrive at the scene of a structure fire within 8 minutes of travel. Although not specifically discussed in the standard, an industry best practice is to have a second uninterrupted water supply which requires a second dedicated engine pump operator. This second, dedicated pump operator brings the total count of firefighters to 17.

[44] NFPA 1710, § 5.2.2.2.5

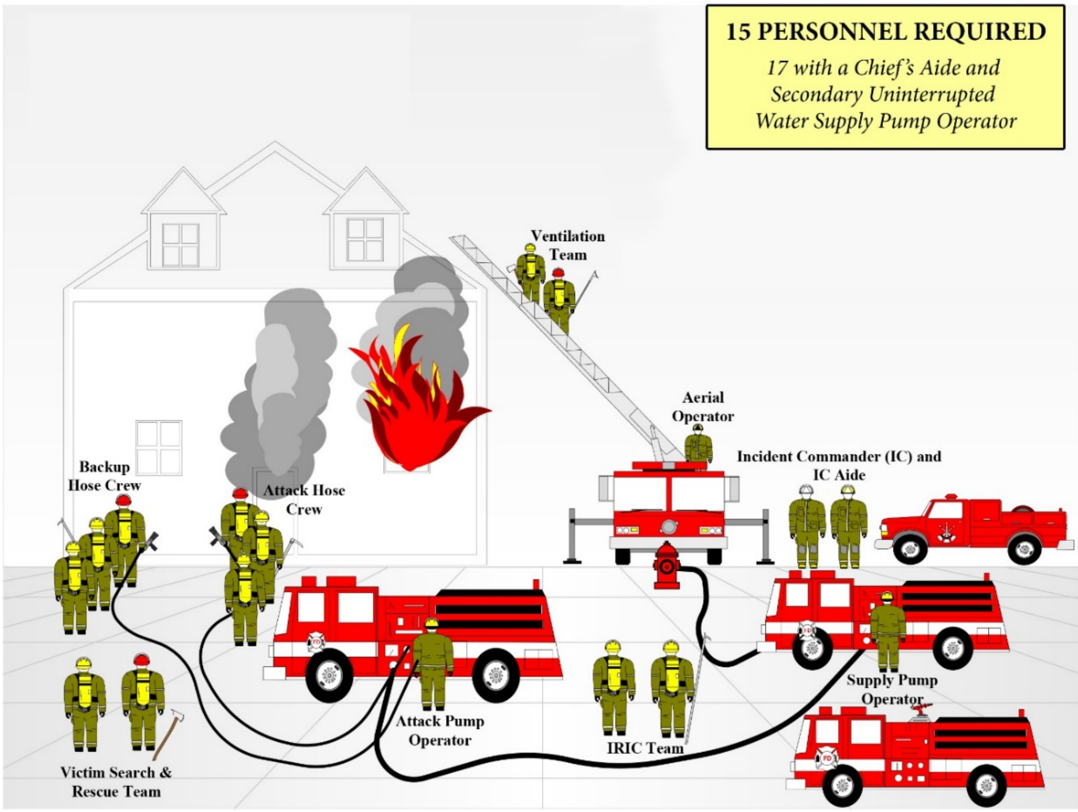

Figure 4: Initial Full Alarm Assignment, 8-Minute Travel Time. The above figure depicts the full alarm assignment discussed in NFPA 1710, with an additional firefighter to act as an incident commander aide, and another additional firefighter to act as a pump operator for a supply apparatus.

In addition, NFPA 1710, §5.2.4.5.2 states, "The fire department shall have the capability to deploy additional alarm assignments that can provide for additional command staff, members, and additional services, including the application of water to the fire; engagement in search and rescue, forcible entry, ventilation, and preservation of property; safety and accountability for personnel; and provision of support activities…"

The ability of adequate fire suppression forces to greatly influence the outcome of a structural fire is undeniable and predictable. Each stage of fire extension beyond the room of origin directly increases the rate of civilian deaths, injuries, and property damage.

Fire growth is exponential, growing in a non-linear manner over time. Extending the time for crew assembly by waiting for additional crews to arrive causes on-scene risk to escalate. The higher the risks at the time firefighters engage in fire suppression, the greater the chance of poor outcomes including civilian injury or death, firefighter injury or death, and increased property loss.

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High-Rise Operations

Although this section specifically addresses fire response to high-rise buildings, it is important to note that the discussion can be extrapolated to large area buildings such as manufacturing centers, warehouses, grocery stores, schools, dormitories, and other structures with a high fire load and populations.

High-rise buildings were once found exclusively in urban cities. However, today they are commonly found in small and mid-sized suburban communities as well. Many high-rise buildings in suburban areas are newer, shorter, and protected by automatic sprinkler systems, although this is not always a guarantee. The NFPA 101, Life Safety Code, 2015 Edition and the International Code Council-published International Building Code both define a high-rise structure as a building more than 75 feet in height, measured from the lowest level of fire department vehicle access to the bottom of the highest occupied floor. High-rises, which are described in NFPA 1710, §A.3.3.28 as high-hazard occupancies, represent an extraordinary challenge to fire departments and are some of the most challenging incidents firefighters encounter.

High-rise buildings may hold thousands of people above the reach of fire department aerial devices, and the chance of rescuing victims from the exterior is greatly reduced once a fire has reached flashover. The risk to firefighters and occupants increases in proportion to the height of the building and the height of the fire above grade level.[45] This is especially true once firefighters are operating above the reach of aerial ladders on truck companies. In these situations, the only viable means of ingress or egress is the interior stairs. Therefore, a sound fire department deployment strategy, effective operational tactics, and engineered fire protection systems cannot be separated from firefighter safety. As in any structure fire, Engine company and Ladder company operations must be coordinated.

High-rise buildings present a unique threat to the fire service. Multi-floor fires such as the Interstate Building fire, One Meridian Plaza fire, World Trade Center collapse, Cook County Administration Building fire, and Deutsche Bank Building fire each represented serious challenges to the operational capabilities of a modern fire department. According to the NFPA, between 2009 and 2013, there were an estimated 14,540 reported high-rise structure fires per year that resulted in annual losses of 4 civilian deaths, 520 civilian injuries, and $154 million dollars in direct property damage per year. Office buildings, hotels, dormitories, apartment

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[45] Klaene, B. and Sanders, R. (2007). Structural Firefighting: Strategies and Tactics- High-Rise. Jones and Bartlett 2007.

buildings, and health care facilities accounted for nearly three quarters (73%) of these high-rise fires.[46]

Although the frequency of fires in high-rise structures is low, they pose a high consequence of loss with regards to injury, loss of life, and property damage. Even if a department does not respond to high-rise buildings at present, it may in the future as urban sprawl continues and/or jurisdictional border restrictions and population growth require taller buildings to meet residential needs.

High-Rise Firefighting Tactics

As has been stated, in a high-rise fire, the risk to firefighters and occupants increases in proportion to the height of the building and the height of the fire above ground level. As the level of the fire floor gets higher, firefighters are required to carry more equipment further and must rely more on the building's standpipe system. A standpipe system is a piping system with discharge outlets at various locations usually located in stairwells on each floor in high-rise buildings that is connected to a water source with pressure supplemented by a fire pump[47] and/or a fire apparatus with pumping capabilities.

A fire in a high-rise building can threaten occupants and responding firefighters. Because of the amount of time it takes firefighters encumbered with equipment to access the involved floors, fire may have expanded well past the area of origin. This means that firefighters can encounter a large volume of fire and darkened conditions when they arrive on the involved floors. This can be further complicated if the building is not equipped with a sprinkler system. Additionally, open-layout floor plans such as office buildings with cubicle farms can challenge both the standpipe's flow capacity and fire department resources in regards to search, rescue, and hoseline deployment. The most effective way to extinguish a high-rise fire is by mounting an offensive attack as early as possible, because in the vast majority of historic high-rise fires, the best life safety tactic is extinguishing the fire. Good high-rise firefighting tactics and firefighter/occupant safety cannot be separated. As with a residential structure fire, the first arriving suppression apparatus should be on the scene within four minutes of travel time. However, when responding to any high-hazard buildings or structures, which include high-rises, first responding fire apparatus should be staffed with five to six firefighters per NFPA 1710, upon determination of the AHJ.

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[46] Ahrens, Marty (2016) High-Rise Building Fires. NFPA
[47] Structural Firefighting Strategy and Tactics 2nd Edition. Klaene B., Sanders R. NFPA 2008

Similar to residential structure fires, there are several critical tasks that must be accomplished. However, unlike residential firefighting in a 2,000 square foot residence, firefighters working at a high-rise fire must travel upwards of more than three stories and carry additional equipment beyond the normal requirements. Additionally, as it takes longer to assemble an effective response force and to access the fire floor, firefighters are likely to encounter a large volume of fire and will therefore have an extended fire attack. Because of this, it is necessary to establish an equipment supply chain to transport equipment and resources up and down the building.

Search and Rescue

Search and rescue are critical fireground tasks that comprise a systematic approach to locating possible victims and removing those victims from known danger to a safe area. In a residential structure fire, searches are normally conducted by a crew of two firefighters, supplemented by an attack or ventilation crew. However, high-rise structures pose challenges regarding search and rescue that are not typically encountered in residential housing. For commercial high-rises and wide-area structures, large open areas and cubicle farms require additional search and rescue teams so that thorough searches can occur over a larger area than found in most residences. In addition to these larger areas, search and rescue can be further complicated because conscious victims may retreat to areas in an attempt to find shelter from the heat and smoke. These areas may differ from places where they are typically seen by coworkers, making locating them difficult if they are unaccounted for.

In residential high-rises, apartments typically lack two exits and usually share a common hallway for egress. Doors left open by victims fleeing fire can allow fire and smoke to spread into the hallway and impact escape attempts. Firefighters will be slowed in their search since they will be required to force their way into numerous apartments to search for victims. For this reason, regardless of property's commercial or residential designation, it is essential for there to be more than one search and rescue team operating per involved floor to quickly locate victims in large surface areas. It is also necessary for additional search and rescue teams to search the floors above the fire and the highest floor of the building, due to how fire and smoke spread to the rest of the building. Search and rescue teams should also be supplemented with evacuation management teams to assist injured or disabled victims down the stairwells so searching can continue. Because of the larger search area, NFPA 1710 requires a minimum of four firefighters for searching and a minimum of four firefighters for evacuation management teams.

Fire Extinguishment

Fire extinguishment is a critical factor, since the intensity and size of the fire will determine the extent to which combustion gases are heated and how high they will rise inside the building. Building suppression systems, both active and passive, can impact fire growth, occupant safety, and firefighter safety and effectiveness. Such features include active fire detection and automatic sprinkler systems and are designed to either extinguish the fire or contain it until firefighters arrive.

Once firefighters are on scene, they will complete a series of fire confinement and extinguishment tasks. Firefighters access the structure, locate the fire, locate any avenues of spread, place hoselines, and establish a water supply. Once a water supply is established, water should be placed at the seat of the fire or in the compartment containing the fire to extinguish it. Unlike residential structure fires where hoselines can be stretched from the fire apparatus into the structure, high-rise structures require the use of standpipes systems to combat fire. This requires firefighters to carry multiple sections of hose to the affected floors and connect into the system to fight fire. Minimally, firefighters must deploy two hoselines to the involved floor and one hoseline to the floor above the fire. The third hoseline supports a number of critical tasks in the suppression effort. Principally, it is used to protect search and rescue teams, but also to stop the spread of fire as a result of conduction and convection through exposed pipes, metal framing, and ventilation systems.

Ventilation

Ventilation affects both search and rescue and fire extinguishment. Ventilation may be implemented at any time during the operation, but it should be coordinated with suppression and interior rescue activities. Ventilation is used to channel and remove heated air, smoke, fire gases, and other airborne contaminants. Applying proper ventilation at the right time and place is key to firefighter and occupant safety. Venting at the wrong time or place can draw active fire toward fresh air, which will injure or kill anyone in its path. In instances of high-rise fire suppression, adequate and appropriate ventilation is important to keep stairways free of smoke and noxious gases for victims who are evacuating.

Because of the size of high-rise buildings and high-hazard structures in general, a larger number of firefighters is required for a ventilation team than would be for a residential structure. NFPA 1710 requires a minimum of four firefighters to be assigned to ventilation.

Support

As has been discussed, fire suppression in a high-rise or high-hazard structure requires the establishment of a supply chain to shuttle equipment to different locations. Additionally, with increased resources and personnel, there is an increased need for additional supervision and accountability.

One critical support variable in high-rise fire operations is the availability of reliable elevators. If firefighters can safely use the elevators to move people and equipment, fire-ground logistics may be significantly improved. When the fire is located several floors above ground level, there is a strong inclination to use the elevators. However, fire service access elevators[48] may not be available in all buildings. Therefore, adequate stairways are necessary for firefighters to transport equipment and reach the fire floor for suppression.

Moving supplies and staff up 10, 20, 30, or more stories is an arduous task. If it is not properly managed, firefighters may be exhausted and unable to fight the fire or rescue trapped occupants. Additionally, joint use of stairways by firefighters moving upward and occupants attempting to evacuate may increase the overall evacuation time of the occupants, as well as delay the firefighters' efforts to begin critical tasks such as fire suppression or search and rescue operations. As such, it is important to have multiple firefighters to help carry equipment upstairs and manage resource distribution.

To accomplish the critical fireground tasks associated with high-rise firefighting and meet the minimum staffing objectives for task completion, NFPA 1710 recommends the following company sizes for the first arriving unit(s) on the scene within four minutes of travel time for response to high-hazard structures:

- In jurisdictions with a high number of incidents or geographical restrictions, as identified by the AHJ, these companies shall be staffed by a minimum of five on-duty members.[49]
- In jurisdictions with tactical hazards, high-hazard occupancies, or dense urban areas, as identified by the AHJ, these companies shall be staffed with a minimum of six on-duty members.[50]

As indicated by the tasks that must be accomplished on a high-rise fireground, understanding the required resources is critical. The number of firefighters needed to safely and effectively combat a high-rise fire may be large. Although an offensive fire attack is the preferred strategy whenever conditions and resources permit, a defensive attack that limits operations to the outside of a building and generally results in more property damage must be considered when risks to firefighter safety are too great and benefits to building occupants are negligible. The offensive vs. defensive decision is based on a number of factors: fireground staffing available to conduct an interior attack, a sustained water supply, the ability to conduct ventilation, and risk vs. benefit analysis regarding firefighter and occupant safety. Table 5, on the following page, displays the minimum number of firefighters required to arrive as part of the initial full alarm assignment to a high-rise fire.

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[48] A fire service elevator is designed to operate in a building during a fire emergency and complying with the Kentucky Building Code, the Kentucky Fire Code and the TTSSA (Technical Standards and Safety Authority).
[49] NFPA 1710. §5.2.3.1.2
[50] NFPA 1710. §5.2.3.1.2.1, §5.2.3.2.2, and §5.2.3.2.2.1.

Assignment	***Required Personnel***
Incident Command	1 Incident Commander 1 Incident Command Aide
Uninterrupted Water Supply	1 Building Fire Pump Observer 1 Fire Engine Operator
Water Flow from Two Handlines on the Involved Floor	4 Firefighters (2 for each line)
Water Flow from One Handline One Floor Above the Involved Floor	2 Firefighters (1 for each line)
Rapid Intervention Crew(RIC) Two Floors Below the Involved Floor	4 Firefighters
Victim Search and Rescue Teams	4 Firefighters (2 per team)
Point of Entry/Oversight Fire Floor	1 Officer 1 Officer's Aide
Point of Entry/Oversight Floor Above	1 Officer 1 Officer's Aide
Evacuation Management Teams	4 Firefighters (2 per team)
Elevator Management	1 Firefighter
Lobby Operations Officer	1 Officer
Trained Incident Safety Officer	1 Officer
Staging Officer Two Floors Below Involved Floor	1 Officer
Equipment Transport to a Floor Below Involved Floor	2 Firefighters
Firefighter Rehabilitation	2 Firefighters (1 must be ALS)
Vertical Ventilation Crew	1 Officer 3 Firefighters
External Base Operations	1 Officer
2 EMS ALS Transport Units	4 Firefighters
Required Minimum Personnel for Full Alarm	**36 Firefighters** **1 Incident Commander** **6 Officers**

Table 5: Number of Firefighters for an Initial Full Alarm to a High-Rise Fire. High-rise firefighting poses many unique obstacles and challenges above those found in a residential structure fire. Hose cannot be deployed directly from fire apparatus and needs to be carried, with other equipment, to the location of the fire. Search and rescue is impacted by large areas and accessibility concerns. Additionally, because of delays in access, firefighters are likely to encounter a high volume of fire which will necessitate a supply chain to equip ongoing suppression efforts. A single alarm response to a high-rise building minimally requires 43 responders, consisting of 36 firefighters, 1 incident commander, and 6 officers.

Fire Department EMS Operations

In recent years, the provision of emergency medical services has progressed from an amenity to a citizen-required service. More than 90% of career and combination fire departments provide some form of emergency medical care, making fire departments the largest group of prehospital EMS providers in North America. In many fire departments that deliver prehospital care, EMS calls can equate to over 75% of total call volume. The Paducah Fire Department provides EMS first response at the BLS level. Currently, EMT-Basic is the minimum level of training for all firefighters.

There are six main components of an EMS incident from start to finish.[51] These are (1) detection of the incident, (2) reporting of the incident to a 9-1-1 center, (3) response to the incident by the appropriate emergency resources, (4) on scene care by emergency response personnel, (5) care by emergency personnel while in transit to a medical care facility, and (6) transfer of the patient from emergency response personnel to the medical care facility. Not all EMS events will necessitate all six components, as when a patient refuses treatment, or is treated at the scene and not transported.

In an analysis of data from over 300 fire departments in the United States, first responder units, which are typically fire engines, arrived prior to ambulances approximately 80% of the time.[52] This is likely due to the fact that fire stations housing first responder units, which are equipped and staffed with multi-role firefighter/emergency medical service technicians and supplies, are more centrally located and are able to affect a quicker response and provide life-saving procedures in advance of an ambulance. This reinforces why it is in the best interest of the public good for the fire department to provide EMS transport as well as first response.

The benefit of providing EMS by the fire department is that fire departments are already geared towards rapid response and rapid intervention. Strategically located stations and personnel are positioned to deliver time critical response and effective fire suppression and are therefore equally situated to provide effective response to time critical requests for EMS service. Both fire suppression and EMS response are required by industry standards to have personnel and

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[51] The Star of Life, designated by Leo R. Schwartz, Chief of EMS Branch, National Highway Traffic Safety Administration (NHTSA) in 1997.

[52] Moore-Merrell, L. et al. (2010) Report on Residential EMS Field Experiments, Fire Fighter Safety and Deployment Study; Montana, DC, September 2010.

resources operating on scene within 4 minutes.[53] In both fire suppression and EMS incidents, time is directly related to the amount of damage, either to the structure or the patient.

When ambulance response is prolonged, a patient will be further delayed in reaching a medical facility to receive definitive care. This is especially dangerous for incidents of chest pain, stroke, and survivable cardiac arrest. Many times, patients experiencing symptoms associated with these events may not recognize the onset indicators and immediately call for assistance.[54] [55] [56] [57] Acute Coronary Syndrome (ACS), or heart attack, is the number two leading cause of death in United States, after cancer. Experts agree that an ACS event should receive definitive care from a hospital within one hour of onset of symptoms. One study found that definitive care for ACS within one hour of onset improves survivability by 50% and 23% if definitive care was given within 3 hours.[58]

Strokes, which are the number three cause of death in the United States, as well as a leading cause of disability, also benefit from expedient treatment in definitive care. Ischemic stroke, which is a stroke caused from a blood clot, can be effectively treated if definitive care is received within 3 to 4.5 hours[59] of onset of symptoms. The sooner a patient receives definitive treatment from onset of symptoms, the less likely a patient is to suffer disability from this type of stroke. However, it is important to emphasize that before the time critical treatment can be administered to the patient in the hospital, there is a time intensive assessment that must be performed to ensure the patient is qualified to receive the treatment. The current benchmark for an ischemic stroke patient "door to needle"[60] is less than or equal to 60 minutes. However, Steps against

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[53] NFPA 1720: Standard for the Organization and Deployment of Fire Suppression Operations, Emergency Medical Operations, and Special Operations to the Public by Career Fire Departments

[54]American Heart Association, *Heart Disease and Stroke Statistics-2005 update,* Dallas, TX: AHA 2005

[55] Time from Symptom Onset to treatment and outcomes after thrombolytic therapy. Newby LK, et al. *J Am Coll Cardiol.* 1996:27:1646-1655

[56] An International Perspective on the Time to Treatment of Acute Myocardial Infarction. Dracup, K. et al. *J Nurs Scholarsh* 2003;35:317-323

[57] Prehospital and In-hospital Delays in Acute Stroke Care. Evanson, KR, et al. *Neuroepidemiology* 2001;20:65-76

[58] Association of patient delays with symptoms, cardiac enzymes, and outcomes in acute myocardial infarction. Rawles, JM. Et al. *Eur Heart J.* 1990; 11:643-648.

[59] Thrombolysis with Alteplase 3 to 4.5 Hours after Acute Ischemic Stroke. Hacke, W. et al. *N Engl J Med*. 2008;359:1317-1329

[60] "Door to Needle" is an industry specific term that refers to the time the patient entered the emergency department to the time the received the treatment. A drug named recombinant tissue plasminogen activator (rt-PA) is utilized to dissolve the thrombosis causing the stroke. Current FDA approvals limit this drug's use to 3-4.5 hours from initial symptoms and require a CT scan and labs before administration.

Recurrent Stroke (STARS) registry shows that the median door to needle time is 96 minutes or 1 hour and 36 minutes.[61]

In two-tiered EMS systems that deploy with sufficient resources, there is an increased likelihood that a patient will receive an ambulance and a first responding fire apparatus in not only a timely manner, but also frequently at the same, or close to the same time. This is extremely beneficial to the patient as most EMS responses, particularly the previously mentioned conditions, are labor intensive. Patients suffering from ACS should not perform any form of exertion as to minimize any damage that is occurring. Patients suffering from strokes are frequently unable to exert due to physical disabilities caused by the incident. An adequately sized crew is able to provide simultaneous interventions while assessment is being performed, thereby reducing the on-scene time. Following completion of critical tasks, the crew can then facilitate a safe removal of the patient to the ambulance and minimize the risk of injury to patient and provider.[62]

One of the most labor intensive and time critical requests for EMS response is cardiac arrest, which affects 20-140 out of every 100,000 people. Traditionally, the American Heart Association (AHA) taught a method of cardiac resuscitation that involved single rescuer performance of prioritized action.[63] However, there was a gap between instruction and practice which led to confusion and may have potentially reduced survival. In reality, providers respond and function in teams larger than two.

The AHA's guidelines for cardiac resuscitation focus on a team-centric approach. Evidence-backed research suggested that the manner in which CPR was being performed was inherently inefficient and only provided 10-30% of the normal blood flow to the heart and 30-40% to the brain.[64] [65] This was linked to provider fatigue from administering chest compressions, and as such, these studies indicate that providers should be rotated to ensure effective depth and rhythm of chest compressions. Consensus documents from the AHA recommend that providers should rotate with every two-minute cycle of CPR. It was also recommended that requests for EMS service for cardiac arrest also have a team leader to organize priorities and direct resources as they arrive or are needed. The team leader would also be responsible for identifying symptoms of fatigue and making appropriate assignment adjustments to ensure maximally efficient CPR.

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[61] Improving Door-to-Needle Times in Acute Ischemic Stroke: The Design and Rational for the American Heart Association/American Stroke Association's Target: Stroke Initiative. Fonarow, Gregg, et al. *Stroke* 2011;42:00-00
[62] National Institute of Standards and Technology Report on Residential EMS Field Experiments September, 2010
[63] Highlights of the 2010 American Heart Association Guidelines for CPR and ECC
[64] Determinants of Blood Flow during Cardiac Resuscitation in Dogs. Halperin, HR et al. *Circulation* 1986;73:539-550
[65] Increased Cortical Cerebral Blood Flow with LUCAS, a New Device for Mechanical Chest Compressions Compared to Standard External Compressions during Experimental Cardiopulmonary Resuscitation. Rubertson S, et al. *Resuscitation*. 2005;65:357-363

Although the AHA and other researchers have not identified what an optimally sized crew for effective team-centric CPR should be, some consensus literature from AHA has mentioned that five providers were best suited to perform resuscitation. However, providers may be required to perform multiple tasks. Industry best practices, through the guidance of medical directors, have suggested six providers would be most successful in minimizing confusion and redundancy.

An EMS crew consisting of six personnel would require four personnel arriving with the first responding fire apparatus and two with the ambulance.[66] Best practices suggest that two of the six should be paramedics, with a minimum of one assigned to each of the responding apparatus. Some EMS systems require two paramedics on the ambulance and a minimum of one on the first responding fire apparatus. However, these deployment options are determined by state directive or medical director's discretion. Regardless of the make-up of the EMS certification level of the providers on scene, an ALS-integrated cardiac arrest response should provide for the following: a lead provider, an airway manager, two providers to interchangeably deliver chest compressions, a provider to establish an intravenous medication line and administer medications, and a provider to operate the monitor.

[66] NFPA 1917: Standard for the Organization and Deployment of Fire Suppression Operations, Emergency Medical Operations, and Special Operations to the Public by Career Fire Departments

Fire Department Deployment

Before discussing the staffing and deployment analysis of the Paducah Fire Department, it is important to understand the intricacies of distribution and concentration. Although adequate staffing is a key element contributing to positive outcomes, fire station locations and apparatus deployment are equally important.

The Importance of Adequate Resources: Distribution

Distribution involves locating geographically distributed, ideal first-due resources for all-risk initial intervention. Distribution describes first due arrival. Station locations are needed to assure rapid deployment for optimal response to routine emergencies within the response jurisdiction. Distribution can be evaluated by the percentage of the jurisdiction covered by the first-due units within adopted public policy service level objectives.[67] In this report, distribution was measured by the percentage of roads and response to historical emergency incidents that are covered from each fire station within 4- and 8-minute travel times.

Distribution study requires geographical analysis of first due resources. Distribution measures may include:[68]

- Population per first due company
- Area served per first-due company (square miles)
- Number of total road miles per first-due company (miles)
- Dwelling unit square footage per first due company
- Maximum travel time in each first-due company's protection area
- Catchment areas (4-minute road response from all fire stations) to determine gap areas and overlaps of first-due resources

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[67] Commission on Fire Accreditation International, 5th Edition. 2008. Page 52.
[68] Commission on Fire Accreditation International, 5th Edition. 2008. Page 52.

- Areas outside of actual performance
    1. Population not served
    2. Area not served (square miles)
    3. Road miles not served (miles)
    4. Dwelling unit square footage not served

- First-due unit arrival times (Engine, Ladder, Hazmat unit, etc.)

A major item to be considered in the distribution of resources is travel time. It should be a matter of public policy that the distribution of fire stations in the community is based on the element of travel time and the response goal. Travel time should be periodically sampled and analyzed to determine whether or not the fire department is achieving a reasonable response performance to handle emergencies.[69]

Evaluating a small number of incidents for response time performance does not reflect the true performance of the department. Analyzing incident demand measured over a 3-5 year period will provide a more accurate assessment of the delivery system performance. Completing the same analysis over a period of time will allow for trend analysis as well.[70]

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[69] Commission on Fire Accreditation International, 5th Edition. 2008. Page 53
[70] Commission on Fire Accreditation International, 5th Edition. 2008. Page 53

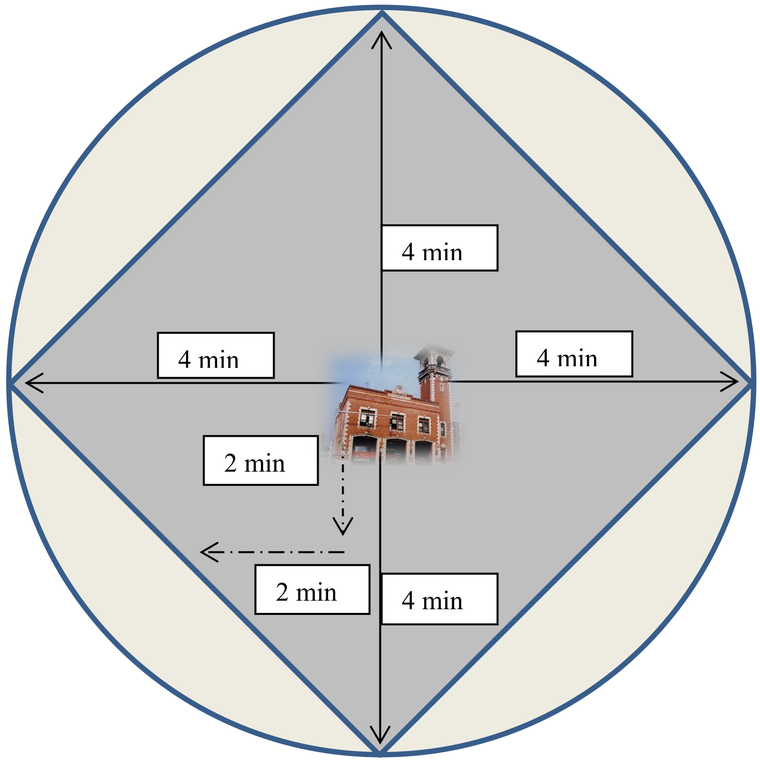

Figure 5: Normal Distribution Model for an Initial 4-Minute Response Area.[71] As depicted in the above figure, fire stations and emergency resources should be distributed throughout a community so that citizens receive equitable coverage and protection. However, there are additional points of concern when modeling a response district such as road network, traffic patterns, and building occupancies.

Distribution strives for an equitable level of outcome: everyone in the community is within the same distance from a fire station. Distribution is based on probabilities that all areas experience equal service demands, but not necessarily the same risk or consequences as those demands for service in other areas. For example, suburban communities in a city may have the same service demand as an industrial factory area, but the level of risk is very different. This can have an impact on fire station locations as placement would probably put the stations near high risk areas with shorter travel times. But, would citizens in lower risk areas accept longer travel times? Additionally, EMS response times based on medical emergencies will drive equal distribution in the community and negate distribution based on risk, as the risk is equal.

First unit arrival times are the best measure of distribution. It should be noted that if an area experiences fire unit arrival times outside the adopted performance measure, in this case 4-minute travel time per NFPA 1710, it does not necessarily mean it has a distribution issue.[72]

[71] Derived from Commission on Fire Accreditation International, 5th Edition. 2008. Page 53

[72] Commission on Fire Accreditation International, 5th Edition. 2008. Page 55

Other issues occur such as reliability, call processing times and turnout times, and traffic which can affect the overall performance of response times.

An effective response force for a fire department is impacted not only by the spacing of fire stations but also by the type and amount of apparatus and personnel staffing the stations. To assemble the necessary apparatus, personnel, and equipment within the prescribed timeframe, all must be close enough to travel to the incident, if available upon dispatch. The placement and spacing of specialty equipment is always challenging.[73] Specialty units tend to be heavy rescue and hazmat units or command personnel. Most often there are less of these types of equipment and personnel compared to the first-line response of engines and ladder trucks. Selecting where to put specialty units requires extensive examination of current and future operations within the fire department and a set goal of response time objectives for all-hazards emergencies within a jurisdiction.

Distribution vs. Concentration

Major fires have a significant impact on the resource allocation of any fire department. The dilemma for any fire department is staffing for routine emergencies and also being prepared for the fire or emergency of maximum effort. This balancing of distribution and concentration staffing needs is one that almost all fire agencies face on an ongoing basis.

The art in concentration spacing is to strike a balance with respect as to how much overlap there should be between station areas. Some overlap is necessary to maintain good response times and to provide back-up for distribution when the first-due unit is unavailable for service or deployed on a prior emergency.

Concentration pushes and pulls distribution. Each agency, *after risk assessment and critical task analysis,* must be able to quantify and articulate why its resource allocation methodology meets the governing body's adopted policies for initial effective intervention on both a first-due and multiple-unit basis.[74]

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[73] Commission on Fire Accreditation International, 5th Edition. 2008. Page 62
[74] Commission on Fire Accreditation International, 5th Edition. 2008. Pages 62-63

Mapping Analysis of the Paducah Fire Department

In creating this document, it was important to ascertain where fire stations are located and if they are located to provide fair and equitable coverage to the citizens. In order to make this assessment, the IAFF created maps of the Paducah Fire Department's response area and plotted the five fire stations. Computer modeling was then used to determine the distance apparatus could travel in 4 and 8 minutes.

Station	Address	Apparatus	Staffing
1	301 Washington Street	Engine 1 Rescue 1 Boat Hazmat Command	3 Firefighters/EMT-B Special Request Special Request Special Request 1 Assistant Chief
2	3000 W. Sullivan Drive	Engine 2	3 Firefighters/EMT-B
3	1421 Friedman Lane	Engine 3	3 Firefighters/EMT-B
4	3189 Jackson Street	Engine 4	3 Firefighters/EMT-B
5	1714 Broadway	Engine 5 Ladder 7 Rescue 2	3 Firefighters/EMT-B Cross-staffed Special Request

Table 6: Current Fire Station Locations and Staffing. The above table displays where apparatus are currently housed and the typical daily staffing.

Travel times were modeled using ESRI ArcPro version 3.0 and ESRI StreetMap Premium version 18.1. Fire stations were identified on GIS maps as starting points with vehicles traveling at posted road speeds using historical traffic patterns occurring on Wednesdays at 5:00 PM.

Prior to drawing conclusions from the mapping analysis, the following issues should be taken into consideration:

- Modeled travel speeds are based on reasonable and prudent road speeds. Actual response speeds may be slower, and the associated travel times greater, with any unpredictable impedances including, but not limited to:
  - Traffic Incidents: Collisions and vehicle breakdowns causing lane blockages and driver distractions.
  - Work Zones: Construction and maintenance activity that can cause added travel time in locations and times where congestion is not normally present.
  - Weather: Severe weather and precipitation impacting roads may result in extra travel time and altered trip patterns.
  - Special Events: Demand may change due to identifiable and predictable causes.
  - Traffic Control Devices: Poorly timed or inoperable traffic signals, railroad grade crossings, speed control systems, and traveler information signs contribute to irregularities in travel time.
  - Inadequate Road or Transit Capacity: The interaction of capacity problems with the aforementioned sources causes travel time to expand much faster than demand.[75]

- Larger emergency vehicles are generally more cumbersome and require greater skill to maneuver. Therefore, response by these vehicles may be more negatively affected by weight, size, and in some cases, inability to travel narrow surface streets.
- Computer modeling only considers travel time of apparatus. Decision makers should understand that once apparatus and personnel arrive on the incident scene there are other essential tasks that must be completed which require additional time before access, rescue, and suppression can take place. Tasks such as establishing a water supply, forcible entry (access), and deployment of an attack line are not considered in the computer modeling.
- The reliability of a community's hydrant system to supply water to fire apparatus.
- Weather conditions

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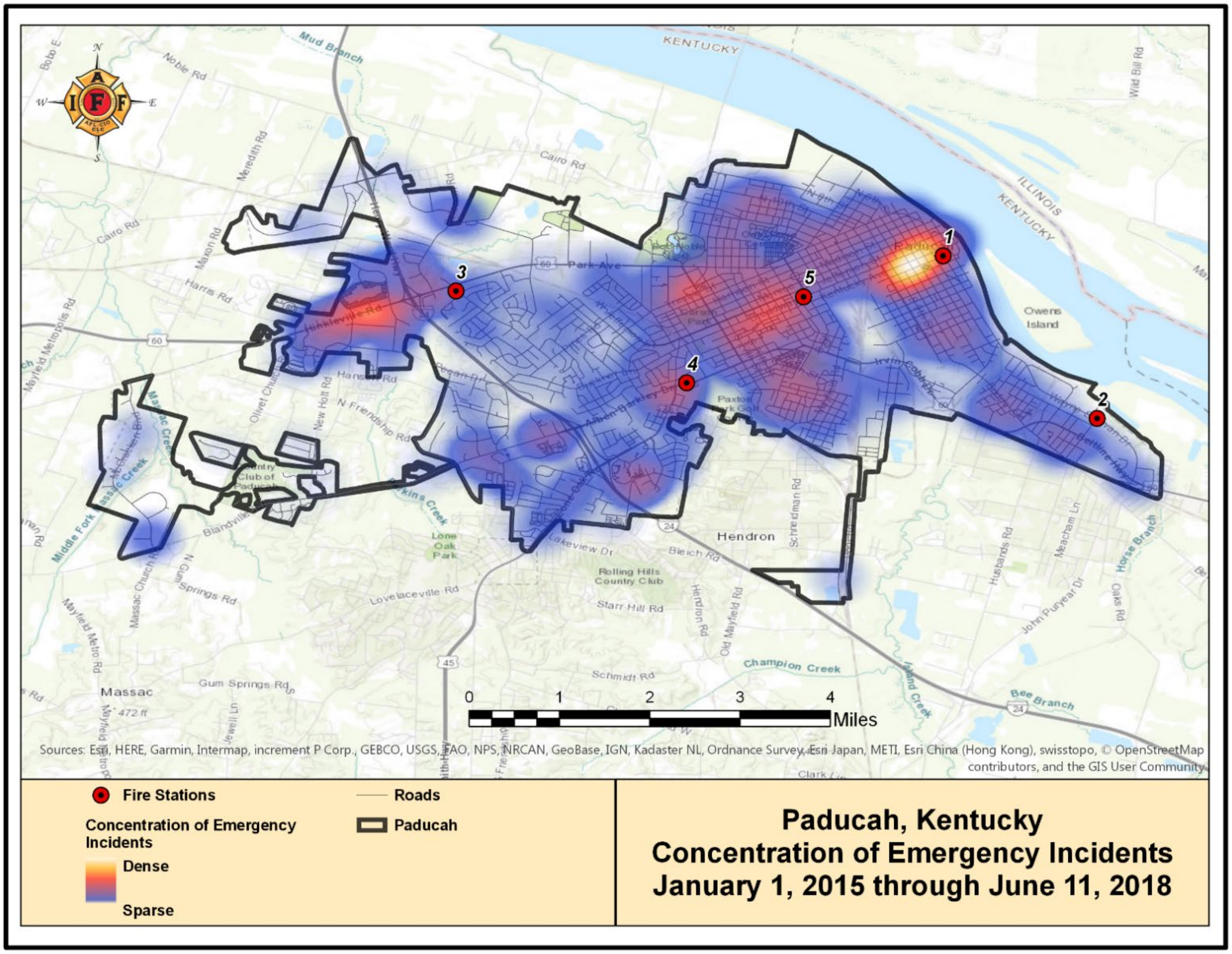
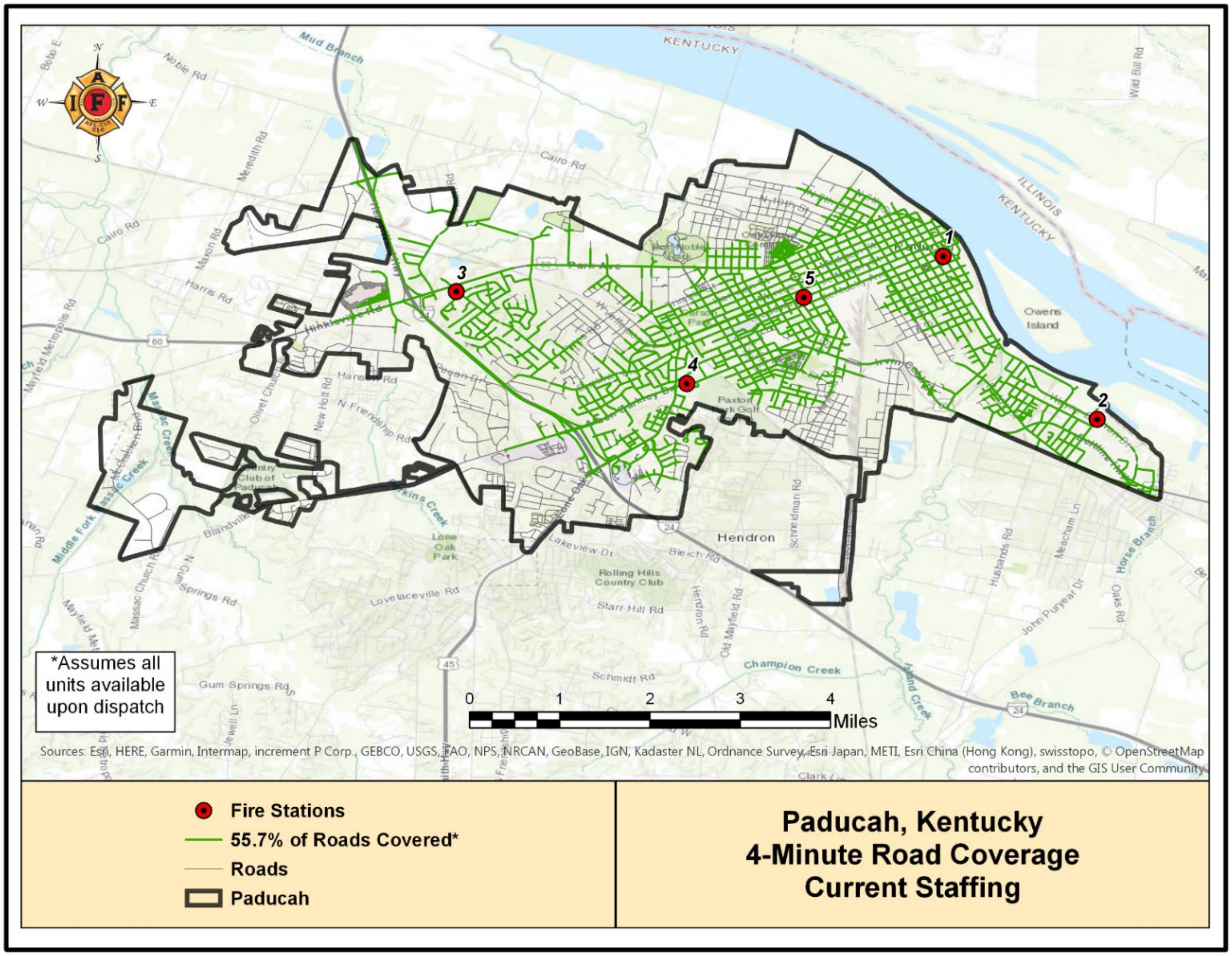
[75] David Shrank and Tim Lomax, The 2003 Urban Mobility Report, (Kentucky Transportation Institute, Kentucky A&M University: September 2003).

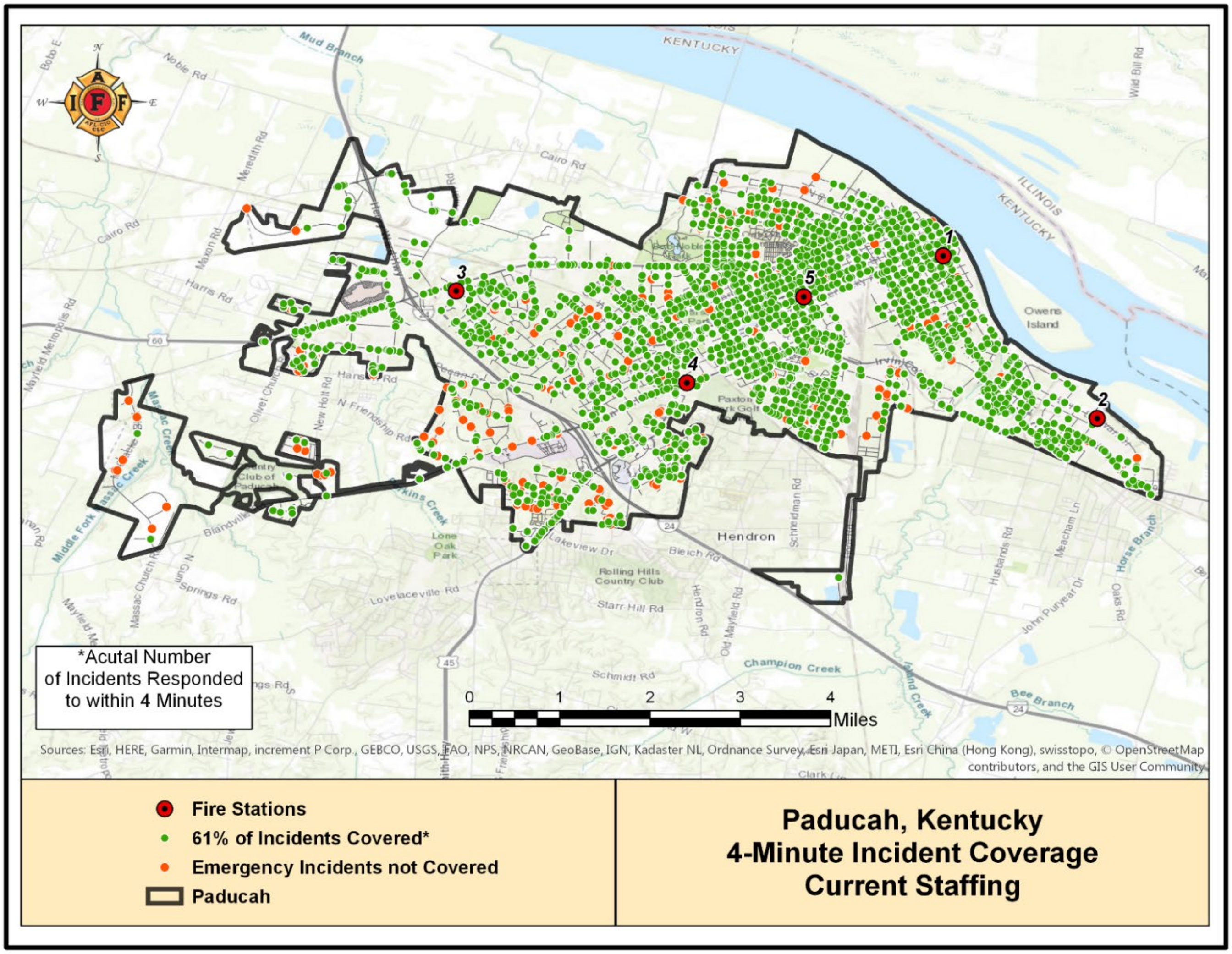


Map 5: Concentration of Emergency Incidents January 1, 2015 through June 11, 2018. Map 5 shows areas of emergency incident concentration from January 1, 2017 through June 11, 2018. Using computer aided dispatch location-based incident data, geographic statistical analysis maps areas of incident concentration. The analysis reveals the highest overall concentration of emergency incidents occurred near Station 1.

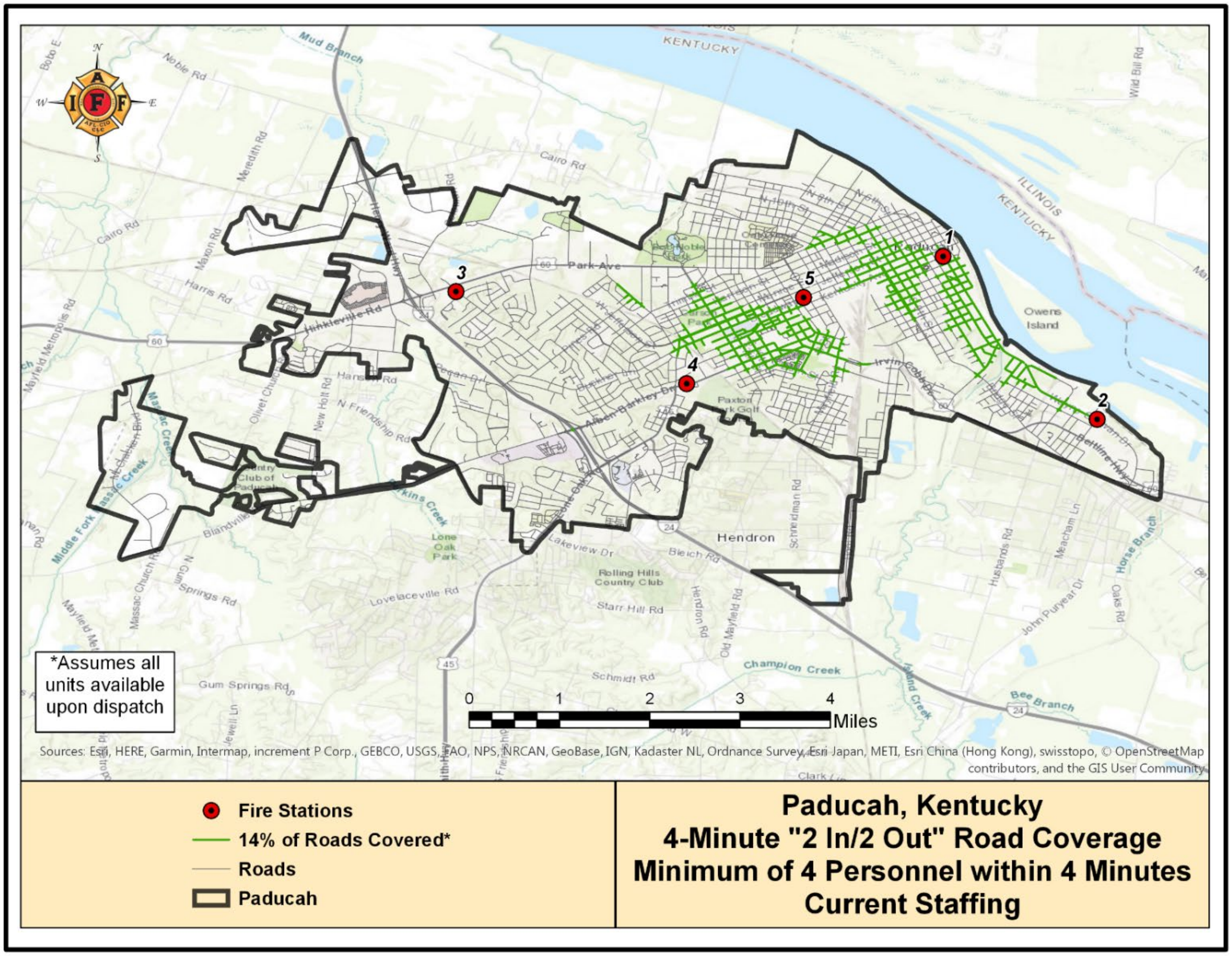
Emergency Response Capabilities- Current Staffing



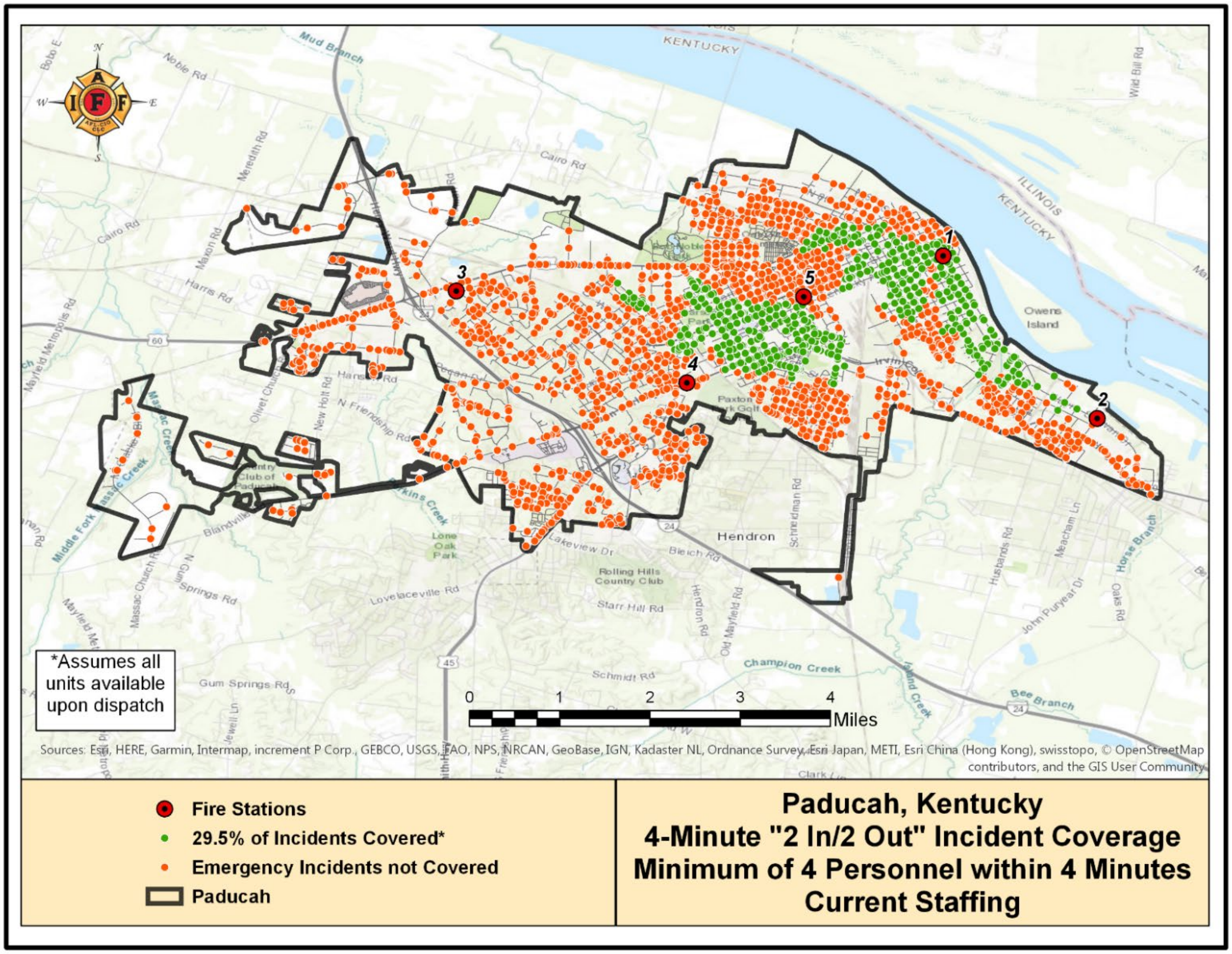
Map 6: 4-Minute Road Coverage, Current Staffing. Map 6 identifies those roads in Paducah where companies can currently respond within 4 minutes or less of travel. Currently, the department is capable of responding on 55.7% of roads within 4 minutes, assuming apparatus are available to respond immediately upon dispatch.



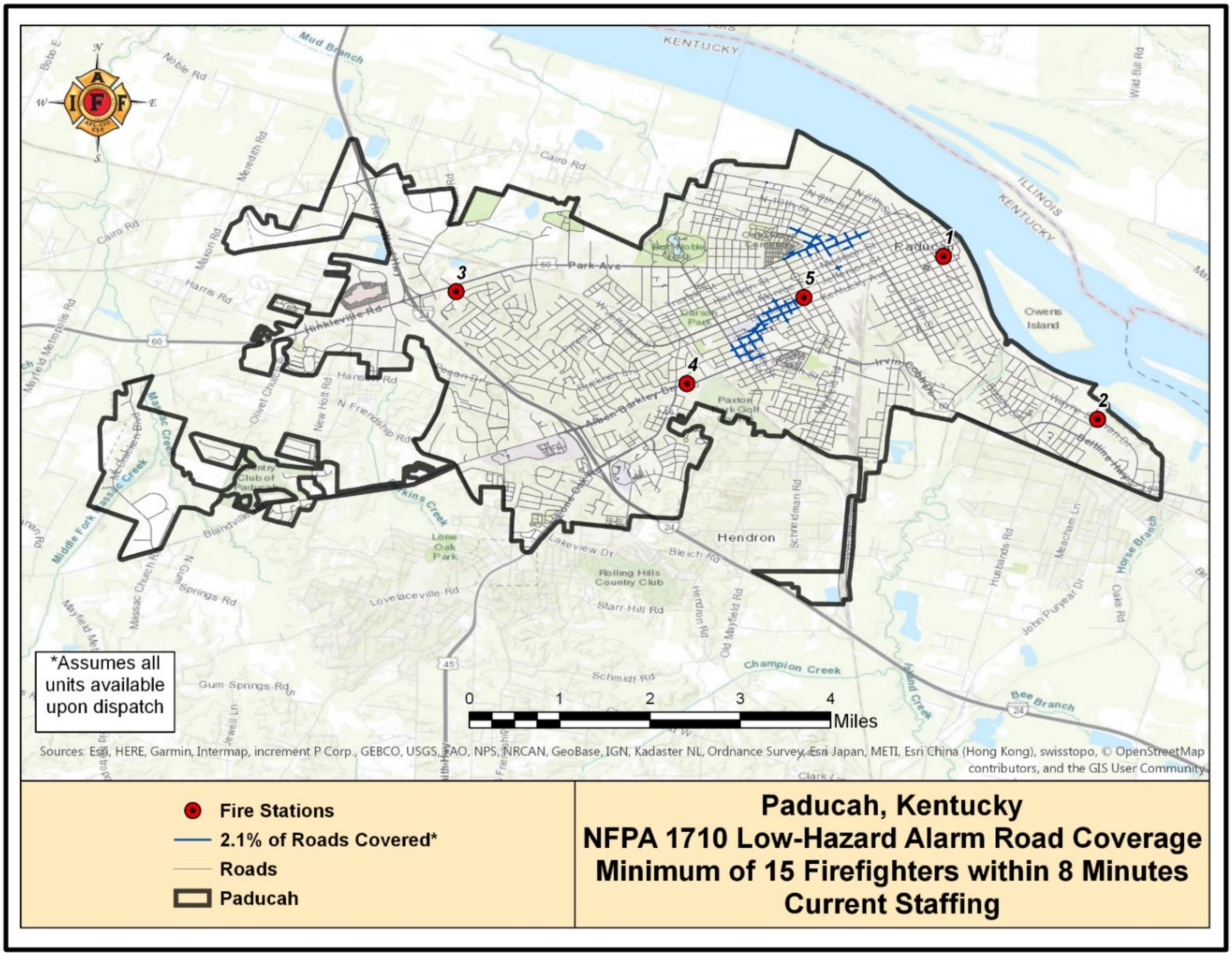
Map 7: 4-Minute Incident Coverage, Current Staffing. Map 7 identifies emergency incident locations from January 1, 2015 through June 11, 2018. The green markers indicate incidents that were responded to within a 4-minute travel time. The map shows that 61% of historical incident locations were reached within 4 minutes, which is less than the 90% objective contained in NFPA 1710.



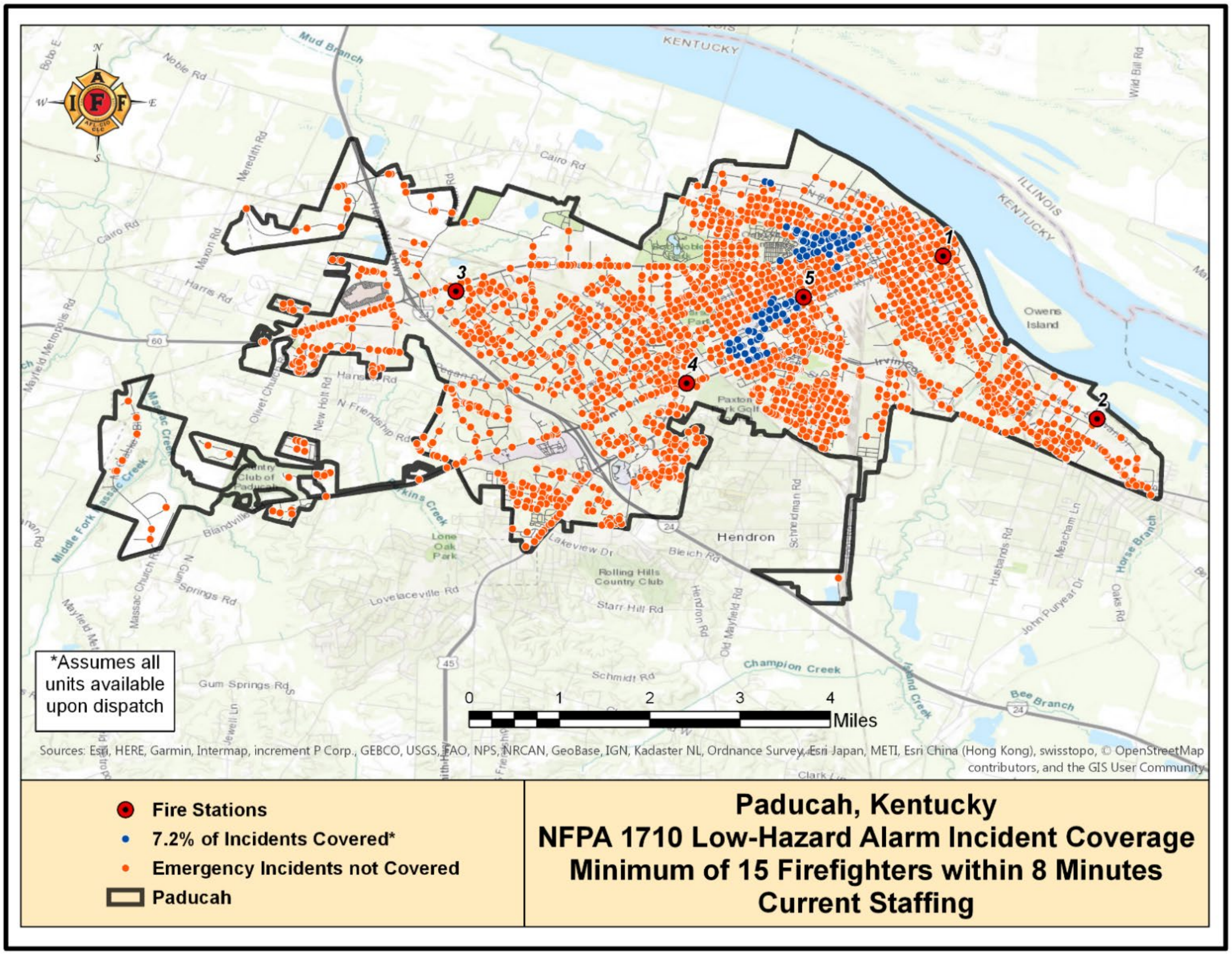
Map 8: 4-Minute "2 In/2 Out" Road Coverage, Minimum of 4 Personnel within 4 Minutes, Current Staffing. Map 8 identifies those roads where a minimum of 4 firefighters can assemble on scene within 4 minutes to meet the objectives of NFPA 1710 and OSHA's "2 In/2 Out" Regulation. Currently, 4 firefighters can assemble on 14% of all roads located in the response jurisdiction in 4 minutes or less, assuming units are available to respond immediately upon dispatch.



Map 9: 4-Minute "2 In/2 Out" Incident Coverage, Minimum of 4 Personnel within 4 Minutes, Current Staffing. Map 9 identifies those emergency incidents from January 1, 2015 through June 11, 2018 where a minimum of 4 firefighters could have assembled on scene within 4 minutes to meet the objectives of NFPA 1710 and OSHA's "2 In/2 Out" Regulation. A minimum of 4 firefighters could have reached 29.5% of incidents located in the response jurisdiction in 4 minutes or less, assuming units were available to respond immediately upon dispatch. Incident locations indicated in green represent those incidents that fall within the 4-minute, 4-personnel road coverage as depicted in Map 8.



Map 10: NFPA 1710 Low-Hazard Alarm Road Coverage, Minimum of 15 Firefighters within 8 Minutes, Current Staffing. Map 10 identifies those roads where a minimum of 15 firefighters can assemble on scene within 8 minutes to meet the objectives of NFPA 1710. Currently, 15 firefighters can assemble on 2.1% of all roads located in the response jurisdiction in 8 minutes or less, assuming units are available to respond immediately upon dispatch.



Map 11: NFPA 1710 Low-Hazard Alarm Incident Coverage, Minimum of 15 Firefighters within 8 Minutes, Current Staffing. Map 11 identifies those incidents from 2014-2017 where a minimum of 15 firefighters could have assembled on scene within 8 minutes to meet the objectives of NFPA 1710. A minimum of 15 firefighters could have assembled on scene at 7.2% of incidents located in the response jurisdiction in 8 minutes or less, assuming units were available to respond immediately upon dispatch. Incident locations indicated in blue represent those incidents that fall within the 8-minute, 15-personnel road coverage as depicted in Map 10.

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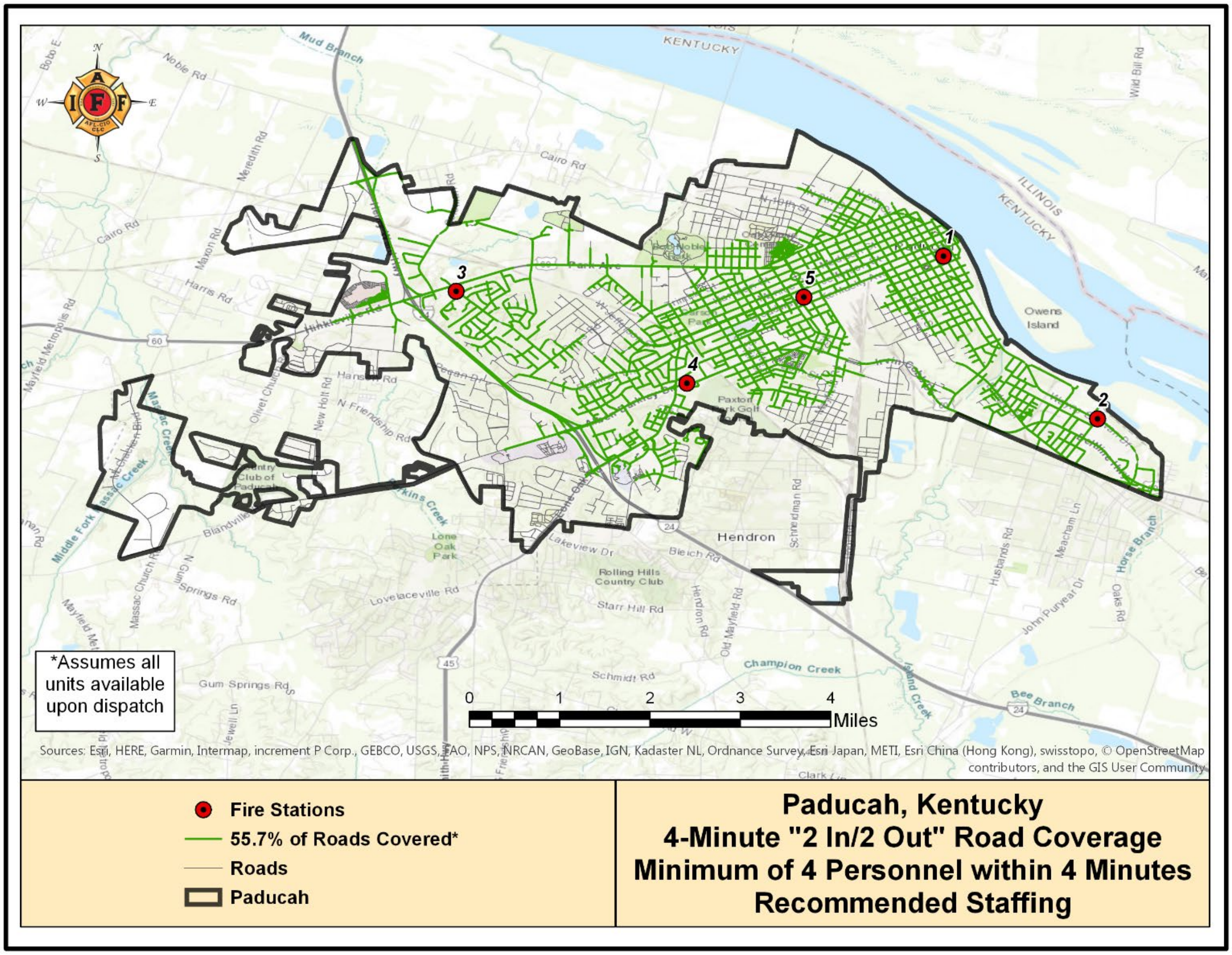
Emergency Response Capabilities- Recommended Staffing

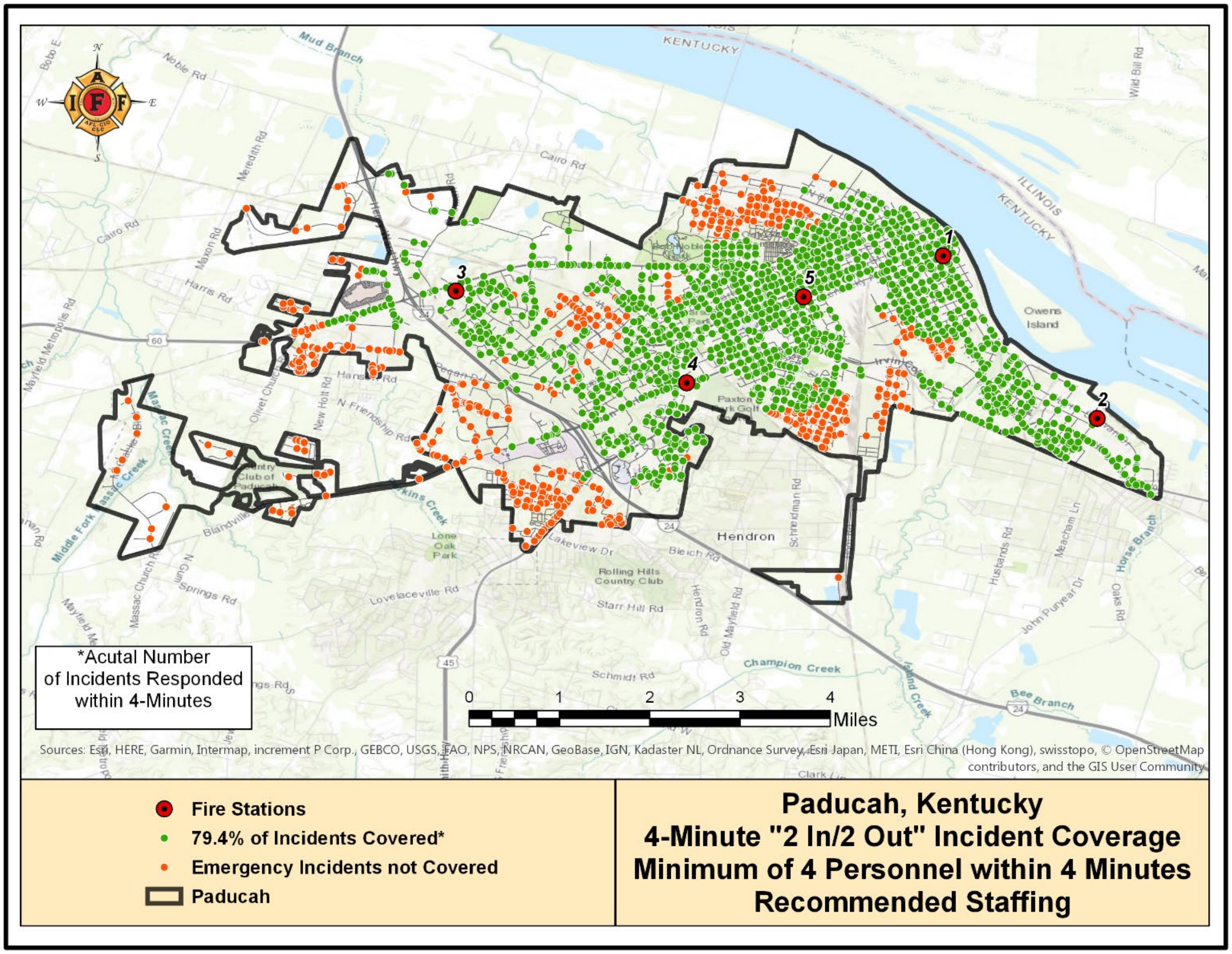
For this portion of the study, an alternate staffing and deployment scenario was examined whereby all suppression apparatus would each deploy with a minimum of four firefighters, including Ladder 7. The following maps depict the changes in coverage likely to occur pursuant to implementing this recommendation. If all suppression apparatus were staffed with four personnel, the first-in unit would be able to begin interior fire suppression and rescue operations immediately, without having to wait for a second unit to arrive. In addition, the department gains one additional apparatus available to respond to incidents.

Station	Address	Apparatus	Staffing
1	301 Washington Street	Engine 1 Engine 6 Rescue 1 Boat Hazmat Command	4 Firefighters/EMT-B Reserve Special Request Special Request Special Request 1 Assistant Chief
2	3000 W. Sullivan Drive	Engine 2 Engine 7	4 Firefighters/EMT-B Reserve
3	1421 Friedman Lane	Engine 3 Ladder 6	4 Firefighters/EMT-B Reserve
4	3189 Jackson Street	Engine 4	4 Firefighters/EMT-B
5	1714 Broadway	Engine 5 Ladder 7 Rescue 2	4 Firefighters/EMT-B 4 Firefighters/EMT-B Special Request

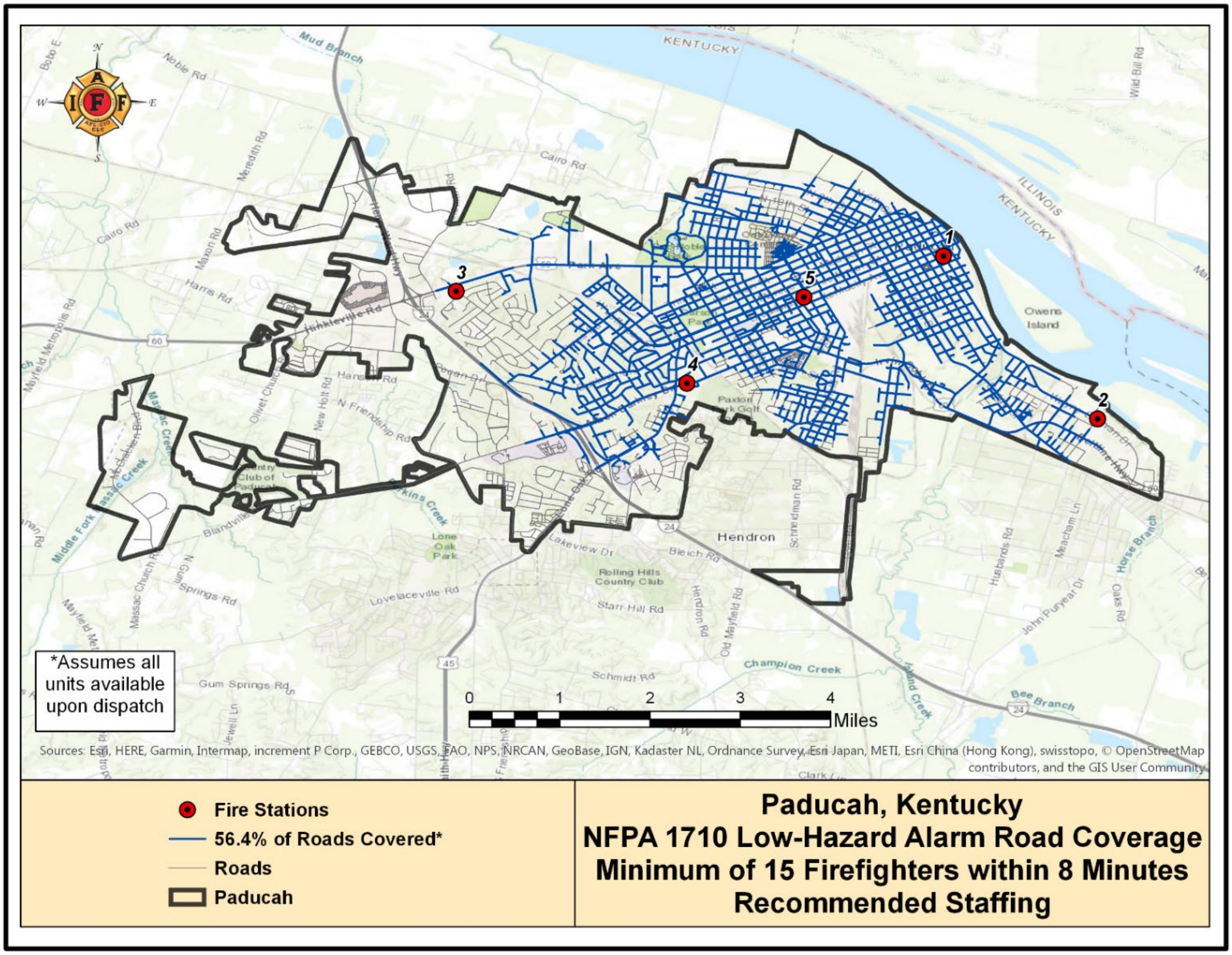
Table 7: Fire Station Locations and Recommended Staffing. The above table displays where apparatus are housed and the recommended daily staffing.



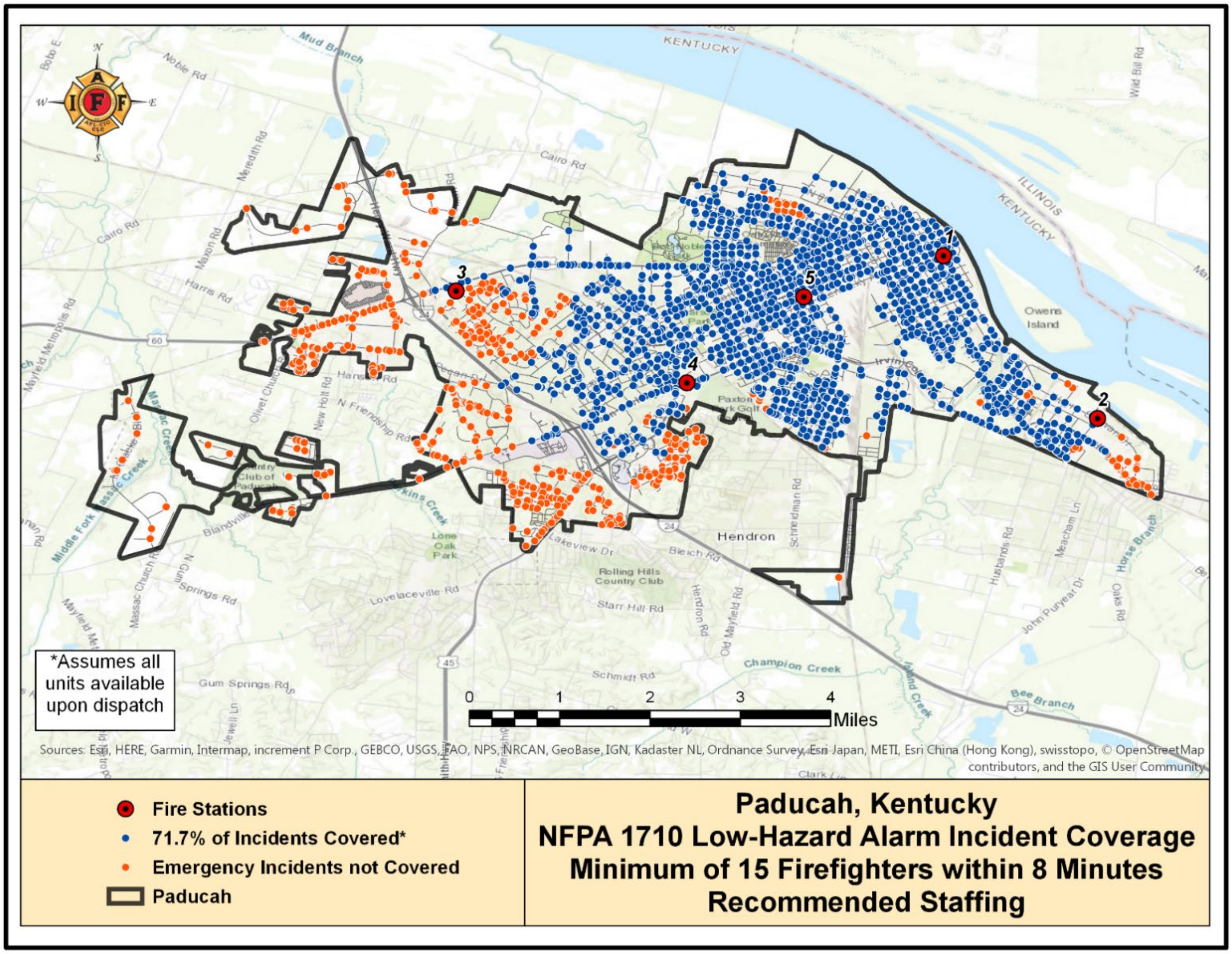
Map 12: "2 In/2 Out" Road Coverage, Minimum of 4 Firefighters within 4 Minutes, Recommended Staffing. Map 12 identifies those roads where a minimum of 4 firefighters would likely be able to assemble on scene within 4 minutes pursuant to the implementation of the recommendations shown in Table 7. In this scenario, 4 firefighters would likely be able to assemble on 55.7% of all roads located in the response jurisdiction in 4 minutes or less, assuming units are available to respond immediately upon dispatch. *This is a 297%* ***increase*** *in road coverage above current conditions.*



Map 13: "2 In/2 Out" Incident Coverage, Minimum of 4 Firefighters within 4 Minutes, Recommended Staffing. Map 13 identifies those incidents from January 1, 2015 through June 11, 2017 where a minimum of 4 firefighters would likely be able to assemble on scene within 4 minutes pursuant to the implementation of the recommendations shown in Table 7. In this scenario, 4 firefighters would likely be able to assemble on scene at 79.4% of incidents located in the response jurisdiction in 4 minutes or less, assuming units are available to respond immediately upon dispatch. *This is a 169%* ***increase*** *in incident coverage above current conditions.* Incident locations indicated in green represent those incidents that fall within the 4-minute, 4-personnel road coverage as depicted in Map 12.



Map 14: NFPA 1710 Low-Hazard Alarm Road Coverage, Minimum of 15 Firefighters within 8 Minutes, Recommended Staffing. Map 14 identifies those roads where a minimum of 15 firefighters can likely assemble on scene within 8 minutes pursuant to the implementation of the recommendations shown in Table 7. In this scenario, 15 firefighters would likely be able to assemble on 56.4% of all roads located in the response jurisdiction in 8 minutes or less, assuming units are available to respond immediately upon dispatch. *This is a 2,601%* ***increase*** *in road coverage above current conditions*.



Map 15: NFPA 1710 Low-Hazard Alarm Incident Coverage, Minimum of 15 Firefighters within 8 Minutes, Recommended Staffing. Map 15 identifies incidents from January 1, 2015 through June 11, 2018 where a minimum of 15 firefighters would likely be able to assemble on scene within 8 minutes pursuant to the implementation of the recommendations shown in Table 7. In this scenario, 15 firefighters would likely be able to assemble on scene at 71.7% of incidents located in the response jurisdiction in 8 minutes or less, assuming units were available to respond immediately upon dispatch. *This is an 897%* ***increase*** *in incident coverage above current conditions*. Incident locations indicated in blue represent those incidents that fall within the 8-minute, 15-personnel road coverage as depicted in Map 14.

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Paducah Fire Department Workload Analysis

The charts in this section show the number of emergency incidents and responses for the department, response times and call volumes for each individual unit, and back-to-back and cover responses. Individual apparatus with high call volumes, long response times, and/or are continually being dispatched may be indicators that additional resources are needed.

The Paducah Fire Department provided historical CAD data for all Paducah Fire Department emergency responses from January 1, 2015 to June 11, 2018. The CAD data include, but are not limited to, details such as incident identifier number, type of incident, location of incident, responding apparatus, dispatch time, en route time, arrival time, and the time when apparatus and personnel have cleared the scene. CAD data have the necessary information needed in order to determine the total number of incidents and apparatus responses, determine the total number of responses for each apparatus, determine the average and 90th percentile travel times, and identify back-to-back responses.

Data Parameters

- Records with errors in reporting en route time and/or arrival time were excluded from the travel time analysis.
- The CAD system is outdated. Some records contain incident information for units that did not actually respond. These records included false dispatch, en route, arrival and available times. Although fire department personnel are tasked with finding and erasing these erroneous records, false records still remain, although the number is unknown.
- Records with travel times over 35 minutes were removed from the dataset, as statistical analysis determined these records were likely incorrect.[76]
- Only data for Engine 1, Engine 2, Engine 3, Engine 4, Engine 5, and Ladder 7 were used for the travel time and back-to-back responses analyses. Reserve units, special request units, and command staff were not included.
- All units, including special request units and command staff, were used for the total number of incidents and unit responses within the department.
- Only incidents inside the Paducah city boundary were used. Mutual aid incidents outside of the city were omitted.[77]

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[76] These records comprised 1.54% of the total dataset.
[77] 38.4% of incidents were outside of city boundaries and therefore excluded.

- Because the CAD data provided did not include call volume for the entire year of 2018, some analyses (number of incidents, apparatus responses per year, and apparatus responses to structure fires) used a forecast model to determine estimated values for the entire year of 2018 to allow for a year-to-year comparison. An exponential smoothing model was used to forecast future values. The exponential smoothing model evaluated historical data to predict future results. The model assigned recent observations (2018 and 2017) a relatively greater importance than older observations (2015 and 2016) when predicting future trends. The model captured the evolving trends and/or patterns of the data and predicted future values. [78]

Call Volume Analysis

An important parameter to consider is the number of incidents compared to the number of apparatus responses. Incidents may, and frequently do, require responses from multiple apparatus. Examining the number of responses performed by each PFD apparatus will assist in determining the workload of each apparatus.

GIS analysis of the department's response capabilities is based on the assumption that all units are available to respond immediately upon dispatch, which allows for a general evaluation of the department's response capabilities. However, instances when all units are available for dispatch at the same time rarely happens. In order to more accurately evaluate the department's workload, incident data must be examined on a smaller scale.

From January 1, 2016 and June 11, 2018, all PFD apparatus and command staff responded to 9,927 incidents and performed 21,556 responses. The department is projected to respond to an additional 1,644 incidents and perform 3,775 responses in 2018. Engine 4 responded to the most incidents compared to other engines and ladders. Most engines and Ladder 7 saw an increase in responses each year. Engine 4 had a 9% increase in responses from 2015 to 2017.

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[78] Exponential smoothing models iteratively forecast future values of a regular time series of values from weighted averages of past values of the series. Exponential smoothing computes the next level or smoothed value from a weighted average of the last actual value and the last level value. The level value refers to the predicted value calculated using the exponential smoothing model. The level values are estimated values used to forecast future values in the time interval that does not have actual values. The method is exponential because the value of each level is influenced by every preceding actual value to an exponentially decreasing degree—more recent values are given greater weight.

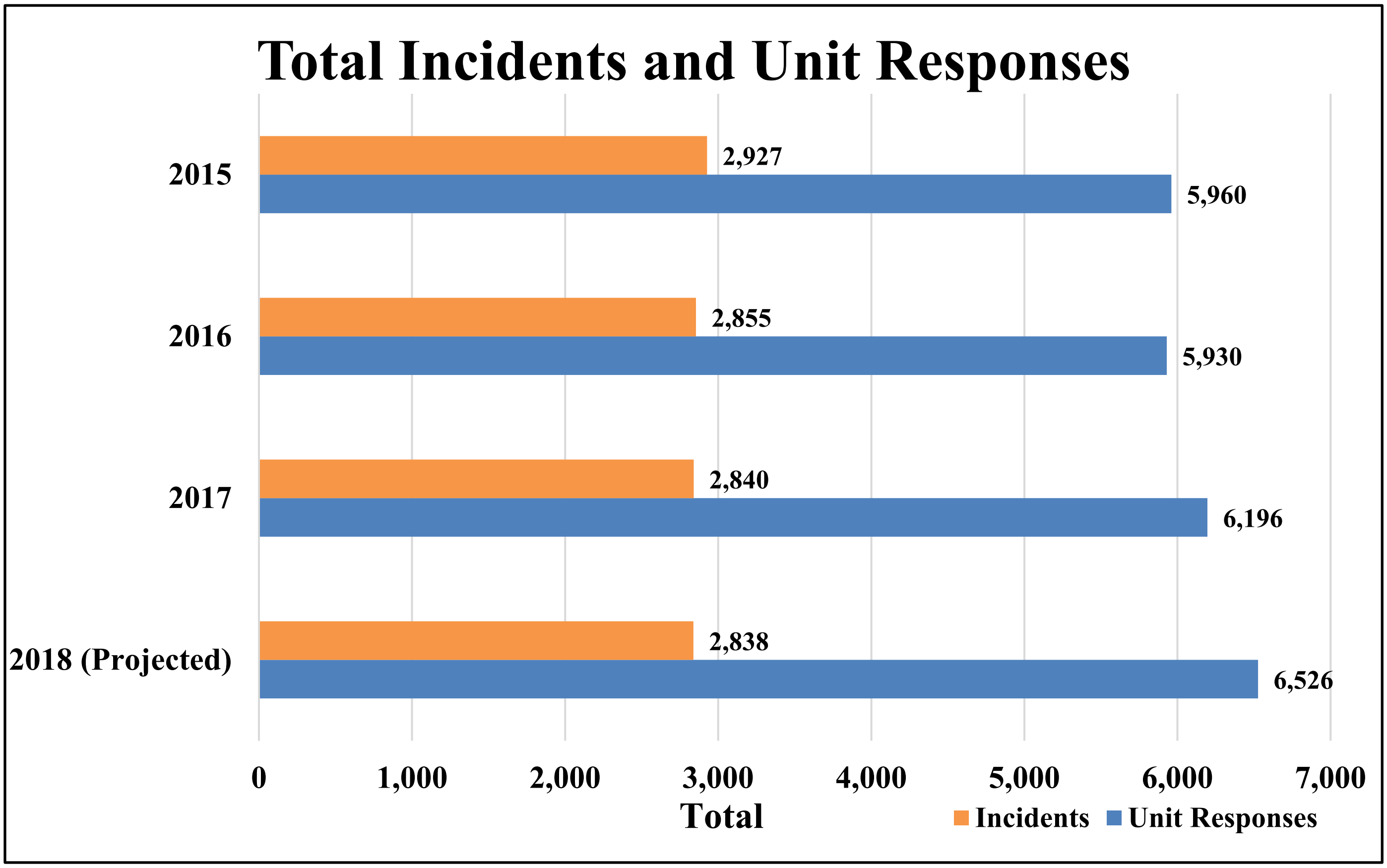


Chart 3: Total Incidents and Unit Responses for All Units. Chart 3 depicts the total number of incidents and apparatus responses executed by PFD in 2015, 2016, 2017, and 2018 (projected). Due to an incomplete dataset of call volume for 2018, analysis was performed to project an estimated number of incidents and responses for the entirety of 2018. Based on these estimates, the department is projected to experience no percent change in incidents and 6.3% **increase** in responses in 2018 compared to 2017. Responses to all incident types can be labor intensive and frequently require personnel from multiple units to complete critical tasks simultaneously.

Total Responses for Fire Suppression Units				
	2015	**2016**	**2017**	**2018 (projected)**
Engine 4	1053	1125	1158	1106
Engine 1	985	932	1006	994
Engine 3	907	871	979	921
Ladder 7	752	767	1031	988
Engine 5	751	745	792	754
Engine 2	614	604	659	671

Chart 4: Total Responses for Fire Suppression Units. Chart 4 depicts the total number of responses for each fire suppression unit. Due to an incomplete dataset of call volume for 2018, analysis was performed to project an estimated number of responses for the entirety of 2018. Based on these estimates, most units will experience an increase in the number of responses from 2017. Engine 4 was the busiest of the fire suppression units over the time period analyzed.

Travel Time Analysis

Travel times for the first arriving engine and ladder apparatus were calculated using the en route and unit arrival times and dates, as included in the CAD. NFPA 1710 states that the first arriving apparatus should be on scene within 4 minutes (240 seconds) or less of travel to 90% of all incidents. Travel times that are consistently higher than this benchmark suggest that the department may need additional resources.

Analysis examined individual apparatus' average and 90th percentile travel times for the engine and ladder companies.

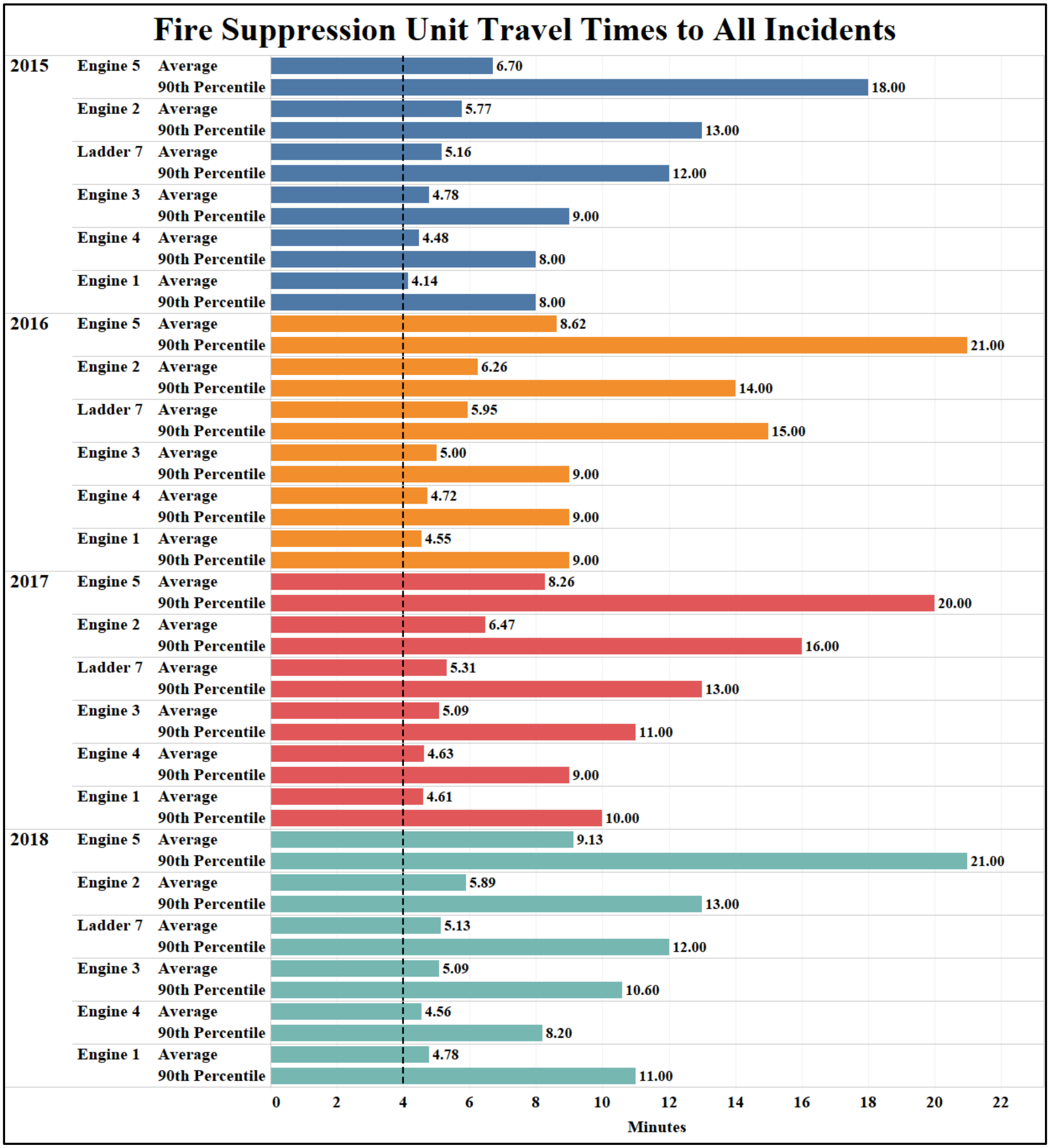


Chart 5: Fire Suppression Unit Travel Times to All Incidents. Chart 5 depicts the fire suppression apparatus' average and 90th percentile travel times for all incidents from January 1, 2015 through June 11, 2018. NFPA 1710 states that the first arriving apparatus should be on scene within 4 minutes of travel for 90% of incidents. For all units, the average travel time was over 5 minutes. The 90th percentile travel time for all units was, at a minimum, over 8 minutes. Engine 5 had much higher average and 90th percentile travel times compared to other units. The dotted line signifies the NFPA 1710 4-minute benchmark.

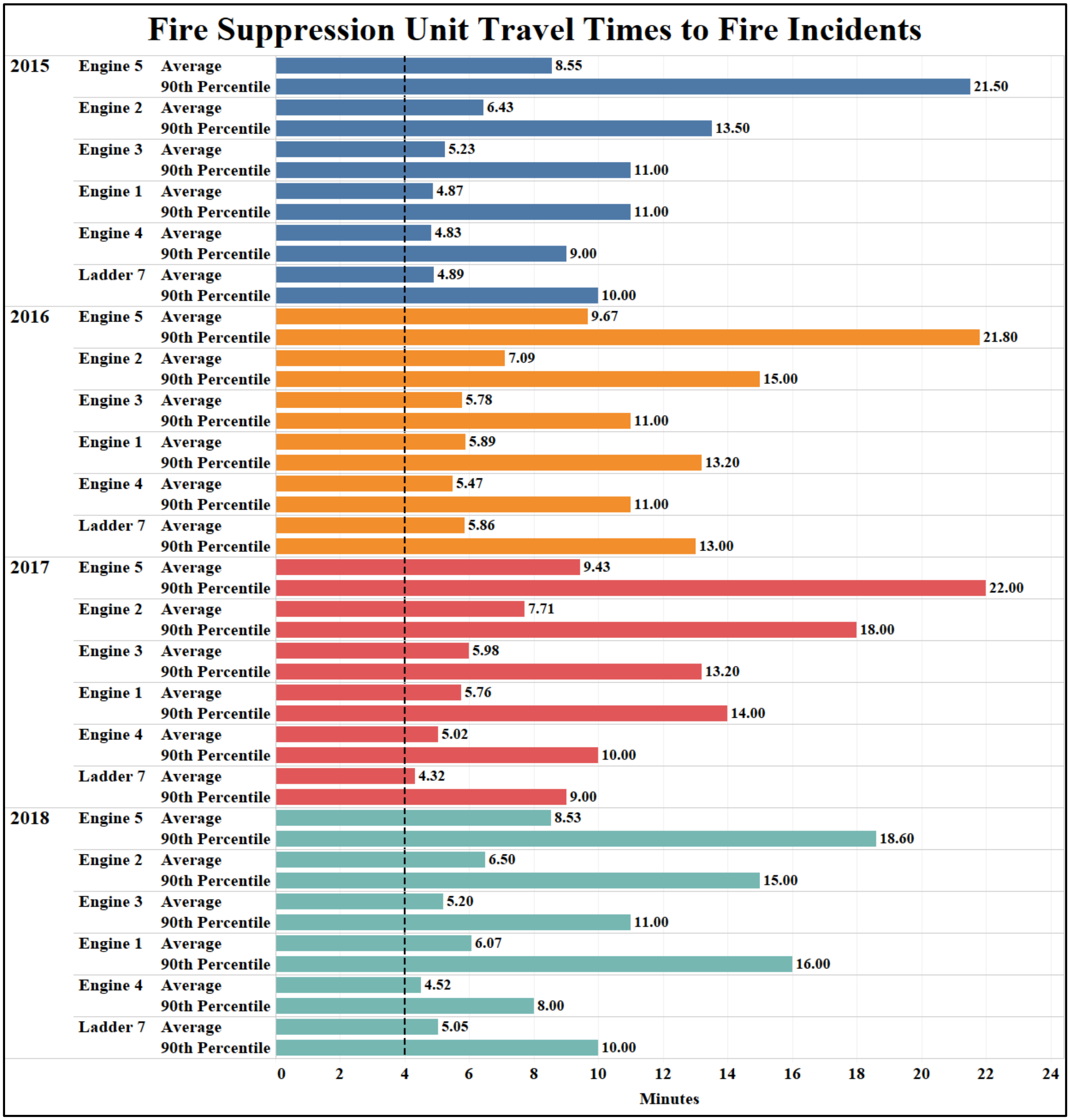
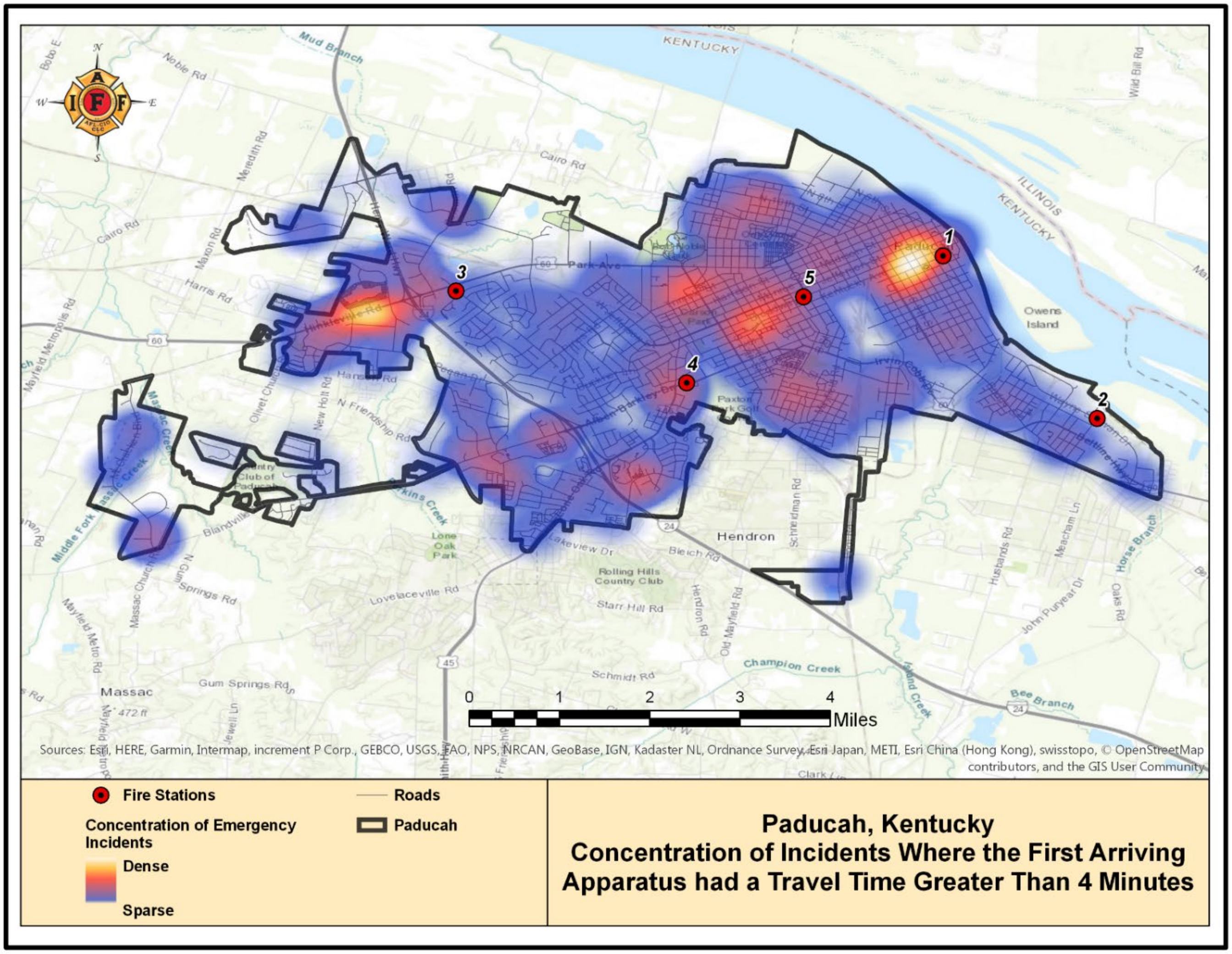


Chart 6: Fire Suppression Unit Travel Times to Fire Incidents. Chart 6 depicts the fire suppression apparatus' average and 90th percentile travel times for fire incidents from January 1, 2017 to June 11, 2018. For all units, the average travel time was over 4 minutes. The 90th percentile travel time for all units was, at a minimum, over 10 minutes. Engine 5 had much higher average and 90th percentile travel times compared to other units. The dotted line signifies the NFPA 1710 4-minute benchmark.



Map 16: Concentration of Incidents where the First Arriving Apparatus had a Travel Time Greater Than 4 Minutes. Map 16 depicts the concentration levels of incidents from January 1, 2011 to June 11, 2018 where the first arriving apparatus had a travel time greater than 4 minutes. The highest concentrations of incidents where the first arriving apparatus had a travel time greater than 4 minutes were located just west of Station 1 and west of Station 3.

Back-to-Back Responses Analysis

Another parameter used to evaluate the department's workload was the number of back-to-back responses, defined as occurrences when apparatus have been dispatched within 10 minutes of becoming available from a previous emergency. Back-to-back responses are dangerous for personnel who operate with a limited rest period between emergencies, and as a consequence, for the community, as personnel may experience both mental and physical fatigue.

A high frequency of back-to-back responses could be an indicator that the PFD needs more resources to meet demand. The total number of back-to-back responses for Paducah's fire apparatus was 907 from January 1, 2015 to June 11, 2018. From the same time period, 53.9% of all back-to-back responses for the primary fire suppression units occurred within 2 minutes or less from the time when these apparatus were cleared from a previous incident. The highest total number of back-to-back responses occurred within 2 minutes for all primary fire suppression units. This suggests that resources may have been immediately dispatched to an ongoing incident due to the lack of available resources at the time the incident was initially dispatched, or that there is a high call volume in the respective first-due response areas of the apparatus that experienced higher numbers of back-to-back responses.

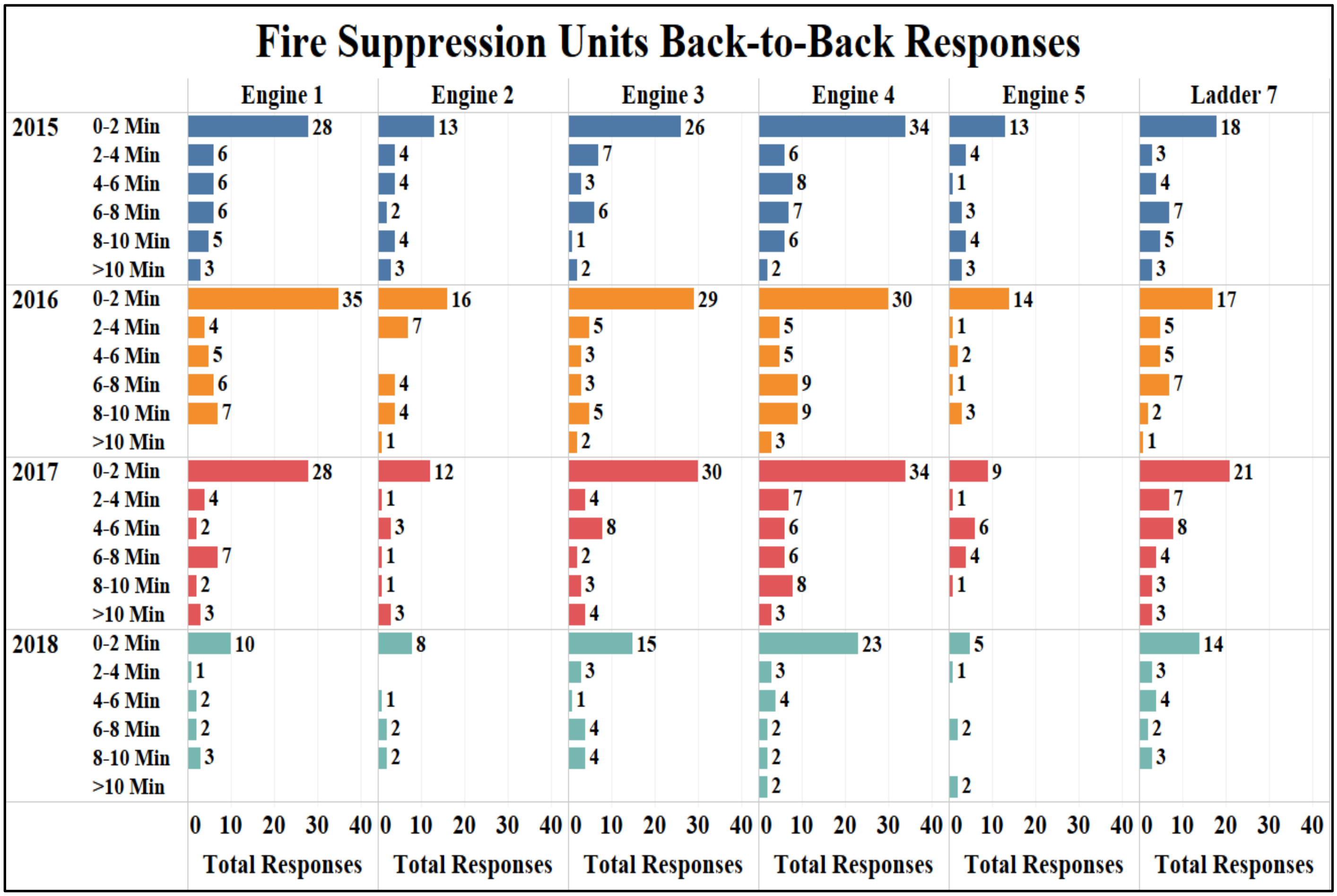


Chart 7: Fire Suppression Units Back-to-Back Responses. Chart 7 depicts the frequency of which Paducah's fire apparatus experienced back-to-back responses. The y-axis shows time intervals of 2 minutes and the x-axis is the count of back-to-back responses. From January 1, 2016 to June 11, 2018, 53.9% of all back-to-back responses occurred within 2 minutes from when a fire suppression apparatus was cleared from a previous incident. Each unit experienced the highest number of back-to-back incidents within 2 minutes of becoming available from a previous emergency.

First-Due Response Area Analysis

Another parameter used to evaluate the department's workload was the number of incidents that occurred in fire stations' first-due response areas. Each fire station within the PFD is assigned a first-due response area. Apparatus assigned to a station will respond first to an incident within that area if available. In Paducah, incidents that require multiple units to respond necessitate primary units traveling outside of their first-due response area. From January 1, 2015 through June 11, 2018, 45.2% responses to incidents made by primary fire suppression apparatus occurred outside of their respective first-due response areas. Engine 4 had the highest number of responses into all first-due areas, including its own. Ladder 7 had the highest number of responses into other first-due areas and not counting its own first due-area (Station 5). Having units respond to other first-due areas can increase response times and may be an indication that the department needs more resources.

Fire Suppression Unit Responses into First-Due Response Areas

First Due Area	Engine 1	Engine 2	Engine 3	Engine 4	Engine 5	Ladder 7	Grand Total
1	1,635	373	288	293	286	397	3,272
2	86	572	52	57	44	78	889
3	258	252	1,383	402	267	369	2,931
4	276	271	411	1,813	310	410	3,491
5	258	183	249	287	1,130	939	3,046
Grand Total	2,513	1,651	2,383	2,852	2,037	2,193	13,629

Chart 8: Fire Suppression Unit Responses into First-due Response Areas. Chart 9 depicts the total number of responses each primary fire suppression unit made into each first-due response area from January 1, 2015 through June 11, 2018. The highest responses by each unit were into their own first-due response area; therefore, Engine 4 had the highest number of responses into its own first-due area and the highest number of total responses. Ladder 7 had the highest total number of responses into other first-due areas, not counting its own first-due area (Station 5). Ladder 7 responds to incidents that require multiple apparatus, so it frequently responds to other first-due areas. Station 4's first-due response area had the highest total number of unit responses. Station 2's first-due response area had the least amount of responses from other units.

Cover Incidents

In addition, units will also have to travel to another first-due area when a primary first-due unit is responding to another incident at the same time, referred to as a cover incident. When a unit responds to cover an incident in another first-due area, it means that the call volume is higher than the number of available primary units. Engine 4 responded to the highest number of cover incidents, mostly into Station 3's first-due area. Engine 1 responded to the fewest number of cover incidents. Station 4's first due response area had the highest number of cover incidents. Station 2's first-due response area had the fewest number of cover incidents. Having units respond to other first-due areas can increase response times and may be an indication that the department needs more resources.

Cover Incidents

First Due Area	Engine 1	Engine 2	Engine 3	Engine 4	Engine 5	Ladder 7	Grand Total
1		23	8	9	14	17	71
2	7		4	2		1	14
3	4	3		26	8	5	46
4	10	8	20		25	23	86
5	19	9	17	17			62
Grand Total	40	43	49	54	47	46	279

Chart 9: Cover Incidents. Chart 9 depicts the total number of responses each primary fire suppression unit made into other first-due areas from January 1, 2015 through June 11, 2018. Engine 4 had the highest number of cover responses. Station 2's first-due response area had the fewest number of cover responses from other units. White boxes signify no data is available, because an apparatus cannot respond to a cover incident in its own first-due area.

Conclusion

In conclusion, the department does not currently meet staffing objectives outlined in industry standards to provide for safe, efficient, and effective response to fires and rescue situations. Deficiencies in staffing contribute to delays in fire suppression, rescue, and response. In addition, the Paducah Fire Department's units are not able to respond to at least 90% of incidents within 4 minutes. If staffing is increased on all fire suppression apparatus, results indicate the department would experience an increase in road and incident coverage when assembling a minimum of 4 firefighters within 4 minutes. Additionally, the result will be an increase in road and incident coverage when assembling a minimum of 15 firefighters within 8 minutes to a low-hazard alarm incident.

The city and department should remedy current deficiencies, by adding staff to daily service. It is essential that departmental resources are able to meet demand and respond to incidents in a safe and efficient manner. The department's current insufficiencies indicate the need for additional staff. As resources become scarce as demand increases, performance will worsen. This increases the risk of death or injury due to fire for both citizens and firefighters of Paducah. It also increases the risk of property loss for housing units and businesses. All fire suppression apparatus deploying from each fire station should be staffed with a minimum of four firefighters at all times.

While it is impossible to predict where most of a jurisdiction's fire emergencies will occur, Paducah Fire Department should examine where emergencies have typically occurred in the past and make efforts to ensure these areas continue to enjoy the same level of coverage, while adjusting resources as needed in an effort to improve service. Areas with accelerated development and population growth will require additional coverage in the future. Any projected increase in emergency response demands should also be considered before changes are implemented, focusing on associated hazard types and planned response assignments.

As explained by the Commission on Fire Accreditation International, Inc. in its Creating and Evaluating Standards of Response Coverage for Fire Departments manual, "If resources arrive too late or are understaffed, the emergency will continue to escalate…What fire companies must do, if they are to save lives and limit property damage, is arrive within a short period of time with adequate resources to do the job. To control the fire before it reaches its maximum intensity requires geographic dispersion (distribution) of technical expertise and cost-effective clustering (concentration) of apparatus for maximum effectiveness against the greatest number and types of risks." Optimally, there needs to be a balance between both elements.

It is generally accepted that a municipality has the right to determine the overall level of fire protection it wants. However, regardless of the level of fire protection chosen by the citizens, neither they nor their elected representatives have the right to jeopardize the safety of the employees providing those services. Citizens pay for protection of life and property through their tax dollars, and they assume that their elected and appointed officials will make informed decisions regarding that protection. Too often, however, that decision-making process has been based solely on budgetary expedience. Irrespective of the resources provided, citizens continue to believe that firefighters are prepared to provide an aggressive interior assault on fires, successfully accomplishing victim rescue, fire control, and property conservation. They do not expect firefighters to take defensive actions- to simply surround and drown a fire- because to do so would be to concede preventable loss of both life and property

The ramifications of low staffing levels, as they pertain to the loss of life and property within a community, are essential when considering a fire department's deployment configuration. A fire department should be designed to adequately respond to a number of emergencies occurring simultaneously in a manner that aims to minimize the loss of life and the loss of property that the fire department is charged to protect. Any proposed changes in staffing and deployment should be made only after considering the historical location of calls, response times to specific target hazards, compliance with departmental Standard Operating Procedures, existing industry standards, including NFPA Standard 1710, and the citizens' expectation of receiving an adequate number of qualified personnel on appropriate apparatus within acceptable time frames to make a difference in their emergency.

Glossary

Key Definitions

The following definitions were created to identify terminology used in the department's CAD reporting system and specific characteristics used to evaluate the department's performance.

90th Percentile: refers to the value below which 90% of observations fall.

Arrival Time & Date: refers to the time when the assigned units and personnel arrive at the incident location.

Available Time & Date: refers to the time when apparatus and personnel have cleared the scene and are available for service.

Back-to-Back Reponses: refers to occurrences where units have been dispatched within 10 minutes of becoming available from a previous emergency.

Computer Aided/Assisted Dispatch (CAD): refers to a combination of hardware and software that provides data entry, makes resource recommendations, notifies and tracks those resources before, during, and after alarms, preserving records of those alarms and status changes for later analysis.[79]

Cover Incident –A cover incident refers to an incident to whereby units must travel to another first-due area when the primary first-due unit is responding to another incident at the same time.

Dispatch Time & Date: refers to the time when units and personnel are assigned to an incident.

En route Time & Date: refers to the time when units and personnel are beginning their travel to the emergency.

First-Due Response Area – refers to a fixed geographical area established by the department's administration which contains a fire station and is normally served by that station's personnel and apparatus.

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[79] NFPA 950 §3.3.5 (2015)

Incident: refers to an emergency to which fire department mobile and personnel resources are dispatched to intervene and mitigate. An incident may require a single or multiple apparatus to respond.

Response: refers to an individual unit, or units, being dispatched and traveling to the scene of an incident.

Response Time: refers to the time interval that begins with call time and ends with on-scene arrival time.

Travel Time: refers to the time interval that begins when a unit is en route to the emergency scene and ends when the unit arrives at the scene.[80]

[80] NFPA 1710 §3.3.53.7 (2016)

Appendix

Performance Standards

NFPA 1710 is the consensus standard for career firefighter deployment, including requirements for fire department arrival time, staffing levels, and fireground responsibilities.[81]

Key Sections included in the 1710 Standard that are applicable to this assessment are:

- 5.2.3
  - **Operating Units**. Fire company staffing requirements shall be based on minimum levels necessary for safe, effective, and efficient emergency operations.

- 5.2.3.1 & 5.2.3.1.1
  - Fire companies, whose primary functions are to pump and deliver water and perform basic firefighting at fires, including search and rescue… shall be staffed with a minimum of four on-duty members.
- 5.2.1.2
  - In jurisdictions with a high number of incidents or geographical restrictions, as identified by AHJ, these companies shall be staffed with a minimum of five on-duty members.

- 5.2.3.2 & 5.2.3.2.1
  - Fire companies whose primary functions are to perform the variety of services associated with truck work, such as forcible entry, ventilation, search and rescue, aerial operations for water delivery and rescue, utility control, illumination, overhaul and salvage work… shall be staffed with a minimum of four on-duty members.

- 5.2.3.1.2 & 5.2.3.2.2
  - In jurisdictions with tactical hazards, high hazard occupancies, high incident frequencies, geographical restrictions, or other factors as identified by the AHJ, these companies shall be staffed with a minimum of five or six on-duty members.

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[81] NFPA 1710, 2016

- 5.2.3.4.1
    - A fire company that deploys with quint apparatus designed to operate as either an engine company or a ladder company, shall be staffed as specified in 5.2.3.

- 5.2.3.4.2
    - If the company is expected to perform multiple roles simultaneously, additional staffing, above the levels specified in 5.2.3, shall be provided to ensure that those operations can be performed as required.

- 5.2.4.1.1
    - The fire department's fire suppression resources shall be deployed to provide for the arrival of an engine company within a 240-second travel time to 90 percent of the incidents.

- 5.2.4.2.1
    - The fire department shall have the capability to deploy an initial full alarm assignment within a 480-second travel time to 90 percent of the incidents.

- 5.2.4.1.1
    - The initial full alarm assignment to a structure fire in a typical 2000 ft^2 … two-story single-family dwelling without basement and with no exposures shall provide for the following

Assignment	***Minimum Required Personnel***
Incident Command	1 Officer
Uninterrupted Water Supply	1 Pump Operator
Water Flow from Two Handlines	4 Firefighters (2 for each line)
Support for Handlines	2 Firefighters (1 for each line)
Victim Search and Rescue Team	2 Firefighters
Ventilation Team	2 Firefighters
Aerial Operator	1 Firefighter
Initial Rapid Intervention Crew (IRIC)	2 Firefighters
Required Minimum Personnel for Full Alarm	**14 Firefighters & 1 Scene Commander**

- 5.2.4.2.1
  - The initial full alarm assignment to a structure fire in a typical open-air strip shopping center ranging from 13,000 ft^2 to 196,000 ft^2 (1203 m^2 to 18,209 m^2) in size

- 5.2.4.3.1
  - The initial full alarm assignment to a structure fire in a typical 1200 ft^2 (111 m^2) apartment within a three-story, garden-style apartment building shall provide for the following:

Assignment	***Minimum Required Personnel***
Incident Command	1 Incident Commander 1 Incident Command Aide
Uninterrupted Water Supply (2)	2 Firefighters
Water Flow from Three Handlines	6 Firefighters (2 for each line)
Support for Handlines	3 Firefighters (1 for each line)
Victim Search and Rescue Teams	4 Firefighters (2 per team)
Ladder/Ventilation Teams	4 Firefighters (2 per team)
Aerial Operator	1 Firefighter
Rapid Intervention Crew (RIC)	4 Firefighters
EMS Transport Unit	2 Firefighters
Required Minimum Personnel for Full Alarm	**27 Firefighters** **1 Incident Commander**

- 5.2.4.4.1
  - Initial full alarm assignment to a fire in a building with the highest Floor 75 ft. (23 m) above the lowest level of fire department vehicle access shall provide for the following:

Assignment	*Required Personnel*
Incident Command	1 Incident Commander 1 Incident Command Aide
Uninterrupted Water Supply	1 Building Fire Pump Observer 1 Fire Engine Operator
Water Flow from Two Handlines on the Involved Floor	4 Firefighters (2 for each line)
Water Flow from One Handline One Floor Above the Involved Floor	2 Firefighters (1 for each line)
IRIC/RIC Two Floors Below the Involved Floor	4 Firefighters
Victim Search and Rescue Team	4 Firefighters
Point of Entry/Oversight Fire Floor	1 Officer 1 Officer’s Aide
Point of Entry/Oversight Floor Above	1 Officer 1 Officer’s Aide
Evacuation Management Teams	4 Firefighters (2 per team)
Elevator Management	1 Firefighter
Lobby Operations Officer	1 Officer
Trained Incident Safety Officer	1 Officer
Staging Officer Two Floors Below Involved Floor	1 Officer
Equipment Transport to a Floor Below Involved Floor	2 Firefighters
Firefighter Rehabilitation	2 Firefighters (1 must be ALS)
Vertical Ventilation Crew	1 Officer 3 Firefighters
External Base Operations	1 Officer
2 EMS ALS Transport Units	4 Firefighters
Required Minimum Personnel for Full Alarm	**36 Firefighters** **1 Incident Commander** **6 Officers**

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