GEOGRAPHIC INFORMATION SYSTEM EMERGENCY SERVICES RESPONSE CAPABILITIES ANALYSIS

FINAL REPORT

International Association of Fire Fighters
1750 New York Avenue, N.W.
Washington, DC 20006

COLUMBUS DIVISION OF FIRE

COLUMBUS, OH

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Dedication

This report is dedicated to the citizens of Columbus, Ohio who deserve the most efficient and effective fire, rescue, and emergency medical services available.

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Table of Contents

Executive Summary

The International Association of Fire Fighters (IAFF) Headquarters was engaged by the Columbus Fire Fighters, IAFF Local 67, to create a data-driven document for the Columbus Division of Fire (CFD) and fire department administrators to assist with informed decisions regarding emergency response.

The CFD provides fire suppression, rescue, Emergency Medical Service (EMS) first response at the Basic Life Support (BLS) and Advanced Life Support (ALS) levels, and patient transport at the ALS level from 35 stations. The department operates 35 engines, 16 ladder trucks, 39 medic units, and five rescue units. The city maintains an automatic mutual aid program and provides dispatch for five neighboring fire departments.

Over the last 10 years, the population of the City of Columbus increased by 14%,[1] and, with it, the number of emergency incidents and the demand on the fire department. This growth has not been matched by an increase in CFD resources. Instead, the department continues to rely on automatic aid from nearby jurisdictions to meet demand. As such, Local 67 reports that some surrounding jurisdictions have experienced significant increases in demand to the point that their responses into Columbus exceed their number of responses in their hometowns. Additionally, this analysis found that mutual aid units responding into Columbus from neighboring departments have longer travel times than CFD units, which increases risk for the victims of both fire and EMS emergencies. The population of Columbus is expected to increase in the next four years at a yearly rate as high as 4.3%. The CFD needs to increase its resource to meet the current and future demand, without regularly relying on mutual aid units from neighboring fire departments.

Between 2017 and 2019, 31,358 incidents that occurred within Columbus city limits required at least one mutual aid unit to be on scene to assist CFD's units. Of these incidents, 18,919 were addressed solely by mutual aid units, that is, CFD did not respond to these incidents because its units were not available or were too far from the scene of the incident to provide a timely response. Mutual aid units were confirmed[2] as the first-arriving units on the scene of incidents in Columbus 18,231 times between 2017 and 2019. These data demonstrate that the CFD does not have sufficient resources to address the demand and needs to regularly rely on mutual aid units, increasing the risk both for the citizens and firefighters of Columbus and of the nearby communities. Mutual aid units responding in Columbus are not able to provide protection to their own cites and have, on average, longer travel times. For example, mutual aid units arriving first

[1] https://www.census.gov/quickfacts/columbuscityohio

[2] For approximately 8% of the incidents the Computer-Aided Dispatch data did not report the time of the arrival at the scene of the incidents, so the travel time could not be estimated.

at the scene of EMS incidents in Columbus arrived within four minutes 45% of the time, while CFD units arriving first, were on scene within four minutes 58% of the time.

CFD units are not staffed to provide for effective, efficient, and safe emergency operations as required by 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*. NFPA 1710 requires a minimum of four, five, and six firefighters for each fire suppression apparatus in suburban, urban, and dense urban areas, respectively.[3] Additionally, the Occupational Safety and Health Administration's (OSHA) "2 In/2 Out" regulation requires at least four firefighters to be on scene before beginning interior fire suppression operations.[4] Currently, the CFD's engines and ladders are staffed with three to four firefighters at most. Studies[5] have shown that the smaller the crew size, the more tasks an individual must complete, which contributes to diminished efficiency and delays in initiating fire attack and containing fire.

The failure to maintain enough resources to meet demand in a timely manner exposes civilians and firefighters to increased risk. It also further drains fire department resources and stresses the emergency response system. This report addresses the current deficiencies within the CFD by examining several metrics including the call volume, the travel time to EMS and fire emergencies, and the frequency that units are engaged in responses at the same time. Through analysis of computer-aided dispatch (CAD) data, the use of geographic information systems (GIS) mapping software, and computer simulations, this report will inform Columbus decision makers on the negative impact that current staffing and deployment practices have on daily operations and how increasing resources will improve the efficiency of the CFD and the safety of Columbus's population.

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[3] NFPA 1710, 2020 edition, 3.3.18, 5.2.3.1.2.1 and 5.2.3.2.2.1

[4] 29 CFR 1910.134.

[5] NIST Report on Residential Fireground Field Experiments and NIST Report on High-Rise Fireground Field Experiments. < https://www.nist.gov/sites/default/files/documents/el/fire_research/Report-on-Residential-Fireground-Field-Experiments.pdf > and < https://www.nist.gov/publications/report-high-rise-fireground-field-experiments >

Key Findings

- Between April 2017 and December 2019, the number of incidents that the CFD responded to increased by 3,138 incidents per year (+2.3%) on average.

- In the most recent year available (2019) the CFD responded to 166,509 incidents, compared to 161,633 incidents of 2018. Considering the months between April and December, the department responded to 127,815 incidents in 2019, compared to 122,775 in 2018 and 122,055 in 2017.

- Incidents often require more than one unit to respond: the number of single CFD unit responses was 217,174 in 2017, 286,945 in 2018 and 292,397 in 2019. The average number of units needed to address EMS and fire incident was 1.7 and 3, respectively. Structure fires required up to 12 units to respond to a single incident.

- The department does not have sufficient resources to address the demand within its jurisdiction: considering incidents occurring within the Columbus city limits, between 2017 and 2019, 31,358 incidents required at least one mutual aid unit from a nearby department to assist the CFD units. Units from neighboring departments made a total of 71,637 responses into Columbus.

- Considering incidents occurring within the Columbus city limits, between 2017 and 2019, 18,919 incidents were addressed exclusively by mutual aid units because no CFD unit was available or close enough to the location of the incidents to provide a timely response.

- Approximately 51% of mutual aid responses from outside the CFD into Columbus were made by medic units and 31% by engines, showing that the department does not have sufficient medic and engine units to address the demand in Columbus.

- The majority of responses from neighboring departments occurred on the east side of the jurisdiction, where CFD stations are located farther away from each other and offer less coverage to the city.

- Relying on mutual aid units increases travel times, and, consequently, risk for the population of Columbus. Mutual aid units arriving first at the scene of fire and EMS incidents in Columbus arrived within the NFPA 1710 travel time objective of four minutes 45% of the time, while CFD units were on scene within four minutes 58% of the time.

- Considering fire incidents only, when a mutual aid engine was the first on scene, the engine arrived within a travel time of four minutes 44% of the time, while CFD engines arrived on scene within a travel time of four minutes or less 65% of the time.

- The department did not meet NFPA 1710 travel time objectives for EMS incidents, which require the first EMS unit to be at the scene of EMS emergencies within four minutes for at least 90% of the incidents. The first-arriving CFD EMS unit was at the scene of EMS incidents within four minutes for 57% of incidents.

- The department did not meet NFPA 1710 travel time objectives for fire incidents, which require the first engine to be at the scene of fire emergencies within four minutes for at least 90% of the incidents. The first-arriving CFD engine was at the scene of fire incidents within four minutes for 65% of incidents.

- The department's ability to meet travel time objectives decreased with the increasing demand: as multiple engines became engaged responding to the same or different incidents, the number of incidents reached within four minutes decreased from 69%, when less than five engines were engaged, to 50% when 14 or more engines were engaged, because there were less engines available to meet the demand.

- Stations 1, 2, and 8 offer protection to the downtown part of the city, which had the highest concentration of incidents. In 2019, the three medic units from these stations were all engaged at the same time for 338 hours. Two of these units, in any combination, were engaged at the same time for 1,347 hours, leaving downtown Columbus with only one or zero EMS transport unit available from the three closest stations for a total of 1,685 hours, approximately 19% of the year.

- Back-to-back responses, where units are dispatched within 10 minutes from being cleared from the previous emergency, increased from 26,287 to 27,892 between 2018 and 2019 (+1,605). These calls are dangerous for CFD personnel who have less time to recover between emergencies and might not be able to efficiently perform critical tasks.

- The risk assessment analysis shows that the variables that increase the probability of EMS emergencies in Columbus are population density, the number of people living with a disability, the number of vacant units, and the crime rate. For fire incidents, the presence of older buildings and the daytime population were the greatest risk factors.

- The risk assessment analysis made by the IAFF categorized most of the census tracts[6] in Columbus as medium- and high-risk areas for both fire and EMS emergencies. Additionally, the Centers for Disease Control (CDC) identified most of the census tracts as having medium to high social vulnerability.[7]

- The population of Columbus is increasing rapidly. In 2018, the U.S. Census estimated that Columbus was the 14th most populous city in the U.S. and the 11th fastest-growing city among cities with a population of 50,000 people or more.[8]

- From the current stations and with the current staffing level, the department cannot reach 55% of city roads within a travel time of four minutes and cannot assemble the minimum response force of four firefighters within four minutes on 70% of these roads.

- From the current stations and with the current staffing level, the department cannot assemble the minimum forces of 17, 28, and 43 firefighters required for low-, medium-, and high-hazard[9] fires on 63%, 78% and 83% of the city roads, respectively.

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[6] A census tract is a geographic unit used by the U.S. Census.

[7] The CDC's social vulnerability score identifies areas in the community that will most likely need assistance before, during, and after a hazardous event

[8] https://www.census.gov/newsroom/press-releases/2019/subcounty-population-estimates.html

[9] A low-hazard structure fire is defined as a fire that occurs in a typical, 2,000 square foot single-family residential home with no basement or exposures. Typical examples of medium-hazard structure fires include any fire in a shopping center ranging in size from 13,000 ft^2 to 196,000 ft^2 and 1,200 ft^2 apartments in a three-story garden-style apartment building. Other examples include offices, mercantile, and industrial occupancies. NFPA 1710, §5.2.4.2.1, §5.2.4.3.1, and §A.5.2.4.1 (2). Examples of high-hazard fires are fires in large-area buildings such as manufacturing centers, warehouses, grocery stores, schools, and other structures with a high fire load and populations.

Recommendations

Based on the GIS and workload analysis findings, the department should consider the following recommendations:

- All engines and ladders should be staffed with a minimum of four firefighters. The recommended staffing level is detailed in Table 7.

- Add a total of six medic units, six engines and four ladder trucks to the current stations and build six additional stations housing a total of six new engines and four new medic units.

The bullet points below show detailed recommendations on what type of apparatus should be added to each station. The department should:

- Add one medic unit to either Station 1 or 9. These stations are housed in the same building at the same location. The additional medic unit is necessary because of the high population growth expected in this part of the city and the presence of high-rise and high-hazard buildings.

- Add one medic unit to Station 2 because of the expected high population growth and the large number of medic unit responses reported in this station's first-in district.

- Add one engine to Station 6 because its first-in district reported the second largest number of fires and the largest number of engines responses. Additionally, the risk assessment analysis showed that this part of the city has a high social vulnerability index.

- Add one ladder truck to Station 7 to provide ladder coverage to an area of the city with a high risk of fire incidents, as shown in the *Risk Assessment* section.

- Add one medic unit to Station 8 because this station offers coverage to the downtown area of the city, which has the highest density of incidents, high social vulnerability, and will experience population growth in the next four years.

- Add one engine to Station 10 to improve response times and reduce Engine 10's workload. This first-in district reported the second largest number of engine responses.

- Add one medic unit to Station 12 to reduce travel times in its first-in district, which has high social vulnerability.

- Add one engine to Station 15 to reduce the number of back-to-back responses made by Engine 15 (523 per year on average) and because of the high vulnerability in this part of the city.

- Add a medic unit in Station 16, because its first-in district reported the second largest number of responses from medic units of nearby departments demonstrating that the department is not able to efficiently serve this part of the city.

- Add one engine to Station 17 because of the high number of back-to-back responses made by Engine 17 and the high social vulnerability of this first-in district.

- Add one ladder truck to Station 18 to provide ladder coverage to an area of the city with a high density of fire incidents.

- Add one ladder truck to Station 20, for the same reason as the previous point.

- Add one engine to Station 24 because its first-in district is among the top five first-in districts for number of engine responses and reported the fourth highest number of responses with a travel times above four minutes for the first-arriving unit at the scene of EMS incidents.

- Add one medic unit to Station 28 because of the high social vulnerability of this area and the large number of medic responses made by units of nearby departments in this first-in district.

- Add one ladder truck to Station 29 because its first-in district reported the highest number of structure fires and the largest number of responses from nearby departments to fire and structure fire incidents demonstrating that CFD cannot provide safe fire coverage to this area of the city. Currently this station does not have a ladder truck.

- Add one engine to Station 32 because of the population growth expected in this part of the city and because its first-in district reported the third highest number of responses from other departments' units to fires and structure fire incidents. This area has also a high risk of EMS and fire incidents, as discussed in the *Risk Assessment* section of this report.

In the longer term, the department should consider building six additional stations. The six additional engines mentioned in the bullet points above should be moved to the additional stations. With these new stations, the department will be able to increase their coverage of the city and address the increasing demand as the population of Columbus increases. The GIS and workload analysis determined the following recommended locations and apparatus for the new stations:

- Proposed Station 36, in the area of E Livingston Ave and South 18^{th} St. This station should house one engine and one medic unit. This station will increase the department's ability to meet NFPA 1710 objectives and increase the four-minute coverage of the downtown area.

- Proposed Station 37, in the area of Koebel Rd and Lockbourne Rd. This station should house one engine, which will help reduce the travel time to the scene of fire and EMS incidents in Station 14's and Station 22's first-in districts. Currently, approximately 4,000 incidents per year are not reached within four minutes in this part of the city.

- Proposed Station 38, in the area of Refugee Rd and Nathaniel Blvd. This station should house one engine and one medic unit. This will help the department to better address the demand in Station 23's first-in district, which reported the fourth highest number of medic and engine unit responses. Additionally, this station will help reach approximately 3,000 incidents per year within a travel time of four minutes.

- Proposed Station 39, in the area of Mock Rd. & Bar Harbor Rd. This station should house one engine and one medic unit and will provide coverage to an area of the city that has high social vulnerability. This station will allow the department to reach the location of approximately 5,500 historical incidents within a travel time of four minutes.

- Proposed Station 40, in the area of W Henderson Rd and Knightsbridge Blvd, housing one engine. This station increases the four-minute road coverage and will help reduce the travel time in Station 11's and Station 19's first-in districts. Currently, approximately 3,300 incidents per year are not reached within a travel time of four minutes in this part of the city.

- Proposed Station 41, in the area of Schrock Rd and Busch Rd. This station should house one engine and one medic unit and would be located in the west side of Station 6's first-in district, which cannot be reached within a travel time of four minutes from the current stations. This station will allow the department to reach the location of 4,800 historical incidents within a travel time of four minutes.

Executive Summary Conclusion

The CFD does not meet industry standards for safe and efficient staffing and travel time to the scene of EMS and fire incidents. The department over-relies on mutual aid units dispatched from nearby departments. Based on the data available for this analysis, in the three years between 2017 and 2019, 31,358 incidents that occurred within Columbus city limits required at least one mutual aid unit to be on scene to assist units from the CFD. Of these incidents, 18,919 were addressed solely by mutual aid units, that is, CFD units did not respond to these incidents because they were not available or were too far from the scene of the incident to provide a timely response. Mutual aid units were the first-arriving units on the scene of EMS and fire incidents that occurred in Columbus 18,231 times between 2017 and 2019, increasing the risk of potentially fatal delays. These data demonstrate that the CFD does not have sufficient resources to address the demand and needs to regularly rely on neighboring fire departments.

The population of Columbus will continue to increase in the next four years at a yearly rate as high as 4.3%. The CFD needs to increase its resources to meet the current and future demand, without regularly relying on mutual aid units.

Currently, the CFD's engines and ladders are staffed with three to four firefighters. As required by NFPA 1710, all the fire suppression apparatus should be staffed with a minimum of four firefighters. Several studies have shown that the smaller the crew size, the more tasks an individual must complete, which contributes to diminished efficiency and delays in initiating fire attack and containing fire.

The department needs additional resources and staffing in the current stations. In the longer term, at least six additional stations will be required. These recommendations will allow the department to meet staffing industry standards and improve the department's ability to meet the travel time objectives, reducing response times. By reducing the demand on the current units and mutual aid units, the department will provide a more efficient response, thus improving the safety of the CFD personnel and citizens of Columbus and the nearby communities, who will have more time for rest and recovery between emergencies.

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Risk Assessment of Columbus, OH

A significant part of planning for future fire department strategies is knowing the risks in the community. As such, risk characteristics for the municipality of Columbus were examined for this report. The years associated with the statistics reported in this section correspond the most recent year available for that particular statistic.

The 2010 U.S. Census determined that Columbus had a population of 787,033 people.[10] The 2019 population estimate was 898,553 people, which is a 14% increase. In 2018, the U.S. Census estimated that Columbus was the 14th most populous city in the U.S. and the 11th fastest-growing city among cities with a population of 50,000 people or more.[11]

In 2018, 17.3% of the population was in a vulnerable category based on age: 7.3% of the population was people under the age of 5, and 10% was people 65 years-old or older. People of these ages are considered more vulnerable because they are typically less able to anticipate, cope with, resist and/or recover from the impacts of disaster. Additionally, in the period 2014-2018, 11.2% of the total population was people under the age of 65 who were living with a disability.

Poverty is another vulnerability factor. The U.S. Census found that 20.4% of the Columbus population lived at or below the poverty level. These are people that generally lack the means to properly maintain residences, which can lead to an increased risk for fire. Typically, people living within the demographics described above are at an increased risk for medical complications and hazard-related injury or death.

When assessing community risk, it is also important to consider housing characteristics. In 2019, the total number of housing units was estimated to be 402,520,[12] of which 34,029 units were vacant. NFPA data show that fires in vacant buildings cause 13% of all the firefighters' injuries.[13] Buildings built in 1939 or earlier were 11.6% of the total, and those built in 1979 or earlier were 51.7% of the total buildings. Older structures constructed before modern day fire codes were developed and vacant units, which lack regular maintenance, are at an increased risk of fires.

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[10] https://www.census.gov/quickfacts/columbuscityohio
[11] https://www.census.gov/newsroom/press-releases/2019/subcounty-population-estimates.html
[12] https://data.census.gov/cedsci/
[13] NFPA Research, "Fires in Vacant Buildings", Marty Ahrens, February 2018.

Risk Factors in Columbus, OH

The IAFF conducted a statistical analysis of the areas where incidents occurred and determined the demographic characteristics that drive the risk of EMS and fire incidents. These characteristics were then used to produce risk maps of the CFD's response area, which will assist the department in allocating current and future resources and implementing prevention measures.

With this statistical[14] risk assessment approach, areas where a low number of incidents occurred in the past might still be categorized as high-risk areas. For example, in a community where a significant number of incidents occurred in areas with a high number of old buildings, other areas with a high number of old buildings could be categorized as high-risk, even if those areas had a low number of incidents in the past. In this analysis, the level of risk can be interpreted as the probability that an incident may occur in the future.

Some risk characteristics have an obvious explanation. For example, in every city, it is safe to assume that areas with higher population densities will experience a higher number of incidents. This analysis focused on additional potential risk factors that might be driving the number of incidents and that might be more specific to Columbus.

U.S. Census Bureau and American Community Survey 5-Year Estimates data were used to extract variables for each census tract[15] in the CFD response area. The probability of incidents occurring in a given census tract is related to the expected number of incidents in that census tract, as obtained from the results of the statistical analysis. The analysis combines the CAD data assembled by the CFD between 2017 and 2019, and the demographic and physical building characteristics of each census tract, to predict the expected number of incidents in a given time period.

Besides population density, the analysis found that the variables that are most strongly associated with a higher risk of EMS incidents are the number of people living with a disability, the number of vacant units and the crime rate. People with disability might have the need for frequent access to medical services, and crime related incidents often require EMS response. The relation with vacant units might be explained by the higher concentration of these buildings in depressed urban areas where it is more likely that the population will lack the means for proper healthcare. Most of the census tracts in Columbus have medium risk, with the highest risk in the downtown area. The analysis shows that the area surrounding Station 32 has a high EMS risk even though the number of incidents reported in this part of the city is not high. This is because the census

[14] A generalized linear regression model was used for this analysis. In statistics, a regression is a kind of analysis where some variables, such as demographic and socioeconomic characteristics, are analyzed against other variables, such as the number of fires and EMS incidents, to establish a relation between them.

[15] A census tract is a geographic unit used by the U.S. Census Bureau.

tract in the vicinity of this station has a higher than average number of vacant units and people living with a disability. The department should consider prevention initiatives and add appropriate resources to areas of the city with high EMS risks.

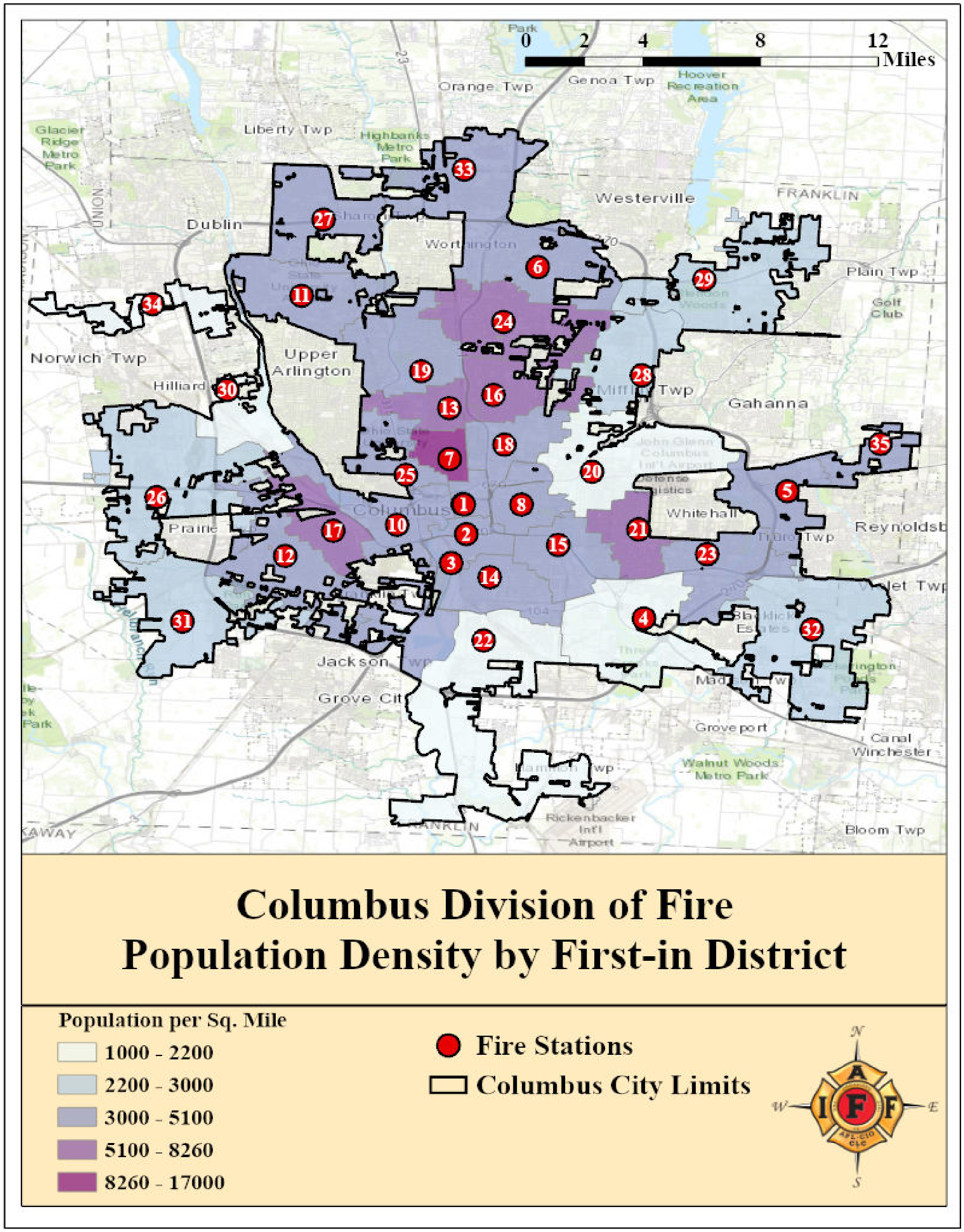
For fire incidents, the presence of older buildings and the daytime population were the most strongly predictive risk factors. Older buildings typically lack the necessary maintenance to reduce the risk of fires. The daytime population can differ from the resident population in specific areas of the city. Commercial and business activities, attracting a large number of people, could be more likely to experience fire emergencies, as confirmed by NFPA studies[16]. Even in this case, most of the tracts have medium risk, with the downtown area and the area around Station 32 having the highest risk. The latter has a high daytime population due both to resident population and the presence of commercial activities.

The maps on the following pages show the locations of CFD fire stations, concentrations of incidents, population density, population growth rate, social vulnerability index (SVI) by census tract, and EMS and fire risks as determined by the regression analysis. The Centers for Disease Control SVI score is determined by examining factors such as socioeconomics, housing composition, residents with disabilities, minority status, languages spoken, and housing and transportation. The difference between an SVI score and the risk maps produced by the regression analysis is that the SVI score identifies areas in the community that will most likely need assistance before, during, and after a hazardous event, while the regression analysis produces probability predictions of the number of EMS and fire incidents that might occur in a given area and identifies the variables that are more likely to lead to incidents. Therefore, the SVI and the regression analysis should both be considered when assessing risk and planning the distribution of resources.

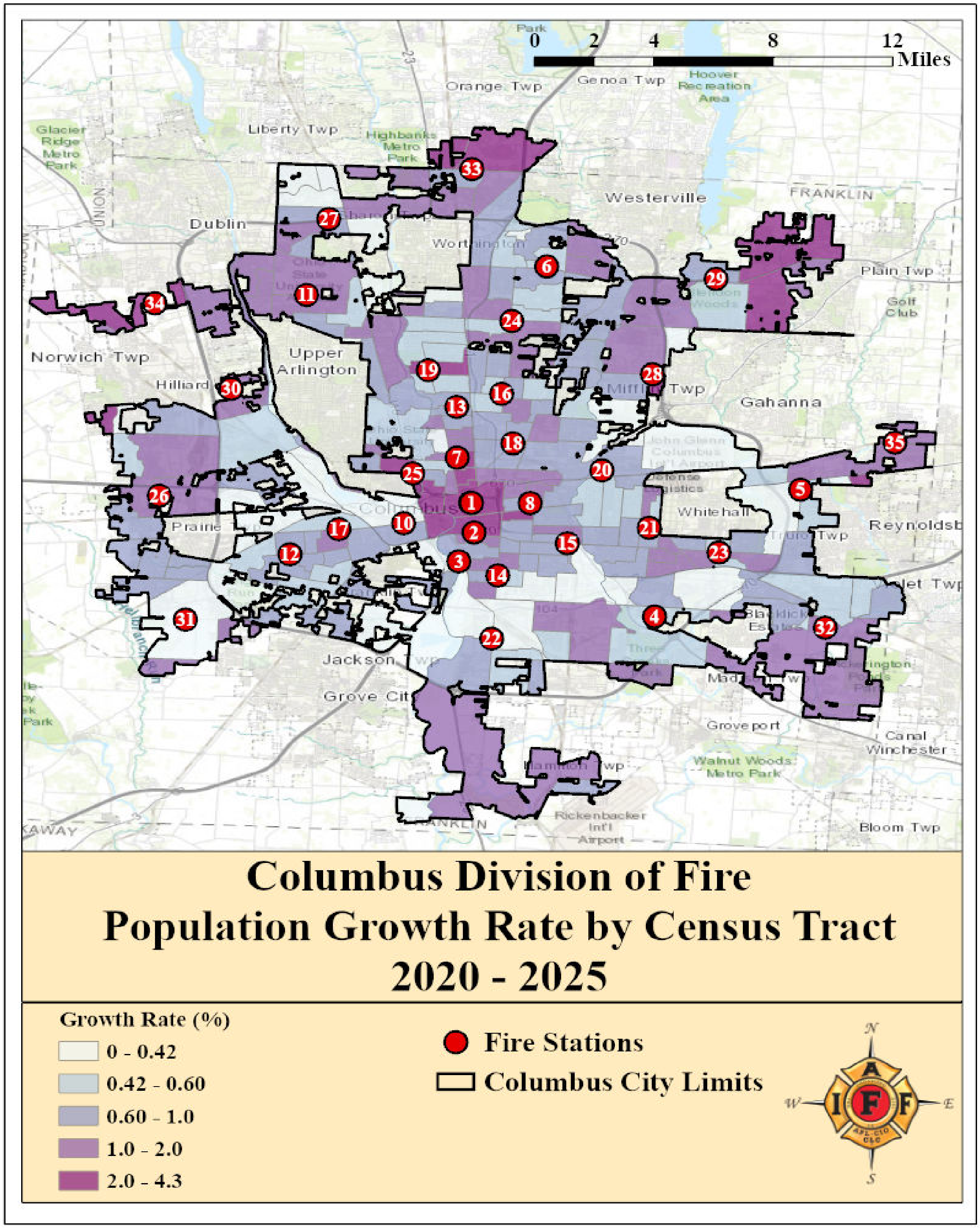
[16] https://www.nfpa.org/News-and-Research/Data-research-and-tools/Building-and-Life-Safety/US-Structure-in-Office-Properties

Map 1: Fire Stations and First-in Districts. This map shows the location of the current stations and the first-in districts[17] defined by the department. First-in districts are areas around each station where the units of that station can respond faster than units from another station. In any case, CFD dispatches its units depending on which unit is closer to the scene of an incident, regardless of the first-in districts' limits. These districts are used in the *Workload Analysis* section to describe the department's workload and travel time performance in different parts of the city.

[17] https://opendata.columbus.gov/datasets/fire-first-in-districts/data

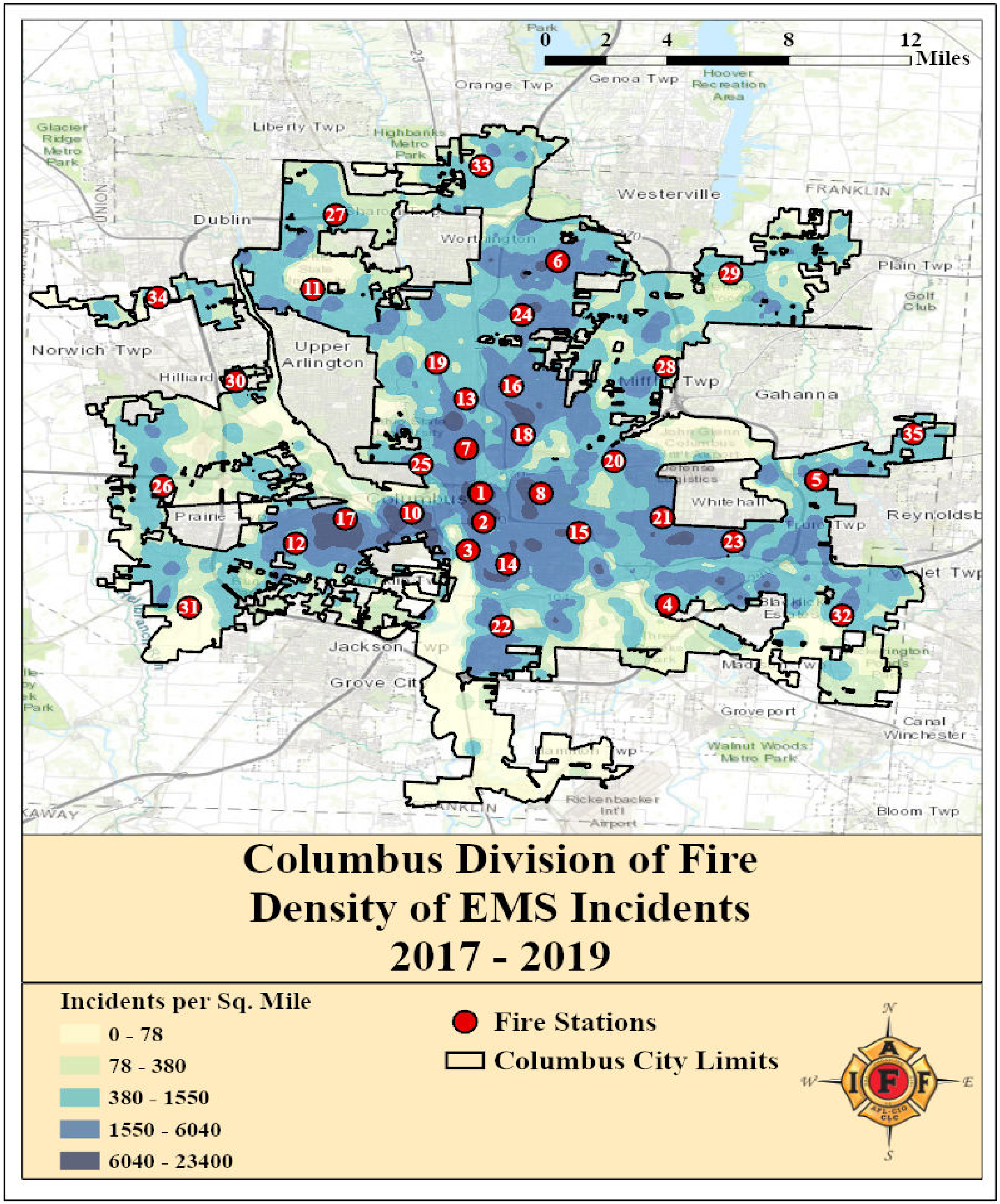


Map 2: Population Density by First-in District. This map shows the population density in each first-in district. The population density in Columbus ranges from 1,000 people per square mile to nearly 17,000 people per square mile.

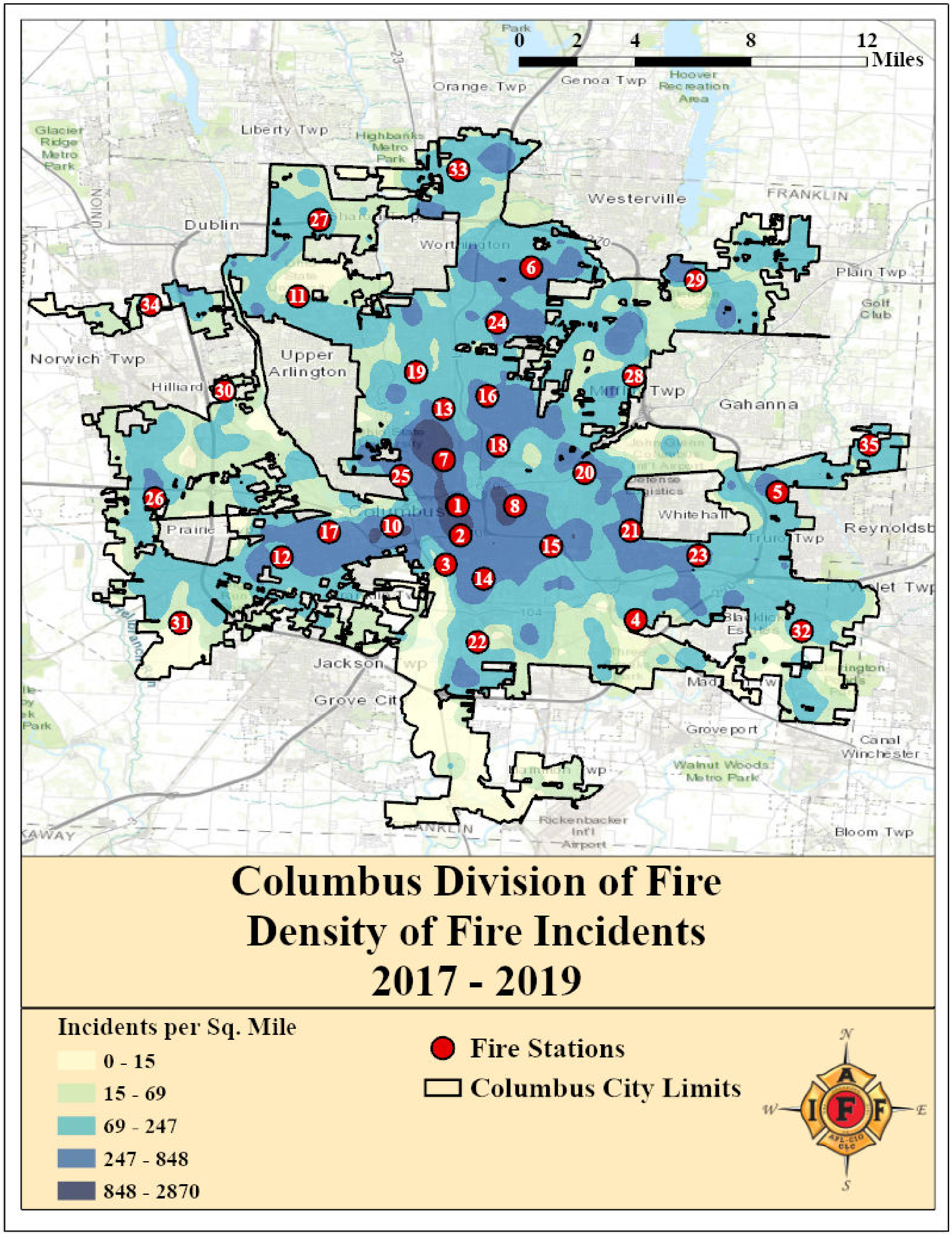


Map 3: Population Growth Rate by Census Tract, 2020 - 2025. This map shows the expected population growth rate by census tract.[18] The population of Columbus is expected to grow in every census tract at a rate of up to 4.3% per year.

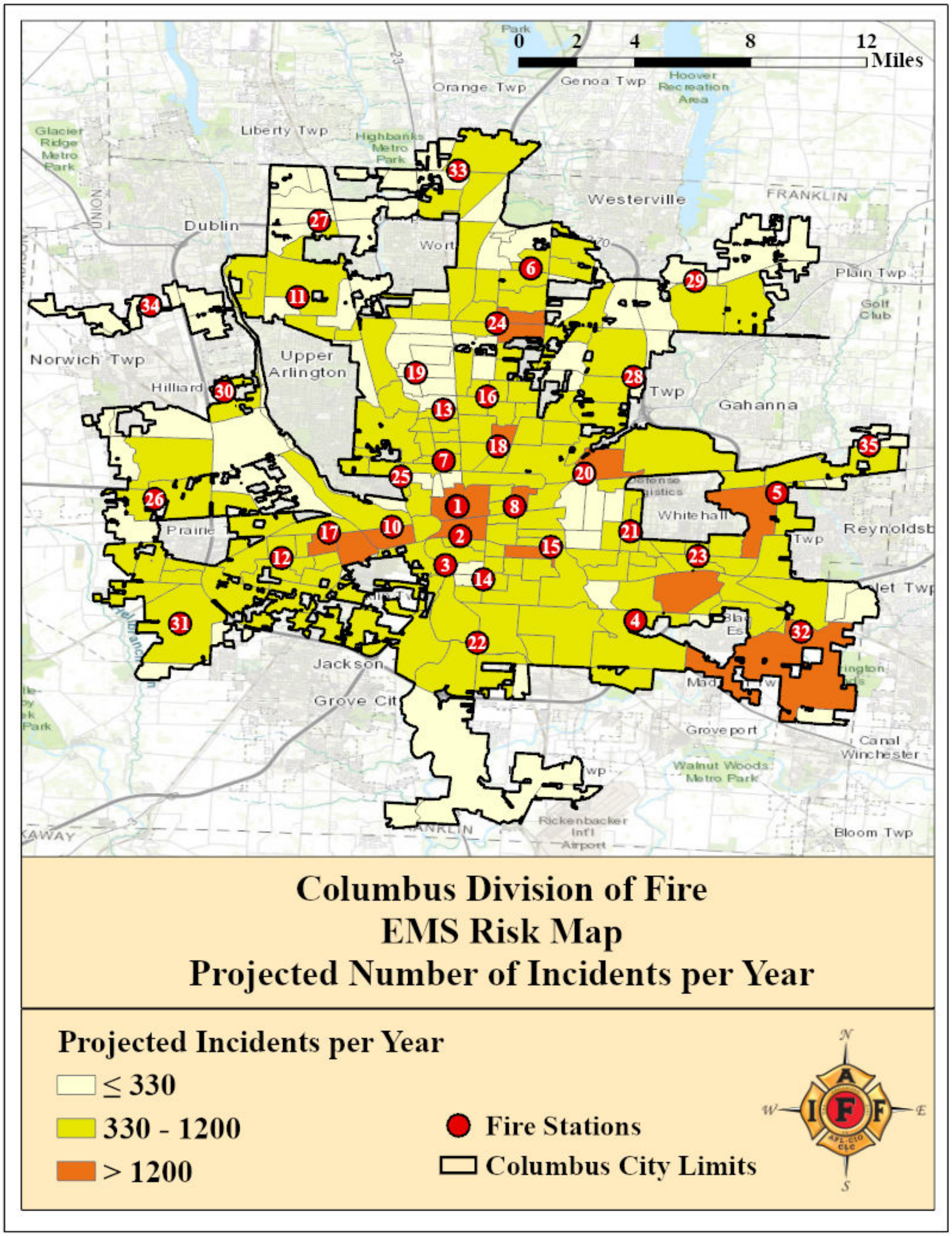
[18] A census tract is a geographic unit defined by the U.S. Census.



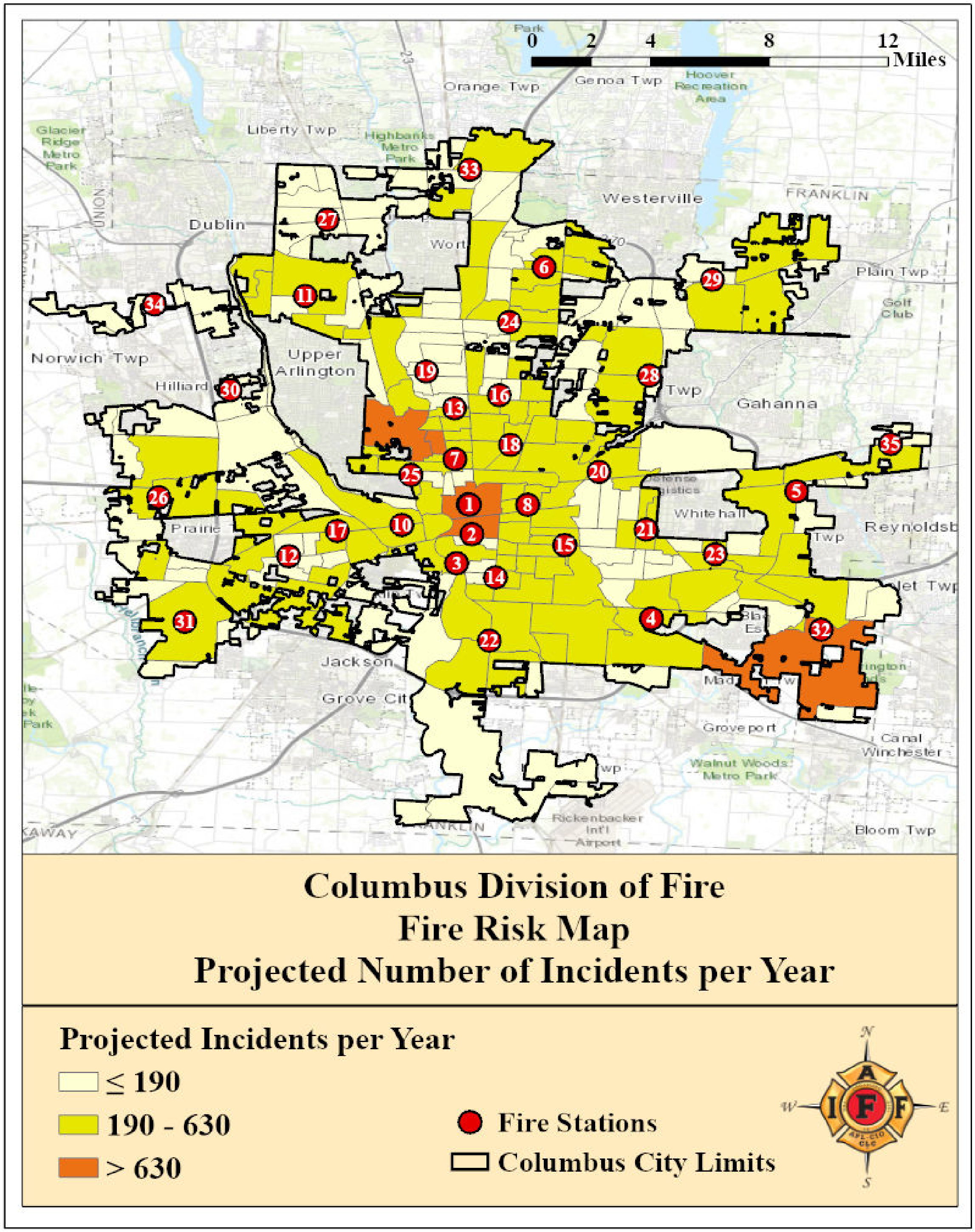
Map 4: Density of EMS Incidents, 2017-2019. This map shows the density of EMS incidents from 2017 to 2019. Most of the incidents occurred in the central part of the city around Stations 1, 2 and 8, and in the area of Stations 10 and 17. However, other areas of high density are present everywhere in the jurisdiction.



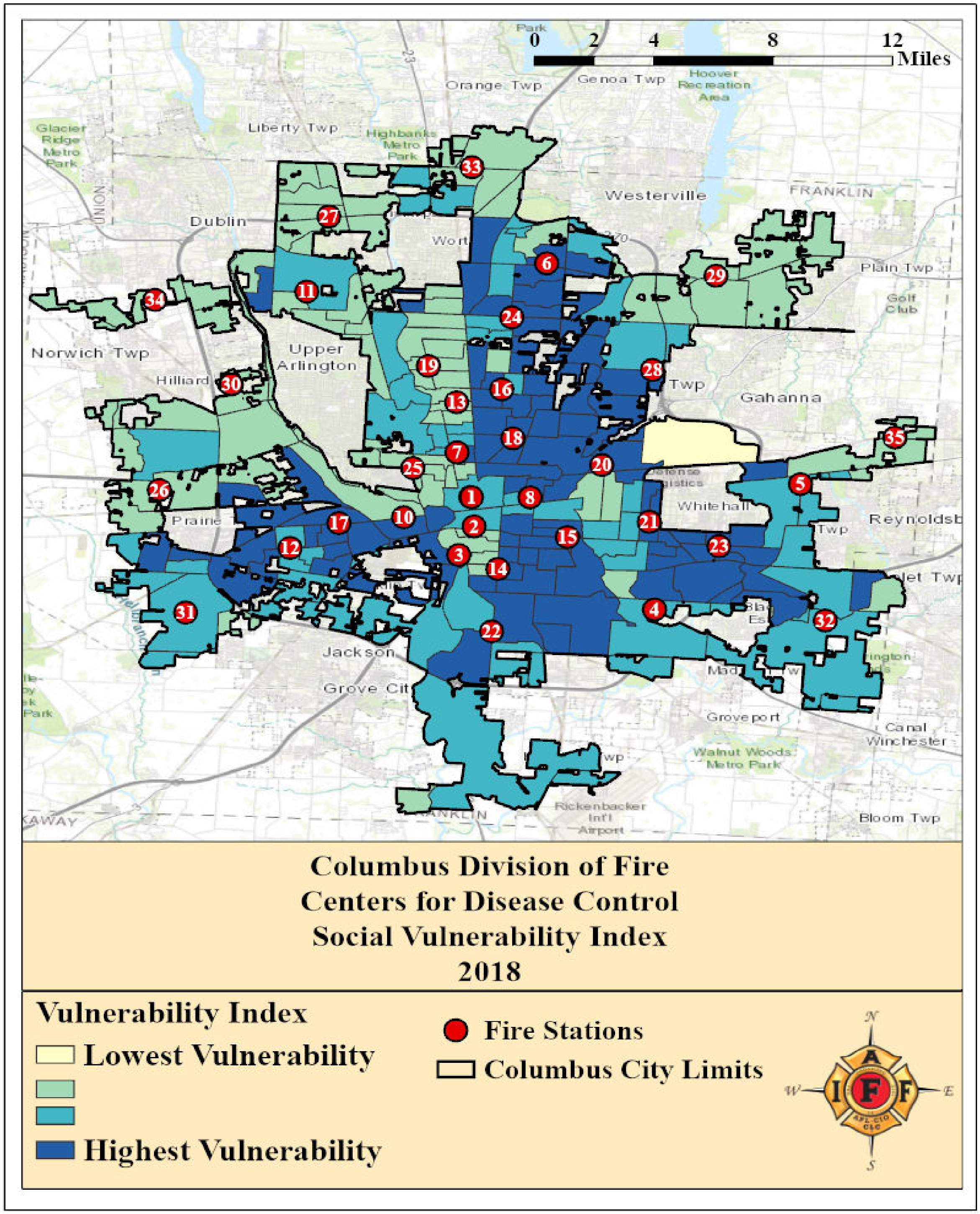
Map 5: Density of Fire Incidents, 2017-2019. This map shows the density of fire incidents from 2017 to 2019. Most of the incidents occurred in the central part of the city around Stations 1, 2, 7 and 8. However, other areas of high density are present everywhere in the jurisdiction.



Map 6: EMS Risk Map, Projected Number of Incidents per Year. This map shows the EMS risk in Columbus by census tract based on the statistical analysis of past incidents and socio-demographic variables. The analysis found that the variables that are associated with a higher risk of EMS incidents are the number of people living with a disability, the number of vacant units and the crime rate.



Map 7: Fire Risk Map, Projected Number of Incidents per Year. This map shows the fire risk in Columbus by census tract based on the statistical analysis of past incidents and socio-demographic variables. The analysis found that buildings' age and the daytime population are the strongest risk factors for fire incidents.



Map 8: Centers for Disease Control, Social Vulnerability Index, 2018. This map shows the Social Vulnerability Index (SVI) as estimated by the CDC. The SVI score is determined by examining factors such as socioeconomics, housing composition, residents with disabilities, minority status, languages spoken, and housing and transportation, and identifies areas in the community that will most likely need assistance before, during, and after a hazardous event.

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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 1,000° Fahrenheit (F). It is generally accepted in the fire service that for a medium growth rate fire,[19] 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 new building 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 fire department response to a low-hazard structure fire. A low-hazard structure fire is defined as a fire that occurs in a typical, 2,000 square foot, single-family residential home with no basement or exposures.[20]

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

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[19] 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.

[20] NFPA 1710, 2020 ed. Pg. 1710-20 A.4.1.2.5.1

converts from a solid and begins to release combustible gases. If enough combustible gases are released the material will begin to burn freely.

This process is exothermic, which means that it produces heat. The heat being generated 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 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 as it would in an open area. In this phase of the 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 burning 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 begins to heat the ceiling, the 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 on to the next stage or the fire has insufficient oxygen available to burn and it progresses back to the incipient stage. 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 aggressive intervention by an adequately staffed fire department, the fire will likely spread to the rest of the structure.

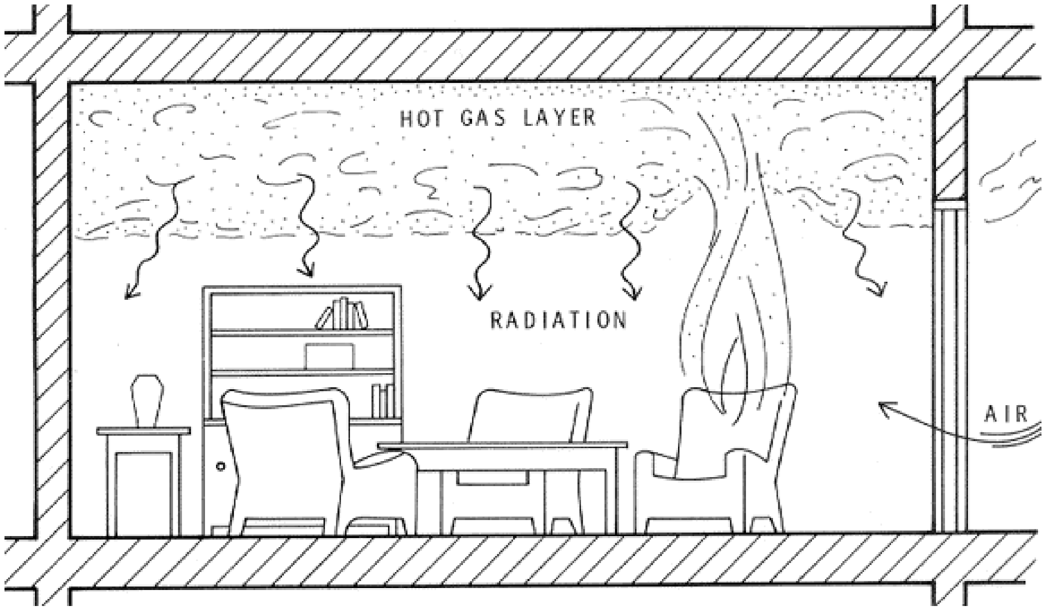

Figure 1: Fire Growth in a Compartment.[21] The above figure depicts the growth of fire in a compartment, which is an enclosed space or room in a building. In a compartment the walls, ceiling, floors, and objects absorb radiant heat produced by the fire. Unabsorbed heat is reflected back to the initial 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. [22]

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 super-heated gas layer at the ceiling that continues to increase, until it begins to bank down to the floor, heating all combustible objects

[21] Image courtesy of University of California at Davis Fire Department
[22] 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 1,200˚ 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 of flames generates a tremendous amount of heat, smoke, and pressure. The pressure generated from this explosion has enough force to push fire 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 the 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 members responding on, or arriving with, each engine and ladder company 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 firefighting force can reach a reasonable number of fire scenes before flashover occurs.[23] 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 such an attack, 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, 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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[23] 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.[24] 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.

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 company, 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

[24] 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.

initiating fire suppression, the supervising officer of the first-arriving engine company is also 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 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.[25] 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 company. Far stagger was defined as a 2-minute time difference in the arrival of each responding company.[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.

[25] Ibid.
[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 Firefighters.

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 2018 alone, 44% 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 tasks 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 truck 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. (2010). Report on Residential Fireground Field Experiments. NIST Technical Note 1661. National Institute of Standards and Technology; Gaithersburg, MD, April 2010.
[29] Fahy, R.F., Molis, J.L. (June, 2019) Firefighter Fatalities in the United States-2018. 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

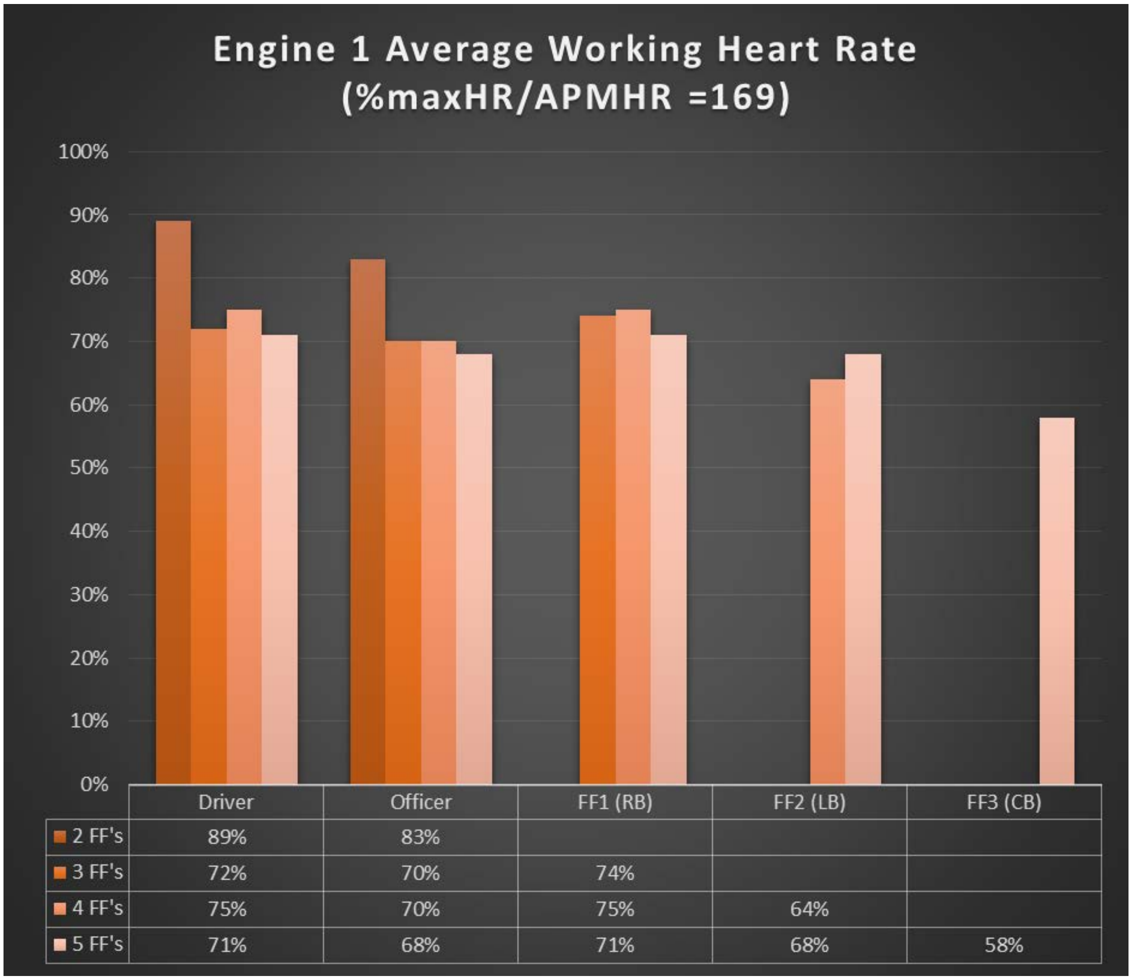

Chart 1: Average Peak Heart Rate of First Engine (E1) with Different Crew Sizes by Riding Position.[31] *In this chart, heart rates are expressed as a percent of maximal age-predicted maximal HR.* The average heart rates for firefighters on the first engine company were above 80% of age-predicted maximum values when only two firefighters were working. When staffing was at two 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

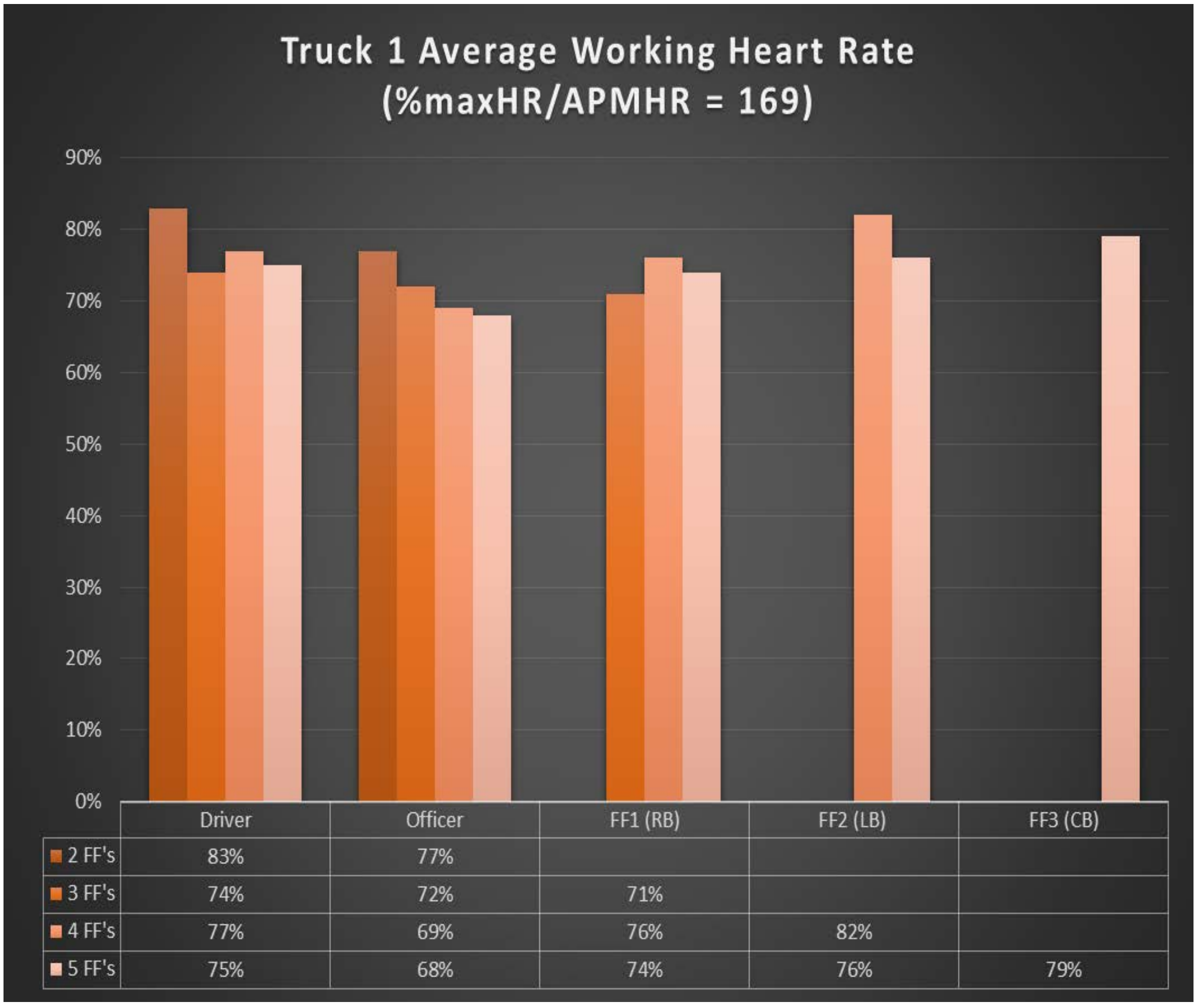

Chart 2: Average Peak Heart Rate of First Truck (T1) with Different Crew Sizes by Riding Position.[33] In this chart, heart rates are expressed as a percent of maximal age-predicted maximal HR. The average heart rates for firefighters on the first truck company were above 80% of age-predicted maximum values when only two 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.

[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 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 showed 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 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			
Flame Spread:	**Civilian Deaths**	**Civilian Injuries**	**Average Dollar Loss per Fire**
Confined fires (identified by incident type)	0.00	8.7	$200
Confined to object of origin	0.4	11.1	$1,200
Confined to room of origin, including confined fires by incident type[36]	1.8	23.8	$4,000
Beyond the room, but confined to floor of origin	16.2	76.3	$35,000
Beyond floor of origin	24.6	55.0	$65,900

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 firefighters 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 environment and, therefore, require the use of respirators. In those cases, at least two standby persons, in addition to the minimum of two persons inside

[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. Homes include one- and two-family homes (including manufactured housing) and apartments or other multifamily housing. These statistics are national estimates based on fires reported to U.S. municipal fire departments and so exclude fires reported only to federal or state agencies. National estimates are projections. Casualty and loss projections can be heavily influenced by the inclusion or exclusion of one unusually serious fire. Property damage has not been adjusted for inflation.

[37] National Fire Protection Association, NFPA 1710 (2020), Table A.5.2.2.2.1 Fire Extension in Residential Structures, 2012-2016.

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]

However, the number of personnel required per fire suppression apparatus increases with risk and demand. NFPA 1710, 2020 edition states that engine and ladder companies that are assigned to first-due districts that have a high number of incidents, geographic restrictions[42], geographic isolation[43], or areas considered to be urban[44] with regards to population density, all as identified by the AHJ, should be staffed with a minimum of five firefighters. First-due districts that have tactical hazards, high-hazard occupancies, or densely populated urban areas[45], as identified by the AHJ, shall have companies that are staffed with six firefighters.[46]

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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] Geographic Restriction is a defined condition, measure, or infrastructure design that limits response and/or results in predictable response delays to certain portions of the jurisdiction.
[43] Geographic Isolation is a first-due response zone or jurisdiction with staffed resources where over 80% of the response area is outside of 10-minute travel time from the next closest staffed suppression apparatus.
[44] An urban area is an incorporated or unincorporated area with a population over 30,000 people and /or a population density over 1,000 people per square mile but less than 2,999 people per square mile.
[45] A dense urban area is an incorporated or unincorporated area with a population density of over 200,000 people and/or a population density of over 3,000 people per square mile.
[46] 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.

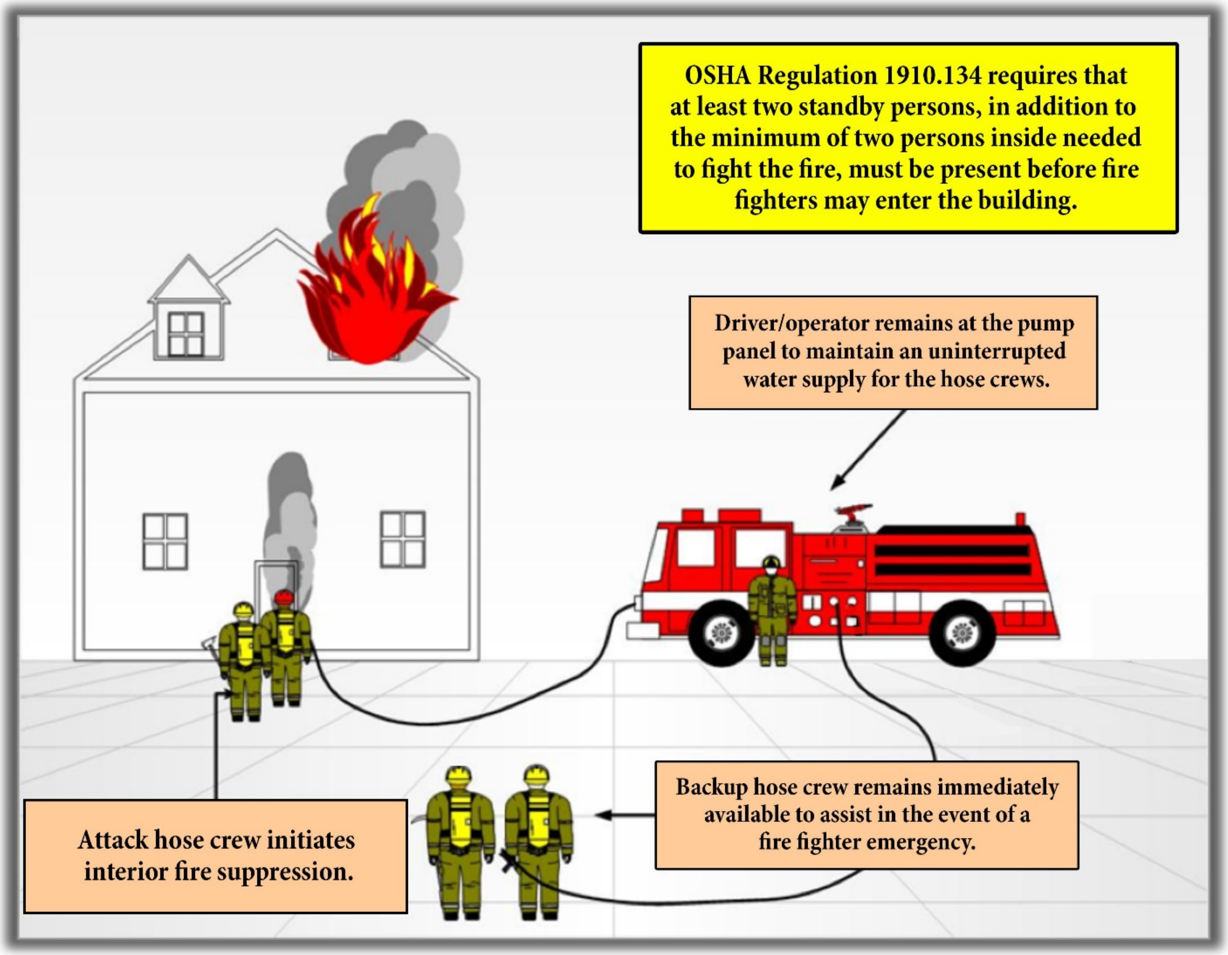

Figure 2: The OSHA "2 In/ 2 Out" regulation. The above figure depicts the number of firefighters required to meet OSHA regulation 1910.134, which demands one firefighter outside for every firefighter inside. The firefighters outside can support a secondary attack line and facilitate the rescue of trapped 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.

Several examples of incidents exist 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 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.

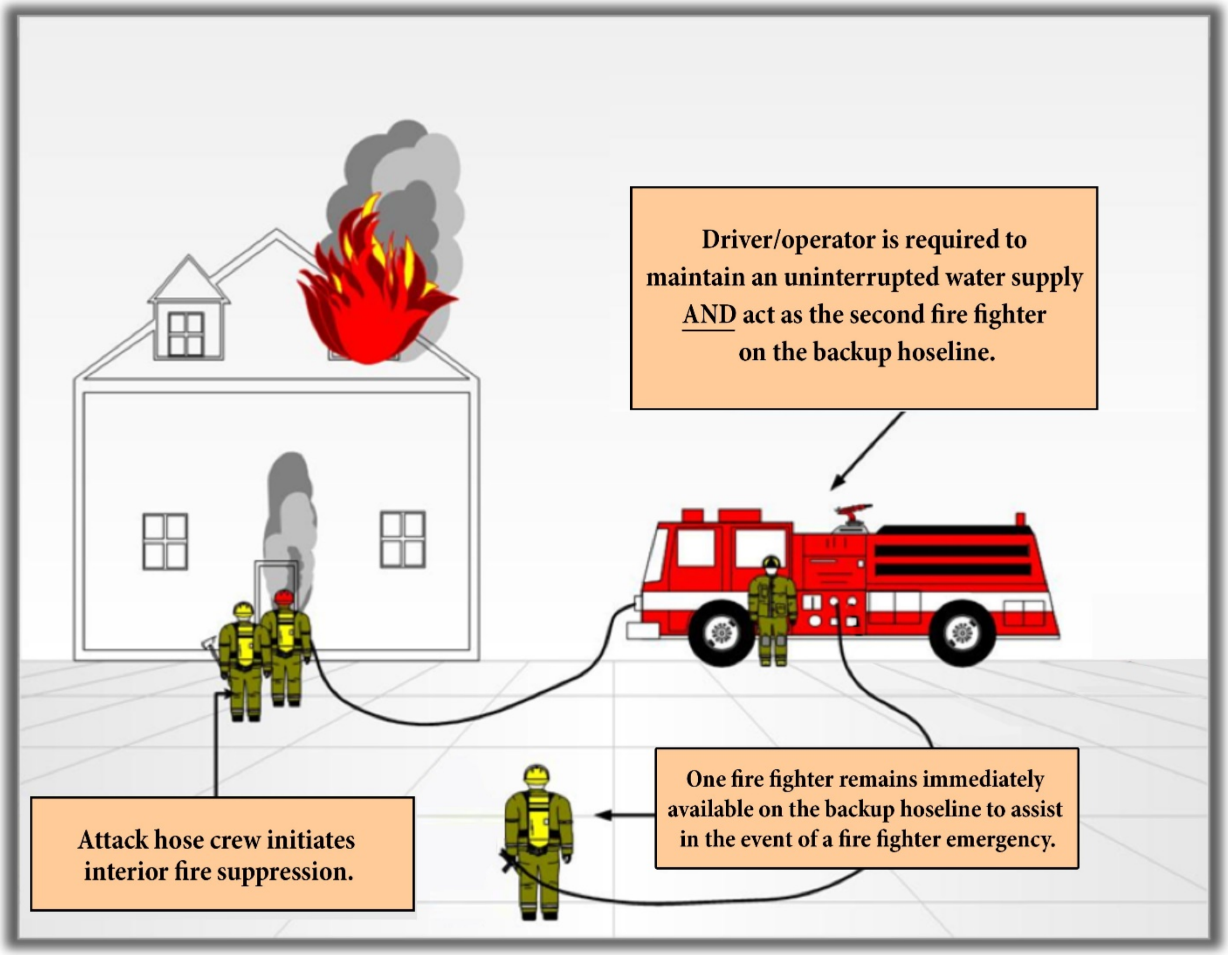

Figure 3: Emergency "2 In/2 Out" Operations. In the emergency model depicted above, the arriving fire apparatus is staffed with a crew of four personnel and operates under emergency conditions. In this case the driver/operator of the fire apparatus is also counted as a firefighter, which means that firefighter 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 can 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 "2 In/2 Out" Regulation, and in a manner that minimizes the threat of personal injury. In crews with fewer than four 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 a minimum of 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

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)	4 Firefighters
Required Minimum Personnel for Full Alarm	**16 Firefighters & 1 Incident 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 17 fire suppression personnel

In addition, NFPA 1710, §5.2.4.6.2 states, "The Fire Department shall have the capability for 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.

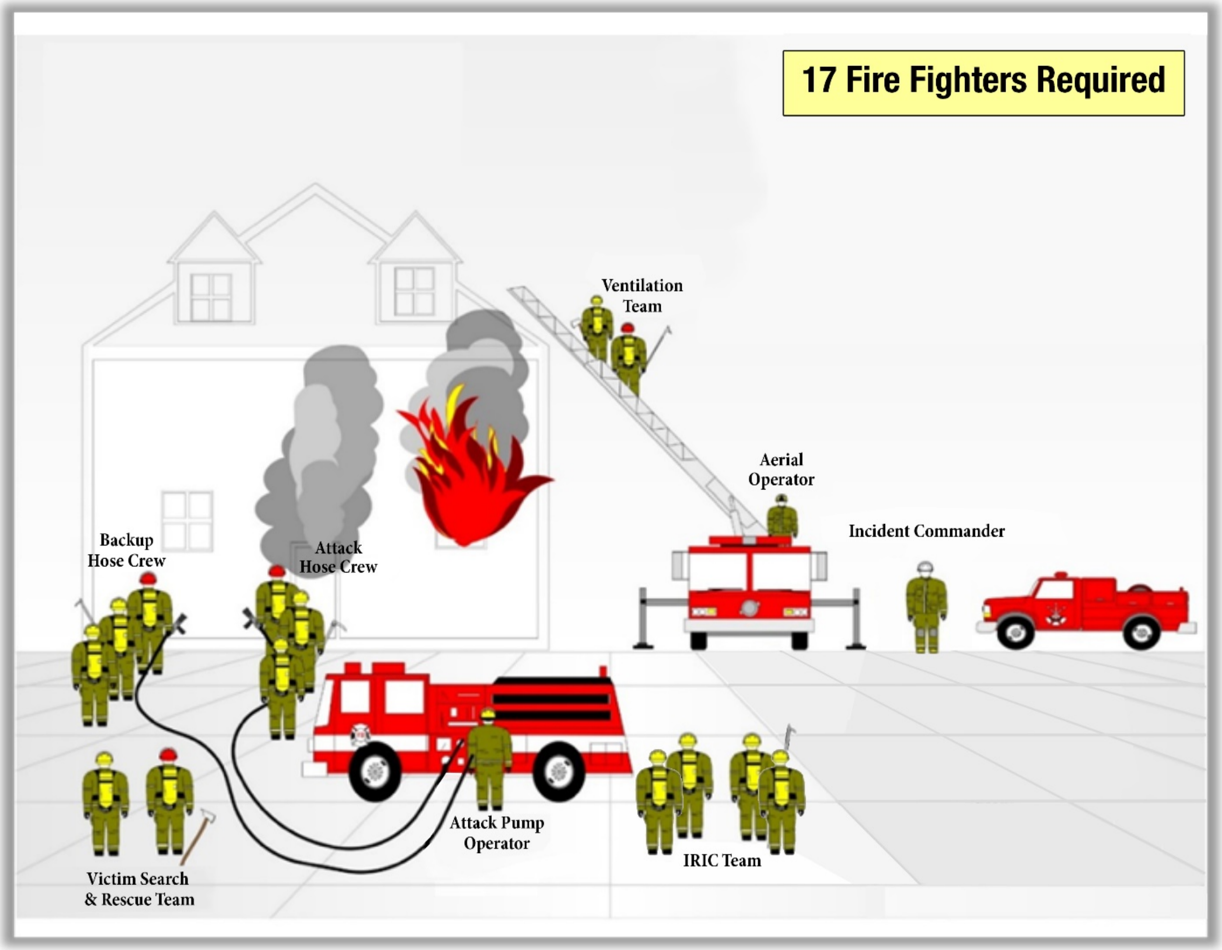

Figure 4: Initial Full Alarm Assignment Deployed Within 8 Minutes, 17 Firefighters Required. The above figure depicts the full alarm assignment required by NFPA 1710 as discussed in Table 4.

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.

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, and other structures with a high fire load and populations.

Overview of High-Rises

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. NFPA 101, Life Safety Code, 2015 Edition and the International Code Council's International Building Code both define a high-rise structure as a building more than 75 ft. (23 m) 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.3.3.36 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 risks to firefighters and occupants increase in proportion to the height of the building and the height of the fire above grade level.[47] 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 truck 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 2007 and 2011, there were an estimated 15,400 reported high-rise structure fires per year that resulted in associated losses of 46 civilian deaths, 520 civilian injuries, and $219

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

million in direct property damage. Office buildings, hotels, apartment buildings, and health care facilities accounted for nearly half of these high-rise fires.[48]

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 risks 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[49] located in the building 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, the 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 regarding 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 most 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.

Like 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 firefighting 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.

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[48] Hall, J.R. (2013), High-Rise Building Fires. NFPA.
[49] Structural Firefighting Strategy and Tactics 2nd Edition. Klaene B., Sanders R. NFPA 2008

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 to find shelter from 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 commercial or residential, it is essential for there to be multiple search and rescue teams 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. It should be noted that in regard to high-rise fire suppression, crews larger than four performed searches faster than crews of four, thus minimizing a person who is trapped exposure to fire and toxic gases.

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 that 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 standpipe 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. Coordinated 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.

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[50] 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

[50] A fire service elevator is engineered to operate in a building during a fire emergency and complying with prescriptive building code requirements and the American Society of Mechanical Engineers (ASME) A 17.1 safety standard for elevators.

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 structure:

- In first-due response areas with a high number of incidents, geographical restrictions, geographical isolation, or urban areas, as identified by the AHJ, these companies shall be staffed by a minimum of five on-duty members.[51]
- In first-due response areas with tactical hazards, high-hazard occupancies, or dense urban areas, as identified by the AHJ, these fire companies shall be staffed with a minimum of six on-duty members.[52]

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 several 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 next page, displays the minimum number of firefighters required to arrive in the first full alarm assignment to a high-rise fire.

[51] NFPA 1710. §5.2.3.1.2 and §5.2.3.2.2
[52] NFPA 1710. §5.2.3.1.2.1 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 Team	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 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. Fighting fire in high-rise structures poses many unique obstacles and challenges other than are 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.

There are six main components of an EMS incident from start to finish.[53] 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.[54] This is likely due to the fact that fire stations housing first responder units, which are equipped and staffed with dual-role firefighter/emergency medical service technicians and supplies, are more centrally located and are able to effect 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 supporting EMS transport within fire department operations 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 adequate personnel and resources operating on scene within 4 minutes. 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,

[53] The Star of Life, designated by Leo R. Schwartz, Chief of EMS Branch, National Highway Traffic Safety Administration (NHTSA) in 1997.
[54] Moore-Merrell, L. et al. (2010) Report on Residential EMS Field Experiments, Fire Fighter Safety and Deployment Study; Washington, DC, September 2010.

and survivable cardiac arrest. Many times, patients experiencing symptoms associated with these events may not recognize the onset indicators and immediately call for assistance.[55] [56] [57] [58] Acute Coronary Syndrome (ACS), or heart attack, is the number one leading cause of death in the United States. 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.[59]

Strokes, which are the number three cause of death in the U.S., 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[60] 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"[61] is less than or equal to 60 minutes. However, Steps Against Recurrent Stroke (STARS) registry shows that the median door to needle time is 96 minutes or 1 hour and 36 minutes.[62]

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

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

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

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

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

[59] 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.

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

[61] "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.

[62] 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

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.[63]

One of the most labor intensive and time critical requests for EMS response is cardiac arrest, which globally 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.[64] 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-based 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.[65] [66] 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 is 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.

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.[67] For an all-ALS system, two of the six should be Paramedics, with a minimum of one assigned to each of the responding apparatus. Some ALS 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

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

[64] Highlights of the 2010 American Heart Association Guidelines for CPR and ECC

[65] Determinants of Blood Flow during Cardiac Resuscitation in Dogs. Halperin, HR et al. *Circulation* 1986;73:539-550

[66] 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

[67] 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

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.

Fire Department Deployment

Before discussing the staffing and deployment analysis of the CFD's resources, it is imperative to understand the intricacies of distribution and concentration.

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.[68] In this case, distribution is measured by the percentage of roads that are covered from each fire station within 4-[69], 6-[70], 8-minute[71] and 10-minutes and 10-seconds[72] travel times to adhere to NFPA 1710, 2020 edition. Four minutes of travel time is the allowable maximum travel time for the first-arriving apparatus at the scene of a fire, first responding unit to an EMS incident, and BLS ambulance if there is not a first responding unit already on the scene.

Distribution study requires geographical analysis of first-due resources. Distribution measures may include:[73]

- 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

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

[69] Four minutes of travel time is the allowable maximum travel time for the first arriving apparatus at the scene of a fire, first responding unit to an EMS incident, and BLS ambulance if there is not a first responding unit already on the scene.

[70] Six minutes of travel time is the maximum amount of travel time permitted for the second arriving apparatus. Although not explicitly stated, it is recommended that this apparatus be the ladder truck or a company that will be assigned to ladder duties.

[71] Eight minutes of travel time is the maximum amount of travel time permitted for a low-hazard alarm assignment and the arrival of an ALS resource, assuming a BLS unit is already on the scene within 4 minutes of travel time.

[72] Ten minutes and ten seconds of travel time is the maximum amount of travel time permitted for a high-hazard alarm assignment.

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

- 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

- 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, Truck, ALS 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 the fire department is achieving a reasonable response performance to handle emergencies.[74]

Evaluating a small number of incidents for response time performance also does not reflect the true performance of the department. Analyzing tens of thousands of incidents measured over 3-5 years will provide a more accurate assessment of the delivery system performance. Completing the same analysis over a period will allow for trend analysis as well.[75]

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 the probability 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 jurisdiction 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 to provide shorter 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.

[74] Commission on Fire Accreditation International, 5th Edition. 2008. Page 53
[75] Commission on Fire Accreditation International, 5th Edition. 2008. Page 53

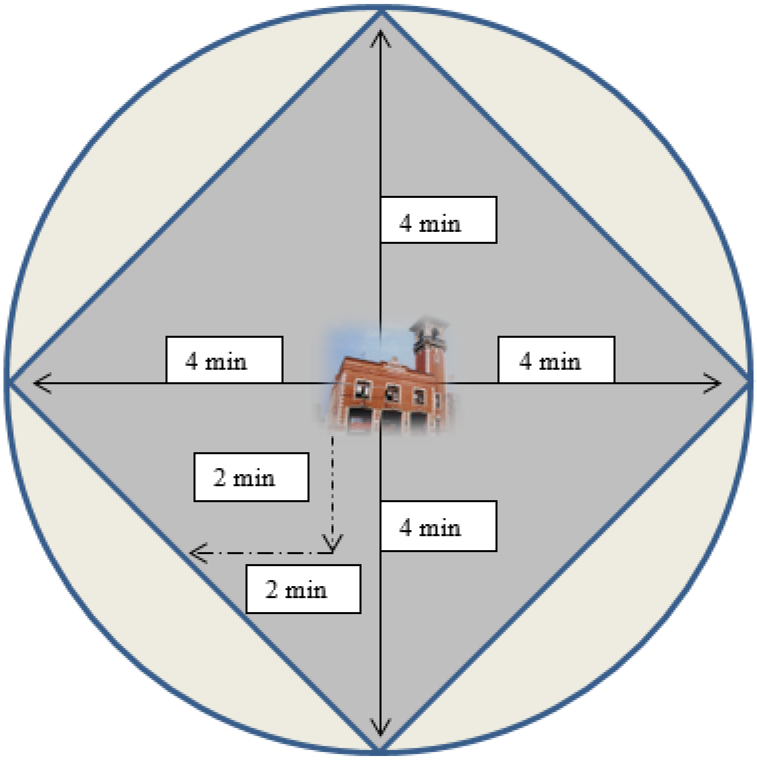

Figure 5: Normal Distribution Model for an Initial 4-Minute Response Area.[76] As depicted in the above figure, fire stations and emergency resources should be distributed throughout a community so that citizens receive equitable coverage and protection. However, there are additional points of concern when modeling a response district such as road network, traffic patterns, and building occupancies.

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.[77] 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.[78] Specialty units tend to be trucks, rescue units, hazmat, or Battalion personnel. Most often there are less of these types of equipment and

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[76] Derived from Commission on Fire Accreditation International, 5th Edition. 2008. Page 53
[77] Commission on Fire Accreditation International, 5th Edition. 2008. Page 55
[78] Commission on Fire Accreditation International, 5th Edition. 2008. Page 62

personnel compared to the first-line response of engines and medic units. 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.[79]

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

Mapping Analysis of the Columbus Division of Fire

In creating this document, it was important to ascertain where stations were located and if they were located to provide fair and equitable coverage to the citizens. In order to make this assessment, the IAFF created maps of the department's response area and plotted the fire stations.

The table on the next pages shows the location of the current stations, the apparatus housed in each station and the typical staffing level.

Station Name/Number	Station Address	Apparatus	Staffing
Station 1/9	300 North Fourth St.	Engine 1 Engine 9 Ladder 1 Medic 1 EMS 10 ES-2	3 FF/EMT 3 FF/EMT 3 FF/EMT 2 FF/EMT 1 Officer 1 Officer
Station 2	150 East Fulton St.	Engine 2 Ladder 2 Medic 2 Battalion 1	3 FF/EMT 3 FF/EMT 2 FF/EMTP 1 Officer
Station 3	222 Greenlawn Ave.	Engine 3 Medic 3 Rescue 3 EMS 11 SO2	3 FF/EMT 2 FF/EMT 3 FF/EMT 1 Officer 1 Officer
Station 4	3030 Winchester Pk.	Engine 4 Rescue 4 Medic 4	5 FF/EMT 3 FF/EMT 2 FF/EMT
Station 5	211 McNaughten Rd.	Engine 5 Ladder 5 Medic 5	3 FF/EMT 4 FF/EMT 2 FF/EMT
Station 6	5750 Maple Canyon Dr.	Engine 6 Medic 6 Medic 806 Battalion 2 EMS-12	3 FF/EMT 2 FF/EMT 2 FF/EMT 1 Officer 1 Officer

Table 6: Current Fire Station Locations and Staffing. The above table displays where apparatus are housed and how they are staffed.

Station Name/Number (continued)	Station Address (continued)	Apparatus (continued)	Staffing (continued)
Station 7	1425 Indianola Ave.	Engine 7 Medic 7 Battalion 3 EMS-13	3 FF/EMT 2 FF/EMT 1 Officer 1 Officer
Station 8	1240 East Long St.	Engine 8 Ladder 8 Medic 8	3 FF/EMT 4 FF/EMT 2 FF/EMT
Station 10	1096 West Broad St.	Engine 10 Ladder 10 Medic 10 Medic 890	3 FF/EMT 3 FF/EMT 2 FF/EMT 2 FF/EMT
Station 11	2160 West Case Rd.	Engine/Air Crash 11 Rescue 11 Medic 11 Battalion 7 EMS-17	4 FF/EMT 3 FF/EMT 2 FF/EMT 1 Officer 1 Officer
Station 12	3200 Sullivant Ave.	Engine 12 Ladder 12 Medic 12	3 FF/EMT 3 FF/EMT 2 FF/EMT
Station 13	309 Arcadia Ave.	Engine 13 Ladder 13 Medic 13	3 FF/EMT 3 FF/EMT 2 FF/EMT
Station 14	1514 Parsons Ave.	Engine 14 Medic 14 Battalion 4	3 FF/EMT 2 FF/EMT 1 Officer

Table 6 (continued): Current Fire Station Locations and Staffing. The above table displays where apparatus are housed and how they are staffed.

Station Name/Number (continued)	Station Address (continued)	Apparatus (continued)	Staffing (continued)
Station 15	1800 Livingston Ave.	Engine 15 Ladder 15 Medic 15 Medic 815 EMS-14	3 FF/EMT 2 FF/EMT 2 FF/EMT 2 FF/EMT 1 Officer
Station 16	1130 East Weber Rd.	Engine 16 Rescue 16 Medic 16	3 FF/EMT 3 FF/EMT 2 FF/EMT
Station 17	2300 West Broad St.	Engine 17 Rescue 17 Medic 17 Medic 817 Battalion 5 EMS-15	3 FF/EMT 3 FF/EMT 2 FF/EMT 2 FF/EMT 1 Officer 1 Officer
Station 18	1551 Cleveland Ave.	Engine 18 Medic 18	3 FF/EMT 2 FF/EMT
Station 19	3601 North High St.	Engine 19 Medic 19	3 FF/EMT 2 FF/EMT
Station 20	2646 East Fifth Ave.	Engine 20 Medic 20	3 FF/EMT 2 FF/EMT
Station 21	3294 East Main St.	Engine 21 Medic 21 Battalion	3 FF/EMT 2 FF/EMT 1 Officer
Station 22	3069 Parsons Ave.	Engine 22 Ladder 22 Medic 22	3 FF/EMT 4 FF/EMT 2 FF/EMT

Table 6 (continued): Current Fire Station Locations and Staffing. The above table displays where apparatus are housed and how they are staffed.

Station Name/Number (continued)	Station Address (continued)	Apparatus (continued)	Staffing (continued)
Station 23	4451 East Livingston Ave.	Engine 23 Ladder 23 Medic 23 Medic 823	3 FF/EMT 3 FF/EMT 2 FF/EMT 2 FF/EMT
Station 24	1585 Morse Rd.	Engine 24 Ladder 24 Medic 24	3 FF/EMT 3 FF/EMT 2 FF/EMT
Station 25	739 West Third Ave.	Engine 25 Medic 25	3 FF/EMT 2 FF/EMT
Station 26	5433 Fisher Rd.	Engine 26 Ladder 26 Medic 26	3 FF/EMT 4 FF/EMT 2 FF/EMT
Station 27	7560 Smokey Row Rd.	Engine 27 Ladder 27 Medic 27	3 FF/EMT 2 FF/EMT 2 FF/EMT
Station 28	3240 McCutcheon Rd.	Engine 28 Ladder 28 Medic 28	3 FF/EMT 3 FF/EMT 2 FF/EMT
Station 29	5151 Little Turtle Wy.	Engine 29 Medic 29	3 FF/EMT 2 FF/EMT
Station 30	3555 Fishinger Blvd.	Engine 30 Medic 30	3 FF/EMT 2 FF/EMT
Station 31	5305 Alkire Rd.	Engine 31 Medic 31	3 FF/EMT 2 FF/EMT

Table 6 (continued): Current Fire Station Locations and Staffing. The above table displays where apparatus are housed and how they are staffed.

Station Name/Number (continued)	Station Address (continued)	Apparatus (continued)	Staffing (continued)
Station 32	3675 Gender Rd.	Engine 32 Ladder 32 Medic 32	3 FF/EMT 4 FF/EMT 2 FF/EMT
Station 33	440 Lazelle Rd.	Engine 33 Ladder 33 Medic 33	3 FF/EMT 4 FF/EMT 2 FF/EMT
Station 34	5201 Wilcox Rd.	Engine 34 Medic 34	3 FF/EMT 2 FF/EMT
Station 35	711 Waggoner Rd.	Engine 35 Medic 35	3 FF/EMT 2 FF/EMT

Table 6 (continued): Current Fire Station Locations and Staffing. The above table displays where apparatus are housed and how they are staffed.

Computer modeling was then used to determine the distance apparatus could travel in four, six, eight and 10 minutes, 10 seconds. The above table specifies the current locations of the current fire stations.

Travel times were modeled using Esri ArcGIS Pro 2.4.2. Fire stations were identified on Geographic Information System (GIS) maps as starting points with vehicles traveling at posted road speeds.

When generating the maps, several assumptions needed to be addressed prior to drawing conclusions from the analysis. These assumptions are as follows:

- Modeled travel speeds are based on reasonable and prudent historical traffic speeds using the historical traffic volume on Wednesday at 5.00 pm. 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: Reduced visibility--road surface problems and uncertain waiting conditions 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.[80]

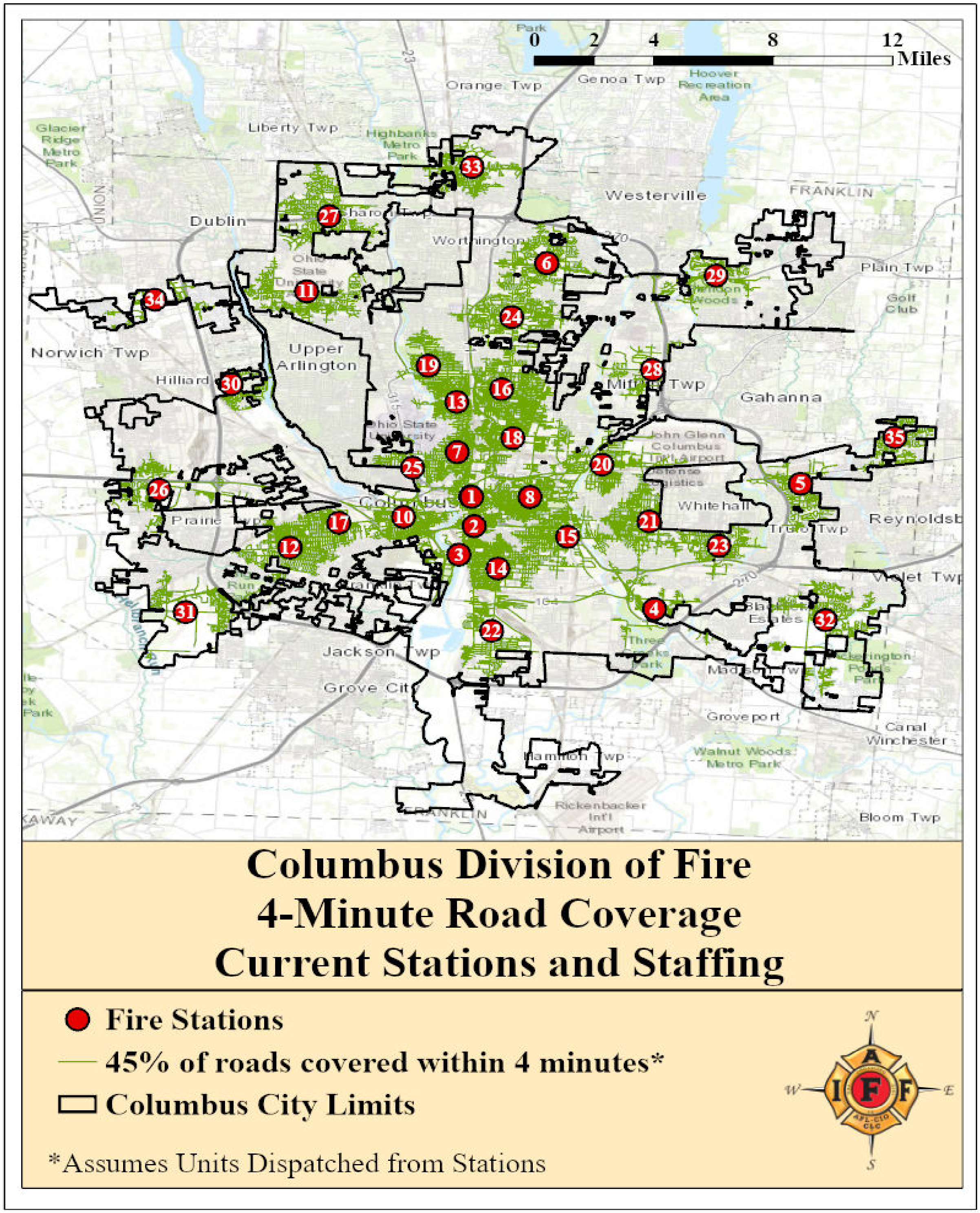
In addition, it is reasonable to suggest that because larger emergency vehicles are generally more cumbersome and require greater skill to maneuver, their response may be more negatively affected by their weight, size, and in some cases, inability to travel narrow surface streets.

As discussed, 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. Other additional factors also include:

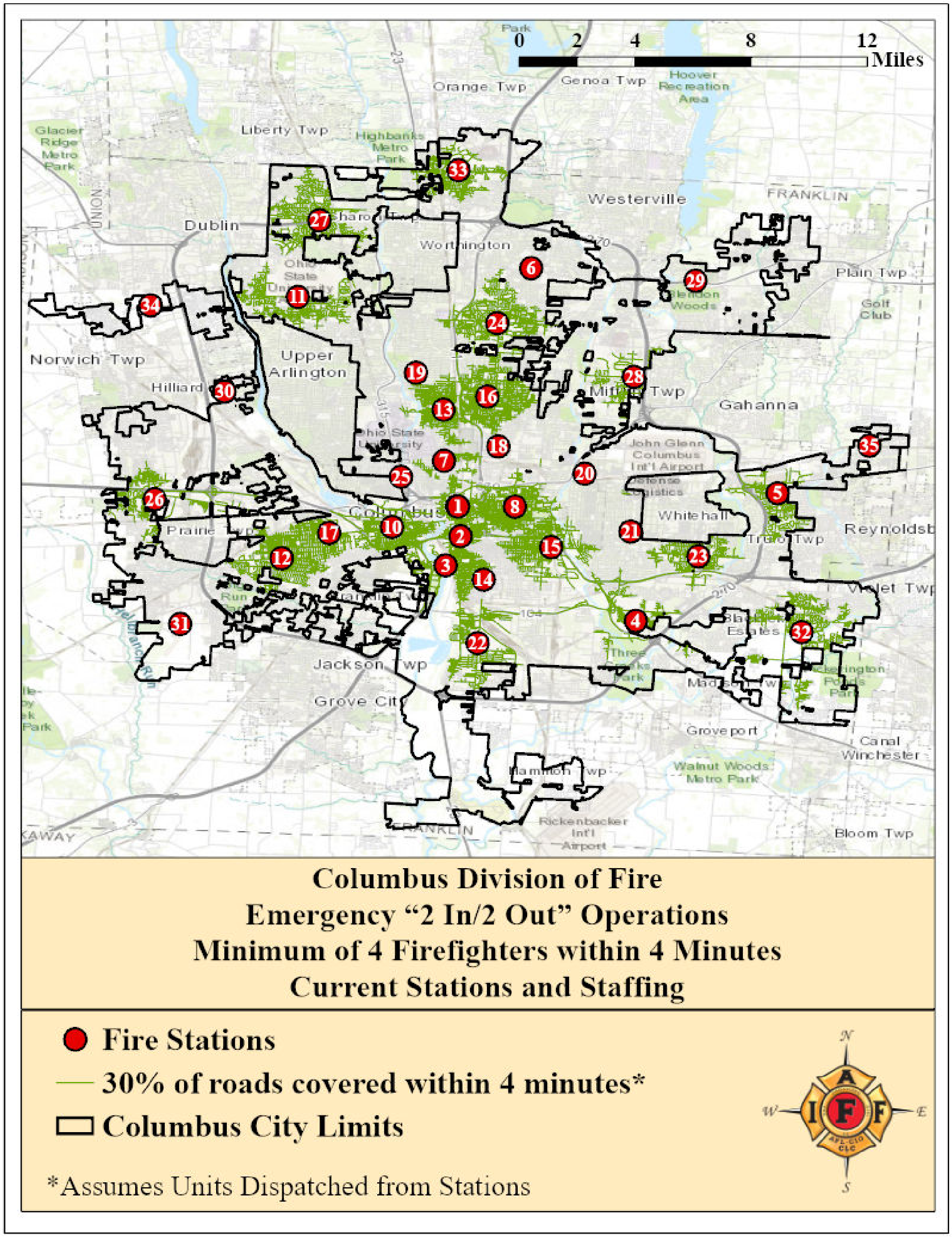
- The time from arrival of the apparatus to the onset of interior fire operations (access interval) must be considered when analyzing response system capabilities.
    - The access interval is dependent upon factors such as distance from the apparatus to the task location and the elevation of the incident and locked doors or security bars which must be breached.
    - Impediments like these may add to the delay between discovery of a fire and the initiation of an actual fire attack.
- The reliability of a community's hydrant system to supply water to fire apparatus.

- Weather conditions.

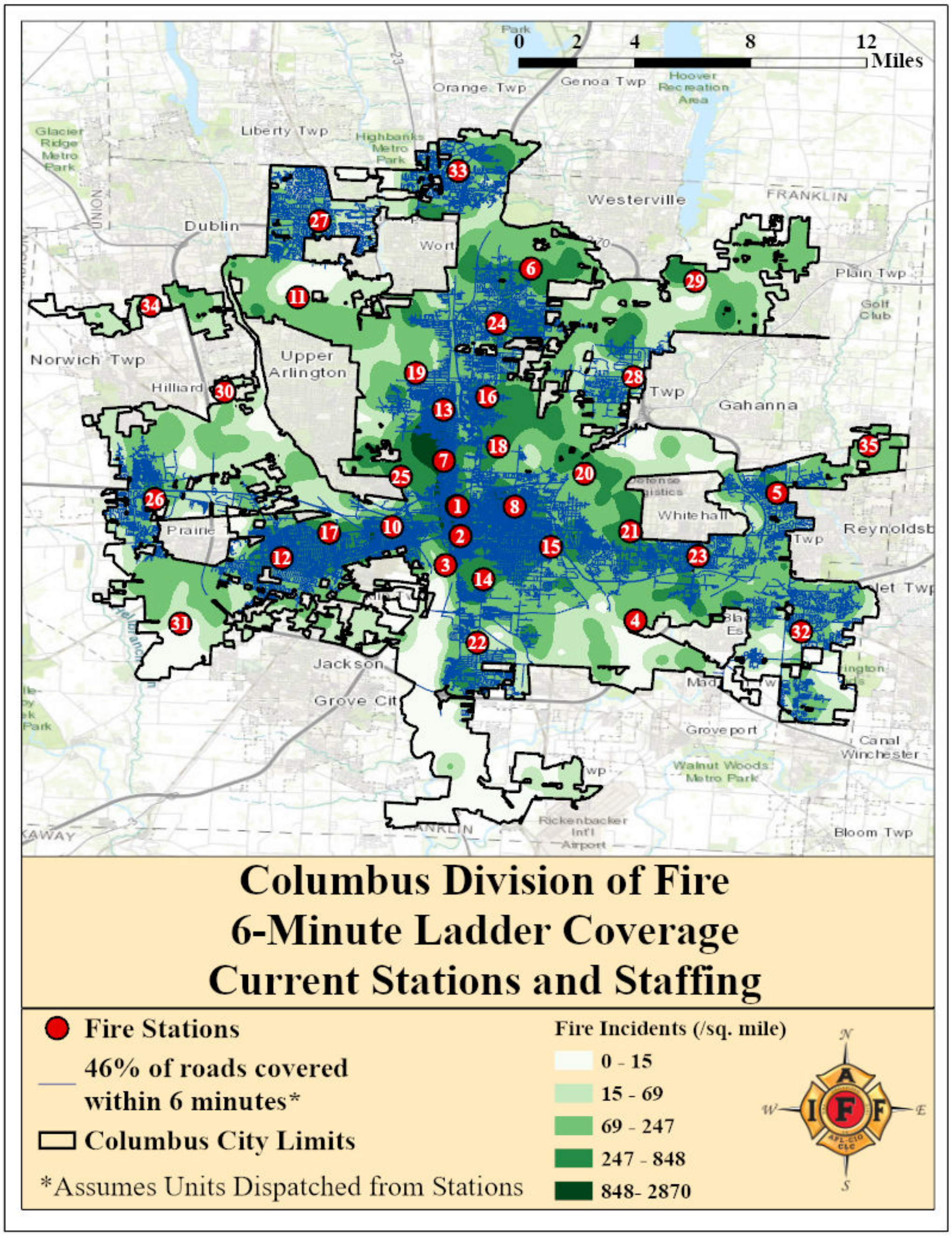
[80] David Shrank and Tim Lomax, The 2003 Urban Mobility Report, (Illinois Transportation Institute, Illinois A&M University: September 2003).



Map 9: 4-Minute Road Coverage, Current Stations and Staffing. This map shows that, assuming all units are available and dispatched from their stations, the department could reach 45% of city roads within four minutes.

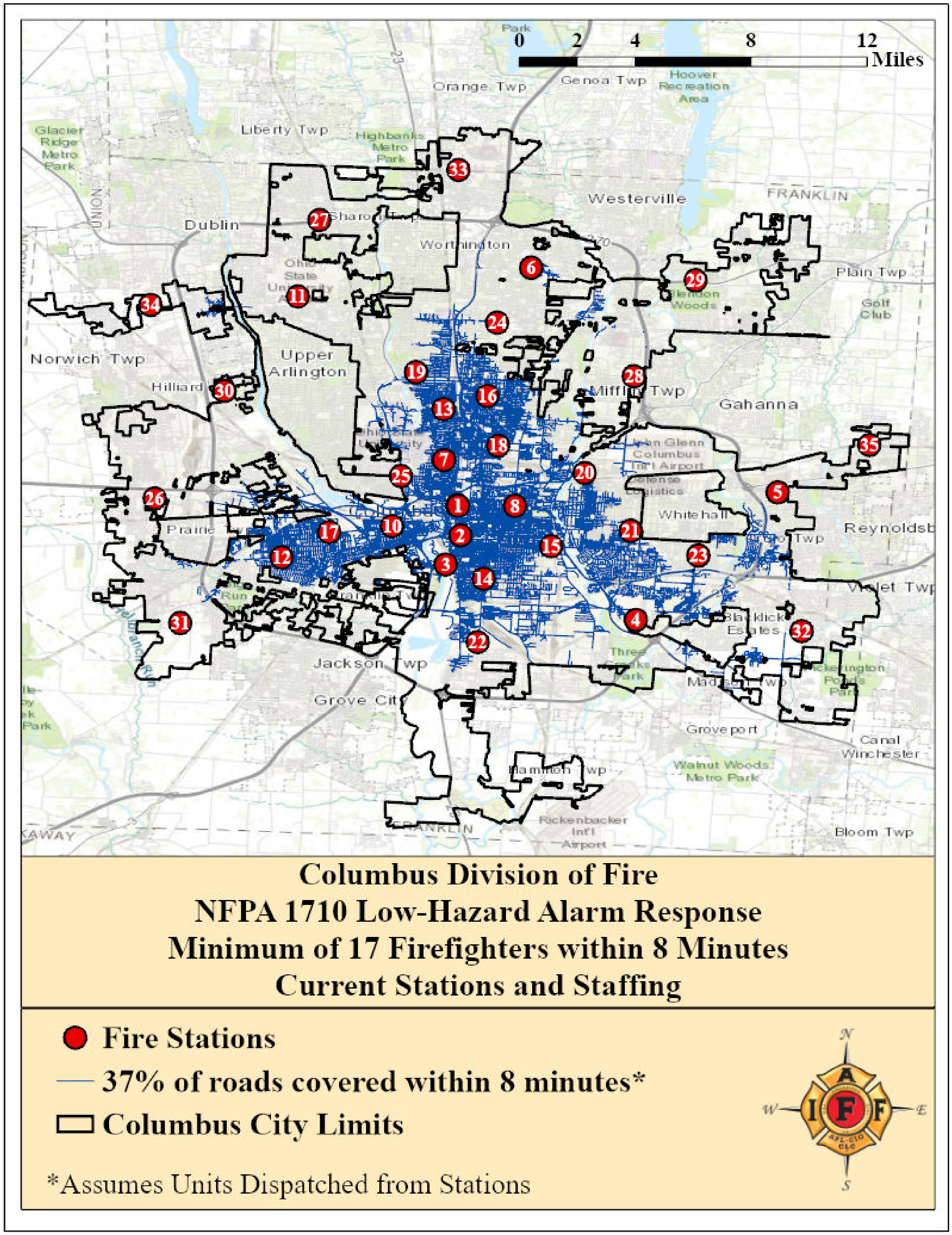


Map 10: Emergency "2 In/2 Out" Operations, Minimum of 4 Firefighters within 4 Minutes, Current Stations and Staffing. This map shows the roads where the department could assemble the minimum force of four firefighters within four minutes. Assuming that the units are available and dispatched from the stations, the department could reach 30% of city roads.

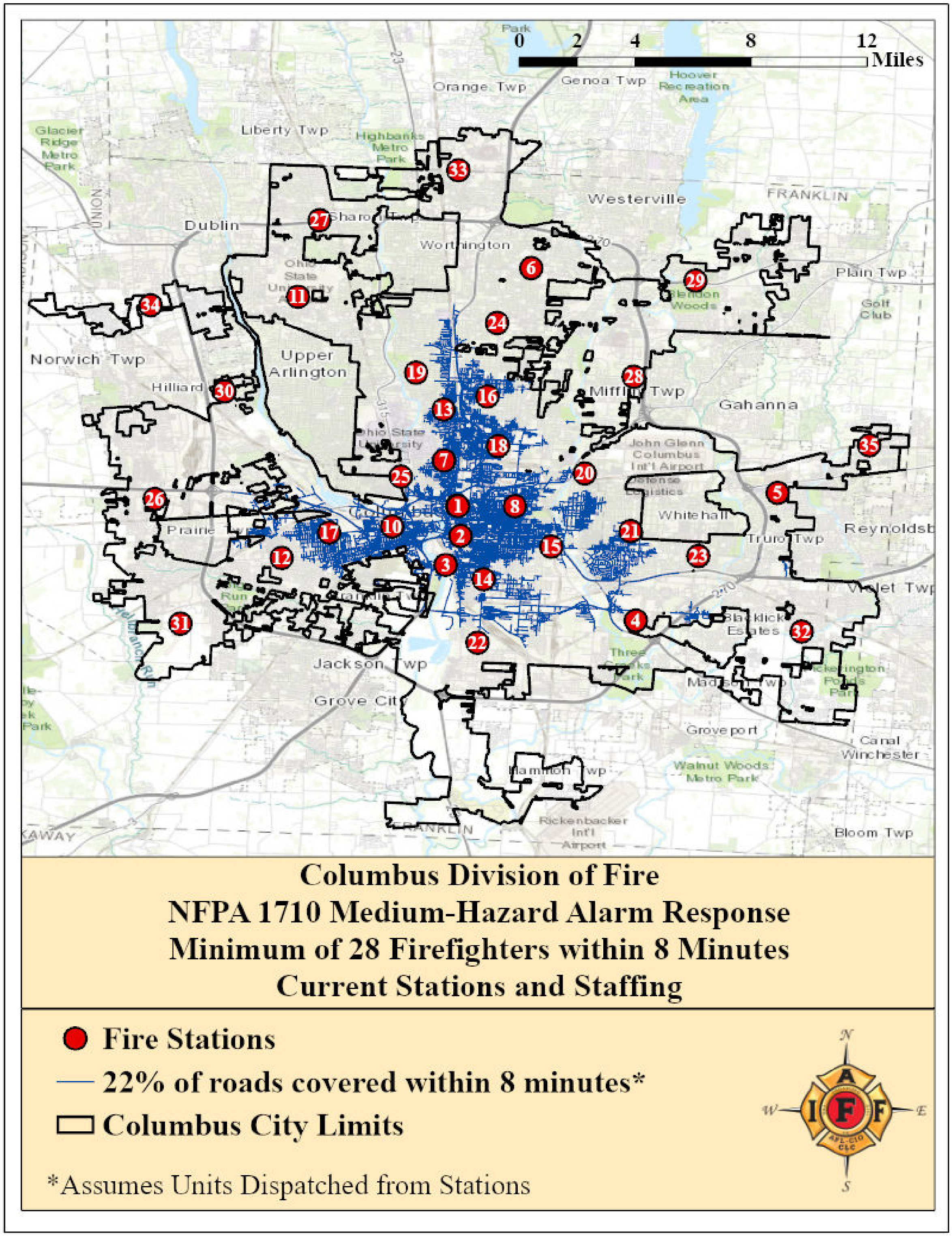


Map 11: 6-Minute Ladder Coverage, Current Stations and Staffing. This map shows the roads that the department's ladder trucks can reach within a travel time of six minutes from the current stations. For comparison, the density of fire incidents is also shown. NFPA 1710 does not establish a travel time objective for ladder trucks, however it states that the second fire suppression apparatus should be on scene within a travel time of six minutes, provided that the first-arriving engine was on scene with four minutes.[81] Given the unique capabilities of a ladder truck, it is important for the department to be able to have a ladder at the scene of fire incidents as soon as possible. The map shows that the department needs to improve the ladder coverage mainly in the areas of Station 7, 18, 20, 29.

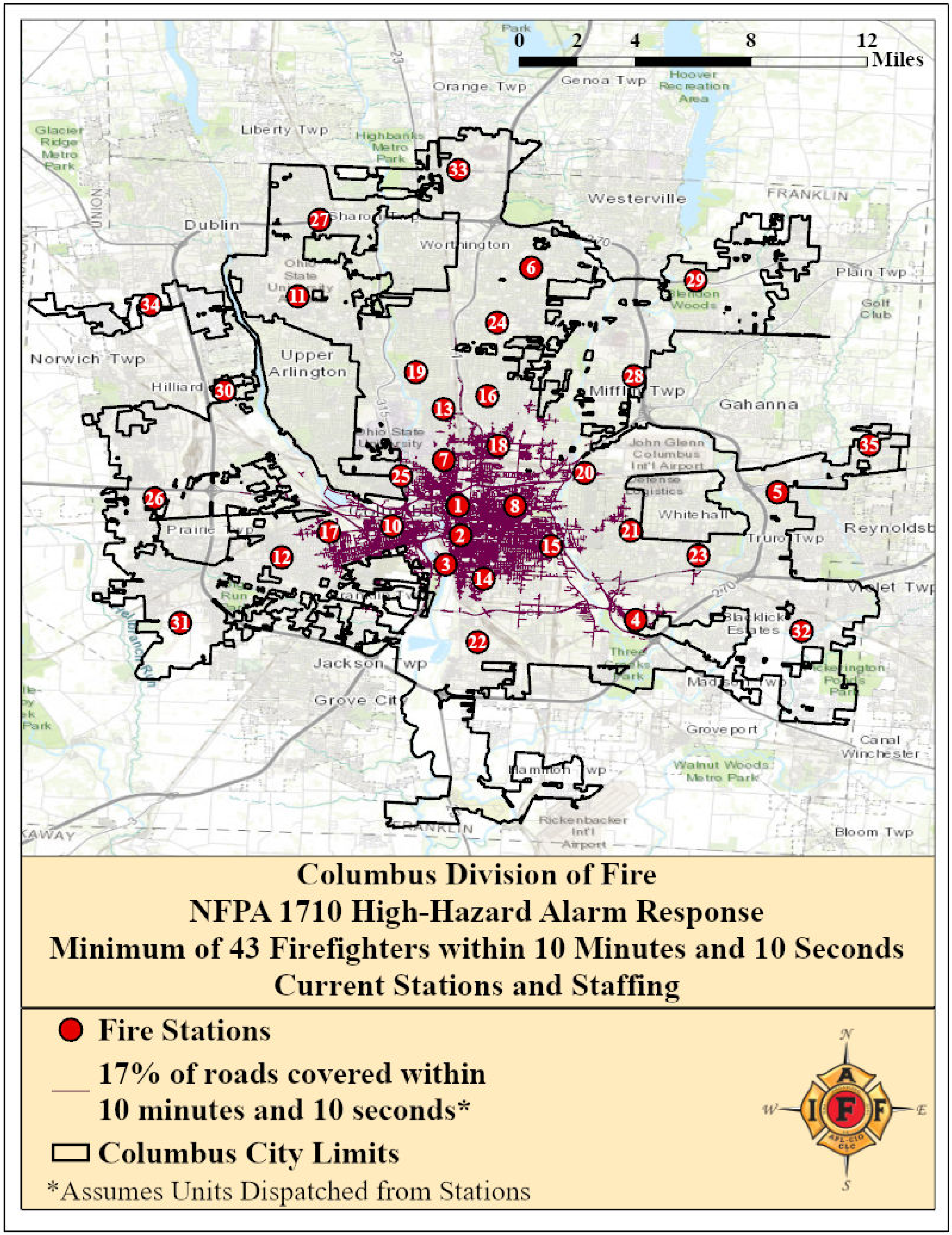
[81] NFPA 1710, 2020 edition, 4.1.2.1



Map 12: NFPA 1710 Low-Hazard Alarm Response, Minimum of 17 Firefighters within 8 Minutes, Current Stations and Staffing. This map shows the roads where the department could assemble the minimum force of 17 firefighters required for low-hazard fires within eight minutes of travel time as required by NFPA 1710. The department could assemble this force on 37% of city roads.



Map 13: NFPA 1710 Medium-Hazard Alarm Response, Minimum of 28 Firefighters within 8 Minutes, Current Stations and Staffing. This map shows the roads where the department could assemble the minimum force of 28 firefighters required for medium-hazard fires within eight minutes of travel time, as required by NFPA 1710. The department could assemble this force on 22% of the city roads.



Map 14: NFPA 1710 High-Hazard Alarm Response, Minimum of 43 Firefighters within 10 Minutes and 10 Seconds, Current Stations and Staffing. This map shows the roads where the department could assemble the minimum force of 43 firefighters for high-hazard fires within 10 minutes and 10 seconds of travel time, as required by NFPA 1710. The department could assemble this force on 17% of the city roads.

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Workload Analysis of the Columbus Division of Fire

The workload analysis presented in this section is based on CAD data provided by the Columbus Fire Fighters, IAFF Local 67, covering the time period from April 2017 through December 31st, 2019. The CAD data include an incident identifier number, responding apparatus, location of incident, dispatch time, en route time, arrival time, the times corresponding to when apparatus and personnel have cleared the incident, and a description of the call type.

CFD uses Automatic Vehicle Location technology to dispatch the closest unit to the scene of an incident. The department also defines a *first-in district* for each station, which is an area where that station's units can respond faster than units from other stations. Although the closest unit to the location of an incident is dispatched first, regardless of the first-in districts' boundaries, these districts are a useful tool for the workload analysis because they allow analysis of the department's performance in different zones of the city. Therefore, the first-in districts will be used, when necessary, in this section of the report.

To evaluate the department's workload, several metrics were considered, including the number of individual apparatus responding to the same incident, travel times of the responding apparatus, responses occurring at the same time, and back-to-back responses. Travel times were also evaluated separately in each response zone to identify areas of the jurisdiction where the department's performance does not meet industry standards.

Call Volume Analysis

Between April 2017 and December 2019, the number of incidents that the CFD responded to increased, on average, by 3,138 incidents per year (+2.3%). In the most recent year available (2019) the CFD responded to 166,509 incidents, compared to 161,633 incidents in 2018. Between April and December 2019, the department responded to 127,815 incidents, compared to 122,775 in 2018 and 122,055 in 2017. Incidents often require more than one unit to respond: the number of single unit responses was 217,174 in 2017, 286,945 in 2018 and 292,397 in 2019. The next chart shows the increasing number of incidents and responses between 2017 and 2019.

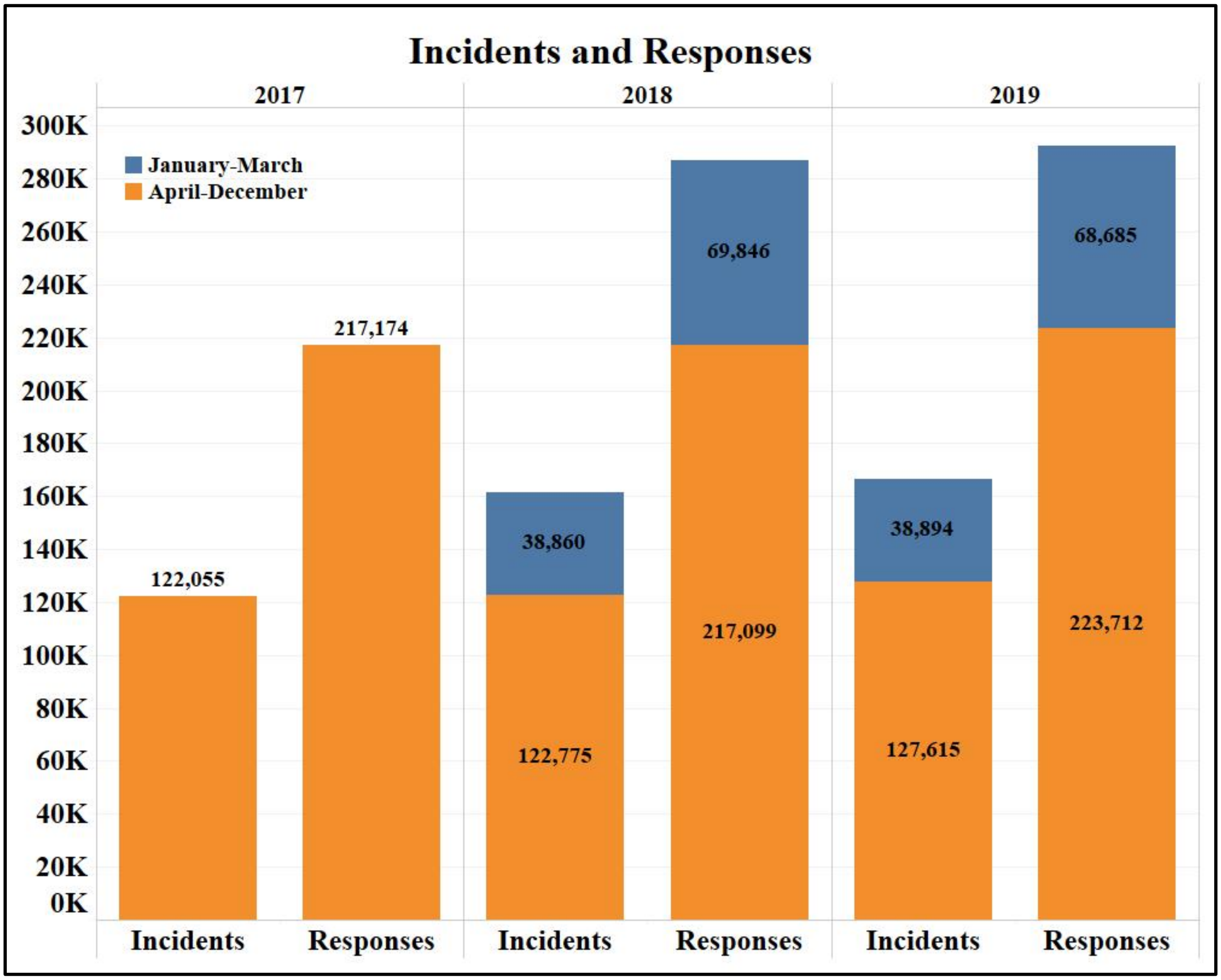


Chart 3: Number of Incidents and Responses. This chart shows the number of incidents and the responses made by single units to address the incidents. Typically, one incident requires more than one unit to respond. Both incidents and responses increased between 2017 and 2019. The different colors facilitate comparison between equivalent time periods. For the year 2017, data between January through March were not available.

Mutual Aid Responses into Columbus

CFD has mutual aid agreements with the fire departments in nearby communities. These agreements are common in the fire service and allow fire departments to better respond to emergencies that might require multiple units and address high demand periods without excessively affecting the jurisdiction's coverage and the department's ability to respond to multiple emergencies occurring at the same time. However, a fire department consistently relying on mutual aid to meet demand within its jurisdiction indicates that its resources are not sufficient to address emergencies in an efficient way. Mutual aid units have longer travel times because they need to travel from stations located outside of the department's jurisdiction. These delays create a risk for the victims of EMS and fire emergencies and increase the risk for firefighters as well, especially in fire emergencies, where a delayed response might lead to fires that are harder to control.

Between 2017 and 2019, CFD relied on mutual aid units to responded to a total of 31,358 incidents occurring within Columbus. Units from neighboring departments made a total of 71,637 responses into Columbus in the same time period. Of the 31,358 incidents requiring mutual aid unit, 18,919[82] incidents were addressed exclusively by mutual aid units, that is, no CFD unit responded to the incident. This occurred because no available CFD unit was close enough to the location of the incidents to provide a timely response.

Approximately 51% of the mutual aid responses from outside department in Columbus were made by medic units and 31% by engines, showing that the department does not have sufficient medic and engine units to address the demand in Columbus. The remaining responses were made by other type of units, such as officer's cars, ladders, or heavy rescue units.

[82] For approximately 8% of the incidents the CAD did not report the time of the arrival at the scene of the incidents, so that the travel time could not be estimated.

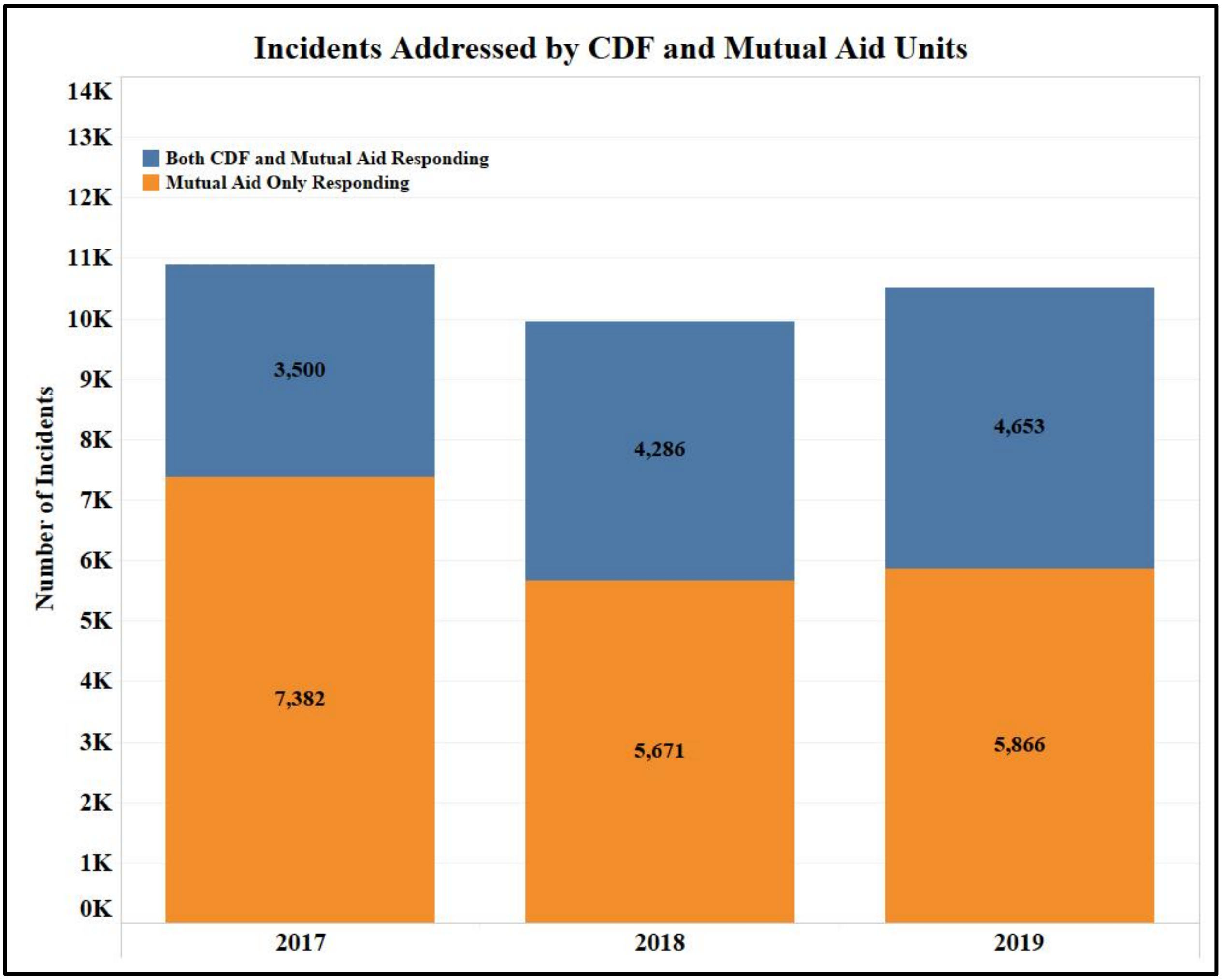


Chart 4: Incidents Addressed by CFD and Mutual Aid Units. This chart shows the number of incidents addressed by mutual aid units only, or by a combination of CFD and mutual aid units. Between 2017 and 2019, CFD relied on mutual aid units to respond to a total of 31,358 incidents occurring within Columbus. Units from neighboring departments made a total of 71,637 responses into Columbus in the same time period. Of the 31,358 incidents requiring mutual aid units, 18,919 incidents were addressed exclusively by mutual aid units.

The analysis of the mutual aid responses into Columbus shows that most of the responses are distributed in the north-south direction on the east side of Columbus. As shown in the next chart, in all the first-in districts, most of the mutual aid responses were made to EMS incidents (60% to 84% of the total). The remaining mutual aid responses were made towards fire and structure fire emergencies. First-in district 29 had the highest number of mutual aid responses to fire and structure fire emergencies. This is because this district has areas of high fire and structure fire incident density, as shown in Map 5. Currently, Station 29 does not have a ladder truck. Given the critical and unique tasks that ladder trucks can perform at the scene of fire incidents and the importance of starting these tasks as soon as possible, as detailed by the studies described above in this report, CFD should add one ladder truck to Station 29.

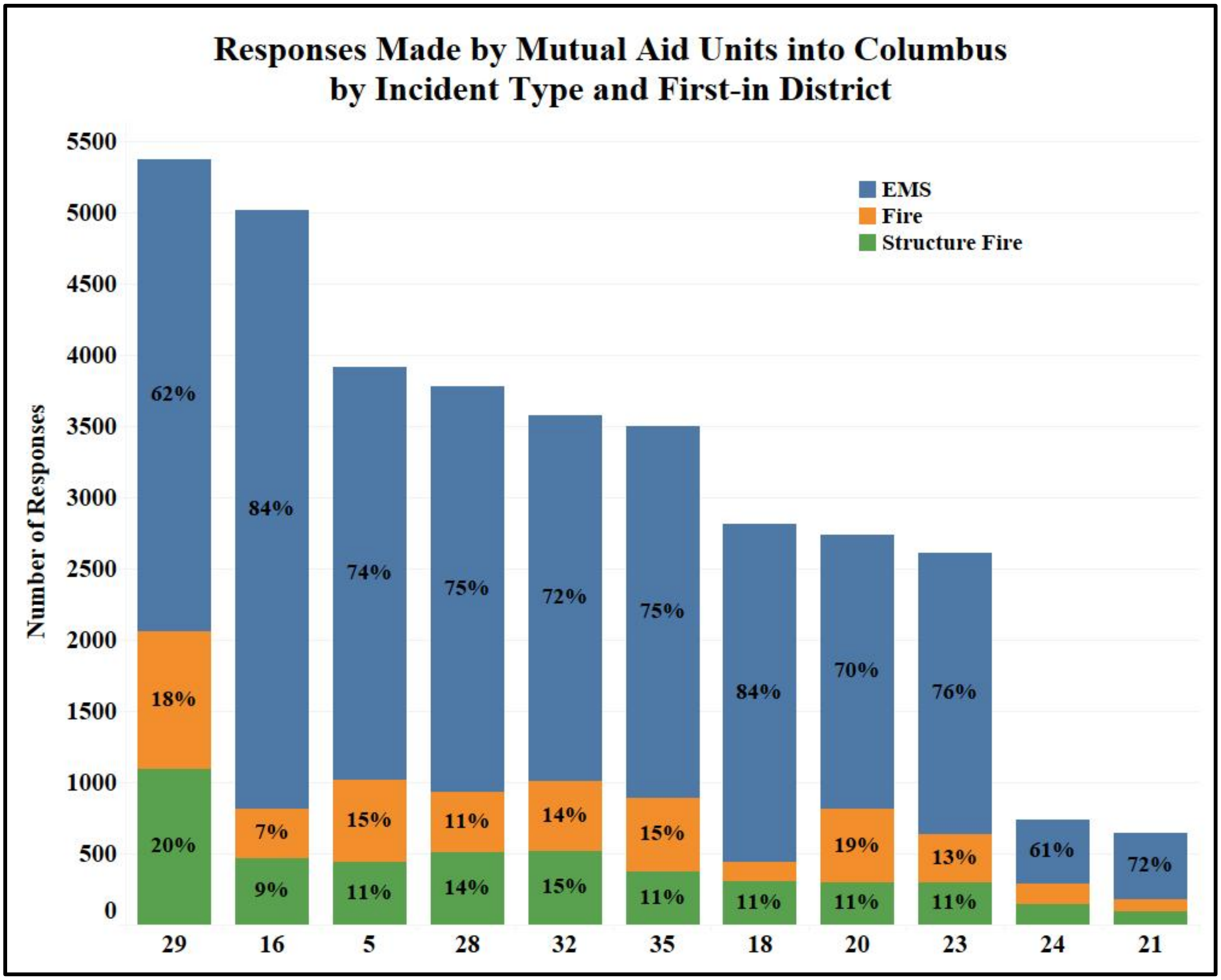


Chart 5: Responses Made by Mutual Aid Units into Columbus by Incident Type and First-in District. This chart shows the first-in districts where the mutual aid units were dispatched more frequently. The color scale and the numbers in the columns identify the type of incidents addressed by these units in each first-in district and with what frequency. Most of the mutual aid responses, ranging from 60% to 84% of the total, were made to EMS incidents. The remaining mutual aid responses were made to fire and structure fire emergencies. First-in District 29 had the highest number of mutual aid responses to fire and structure fire emergencies. This district is also a hot spot for this type of incidents, as shown in Map 5.

Travel Time Analysis

The travel time analysis examined the en route and arrival on scene times included in the CAD data to calculate the travel times for apparatus responding to incidents. NFPA 1710 requires a travel time of four minutes (240 seconds) or less for the first-arriving engine company at the scene of fire incidents and for the first-arriving EMS company with BLS capability, or higher, at the scene of EMS incidents, for at least 90% of the incidents. Travel times that are consistently higher than these benchmarks pose a risk to the community and suggest that the department needs additional resources.

The department does not meet NFPA 1710 travel time objectives for EMS and fire incidents. The first-arriving CFD EMS unit was at the scene of EMS incidents within four minutes for 57% of incidents. The first-arriving CFD engine was at the scene of fire incidents within four minutes for 65% of incidents. The analysis did not find significant variation in these percentages from year to year.

The following charts show how frequently the first-arriving unit was on scene within a given travel time for fire and EMS emergencies. Besides demonstrating how the department does not meet NFPA 1710 travel time objectives, these charts show that between 2017 and 2019, 158,007 EMS incidents and 3,780 fire incidents received the first unit with a travel time of six minutes or longer, representing 14.3% and 12% of the total EMS and fire incidents, respectively. These particularly long response times pose a significant risk to the community and the firefighters and indicate that the department needs to increase its resources to improve travel times and provide a more efficient response.

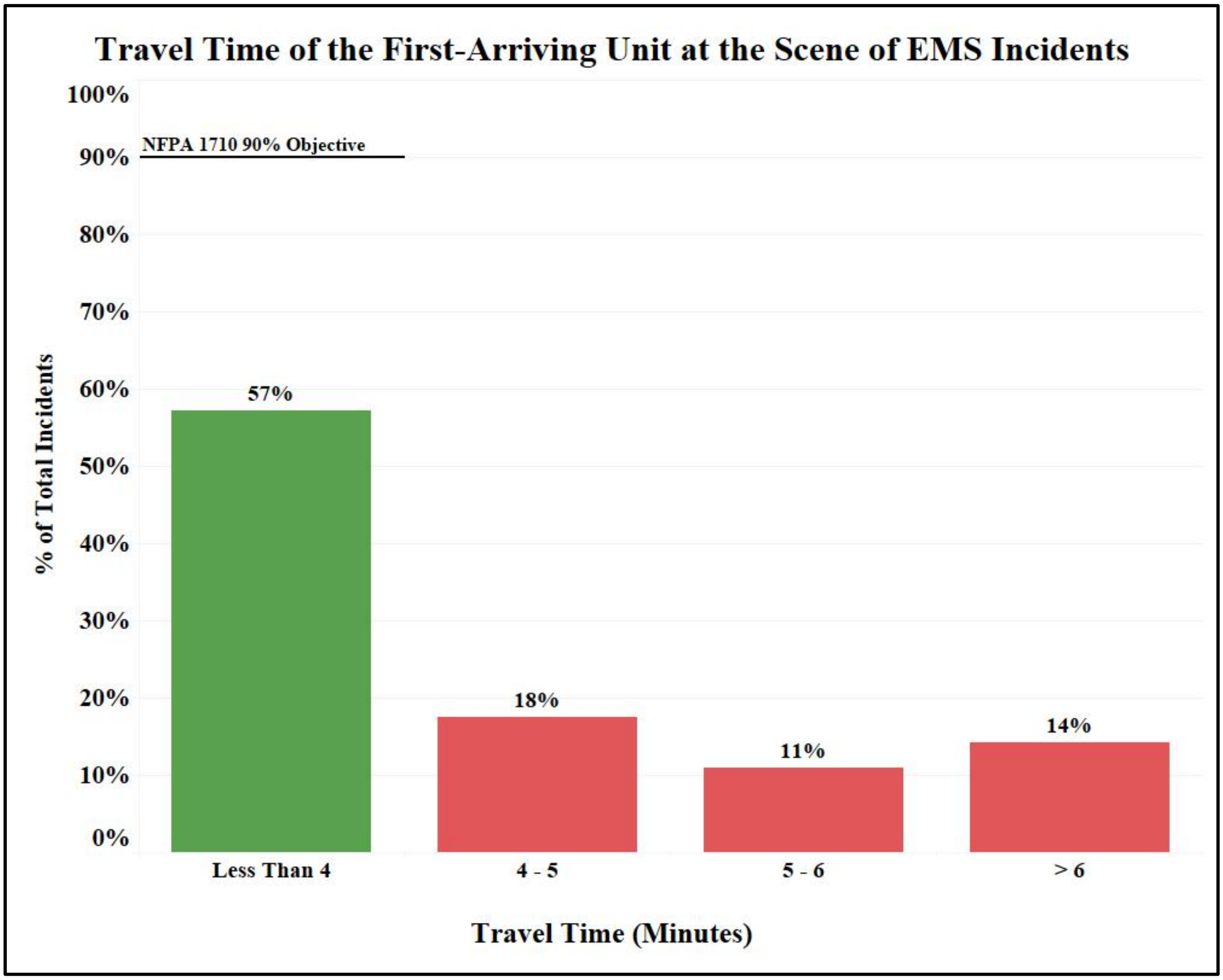


Chart 6: Travel Time of the First-Arriving Unit at the Scene of EMS Incidents. This chart shows the percentage of incidents reached within a certain travel time. Fifty-seven percent (57%) of EMS incidents were reached with a travel time of four minutes or less, while NFPA 1710 establishes a 90% objective. The department should increase resources, as detailed later in this document, to bring its travel time performance closer to NFPA 1710 objectives.

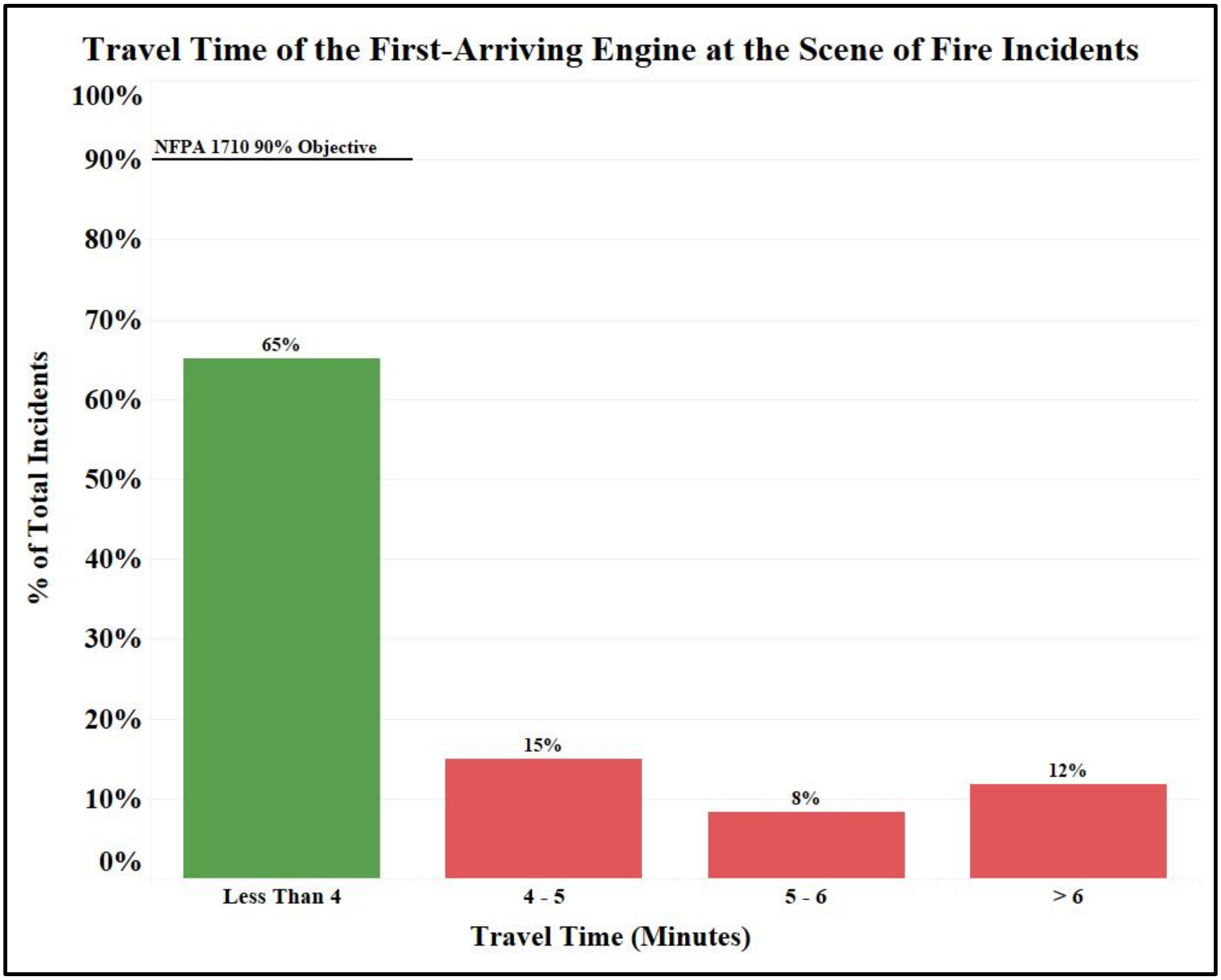


Chart 7: Travel Time of the First-Arriving Unit at the Scene of Fire Incidents. This chart shows the percentage of fire incidents reached by the first engine within a certain travel time. Sixty-five (65%) of fire incidents were reached within a travel time of four minutes or less, while NFPA 1710 establishes a 90% objective. Twelve percent (12%) of the fire incidents were reached by the first engine with a travel time of six minutes or more. These long travel times increase the probability of the fire growing uncontrolled, consequently increasing the risk for the firefighters and the population.

For both fire and EMS emergencies, the first-in district where the department reported the worst travel time performance was first-in district 34; the first unit was on scene within four minutes at 24% and 21% of incidents, respectively. The best performance was reported in first-in district 1, where the first engine and EMS unit arrived at the scene of fire and EMS incidents within four minutes 88% and 77% of the time, respectively. In any case, the fire department did not meet the 90% NFPA 1710 objective in any of the first-in districts.

The next charts show the number of incidents that received the first EMS and engine unit with a travel time longer than four minutes in each first-in district. For both EMS and fire incidents, first-in district 6 was the district with the highest number of incidents not reached within a travel time of four minutes. CFD should focus on the districts with the highest number of incidents not reached within the NFPA 1710 objectives and add resources to help reduce travel times, meet industry standards and increase the safety of the Columbus community. Detailed recommendations on where and which resources CFD should add are provided in the next section of this report.

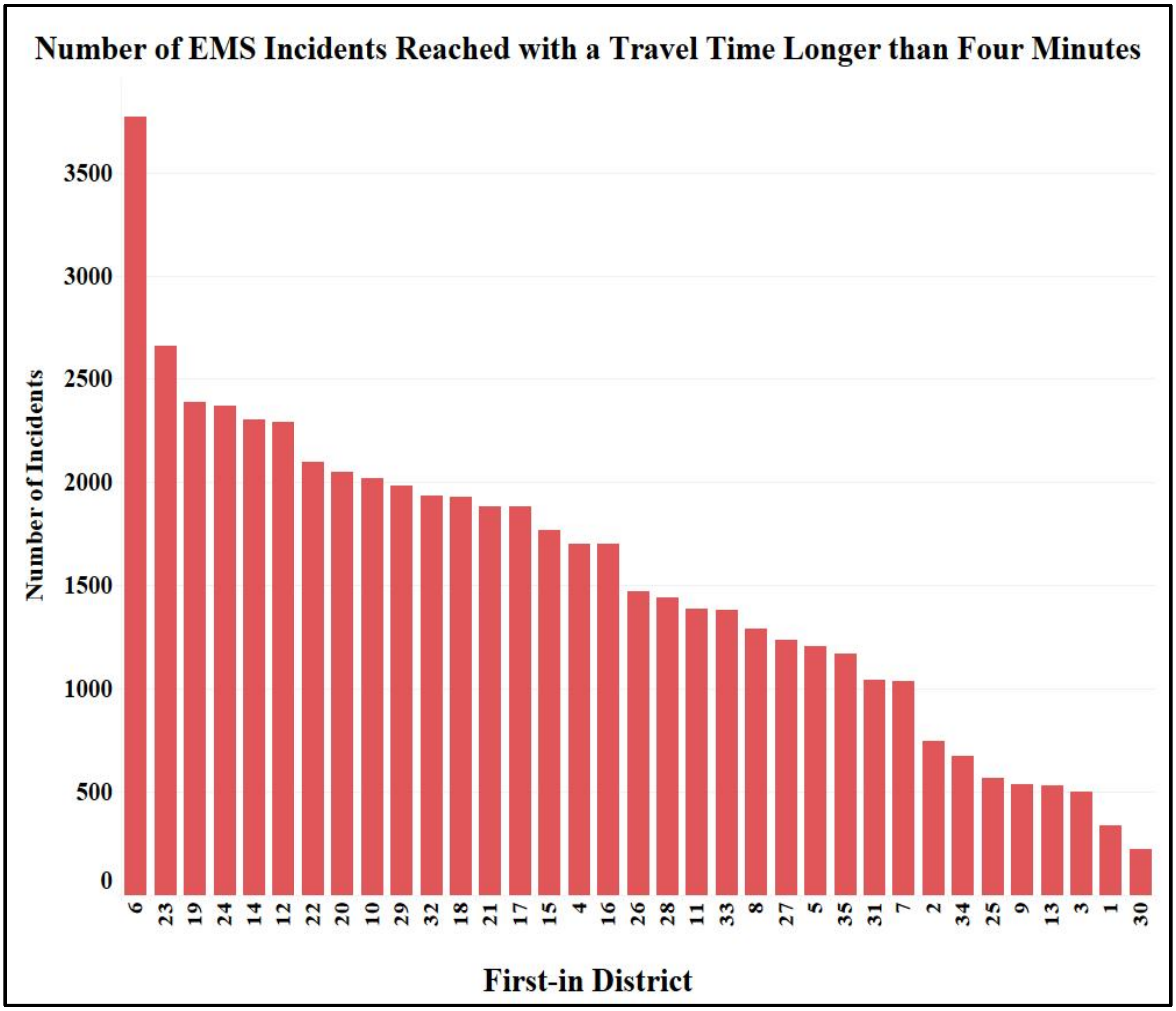


Chart 8: Number of EMS Incidents Reached with a Travel Time Longer than Four Minutes. This chart shows the first-in districts that reported the highest number of EMS incidents reached with a travel time longer than four minutes. When interpreting this chart, it should be considered that the first-in districts do not have all the same area. Therefore, first-in districts with a low number of incidents in this chart could still be located in areas of high incident density, for example, first-in district 1 (see also Map 1). This chart should be analyzed in combination with the density and risk maps to determine where additional resources should be placed.

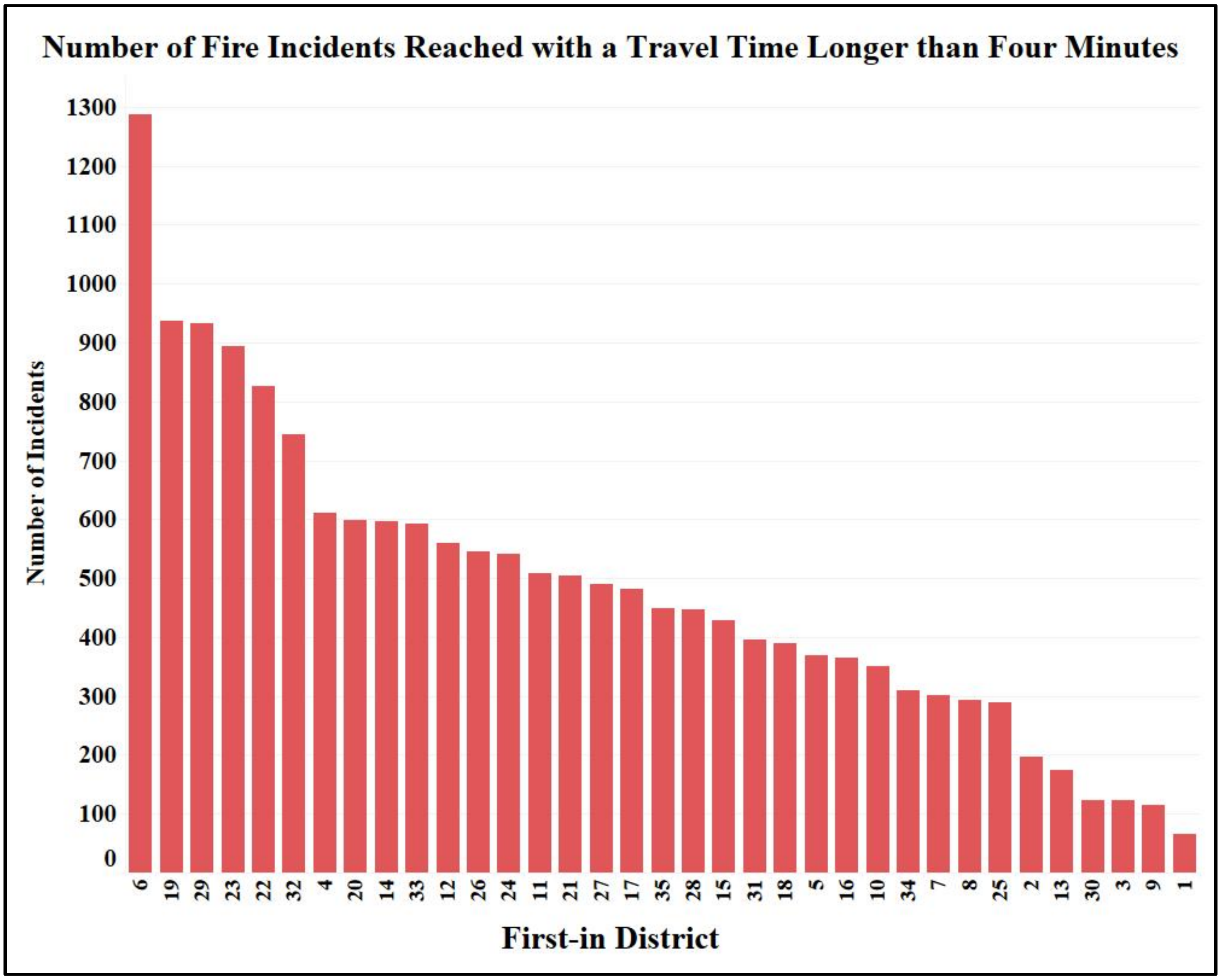


Chart 9: Number of Fire Incidents Reached with a Travel Time Longer than Four Minutes. This chart shows the first-in districts which reported the highest number of fire incidents reached with a travel time longer than four minutes. For both EMS and fire incidents, first-in district 6 was the district with the highest number of incidents not reached within a travel time of four minutes.

Between 2017 and 2019, 18,919 incidents were addressed exclusively by mutual aid units because no CFD unit was available or close enough to the location of the incident to provide a timely response. Mutual aid units responding in Columbus have longer travel times than CFD units, on average by 39 seconds. Mutual aid units arriving first at the scene of fire and EMS incidents in Columbus were able to arrive within the NFPA 1710 objective of four minutes 45% of the time, while CFD units were able to be on scene within four minutes 58% of the time. The difference increases when considering fire incidents only: when a mutual aid engine was the first on scene, the engine arrived within a travel time of four minutes 44% of the time, while CFD engines arrived on scene with a travel time of four minutes or less for 65% of incidents. The average travel time of a mutual aid engine arriving first at the scene of a fire incident was 387 seconds (six minutes and 27 seconds); that is, two minutes and 40 seconds longer than the average travel time of a CFD engine arriving first at the scene of a fire incident (247 seconds, or four minutes and seven seconds). These delays represent a risk both for the firefighters and the civilians involved in fire incidents and increase the risk of deaths and injuries. As discussed in the *Fire Suppression Operations* section above, flashover is likely to occur within eight minutes of fire ignition. This means that delays of few minutes can cause the fire to quickly become more destructive and difficult to suppress.

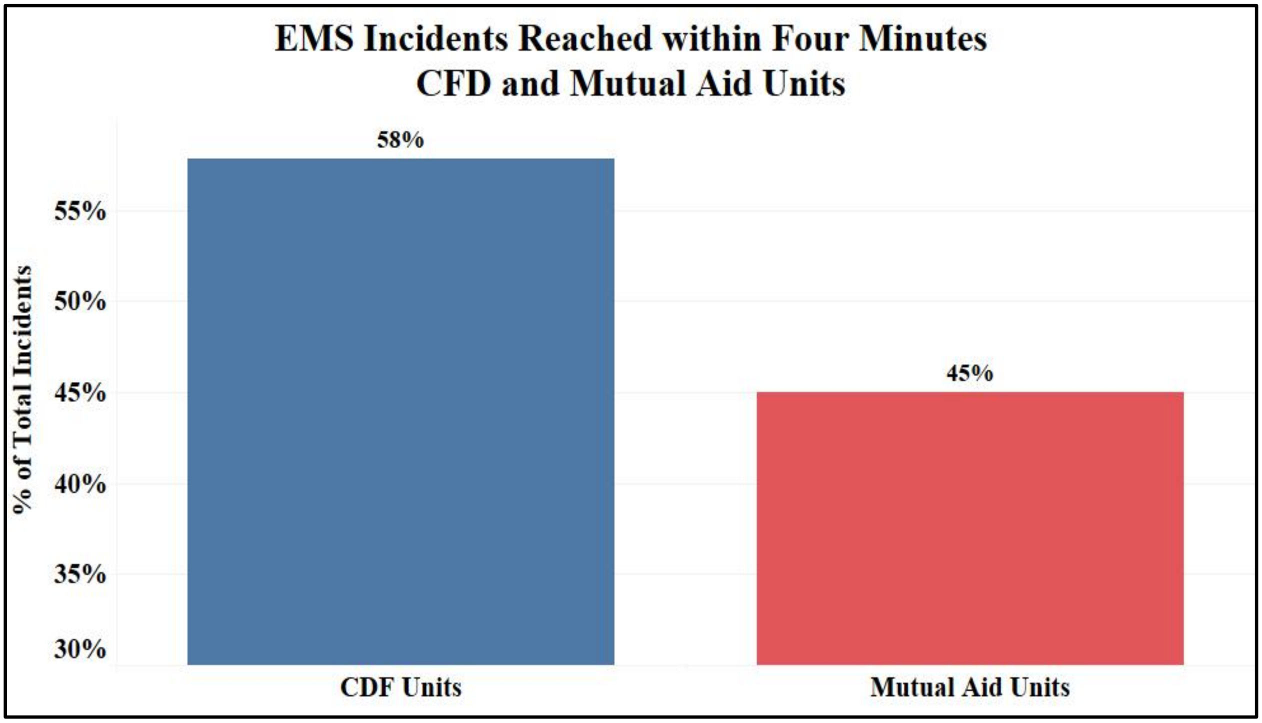


Chart 10: EMS Incidents Reached within Four Minutes, CFD and Mutual Aid Units. This chart shows that when CFD Units arrived first at the scene of EMS incidents, they reached 58% of the incidents within four minutes. Conversely, mutual aid units arriving first reached 45% of the incidents within four minutes. Relying on mutual aid units, like CFD does, creates a significant risk for the community.

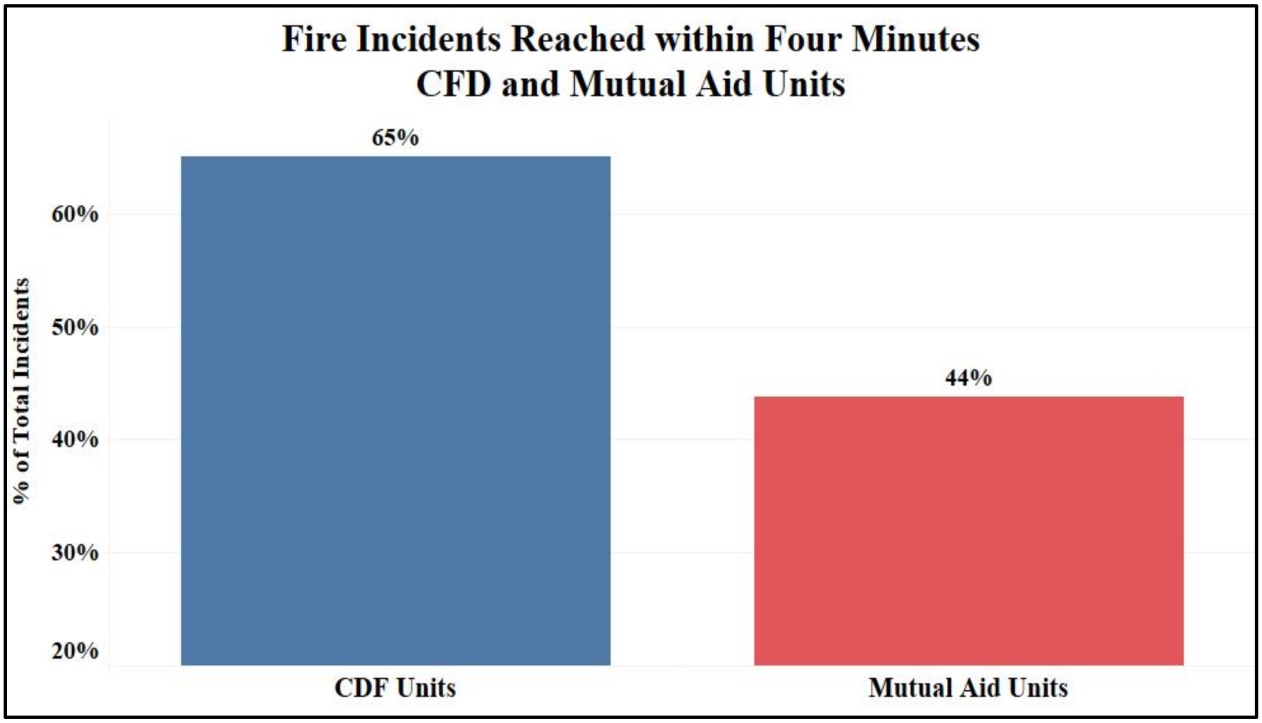


Chart 11: Fire Incidents Reached within Four Minutes, CFD and Mutual Aid Units. This chart shows that when the first-arriving engine at the scene of fire incidents was a CFD engine, 65% of incidents was reached within a travel time of four minutes. Mutual aid engines arriving first at the scene of fire incidents reached 44% of the incidents within four minutes, increasing the risk for firefighters and the population affected by these incidents.

The travel time to the scene of fire and EMS incidents can be reduced by adding apparatus to the current stations because with more units in service, it would be more likely that at the time that an incident occurs, a unit will be at the incident location within a travel time of four minutes.

This is shown by the next chart, which reports the travel time of the first-arriving engine at the scene of an incident depending on the number of other engines that were already engaged in responses. When multiple engines are engaged, there are less engines available to cover the CFD jurisdiction, and a new incident will be less likely to have an available unit nearby. For example, when one to five engines were engaged, the remaining engines could reach the scene of an incident within four minutes 69% of the time. With 11 to 15 engines engaged, the ability to reach incidents within four minutes decreased to 61%. Moreover, with more than 15 engines engaged at the same time, the remaining engines could reach new incidents within four minutes 50% of the time.

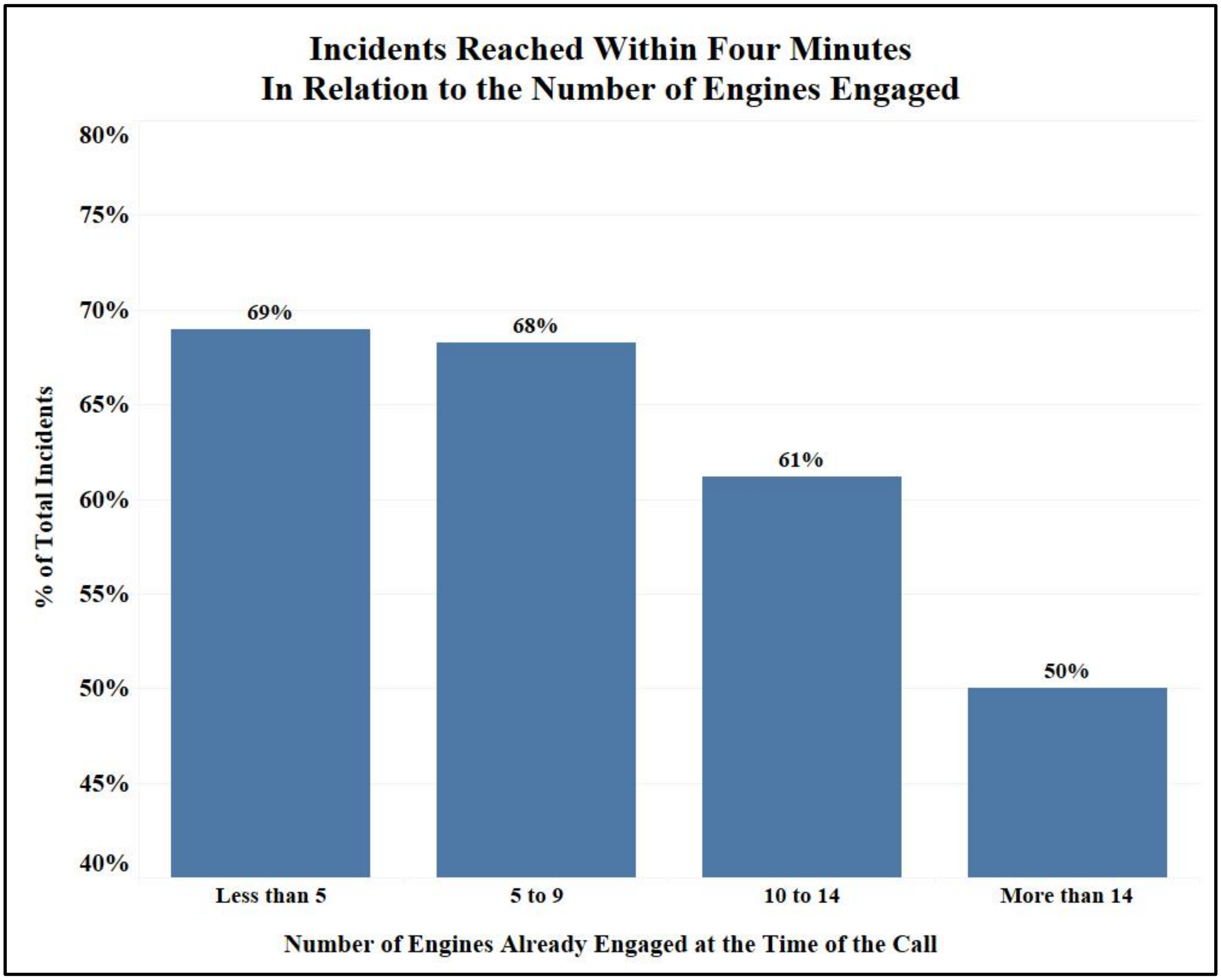


Chart 12: Incidents Reached Within Four Minutes in Relation to the Number of Engines Engaged. This chart shows the number of incidents reached within four minutes in relation to the number of engines that were already engaged at the time of the call. For example, when less than five engines were engaged in responses, the department had 30 engines still available to respond to new calls. In this case, 69% of the new calls were reached within a travel time of four minutes. When more than 14 engines were engaged in responses, the department had no more than 21 engines available to cover the entire jurisdiction. In this case, new calls were reached within four minutes 50% of the time because it was more likely for a call to not have an engine within a travel time of four minutes. This chart demonstrates how increasing the number of engines can help the department improve travel time performance and safety for the population of Columbus.

Medic Units Overlapping Responses

This section analyzes the total time that multiple medic units were engaged at the same time, either responding to the same incident or to different incidents. The more units are engaged on assignment at the same time, the more difficult it is for the department to provide a timely response to a new incoming call. Medic units provide EMS transport, which is crucial for the safety of the population affected by both fire and EMS incidents. When multiple medic units are engaged at the same time, the risk for the victims of EMS and fire incidents increases. The next chart shows the total time with less than ten medic units engaged at the same time decreased by 6%, from 5,017 hours in 2018 to 4,737 hours in 2019, while the total time with 10 to 19 medic units engaged simultaneously increased by 9%, from 3,599 to 3,908 hours. This demonstrates that it is becoming more likely, for an increasingly larger number of CFD's medic units, to be engaged at the same time.

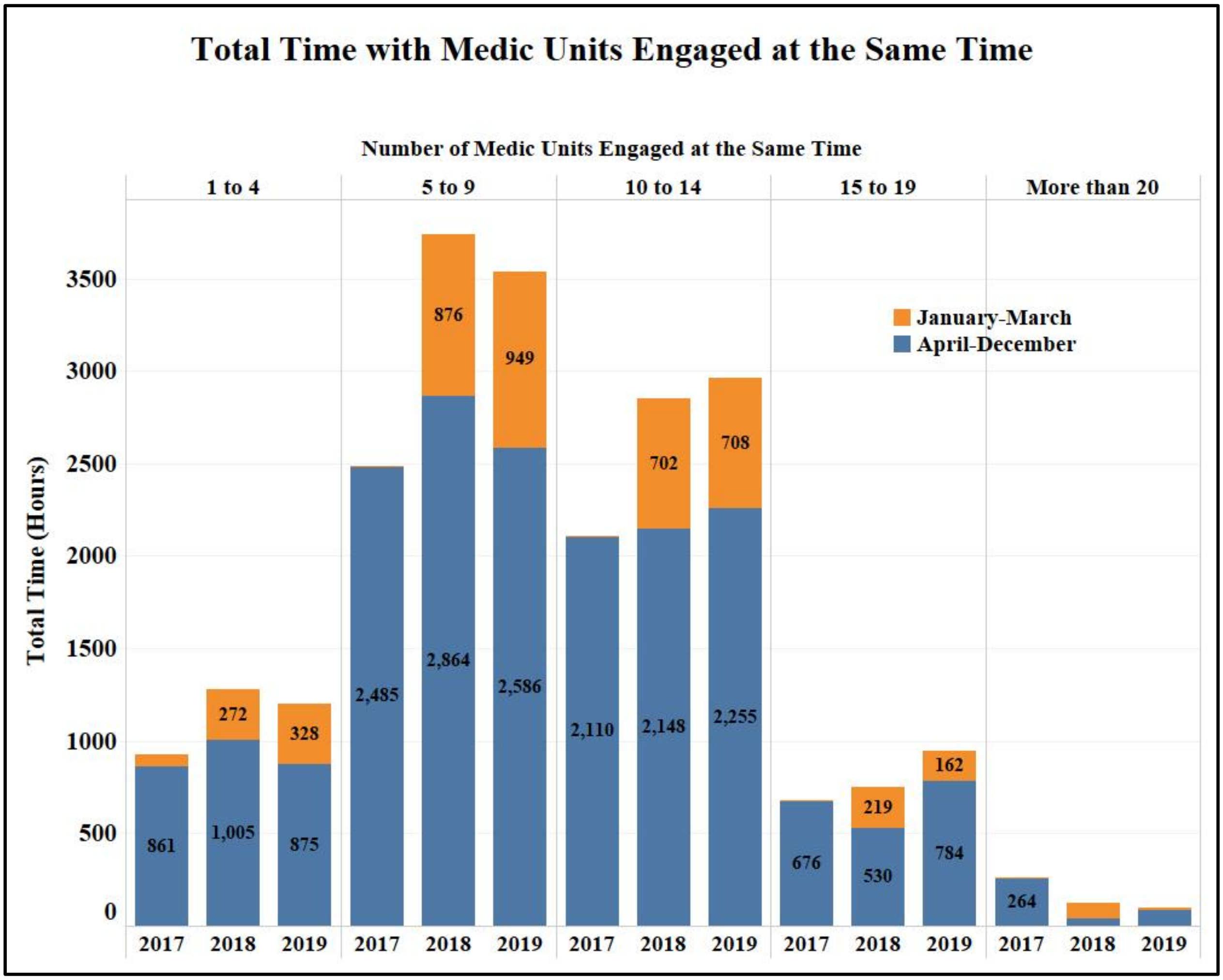


Chart 13: Total Time with Medic Units Engaged at the Same Time. This chart shows the total time with a certain number of medic units engaged at the same time. Different colors show different time periods. The time with less than ten medic units engaged at the same time decreased by 6%, from 5,017 hours in 2018 to 4,737 hours in 2019, while the total time with 10 to 19 medic units engaged simultaneously increased by 9%, from 3,599 to 3,908 hours, demonstrating that it is becoming more likely, for an increasingly larger number of CFD's medic units, to be engaged at the same time.

When analyzing overlapping responses, it is also important to assess if these responses occurred more frequently in a specific area of the jurisdiction. For example, even if CFD has 39 medic units, if three units from stations close to each other are engaged at the same time, an entire area of the city might be left without medic units available within a safe travel time, even if the remaining 36 medic units were available in their stations. As a result, the risk for the citizens living in that area of the city would increase regardless of how many of the remaining medics are available.

The analysis detected that the medic units from the three stations closest to downtown, Medic 1, Medic 2 and Medic 8, were engaged at the same time for an increasing amount of time. This area of the city reported the highest concentration of incidents and it has the highest population growth rate per year, up to 4.3%. Considering the most recent full year with data available (2019), the total time with two of these medic units engaged at the same time, in any combination, was 1,347 hours, equivalent to 56 days, or 15% of the year. During this time, there was only one medic unit available within a travel time of four minutes. These three medic units were all engaged at the same time for a total of 338 hours, which is equivalent to 14 days. During this time, EMS calls requiring medic units could not be addressed by any of the three closest stations.

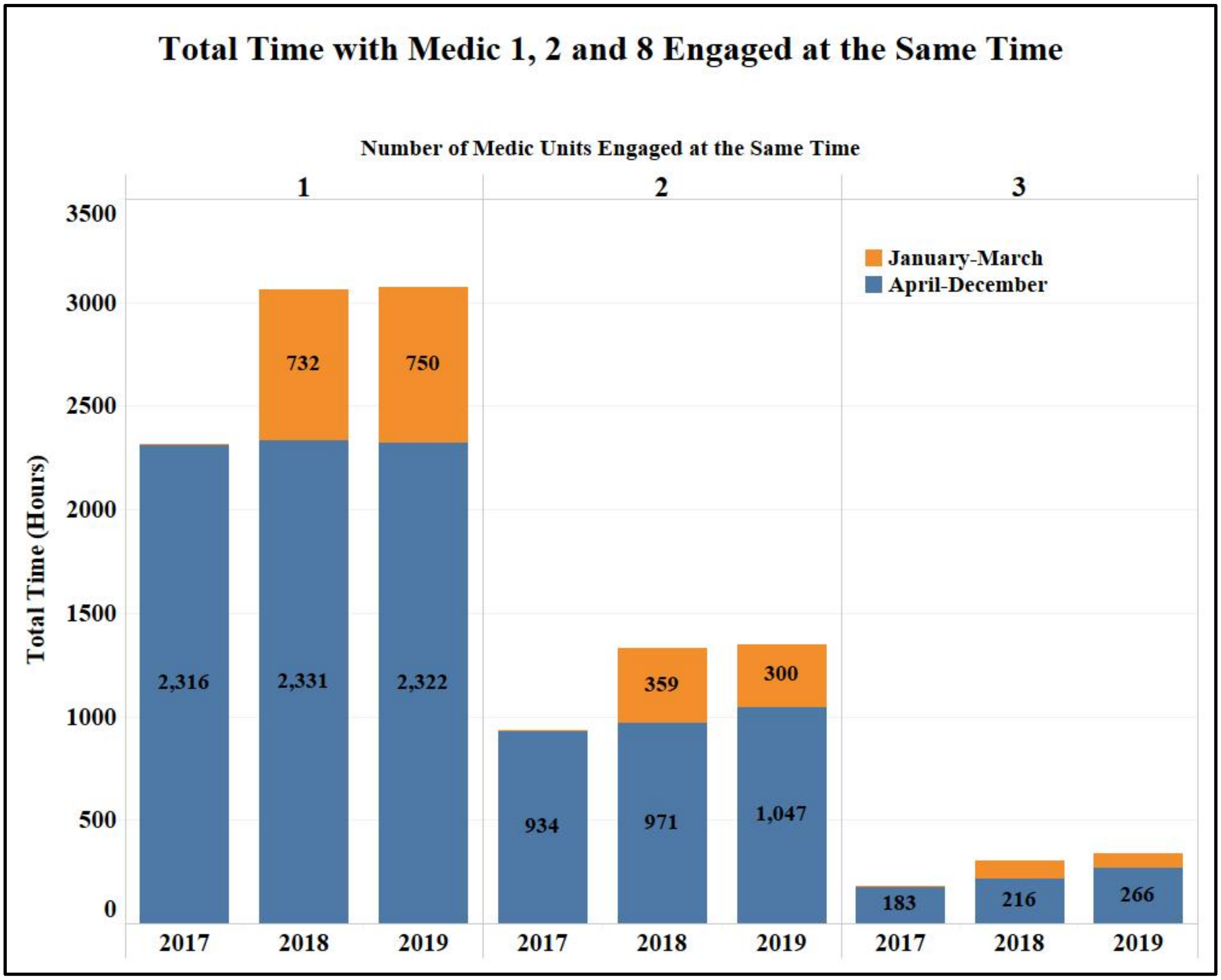


Chart 14: Total Time with Medics 1, 2 and 8 Engaged at the Same Time. This chart focuses on the three medic units serving downtown, which is the area of the city with the highest concentration of incidents. These units were engaged simultaneously for an increasing amount of time, increasing the risk for the victims of EMS incidents in the area of the city with the highest concentration of emergencies.

Back-to-back Responses

Back-to-back responses are defined as occurrences where units have been dispatched within 10 minutes of becoming available from a previous emergency. The *turnaround time* is defined as the time period between the time when the unit is marked as available and the time when the same unit is dispatched to a new incident. Back-to-back responses are dangerous for personnel, who operate with a limited rehabilitation period between emergencies, and therefore, for the community. An increasing frequency of back-to-back responses indicates that the department needs additional resources to meet demand in a way that is safe both for the community and the department's personnel.

The chart below shows that the number of back-to-back responses made by the CFD engines, ladders and medic units increased every year. Back-to-back responses increased from 25,842 responses in 2018 to 27,426 in 2019 (+1,584). Considering similar time periods, the back-to-back responses increased from 20,130 in 2017 (April through December), to 21,338 in the same months of 2019 (+1,208). The units that made most of the back-to-back responses were the medic units.

Medics 8, 14 and 1 made, in decreasing order, most of the back-to-back responses. Medics 8 and 1 are located in Stations 8 and 1, respectively, and serve the downtown area of the city, which confirms the need for additional medic units in this part of Columbus. Among the engines, Engines 6, 15, and 17 made, in decreasing order, most of the back-to-back responses.

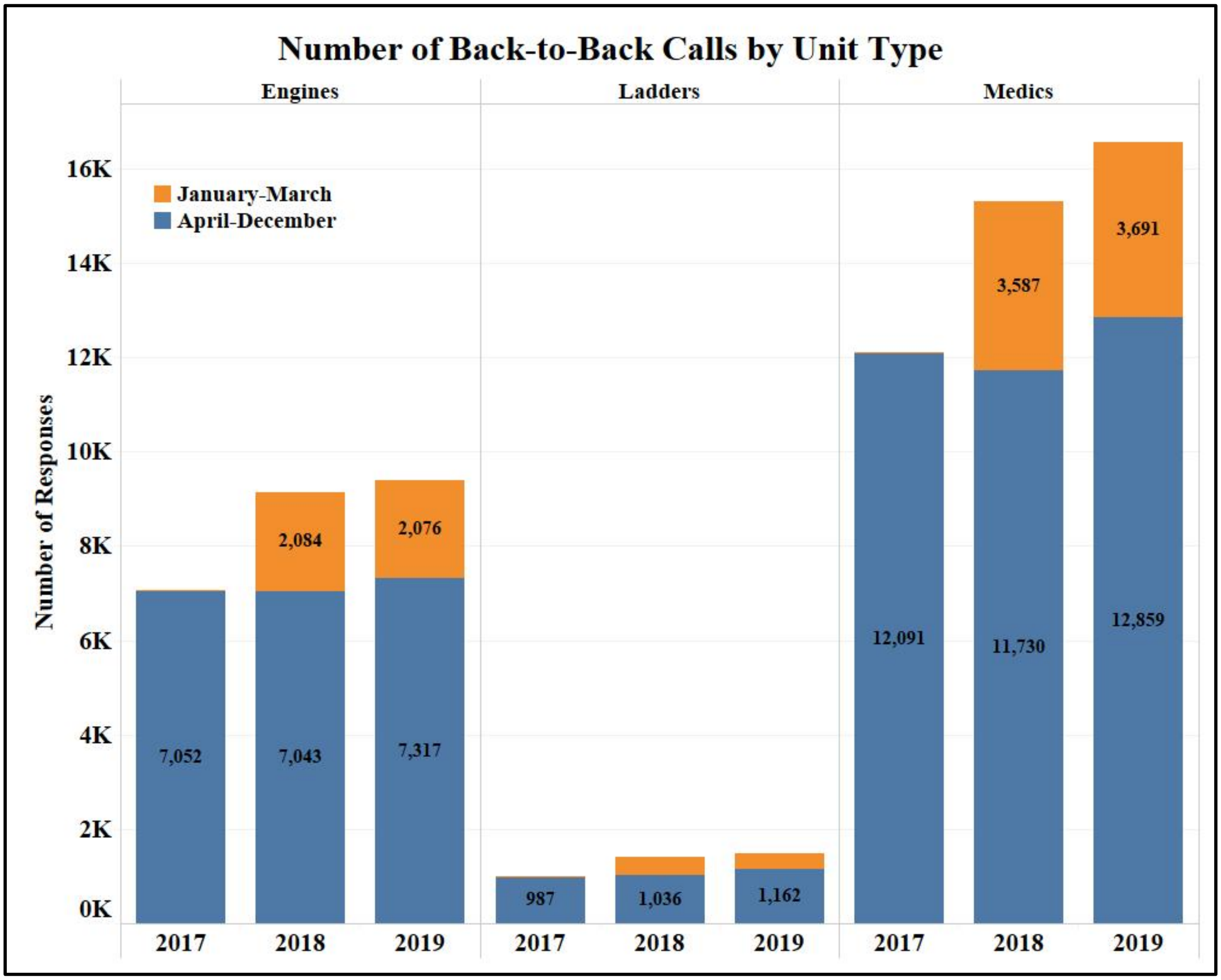


Chart 15: Number of Back-to-Back calls by Unit Type. This chart shows the number of back-to-back responses by unit type. These responses increased every year for all the units. Medics 8, 14, and 1 made, in decreasing order, most of the back-to-back responses. Medics 8 and 1 are located in Stations 8 and 1, respectively, and serve the downtown area of the city, which confirms the need for additional medic units in this part of Columbus. Among the engines, Engines 6, 15, and 17 made, in decreasing order, most of the back-to-back responses.

Emergency Response Capabilities, Recommended Stations and Staffing

The following table shows the recommended staffing level of the department. In order to meet staffing objectives outlined in NFPA 1710, the department should staff the fire suppression apparatus with a minimum of four firefighters, depending on the population density of the first-in district they serve. The recommendations are based each area's population density.

To better assist the department in increasing its resources as the population of Columbus increases, this section will consider two sets of recommendations: a shorter term recommendation, where the department adds apparatus to the current stations and increases the staffing level of fire suppression apparatus, and a longer term recommendation, where the department, in addition to adding apparatus and staff to its current stations, builds six additional stations. The GIS analysis determined the recommended locations for the new stations. Further details on the siting the stations using the location-allocation method are provided in the *ArcGIS Location-Allocation* section.

The recommendations on what type of apparatus should be added to each station were based on the combination of the risk assessment, the GIS and workload analysis, and the current travel time performance of the department.

Recommendation: Add Apparatus to the Current Stations and Increase Staff

The department should add a total of six medic units, six engines and four ladder trucks. IAFF Local 67 reported that the department plans to add two heavy rescue units, one in Station 5 and the other in Station 28. Per Local 67's request, these units will be considered in this recommendation and in the analysis of the department's projected capabilities.

With these recommendations, the department will increase the roads that could be reached within four minutes by the minimum force of four firefighters (required by the "2 In/2 Out" regulation) from 30% to 45% of the total city roads, a 50% increase. Additionally, the department would increase the roads where the minimum force for low- and medium-hazard fires could be assembled within eight minutes by 67% and 95%, respectively. The high-hazard coverage would not change compared to the current capabilities, and the relative map is not shown, as it would be identical to Map 14**.** The department's ladders would also be able to reach 55% of the roads and 70% of historical fire incident locations within a travel time of six minutes, which is a 20% increase over the current capabilities. Specifically, the department should:

- Add one medic unit to either Station 1 or 9. These stations are housed in the same building at the same location. The additional medic unit is necessary because of the high population growth expected in this part of the city and the presence of high-rise and high-hazard buildings.

- Add one medic unit to Station 2 because of the expected high population growth and the large number of medic unit responses reported in this station's first-in district.

- Add one engine to Station 6 because its first-in district reported the second largest number of fires and the highest number of engines responses. Additionally, the risk assessment analysis showed that this part of the city has a high social vulnerability index score.

- Add one ladder truck to Station 7 to provide ladder coverage to an area of the city with a high risk of fire incidents, as shown in the *Risk Assessment* section of this report.

- Add one medic unit to Station 8 because this station offers coverage to the downtown area of the city, which has the highest density of incidents, high social vulnerability and will experience population growth in the next four years.

- Add one engine to Station 10 to improve response times and reduce Engine 10's workload. This first-in district reported the second largest number of engine responses.

- Add one medic unit to Station 12 to reduce travel times in its first-in district, which has high social vulnerability.

- Add one engine to Station 15 to reduce the number of back-to-back responses made by Engine 15 (523 per year on average) and because of the high vulnerability in this part of the city.

- Add a medic unit in Station 16 because its first-in district reported the second largest number of responses from medic units of nearby departments, demonstrating that the department is not able to efficiently serve this part of the city.

- Add one engine to Station 17 because of the high number of back-to-back responses made by Engine 17 and the high social vulnerability of this first-in district.

- Add one ladder truck to Station 18 to provide ladder coverage to an area of the city with a high density of fire incidents.

- Add one ladder truck to Station 20, for the same reason as the previous point.

- Add one engine to Station 24 because its first-in district is among the top five first-in districts for number of engine responses and reported the fourth highest number of responses with a travel time above four minutes for the first-arriving unit at the scene of EMS incidents.

- Add one medic unit to Station 28 because of the high social vulnerability of this area and the large number of medic responses made by units from nearby departments in this first-in district.

- Add one ladder truck to Station 29 because its first-in district reported the highest number of structure fires and the largest number of responses from nearby departments to fire and structure fire incidents, demonstrating that CFD cannot provide a safe fire coverage to this area of the city. Currently, this station does not have a ladder truck.

- Add one engine to Station 32 because of the population growth expected in this part of the city and because its first-in district reported the third highest number of responses from other departments' units to fires and structure fire incidents. This area also has a high risk of EMS and fire incidents, as discussed in the *Risk Assessment* section of this report.

The next table shows the recommended staffing level, additional apparatus, and where they should be housed.

Station Name/Number	Station Address	Apparatus	Staffing
Station 1/9	300 North Fourth St.	Engine 1 Engine 9 Ladder 1 Medic 1 Additional Medic EMS 10 ES-2	4 FF/EMT 4 FF/EMT 4 FF/EMT 2 FF/EMT 2 FF/EMT 1 Officer 1 Officer
Station 2	150 East Fulton St.	Engine 2 Ladder 2 Additional Medic Medic 2 Battalion 1	4 FF/EMT 4 FF/EMT 2 FF/EMT 2 FF/EMT 1 Officer
Station 3	222 Greenlawn Ave.	Engine 3 Medic 3 Rescue 3 EMS 11 SO2	4 FF/EMT 2 FF/EMT 3 FF/EMT 1 Officer 1 Officer
Station 4	3030 Winchester Pk.	Engine 4 Rescue 4 Medic 4	5 FF/EMT 3 FF/EMT 2 FF/EMT
Station 5	211 McNaughten Rd.	Engine 5 Ladder 5 Additional Rescue Medic 5	4 FF/EMT 4 FF/EMT 3 FF/EMT 2 FF/EMT

Table 7: Recommended Staffing and Apparatus. This table shows the recommended staffing level of fire suppression apparatus and where additional apparatus should be located. Recommended changes are highlighted.

Station Name/Number (continued)	Station Address (continued)	Apparatus (continued)	Staffing (continued)
Station 6	5750 Maple Canyon Dr.	Engine 6 Additional Engine Medic 6 Medic 806 Battalion 2 EMS-12	4 FF/EMT 4 FF/EMT 2 FF/EMT 2 FF/EMT 1 Officer 1 Officer
Station 7	1425 Indianola Ave.	Engine 7 Additional Ladder Medic 7 Battalion 3 EMS-13	4 FF/EMT 4 FF/EMT 2 FF/EMT 1 Officer 1 Officer
Station 8	1240 East Long St.	Engine 8 Ladder 8 Medic 8 Additional Medic	4 FF/EMT 4 FF/EMT 2 FF/EMT 2 FF/EMT
Station 10	1096 West Broad St.	Engine 10 Additional Engine Ladder 10 Medic 10 Medic 890	4 FF/EMT 4 FF/EMT 4 FF/EMT 2 FF/EMT 2 FF/EMT
Station 11	2160 West Case Rd.	Engine/Air Crash 11 Rescue 11 Medic 11 Battalion 7 EMS-17	4 FF/EMT 3 FF/EMT 2 FF/EMT 1 Officer 1 Officer
Station 12	3200 Sullivant Ave.	Engine 12 Ladder 12 Medic 12 Additional Medic	4 FF/EMT 4 FF/EMT 2 FF/EMT 2 FF/EMT
Station 13	309 Arcadia Ave.	Engine 13 Ladder 13 Medic 13	4 FF/EMT 4 FF/EMT 2 FF/EMT

Table 7 (continued): Recommended Staffing and Apparatus. This table shows the recommended staffing level of fire suppression apparatus and where additional apparatus should be located. Recommended changes are highlighted.

Station Name/Number (continued)	Station Address (continued)	Apparatus (continued)	Staffing (continued)
Station 14	1514 Parsons Ave.	Engine 14 Medic 14 Battalion 4	4 FF/EMT 2 FF/EMT 1 Officer
Station 15	1800 Livingston Ave.	Engine 15 Additional Engine Ladder 15 Medic 15 Medic 815 EMS-14	4 FF/EMT 4 FF/EMT 4 FF/EMT 2 FF/EMT 2 FF/EMT 1 Officer
Station 16	1130 East Weber Rd.	Engine 16 Rescue 16 Medic 16 Additional Medic	4 FF/EMT 3 FF/EMT 2 FF/EMT 2 FF/EMT
Station 17	2300 West Broad St.	Engine 17 Additional Engine Rescue 17 Medic 17 Medic 817 Battalion 5 EMS-15	4 FF/EMT 4 FF/EMT 3 FF/EMT 2 FF/EMT 2 FF/EMT 1 Officer 1 Officer
Station 18	1551 Cleveland Ave.	Engine 18 Additional Ladder Medic 18	4 FF/EMT 4 FF/EMT 2 FF/EMT
Station 19	3601 North High St.	Engine 19 Medic 19	4 FF/EMT 2 FF/EMT

Table 7 (continued): Recommended Staffing and Apparatus. This table shows the recommended staffing level of fire suppression apparatus and where additional apparatus should be located. Recommended changes are highlighted.

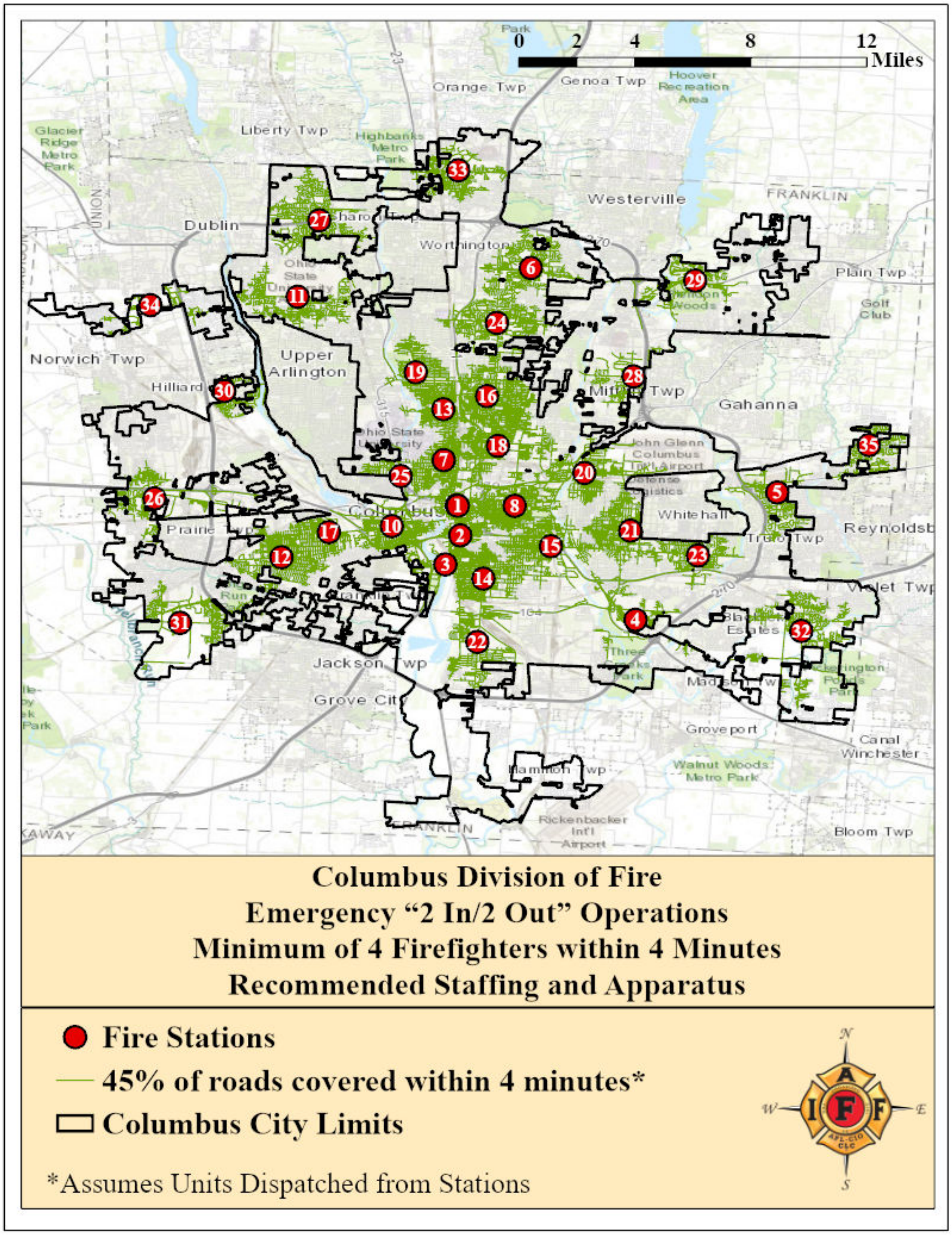
Station Name/Number (continued)	Station Address (continued)	Apparatus (continued)	Staffing (continued)
Station 20	2646 East Fifth Ave.	Engine 20 Additional Ladder Medic 20	4 FF/EMT 4 FF/EMT 2 FF/EMT
Station 21	3294 East Main St.	Engine 21 Medic 21 Battalion	4 FF/EMT 2 FF/EMT 1 Officer
Station 22	3069 Parsons Ave.	Engine 22 Ladder 22 Medic 22	4 FF/EMT 4 FF/EMT 2 FF/EMT
Station 23	4451 East Livingston Ave.	Engine 23 Ladder 23 Medic 23 Medic 823	4 FF/EMT 4 FF/EMT 2 FF/EMT 2 FF/EMT
Station 24	1585 Morse Rd.	Engine 24 Additional Engine Ladder 24 Medic 24	4 FF/EMT 4 FF/EMT 2 FF/EMT 2 FF/EMT
Station 25	739 West Third Ave.	Engine 25 Medic 25	4 FF/EMT 2 FF/EMT
Station 26	5433 Fisher Rd.	Engine 26 Ladder 26 Medic 26	4 FF/EMT 4 FF/EMT 2 FF/EMT
Station 27	7560 Smokey Row Rd.	Engine 27 Ladder 27 Medic 27	4 FF/EMT 4 FF/EMT 2 FF/EMT

Table 7 (continued): Recommended Staffing and Apparatus. This table shows the recommended staffing level of fire suppression apparatus and where additional apparatus should be located. Recommended changes are highlighted.

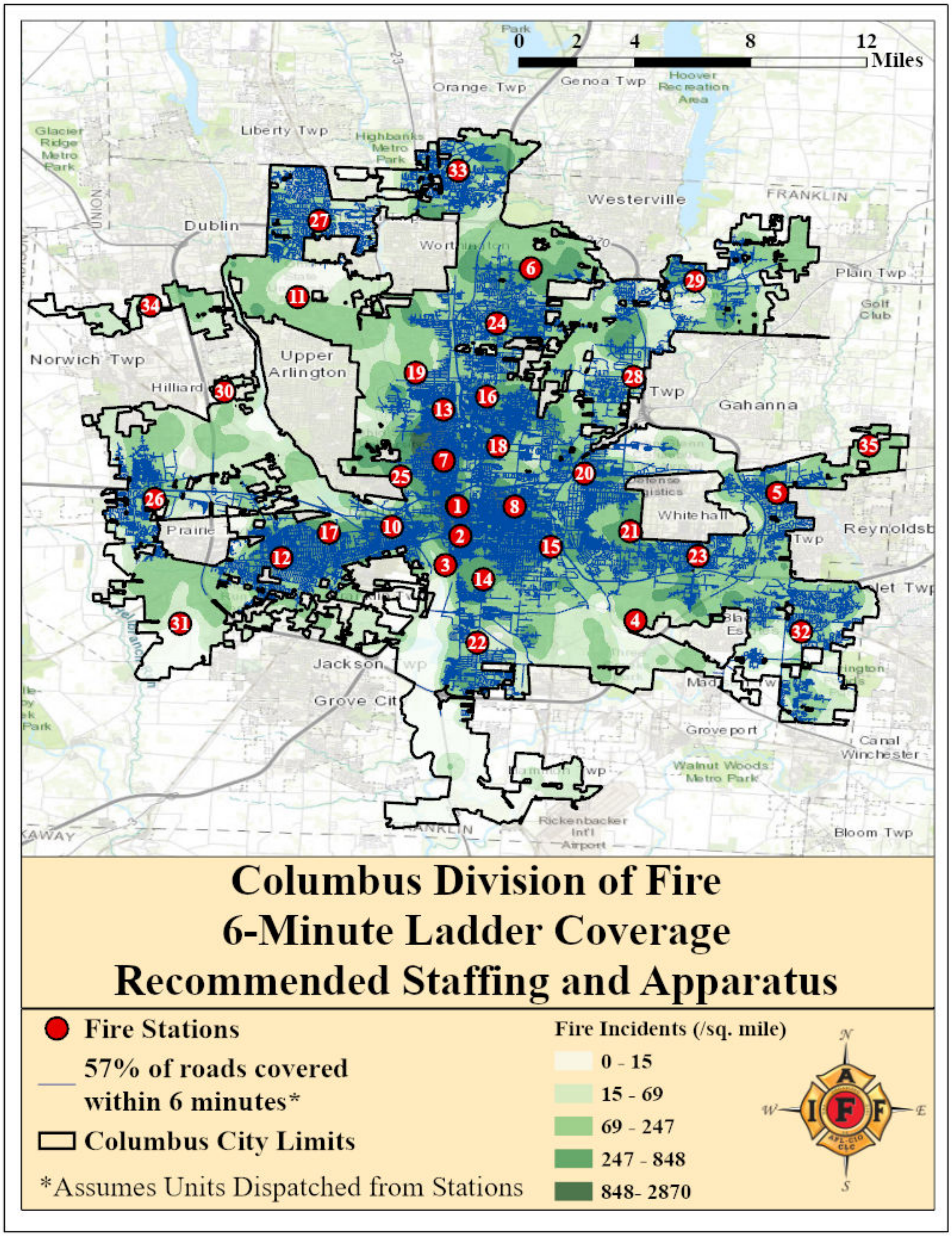
Station Name/Number (continued)	Station Address (continued)	Apparatus (continued)	Staffing (continued)
Station 28	3240 McCutcheon Rd.	Engine 28 Ladder 28 Medic 28 Additional Medic Additional Rescue	4 FF/EMT 4 FF/EMT 2 FF/EMT 2 FF/EMT 3 FF/EMT
Station 29	5151 Little Turtle Wy.	Engine 29 Additional Ladder Medic 29	4 FF/EMT 4 FF/EMT 2 FF/EMT
Station 30	3555 Fishinger Blvd.	Engine 30 Medic 30	4 FF/EMT 2 FF/EMT
Station 31	5305 Alkire Rd.	Engine 31 Medic 31	4 FF/EMT 2 FF/EMT
Station 32	3675 Gender Rd.	Engine 32 Additional Engine Ladder 32 Medic 32	4 FF/EMT 4 FF/EMT 4 FF/EMT 2 FF/EMT
Station 33	440 Lazelle Rd.	Engine 33 Ladder 33 Medic 33	4 FF/EMT 4 FF/EMT 2 FF/EMT
Station 34	5201 Wilcox Rd.	Engine 34 Medic 34	4 FF/EMT 2 FF/EMT
Station 35	711 Waggoner Rd.	Engine 35 Medic 35	4 FF/EMT 2 FF/EMT

Table 7 (continued): Recommended Staffing and Apparatus. This table shows the recommended staffing level of fire suppression apparatus and where additional apparatus should be located. Recommended changes are highlighted.

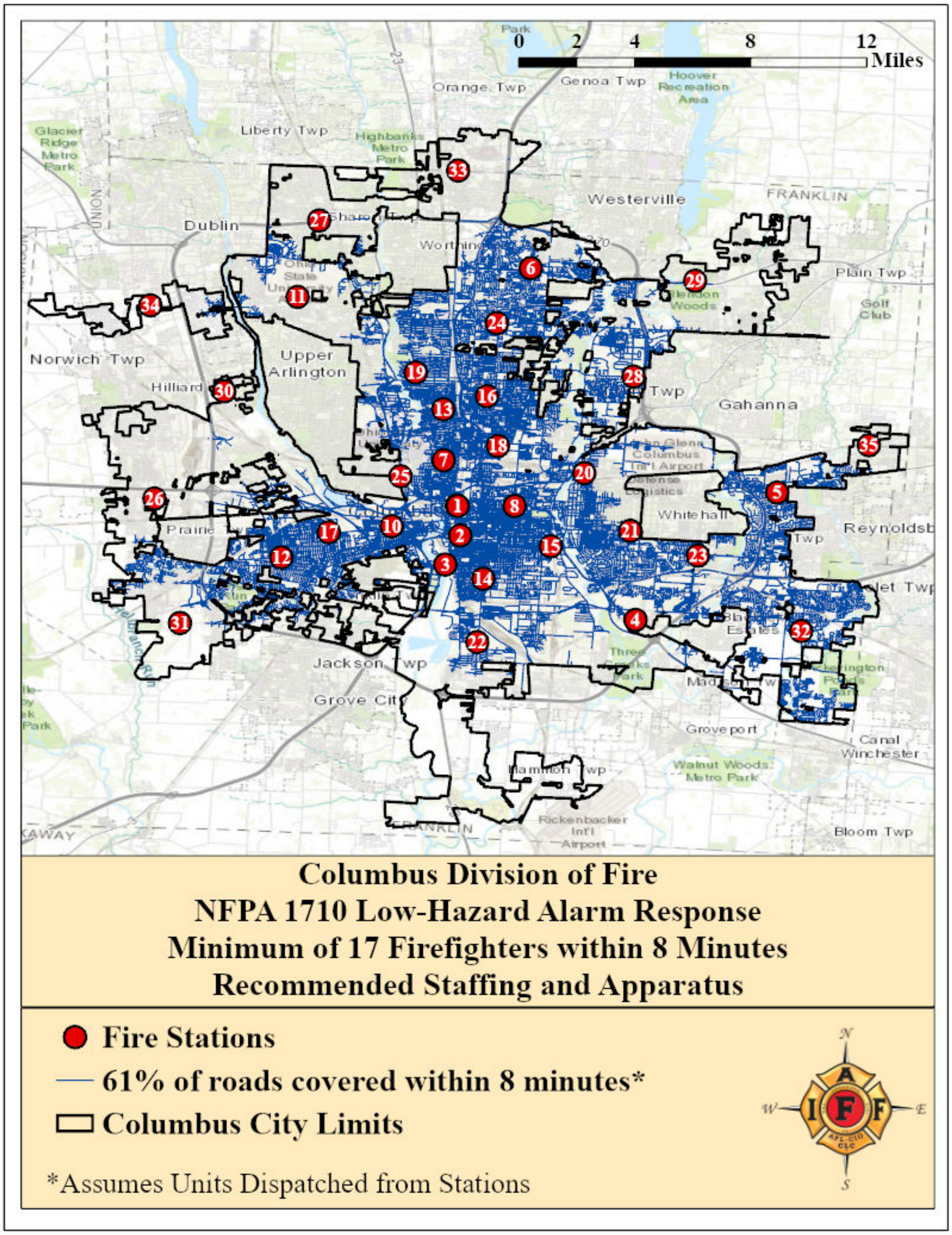
The following maps shows how the coverage of the CFD jurisdiction will improve with the additional staffing and apparatus.



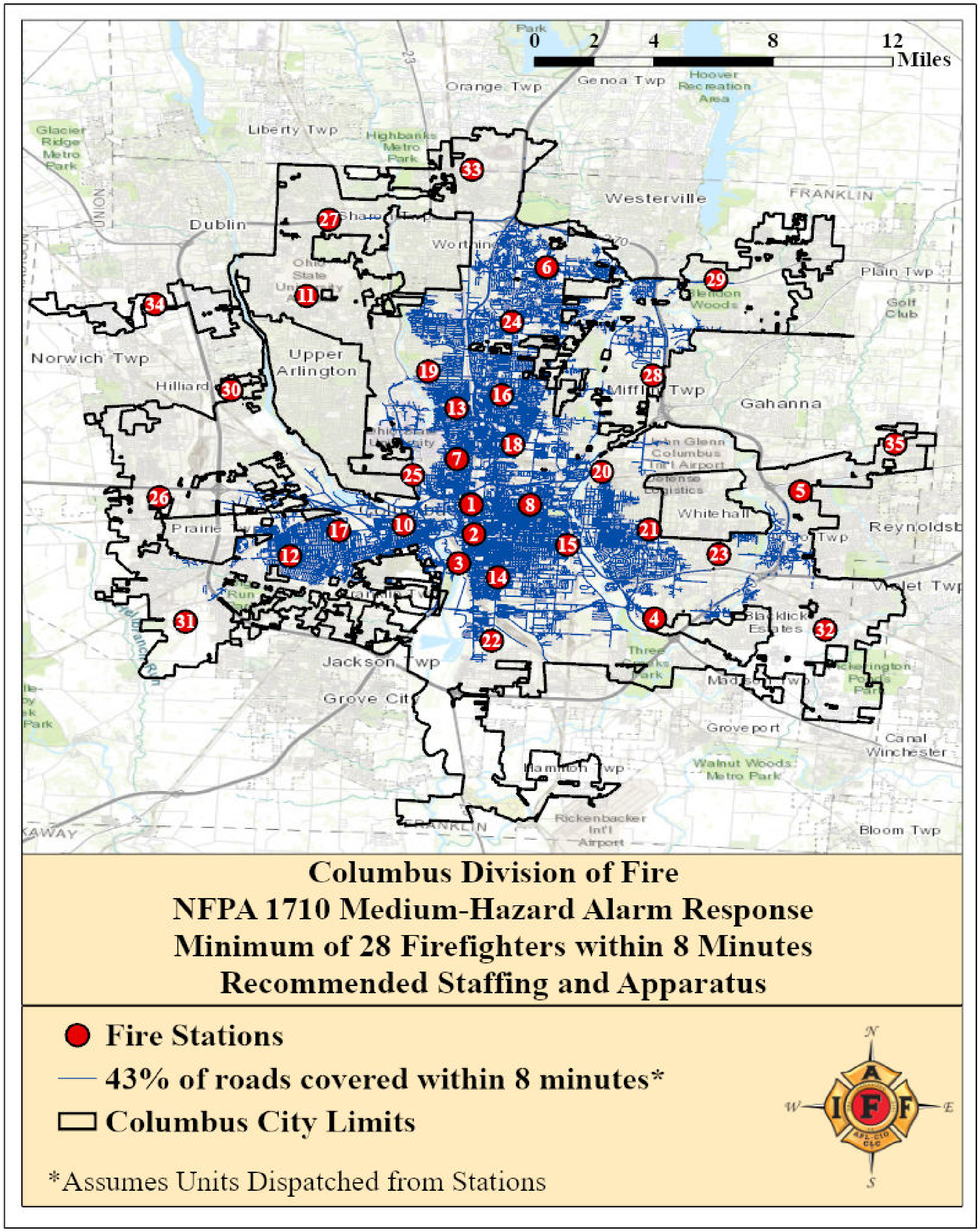
Map 15: Emergency "2 In/2 Out" Operations, Minimum of 4 Firefighters within 4 Minutes, Recommended Staffing and Apparatus. This map shows the roads where the department could assemble the minimum force of four firefighters within four minutes with the recommended staffing and apparatus. The CFD would increase its capabilities by 50% and would be able to assemble this force on 45% of the city roads, compared to the current 30%. This map also represents the four-minute road coverage, which would be unchanged compared to the current staffing level.



Map 16: 6-Minute Ladder Coverage, Recommended Staffing and Apparatus. This map shows the roads that the department's ladder trucks could reach within a travel time of six minutes from the current stations. For comparison, the density of fire incidents is also shown. With the additional ladders in Stations 7, 18, 20 and 29 the department could reach 57% of city roads, a 20% increase, and 69% of historical fire incidents, also a 20% increase.



Map 17: NFPA 1710 Low-Hazard Alarm Response, Minimum of 17 Firefighters within 8 Minutes, Recommended Staffing and Apparatus. This map shows the roads where the department could assemble the minimum force of 17 firefighters required for low-hazard fires within eight minutes of travel time. The department would increase its current capabilities by 67%, from 30% to 61% of the total roads.



Map 18: NFPA 1710 Medium-Hazard Alarm Response, Minimum of 28 Firefighters within 8 Minutes, Recommended Staffing and Apparatus. This map shows the roads where the department could assemble the minimum force of 28 firefighters required for medium-hazard fires within eight minutes of travel time with the recommended staffing and apparatus. The department would increase its current capabilities by 95%, from 22% to 43% of the total roads.

Recommendation: Add Apparatus, Staff and New Stations

In the longer term, in addition to the recommendations presented in the previous sub-section, the department should also build six additional stations. The six additional engines mentioned in the previous recommendations will be moved to these new stations. With these recommendations, the department will increase the roads that could be reached within four minutes by the minimum force of four firefighters (required by the "2 In/2 Out" regulation) from 30% to 50% of the total city roads. Additionally, the department would increase the roads where the minimum force for low- and medium-hazard fires could be assembled within eight minutes by 82% and 112%, respectively. The high-hazard coverage would increase by 187%**.** These new stations will allow the department to address the increasing demand as the population of Columbus increases. The GIS and workload analysis determined the following recommended locations and apparatus for the new stations:

- Proposed Station 36, in the area of East Livingston Ave. and South 18th St. This station should house one engine and one medic unit. This station will increase department's ability to meet NFPA 1710 objectives and increase the four-minute coverage of the downtown area.

- Proposed Station 37, in the area of Koebel Rd. and Lockbourne Rd. This station should house one engine, which will help reduce the travel time to the scene of fire and EMS incidents in Station 14's and 22's first-in districts. Currently, approximately 4,000 incidents per year are not reached within four minutes in this part of the city.

- Proposed Station 38, in the area of Refugee Rd. and Nathaniel Blvd. This station should house one engine and one medic unit. This will help the department better address the demand in Station 23's current first-in district, which reported the fourth highest number of medic and engine unit responses. Additionally, this station will help reach approximately 3,000 incidents per year within a travel time of four minutes.

- Proposed Station 39, in the area of Mock Rd. & Bar Harbor Rd. This station should house one engine and one medic unit and will provide coverage to an area of the city that has high social vulnerability. This station will allow the department to reach the location of approximately 5,500 historical incidents within a travel time of four minutes.

- Proposed Station 40, in the area of West Henderson Rd. and Knightsbridge Blvd, housing one engine. This station will increase the four-minute road coverage and will help reduce the travel time in Station 11's and 19's first-in districts. Currently, approximately 3,300 incidents per year are not reached within a travel time of four minutes in these areas.

- Proposed Station 41, in the area of Schrock Rd. and Busch Rd. This station should house one engine and one medic unit and would be located in the west side of Station 6's first-in district, which currently cannot be reached within a travel time of four minutes from the current stations. This station will allow the department to reach the locations of 4,800 historical incidents within a travel time of four minutes.

With the additional stations, staffing and apparatus, the department could assemble the minimum force of four firefighters on 50% of city roads, increasing the department's ability to meet the "2 In/2 Out" regulation by 66%. Additionally, CFD would increase its ability to assemble the minimum force for low-, medium- and high-hazard fires by 82%, 112% and 187%, respectively. The ladder coverage would not change compared to the previous recommendation (Map 16).

The next table shows the recommended staffing level and proposed locations for the additional stations.

ArcGIS Location Allocation

This section describes the computer modeling used to determine the recommended locations of the new stations. A community must carefully locate fire stations in areas to reach the most people, hazards and demand within the shortest amount of time with the right amount of resources. In order to determine the best possible number of stations, and their respective locations, to meet NFPA 1710 requirements, the ArcGIS Location Allocation tool within the Network Analyst toolset was used to perform an analysis to create various facility configurations for the CFD.

The Location Allocation tool is helpful as it allows decision makers to have flexibility and offers the ability to present several different resource scenarios in an objective manner. Location allocation can show where to place any number of fire stations needed or planned for the community. Depending on the scenario inputs entered while setting up the Location Allocation tool, different locations can result from each scenario. Location allocation is a process that helps decision makers answer questions; however, it is not a process that completely answers the question. The software outputs a recommendation of a location or locations based on time requirements and demand points. Other factors may play a role in final station locations that go beyond GIS analysis such as anticipated community risk, frequency of simultaneous calls for service, and available land.

It is also important to note that as population and development increases, it is likely that demand for emergency services will also increase. Decision makers should consider adding additional stations and resources now, while land is available, as a means of increasing public safety resources in line with the accelerated growth of the community.

The Location Allocation tool uses demand points as features that are allocated to each individual fire station. For this analysis, the location of historical incidents was used to identify demand points. The analysis uses the location of these demand points to choose the locations of new stations to maximize the number of demand points which can be reached within a travel time of four minutes from the stations.

Location allocation is frequently used to locate fire stations because emergency services are often required to arrive at all demand points within a specified response time. Note that it is important for all organizations, and critical for emergency services, to have accurate and precise data so that analysis results correctly model real-world results.

The following list describes how the location allocation tool handles demand:

- Any demand point outside all facilities' travel time is not assigned.
- A demand point inside the travel time of one facility is assigned to that facility.
- A demand point inside the travel time of two or more facilities is assigned to all facilities.

Facilities (fire stations) that are allocated the highest number of demand points are selected as actual locations for additional stations. This means that these recommended locations can arrive to the most amount of demand points within the specific time interval. The location of candidate facilities was determined by creating a set of evenly distributed geographic points within the limits of the fire department jurisdiction. The distance between these points is approximately 0.5 miles in the North-South and East-West directions. The GIS analysis considered all the possible combinations of a varying number of these points, to determine the optimal location of new stations. The output of the location allocation analysis recommends future station locations, but other factors may play a role in the final decisions that go beyond GIS analysis such as anticipated community risk, future development, and available land.

Once the locations were determined, each station was examined to determine what types of apparatus should be placed at these stations. The positioning of resources was primarily based on the goal to increase the ability of the CFD to meet the four-minute travel time coverage required by NFPA 1710.

Station Name/Number	Station Address	Apparatus	Staffing
Station 1/9	300 North Fourth St.	Engine 1 Engine 9 Ladder 1 Medic 1 Additional Medic EMS 10 ES-2	4 FF/EMT 4 FF/EMT 4 FF/EMT 2 FF/EMT 2 FF/EMT 1 Officer 1 Officer
Station 2	150 East Fulton St.	Engine 2 Ladder 2 Additional Medic Medic 2 Battalion 1	4 FF/EMT 4 FF/EMT 2 FF/EMT 2 FF/EMT 1 Officer
Station 3	222 Greenlawn Ave.	Engine 3 Medic 3 Rescue 3 EMS 11 SO2	4 FF/EMT 2 FF/EMT 3 FF/EMT 1 Officer 1 Officer
Station 4	3030 Winchester Pk.	Engine 4 Rescue 4 Medic 4	5 FF/EMT 3 FF/EMT 2 FF/EMT
Station 5	211 McNaughten Rd.	Engine 5 Ladder 5 Additional Rescue Medic 5	4 FF/EMT 4 FF/EMT 3 FF/EMT 2 FF/EMT

Table 8: Recommended Fire Stations and Staffing. The above table displays the recommended apparatus, staffing level, and locations of the proposed stations.

Station Name/Number (continued)	Station Address (continued)	Apparatus (continued)	Staffing (continued)
Station 6	5750 Maple Canyon Dr.	Engine 6 Medic 6 Medic 806 Battalion 2 EMS-12	4 FF/EMT 2 FF/EMT 2 FF/EMT 1 Officer 1 Officer
Station 7	1425 Indianola Ave.	Engine 7 Additional Ladder Medic 7 Battalion 3 EMS-13	4 FF/EMT 4 FF/EMT 2 FF/EMT 1 Officer 1 Officer
Station 8	1240 East Long St.	Engine 8 Ladder 8 Medic 8 Additional Medic	4 FF/EMT 4 FF/EMT 2 FF/EMT 2 FF/EMT
Station 10	1096 West Broad St.	Engine 10 Ladder 10 Medic 10 Medic 890	4 FF/EMT 4 FF/EMT 2 FF/EMT 2 FF/EMT
Station 11	2160 West Case Rd.	Engine/Air Crash 11 Rescue 11 Medic 11 Battalion 7 EMS-17	4 FF/EMT 3 FF/EMT 2 FF/EMT 1 Officer 1 Officer
Station 12	3200 Sullivant Ave.	Engine 12 Ladder 12 Medic 12 Additional Medic	4 FF/EMT 4 FF/EMT 2 FF/EMT 6FF/EMT
Station 13	309 Arcadia Ave.	Engine 13 Ladder 13 Medic 13	4 FF/EMT 4 FF/EMT 2 FF/EMT

Table 8 (continued): Recommended Fire Stations and Staffing. The above table displays the recommended apparatus, staffing level, and locations of the proposed stations.

Station Name/Number (continued)	Station Address (continued)	Apparatus (continued)	Staffing (continued)
Station 14	1514 Parsons Ave.	Engine 14 Medic 14 Battalion 4	4 FF/EMT 2 FF/EMT 1 Officer
Station 15	1800 Livingston Ave.	Engine 15 Ladder 15 Medic 15 Medic 815 EMS-14	4 FF/EMT 4 FF/EMT 2 FF/EMT 2 FF/EMT 1 Officer
Station 16	1130 East Weber Rd.	Engine 16 Rescue 16 Medic 16 Additional Medic	4 FF/EMT 3 FF/EMT 2 FF/EMT 2 FF/EMT
Station 17	2300 West Broad St.	Engine 17 Rescue 17 Medic 17 Medic 817 Battalion 5 EMS-15	4 FF/EMT 3 FF/EMT 2 FF/EMT 2 FF/EMT 1 Officer 1 Officer
Station 18	1551 Cleveland Ave.	Engine 18 Additional Ladder Medic 18	4 FF/EMT 4 FF/EMT 2 FF/EMT
Station 19	3601 North High St.	Engine 19 Medic 19	4 FF/EMT 2 FF/EMT

Table 8 (continued): Recommended Fire Stations and Staffing. The above table displays the recommended apparatus, staffing level, and locations of the proposed stations.

Station Name/Number (continued)	Station Address (continued)	Apparatus (continued)	Staffing (continued)
Station 20	2646 East Fifth Ave.	Engine 20 Additional Ladder Medic 20	4 FF/EMT 4 FF/EMT 2 FF/EMT
Station 21	3294 East Main St.	Engine 21 Medic 21 Battalion	4 FF/EMT 2 FF/EMT 1 Officer
Station 22	3069 Parsons Ave.	Engine 22 Ladder 22 Medic 22	4 FF/EMT 4 FF/EMT 2 FF/EMT
Station 23	4451 East Livingston Ave.	Engine 23 Ladder 23 Medic 23 Medic 823	4 FF/EMT 4 FF/EMT 2 FF/EMT 2 FF/EMT
Station 24	1585 Morse Rd.	Engine 24 Ladder 24 Medic 24	4 FF/EMT 2 FF/EMT 2 FF/EMT
Station 25	739 West Third Ave.	Engine 25 Medic 25	4 FF/EMT 2 FF/EMT
Station 26	5433 Fisher Rd.	Engine 26 Ladder 26 Medic 26	4 FF/EMT 4 FF/EMT 2 FF/EMT
Station 27	7560 Smokey Row Rd.	Engine 27 Ladder 27 Medic 27	4 FF/EMT 4 FF/EMT 2 FF/EMT

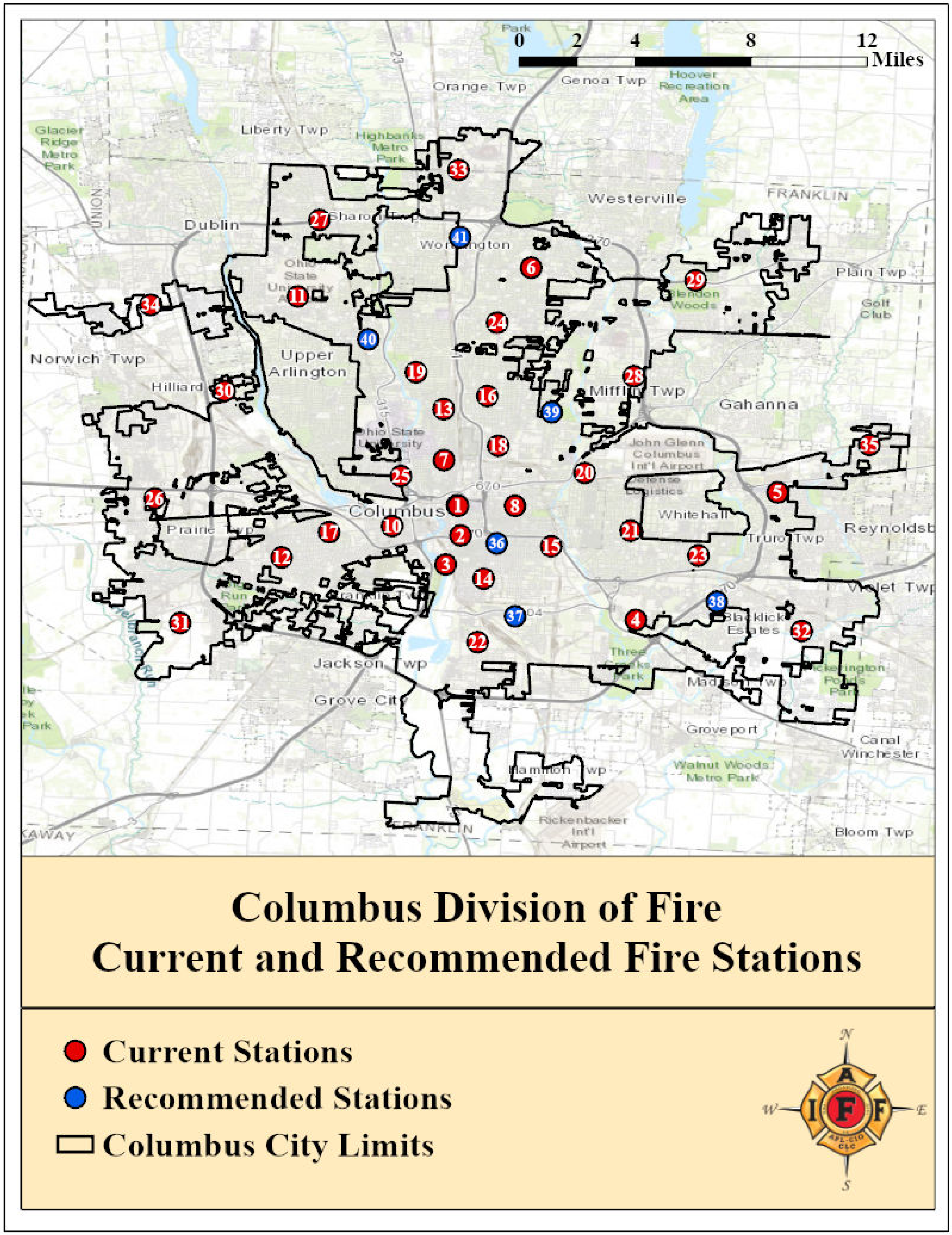
Table 8 (continued): Recommended Fire Stations and Staffing. The above table displays the recommended apparatus, staffing level, and locations of the proposed stations.

Station Name/Number (continued)	Station Address (continued)	Apparatus (continued)	Staffing (continued)
Station 28	3240 McCutcheon Rd.	Engine 28 Ladder 28 Medic 28 Additional Medic Additional Rescue	4 FF/EMT 4 FF/EMT 2 FF/EMT 2 FF/EMT 3 FF/EMT
Station 29	5151 Little Turtle Wy.	Engine 29 Additional Ladder Medic 29	4 FF/EMT 4 FF/EMT 2 FF/EMT
Station 30	3555 Fishinger Blvd.	Engine 30 Medic 30	4 FF/EMT 2 FF/EMT
Station 31	5305 Alkire Rd.	Engine 31 Medic 31	4 FF/EMT 2 FF/EMT
Station 32	3675 Gender Rd.	Engine 32 Ladder 32 Medic 32	4 FF/EMT 4 FF/EMT 2 FF/EMT
Station 33	440 Lazelle Rd.	Engine 33 Ladder 33 Medic 33	4 FF/EMT 4 FF/EMT 2 FF/EMT
Station 34	5201 Wilcox Rd.	Engine 34 Medic 34	4 FF/EMT 2 FF/EMT
Station 35	711 Waggoner Rd.	Engine 35 Medic 35	4 FF/EMT 2 FF/EMT

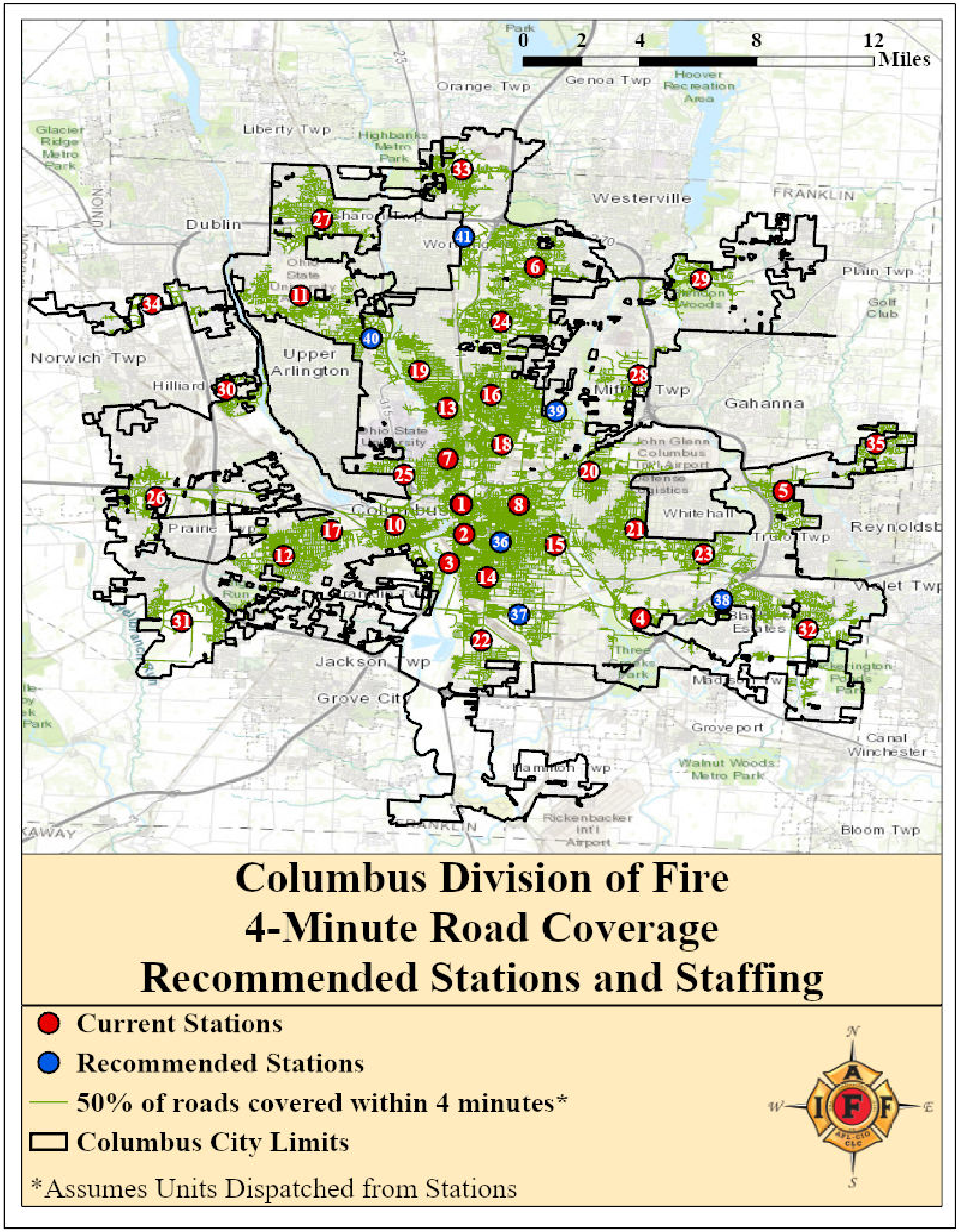
Table 8 (continued): Recommended Fire Stations and Staffing. The above table displays the recommended apparatus, staffing level, and locations of the proposed stations.

Station Name/Number (continued)	Station Address (continued)	Apparatus (continued)	Staffing (continued)
Recommended Station 36	In the area of E Livingston Ave and South 18th Street	Proposed Engine Proposed Medic	4 FF/EMT 2 FF/EMT
Recommended Station 37	In the area of Koebel Rd and Lockbourne Rd	Proposed Engine	4 FF/EMT
Recommended Station 38	In the area of Refugee Rd and Nathaniel Blvd	Proposed Engine Proposed Medic	4 FF/EMT 2 FF/EMT
Recommended Station 39	In the area of Mock Rd. & Bar Harbor Rd	Proposed Engine Proposed Medic	4 FF/EMT 2 FF/EMT
Recommended Station 40	In the area of W Henderson Rd and Knightsbridge Blvd	Proposed Engine	4 FF/EMT
Recommended Station 41	In the area of Schrock Rd and Busch Rd	Proposed Engine Proposed Medic	4 FF/EMT 2 FF/EMT

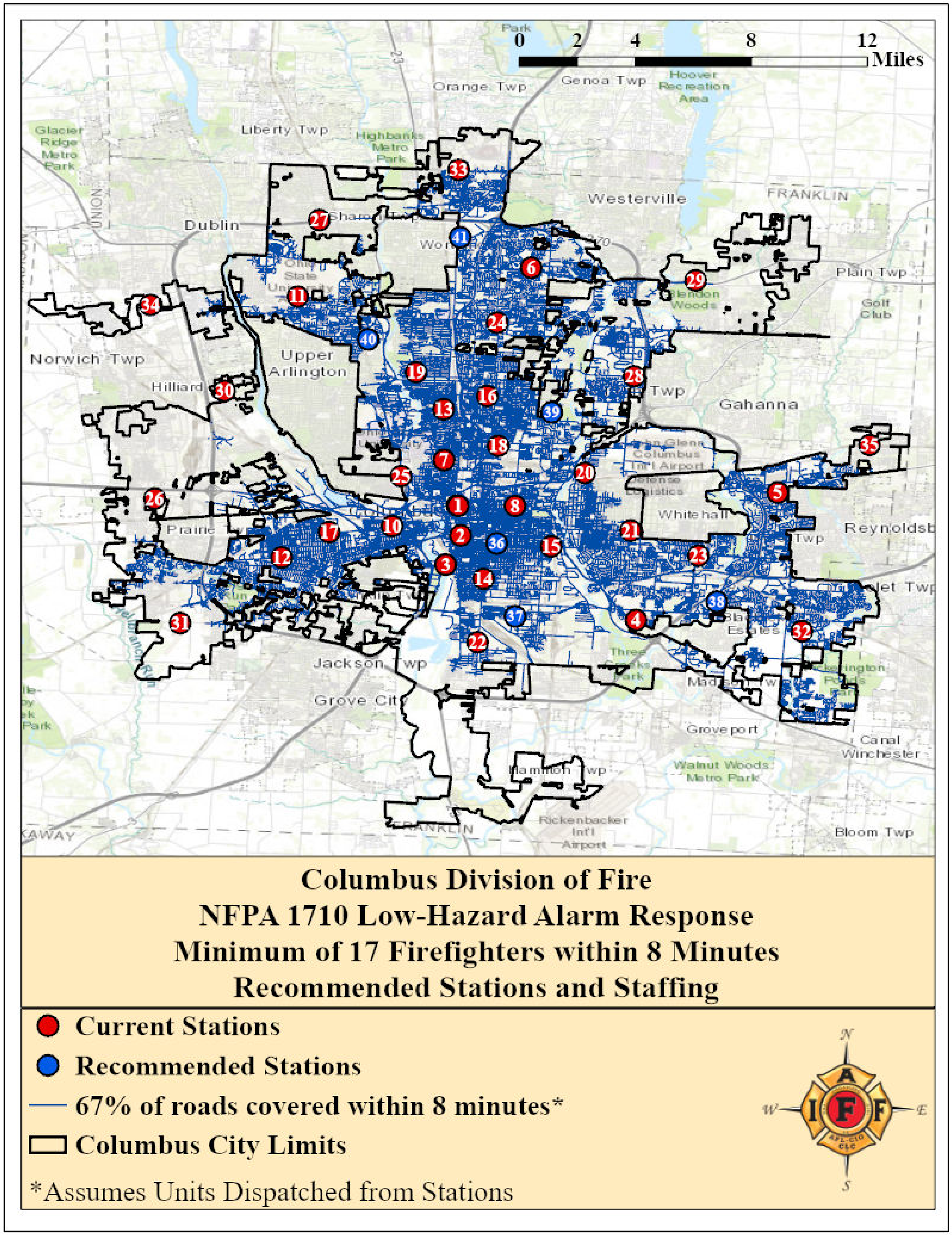
Table 8 (continued): Recommended Fire Stations and Staffing. The above table displays the recommended apparatus, staffing level, and locations of the proposed stations.



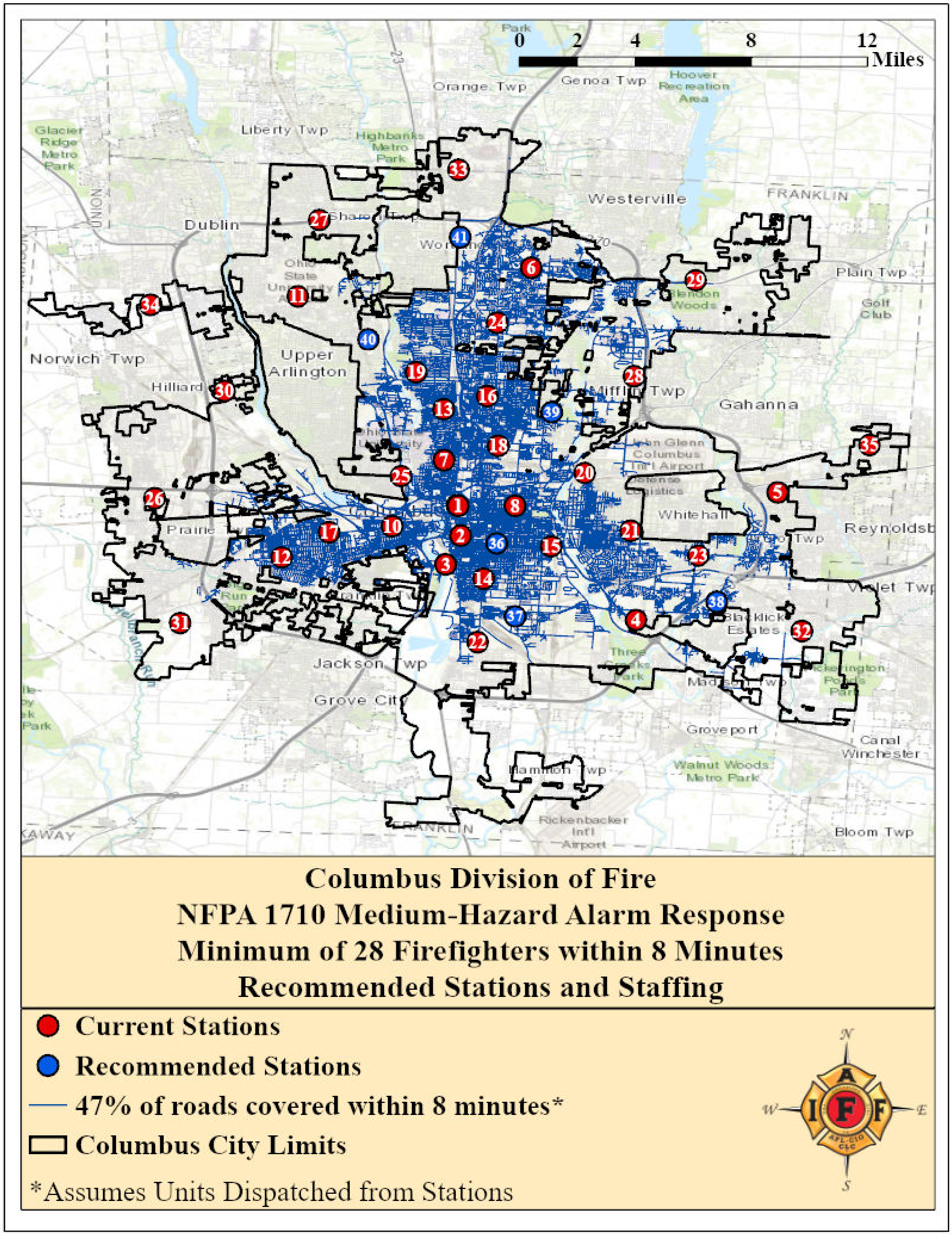
Map 19: Current and Recommended Fire Stations. This map shows the location of the current and the six recommended fire stations.



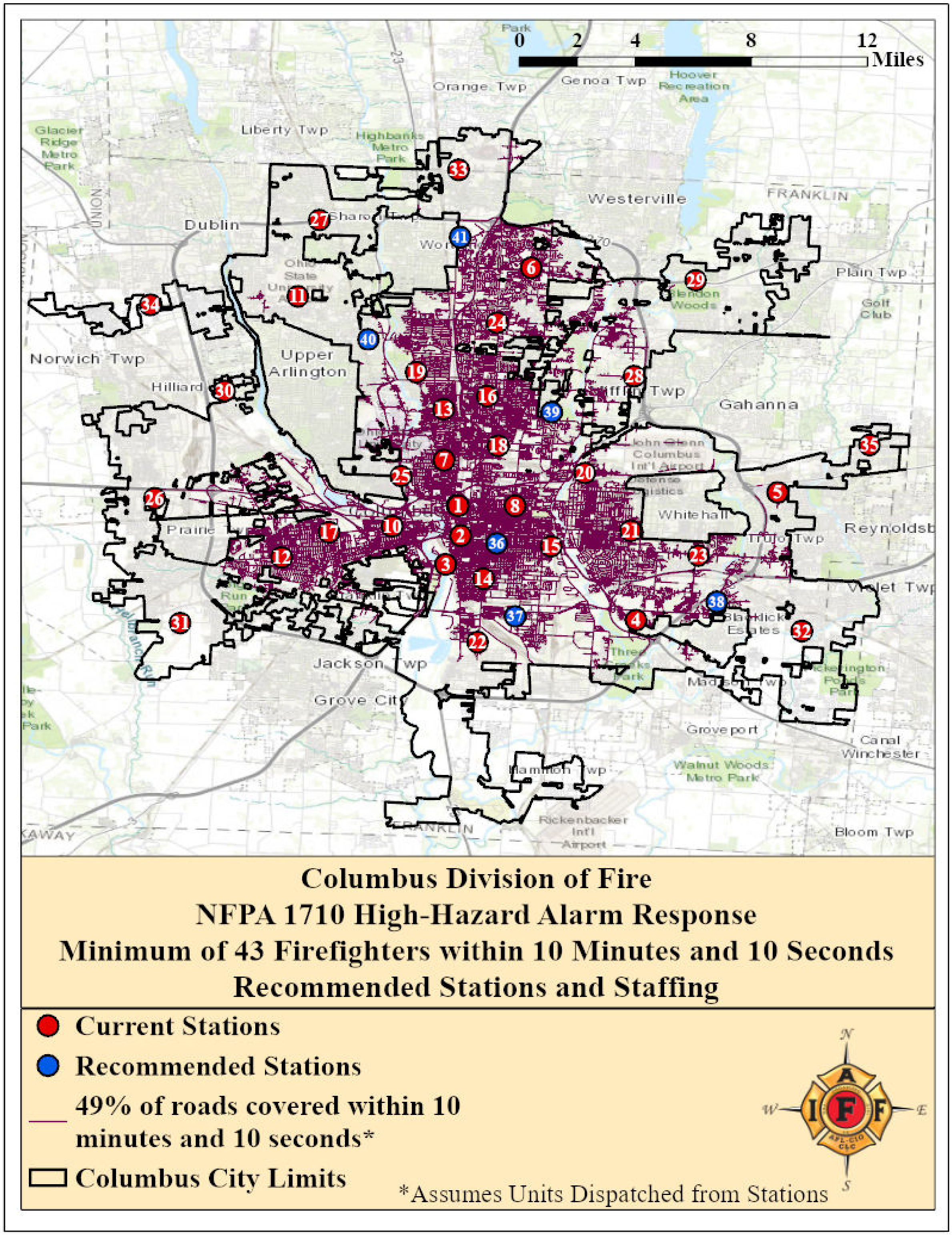
Map 20: 4-Minute Road Coverage, Recommended Stations and Staffing. This map shows that the department could reach 50% of the city roads within four minutes with the recommended stations. This would be a 12% improvement over the current capabilities. These are also the roads where the department could assemble the minimum force of four firefighters within four minutes. Currently, the department can assemble this force on 30% of city roads. With these recommendations, the department's ability to meet the "2 In/2 Out" regulation would increase by 66%.



Map 21: NFPA 1710 Low-Hazard Alarm Response, Minimum of 17 Firefighters within 8 Minutes, Recommended Stations and Staffing. This map shows that with the recommended stations and staffing the department would increase its ability to assemble the minimum force for low-hazard fires by 82%, from 37% to 67% of the total roads.



Map 22: NFPA 1710 Medium-Hazard Alarm Response, Minimum of 28 Firefighters within 8 Minutes, Recommended Stations and Staffing. This map shows that with the recommended stations and staffing the department would increase its ability to assemble the minimum force for medium-hazard fires (28 firefighters within eight minutes) by 112%, from 22% to 47% of the total roads.



Map 23: NFPA 1710 High-Hazard Alarm Response, Minimum of 43 Firefighters within 10 Minutes and 10 Seconds, Recommended Stations and Staffing. This map shows that with the recommended stations and staffing the department would increase its ability to assemble the minimum force for high-hazard fires (43 firefighters within 10 minutes, 10 seconds) by 187%, from 17% to 49% of the total roads.

Projected Travel Time Performance, Recommended Stations and Staffing

The recommendations presented in this report will allow the department to increase the percent of roads where an effective response force can be assembled and to become less reliant on mutual aid units. The travel time to the scene of incidents will improve in several areas of the city, and the number of back-to-back calls will decrease, increasing the safety of the firefighters and the citizens of Columbus.

The IAFF produced a computer simulation of the CFD response area based on the current demand and its geographic distribution. The expected travel time performance for the current staffing level and for the increased staffing level (four additional medic units, eight additional engines and one ladder truck) were analyzed.

The software developed by the IAFF sampled a time period of one month. Simulating longer time periods does not produce different results. The simulation considers the jurisdiction's road network and the typical traffic on Wednesday at 5:00 pm, like the mapping analysis presented in the previous sections. Therefore, it is important to note that this simulation represents a worst-case scenario because the traffic level is assumed to be at the highest volume through the entire simulated period regardless of the time of the day. The reason for this assumption is that the department should be ready to respond efficiently even under the worst conditions. Further details about the simulation and software used for these projections are provided in Appendix B.

The next chart shows the 10 first-in districts that would report the most significant improvement in travel time performance pursuant to the recommendations made herein. In Station 2's first-in district the department could reach 82% of incidents within four minutes, compared to the current 74%, an approximately 300 additional incidents per year in this area of the city. The largest improvement would be in Station 28's first-in district, where the incidents reached within four minutes would nearly double, from the current 10% to 18% of total incidents. Across the entire jurisdiction, the additional units will increase the number of incidents receiving the first unit within four minutes by 5,000 per year.

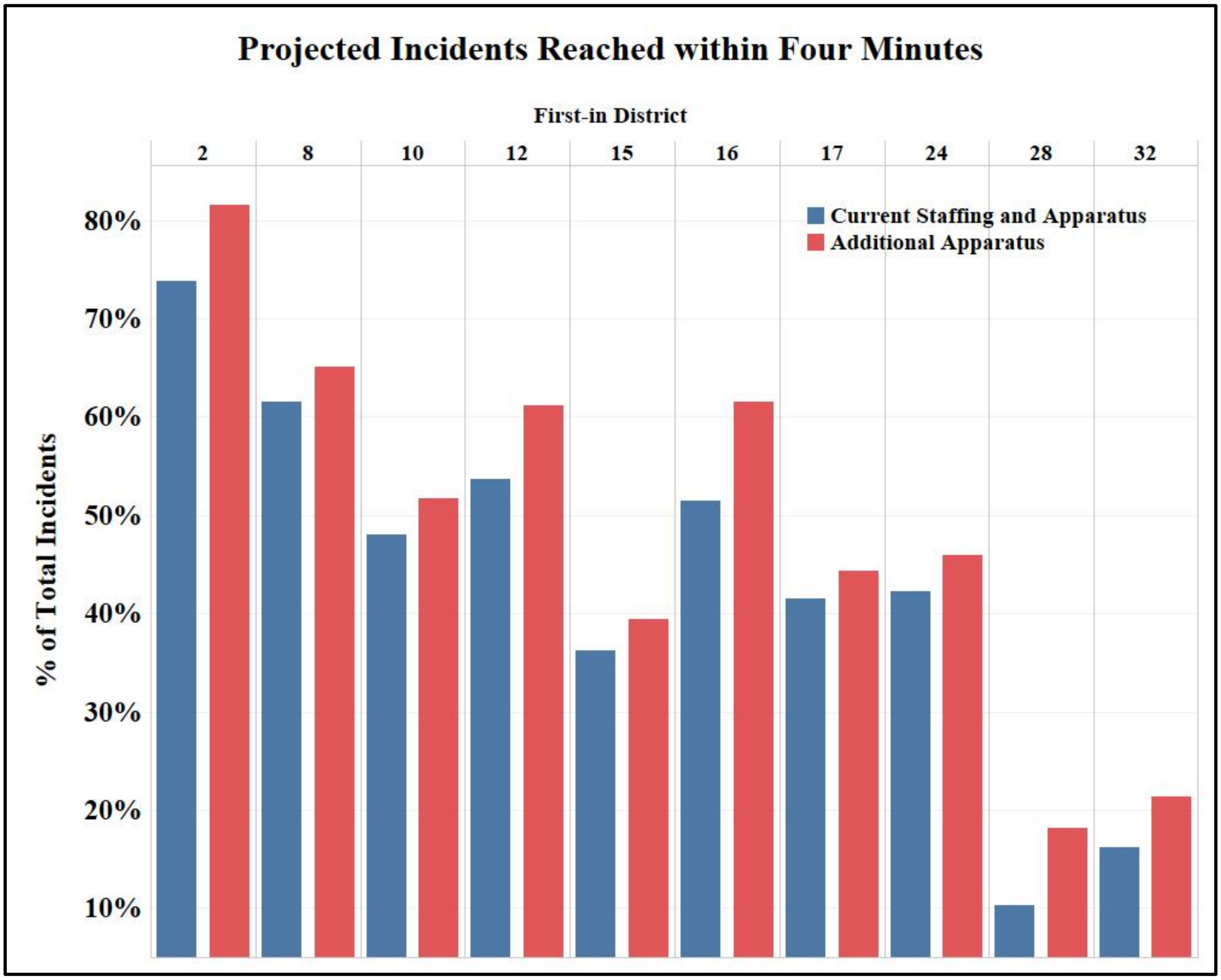


Chart 16: Projected Incidents Reached within Four Minutes. This chart shows the 10 first-in districts that would report the most significant improvement in travel time performance pursuant to the recommendations made herein. In Station 2's first-in district the department could reach 82% of the incidents within four minutes corresponding to approximately 300 additional incidents per year. The largest improvement would be reported in Station 28's first-in district, where the incidents reached within four minutes would nearly double, from the current 10% to 18% of total incidents. Across the entire jurisdiction, the additional units will increase the number of incidents receiving the first unit within four minutes by 5,000 per year.

The next chart highlights the improvement in the downtown area of the city, where most of the incidents occur. The chart focuses on the incidents occurring in downtown and on the units from the three stations closer to downtown, Stations 1/9, 2 and 8. With the current apparatus, as the number of units engaged from these stations increases, the travel time to new emergencies also increases because there are less units available to address new emergencies, and it is less likely to find a unit within a travel time of four minutes from the scene of the incident. Instead, with the additional apparatus, even as the number of units engaged increases, the department would be able to maintain a safer average travel time to the scene of incidents. For example, with the current apparatus, when all the units are available, the average travel time to the scene of an incidents would be 191 seconds (three minutes and 11 seconds), which increases by nearly three minutes, to 363 seconds (six minutes and three seconds) when two or more units are engaged. With additional apparatus, even with two or more units already engaged, the average travel time would increase by less than one minute (51 seconds) compared to the case when all the units are available. This is a two minute and 10 seconds improvement compared to the same case with the current apparatus.

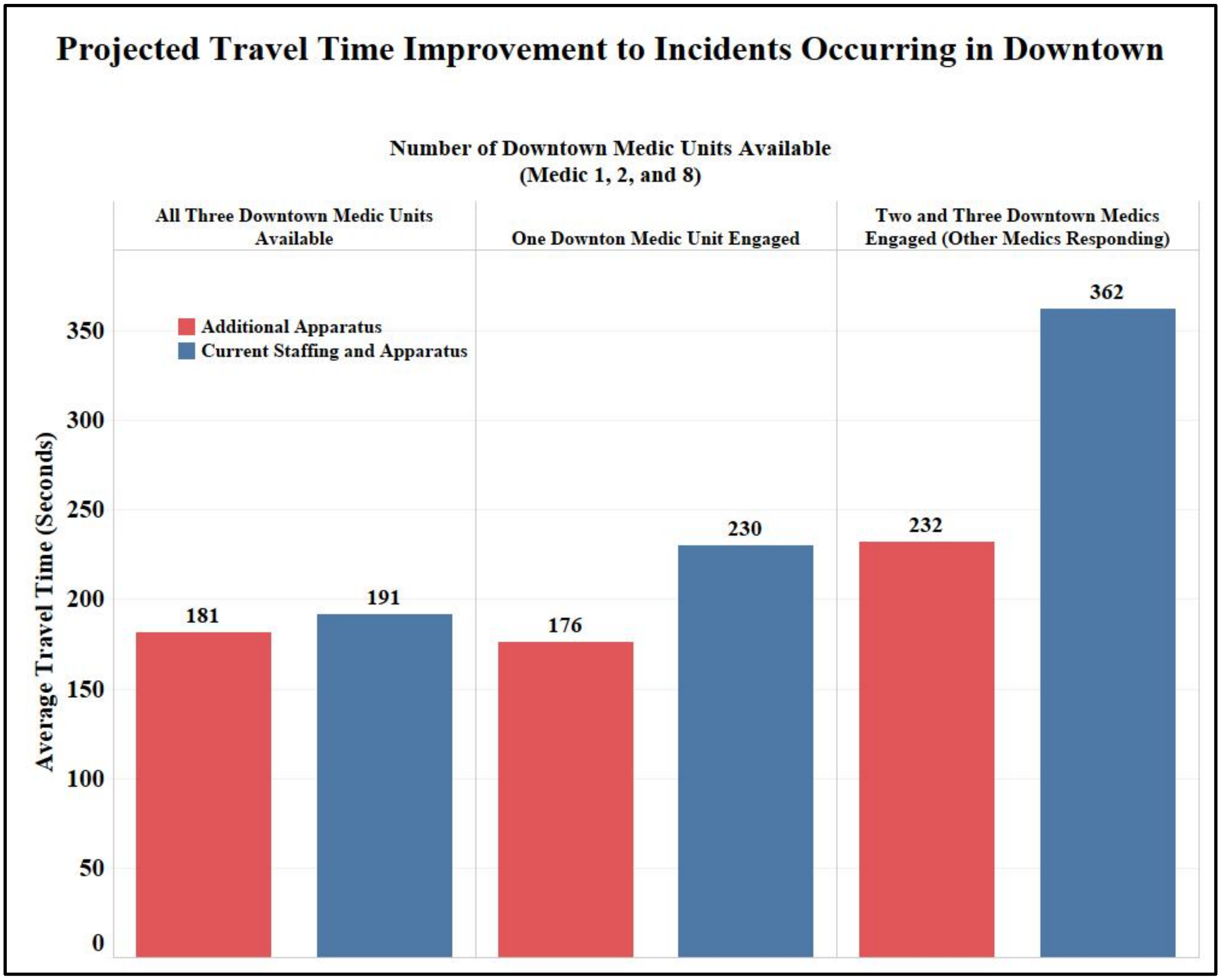


Chart 17: Projected Travel Time Improvement to Incidents Occurring in Downtown. This chart focuses on the incidents occurring in downtown, and on the units from the three stations closer to downtown, Stations 1/9, 2, and 8. With the current apparatus, as the number of units engaged from these stations increases, the travel time to new emergencies also increases because there are less units available to address new emergencies, and it is less likely to find a unit within a travel time of four minutes from the scene of the incident. Instead, with the additional apparatus, even as the number of units engaged increases, the department would be able to maintain a safer travel time to the scene of incidents.

The next chart shows the expected number of back-to-back responses for the department's engines. By adding eight engines, these responses will decrease, allowing more time for the personnel to rest and recover, increasing the safety of the firefighters and the efficiency of the response. The number of back-to-back responses made by the engines in one year is expected to decrease by 1,548 on average pursuant to implementing the recommendations.

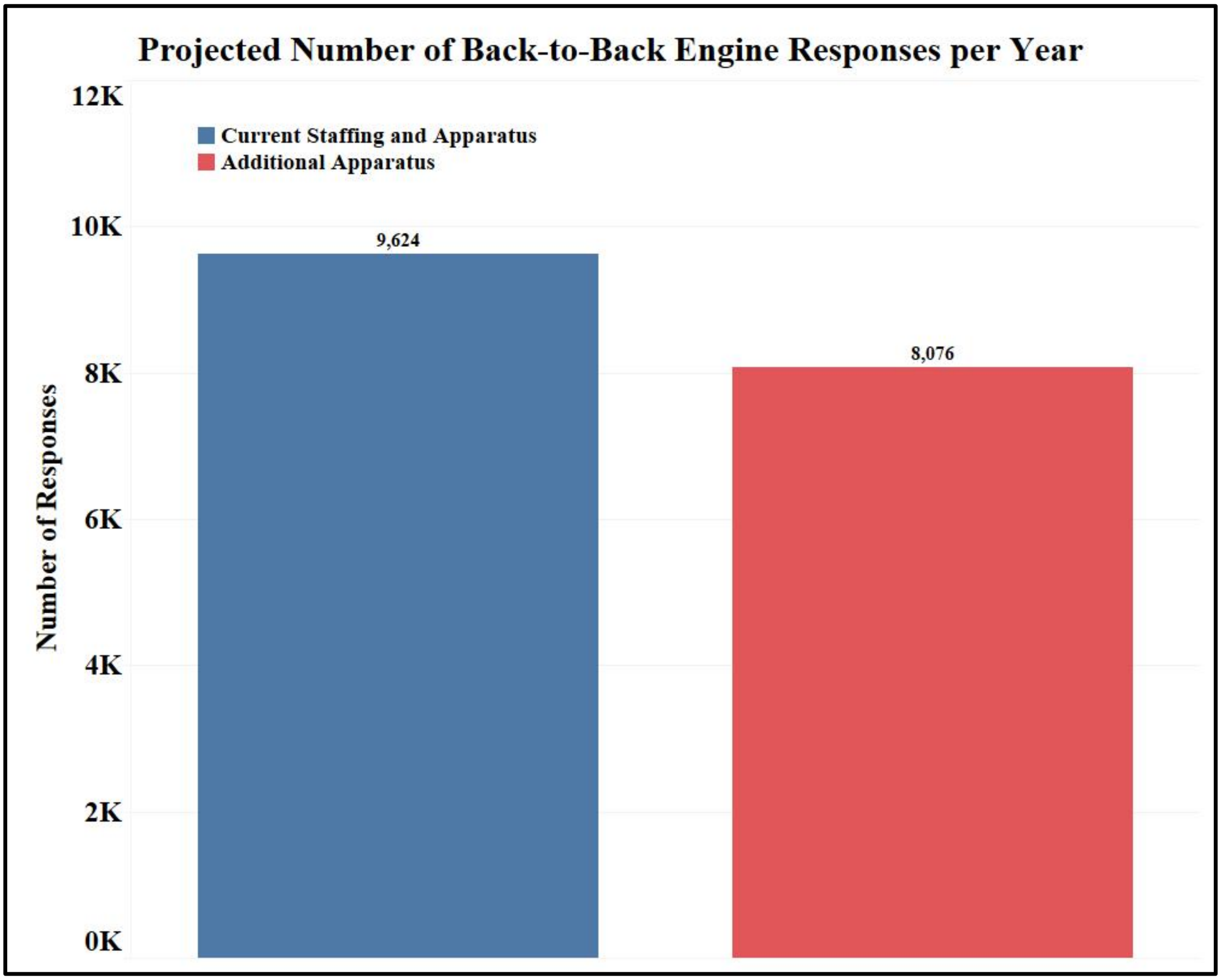


Chart 18: Projected Number of Back-to-Back Engine Responses per Year. This chart shows the expected number of back-to-back responses for the department's engines. By adding eight engines, these responses will decrease, allowing more time for the personnel to rest and recover, increasing the safety of the firefighters and the efficiency of the response. The number of back-to-back responses made by the engines in one year is expected to decrease by 1,548 responses on average pursuant to implementing the recommendations.

Conclusion

Over the last 10 years, the population of the City of Columbus increased by 14%, and, with it, the number of emergency incidents and the demand on the fire department has also increased. This growth has not been balanced by an adequate increase in CFD resources. The department continues to rely on automatic aid from nearby jurisdictions to meet demand. In the three years between 2017 and 2019, 31,358 incidents occurred within Columbus city limits that required at least one mutual aid unit to be on scene to assist units from the CFD. Of these incidents, 18,919 were addressed solely by mutual aid units, that is, CFD units did not respond to these incidents because they were not available or were too far from the scene of the incident to provide a timely response. Mutual aid units were the first-arriving unit on the scene of incidents that occurred in Columbus 18,231 times between 2017 and 2019. Mutual aid units responding into the City of Columbus have longer travel times on average, which enhances risk for the victims of both fire and EMS emergencies.

The department does not meet NFPA 1710 travel time objectives for EMS and fire incidents that require the first EMS unit and engine to be at the scene of EMS and fire emergencies within four minutes for at least 90% of incidents. The first-arriving CFD EMS unit was at the scene of EMS incidents within four minutes for 57% of incidents. The first-arriving CFD engine was at the scene of fire incidents within four minutes for 65% of incidents. As the population of Columbus increases, the travel time performance of the department will likely worsen, as the same units would have to serve an increasing number of calls.

The CFD units are not staffed in agreement with NFPA 1710 objectives for an efficient and safe response. CFD should increase the staffing level to staff all the fire suppression apparatus with four firefighters.

In order to improve the coverage of the jurisdiction, the ability to assemble an effective response force for low, medium, and high-hazard fires, and improve the travel time to the scene of incidents, the department should add six engines, six medic units and four ladder trucks. In the longer term, in addition to adding staff and apparatus to the current stations, the department should build six additional stations to increase the city's coverage and address the increasing demand as its population increases. The six additional engines previously added to the current stations should be moved to the new stations that will also house a total of four medic units.

The risk assessment analysis identified areas where emergencies have typically occurred in the past and where are likely to occur in the future. The department should make efforts to ensure these areas continue to enjoy the same level of coverage, while adjusting resources and deployment as needed in an effort to achieve complete compliance with industry standards. 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.

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 several 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, deployment and station location 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 1500 and 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.

Appendix A

Performance Standards

The National Fire Protection Association (NFPA) produced NFPA 1710 *Organization and Deployment of Fire Suppression Operations, Emergency Medical Operations, and Special Operations to the Public by Career Fire Departments*. NFPA 1710 is the consensus standard for career firefighter deployment, including requirements for fire department arrival time, staffing levels, and fireground responsibilities.[83]

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

- **4.1.2.1** The fire department shall establish the following performance objectives for the first-due response zones that are identified by the AHJ:
    - (3) 240 seconds or less travel time for the arrival of the first engine company at a fire suppression incident[84]
    - (4) 360 seconds or less travel time for the arrival of the second company with a minimum staffing of 4 personnel at a fire suppression incident
    - (5) For other than high-rise, 480 seconds or less travel time for the deployment of an initial full alarm assignment at a fire suppression incident
    - (6) For high-rise, 610 seconds or less travel time for the deployment of an initial full alarm assignment at a fire suppression incident
    - (7) 240 seconds or less travel time for the arrival of a unit with first responder with automatic external defibrillator (AED) or higher-level capability at an emergency medical incident
    - (8) 480 second or less travel time for the arrival of an advanced life support (ALS) unit at an emergency incident, where this service is provided by the fire department provided a first responder with an AED or basic life support (BLS) unite arrived in 240 seconds or less travel time.
- **4.3.2** The fire department organizational statement shall ensure that the fire department's emergency medical response capability includes personnel, equipment, and resources to deploy at the first responder level with AED or higher treatment level.

[83] NFPA 1710, 2020
[84] All travel time objectives are to be achieved 90% of the time

- **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 Engine Companies.** Fire companies, whose primary functions are to pump and deliver water and perform basic firefighting at fires, including search and rescue, shall be known as engine companies shall be staffed with a minimum of four on-duty personnel.
    - 5.2.3.1.1 These companies shall be staffed with a minimum of four on-duty personnel.
    - 5.2.3.1.2 In first-due response zones with a high number of incidents, geographical restrictions, geographic isolation, or urban areas, as identified by the AHJ, these companies shall be staffed with a minimum of five on-duty members.
    - 5.2.3.1.2.1 In first-due response zones with tactical hazards, high-hazard occupancies, or dense urban areas, as identified by the AHJ, these fire companies shall be staffed with a minimum of six on-duty members.

- **5.2.3.2 Ladder/Truck Companies.** 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 known as ladder or truck companies… shall be staffed with a minimum of four on-duty personnel.
    - 5.2.3.2.1 These companies shall be staffed with a minimum of four on-duty personnel.
    - 5.2.3.2.2 In first-due response zones with a high number of incidents, geographical restrictions, geographic isolation, or urban areas, as identified by the AHJ, these companies shall be staffed with a minimum of five on-duty members.
    - 5.2.3.2.2.1 In first-due response zones with tactical hazards, high-hazard occupancies, or dense urban areas, as identified by the AHJ, these fire companies shall be staffed with a minimum of six on-duty members.

- **5.2.3.4 Fire Companies with Quint Apparatus**
    - 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** 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	***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)	4 Firefighters
Required Minimum Personnel for Full Alarm	**16 Firefighters & 1 Incident Commander**

- **5.2.4.2 Open-Air Strip Shopping Center Initial Full Alarm Assignment Capability**
    - 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

And

- **5.2.4.3 Apartment Initial Full Alarm Assignment Capability**
    - 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[85]	2 Firefighters
Required Minimum Personnel for Full Alarm	**27 Firefighters** **1 Incident Commander**

[85] The Standard further states, "Where this level of emergency care is provided by outside agencies or organizations, these agencies and organizations shall be included in the department plan and meet these requirements."

- **5.2.4.4 High-Rise Initial Full Alarm Assignment Capability.**
    - 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)
Rapid Intervention Crew (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 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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Appendix B

Travel Time Projections

The software used for the travel time projections was developed by the IAFF using the Python programming language. It simulates dispatch of the department's units for the current and recommended staffing and apparatus. In the simulation, the computer dispatches units to the scene of incidents depending on where the incident occurs and what units are available and closer to the scene of the incidents. Units could be dispatched to the scene of an incident while they are traveling back to their station, for example after clearing a previous incident. This aspect ameliorates the limits of the GIS analysis, where it is assumed that units are dispatched from the stations. Additionally, this computer simulation considers that multiple units could be engaged at the same time, either responding to different incidents occurring at different locations or responding to the same incident. This allows for a more realistic estimation of the travel time performance, as opposed to assuming that that all the units are always available in their stations.

In the simulation, the time that a unit takes to clear one incident is based on the average time that a unit takes to clear an incident as estimated from the CAD data. However, the process has a random component, so that, even if on average the simulated time to clear the incident matches the real average, random variations can occur, like would happen in the real world.

The location of incidents is also simulated and randomized, but in a way that reflects the real incident density: the simulated random incidents are more likely to occur in areas with a high density of incidents as observed from the CAD data and detailed in the *Risk Assessment* section of this report. Four different types of incidents are considered: EMS, fires, structure fires, and other.[86]

The simulation spans a time period of one month, which was found to be sufficient for statistical significance and to obtain stable results.[87]

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[86] This category includes less common and less frequent types of incidents such as public service calls and HazMat.
[87] Meaning that simulating a longer time period would not affect the conclusions.

International Association of Fire Fighters
1750 New York Ave., NW, Washington, DC 20006
www.iaff.org

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