

**Title of Paper:**

Fire Suppression and Emergency Medical Services Response Capabilities Analysis

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**Abstract:**

Analyze fire department apparatus and alarm coverage areas using station locations, apparatus allocation and staffing. The coverage areas, based on either road segment lengths or travel times, are created using Network Analyst to determine which jurisdiction's road segments are covered by the fire department apparatus or alarm configurations. The two components necessary for the service area analysis are the identified road segments covered within a given travel time and the service areas for each station. Manipulation and analysis of these travel-time polygons allows the identification of areas covered by apparatus from specific stations within 4 and 8 minutes. The deliverable reports combine data received from the fire department, maps, and references to accepted fire fighting practices and national standards, including NFPA 1710. The studies allow public safety personnel to effectively plan for emergency response, determine mitigation priorities, analyze historical events, predict future events, and provide critical information to emergency responders.

**Paper Body:****Introduction**

This report summarizes the geographic analysis process performed for assessing the response capabilities of a fire department's fire suppression and emergency medical services. The analytical process examines the predicted response times and geographic response coverage areas for emergency response units deployed from existing fire station locations, functioning as the primary providers of fire, rescue, and disaster response services. This process uses geographic information systems (GIS) as a tool for evaluating, planning, and proposing fire department apparatus and alarm response capabilities from fire department data. This analysis cannot be performed without essential operational fire department data, such as fire station locations, apparatus allocation, shift staffing, and alarm configurations. In addition to the necessary fire department operational data, fire response district boundary and associated streets are also required to perform the analysis. The geographic data elements contained within the fire department data offer the base on which this study is performed. All data elements derived from this geographic analysis are based on modeled core fire department data, such as fire station locations and staffing. In conjunction with referenced street data, key fire department data, and an analytical GIS processes create essential benchmark geographic data about a fire departments response system.

The analysis calculates the individual response areas for each fire station and determines the overall 4 and 8-minute response capabilities of the fire department within its fire response district. The study evaluates the 4 and 8-minute response capabilities of all staffed fire stations, apparatus companies, alarm configurations, and measures the level compliance with OSHA "2 In/ 2 Out" and NFPA 1710 response and staffing standards. Included in this study

are the iterative response capabilities analysis evaluations consisting of the existing fire department configuration, any proposed configurations, as well as an IAFF suggested NFPA 1710 compliant configuration are.

The deliverable report produced combines all data received from the fire department, generated maps, references to accepted fire fighting practices, and national standards, including NFPA 1710. The results of the analysis allow public safety personnel to effectively plan for emergency response, determine mitigation priorities, analyze historical events, predict future events, and provide critical information to emergency responders.

### **Purpose of Study**

The purpose of this report is to provide a comprehensive analysis of fire departments response capabilities. The report provides suggestions for appropriate deployment of fire suppression apparatus and apparatus staffing, as a tool to aid in the development, enhancement, and protection of fire department working conditions and response capabilities. This study is performed for fire departments that need a comprehensive assessment of their current response capabilities to justify current deployment configurations or additional fire suppression resources. This comprehensive response capability assessment information can be used to stave off threats of system down sizing, in system upgrades, or in comparison of OSHA and NFPA 1710 compliance. Each analysis report is customized to the specific needs of the requesting International Association of Fire Fighters (IAFF) local affiliate. In addition to the basic need of this analysis report, a general understanding of short-term and long-term response goals is required when this report is requested.

### **Data**

Once a request has been made, the acquisition and evaluation of essential fire department configuration data is the first analysis step. The required fire department data used in the analysis encompasses intricate details about fire stations, staffing, and alarms. The essential fire department data elements are fire station locations, apparatus allocation, shift staffing, and alarm configurations. The additional data necessary is a fire response boundary area, the response district, such as jurisdiction boundaries, and local street data.

Something as simple as a commercial gas station local reference map, containing the all the necessary geographic data components of the fire department, including fire station locations, fire response area boundaries, significant landmarks, high-risk areas, areas with high call volumes, hazardous materials areas, or any other significant geographic places related to the fire department, is adequate in order to begin the analysis. Anything from a pen to a sticker can be used to indicate and/or label the items listed above on a paper map to verify the geographic location of the data. Once the geographic location of the fire department data is determined, it can be converted into a geographically referenced file, containing geographic coordinates.

### **Fire Stations**

One of the major components of the core data required in this analysis surrounds the individual fire stations within the fire response district. The specific data required for each fire station includes the name, the physical location, and the staffed apparatus, including function, and staffing details, including certification levels. All fire station information must

be obtained for all the existing and proposed scenarios to be evaluated. Fire station location information must include a street address; with associated zip code and cross street intersections, XY coordinates, have a physical location on a map, or be in a GIS compatible file format.

**Apparatus and staffing details**

In addition to fire station data, detailed apparatus data is necessary to complete this analysis. Without detailed apparatus information only individual fire station response capabilities can be determined. With a complete list of apparatus, including staffing specifications, fire department response can be modeled in detail including alarm configurations. A standard fire station table, as featured below, contains detailed fire station apparatus staffing information. The requested detailed staffing data includes characteristics such as minimum and maximum staffing, and cross-staffing details, as well as EMS training levels, such as EMT-Basic or Paramedic, for each fire fighter. Table 1 below is an example of a fire station data table containing all the necessary data elements from the IAFF website.

**Table1. Sample IAFF Fire Station Data Table**

Station Name	Station 1	Station 2	Station 3
Station Address	21 Hobart St.	123 Main St.	222 Pine St.
Station Zip Code	11111	11111	11110
Left Cross-Street	Seventh Ave.	Oak St.	Main St.
Right Cross-Street	Daffodil Ct.	Pine St.	Airport Dr.
Apparatus/ Staffing	Engine 1/ 4 FF/EMT-B  Ladder 1/ 4 FF/EMT-B  Rescue 1/ 2 FF/EMT-P  B/C Car/ 1 Batt. Chief	Engine 2/ 4 FF/EMT-B  Ladder 2/ 4 FF/EMT-B	Engine 3/ 3 FF/EMT-B 1 FF/EMT-P  Crash 3/ 4 FF/EMT-B

If an apparatus is a combination unit such as a quint, which can function as an engine or a ladder, detailed information is required about its primary and secondary functions and role in alarm configurations.

**Alarm responses**

A major component of fire department response capabilities are measured by alarm configuration response capabilities. Alarm response capabilities can be measured against fire department criteria, for example time objectives, and will be measured, in this analysis, against the NFPA 1710 Standard. In this analysis, the typical configurations measured are the full-alarm assignment and the first due units to both fire and EMS responses, though

many unique alarms are typically calculated. Individual fire station and apparatus company 4 and 8-minute alarm response capabilities are calculated in conjunction with the staffing specifications and model the alarm response capabilities.

The 4-minute alarm response incorporates one minute of turnout time and three minutes of travel time and the eight-minute alarm response incorporates one minute of turnout time and seven minutes of travel time. A detailed description of the following alarms is also requested from the local. Typical alarms required are the BLS Medical Call, ALS Medical Call, Small fires, and the Full-Alarm. Detailed information must also be provided for all instances of automatic aid, either provided to or received from another fire department. A detailed description of all automatic aid resources such as staffing, fire station location, and response boundaries are also required.

The following table is an example of the alarm response information required from the requesting local to perform a system analysis of resource capabilities from the IAFF website.

**Table 2. Sample IAFF Response Information**

Average Speed: 30 mph
Turnout Time: 1 minute 0 seconds
Response Time Objectives: First unit on the scene within 4 minutes 0 seconds of dispatch and/or a full-alarm assignment on the scene within 8 minutes 0 seconds of dispatch.
BLS Medical Assignment: 1 Rescue
ALS Medical Assignment: 1 Engine and 1 Rescue
Still Alarm (Fire): 1 Engine
Full-Alarm Assignment: 2 Engines, 1 Ladder, 1 Rescue, and 1 Battalion Chief

**Fire Response District**

Fire response district boundaries are also an essential piece of data for this analysis. Fire response district boundaries, which may or may not be coincident to a political boundary, are necessary to determine overall response capabilities of a fire department. The overall response capabilities are measured in a percentage of total fire response roads covered. Utilized as the baseline measure to evaluate overall response capabilities, the fire response district boundary is essential. It is important to include the most up-to-date version of the fire response district boundary, including recent annexations. The fire response district boundary could be a single political boundary or something much more complex such as an aggregate of several geographic areas or a portion of one political area. If the fire response district boundary is representative of a single or multiple political boundaries, they can be extracted from an in-house national data set. Fire response district boundaries can also be manually created, transposed from the above mentioned hand drawn map, into a GIS compatible file.

### **Street Network**

Not only is the fire department data, detailed above, necessary to determine the response capabilities of a fire department. A major component in the ability to determine the response capabilities of a fire department is the road network within the fire response district. The road network, encoded with either road segment length or calculated travel time, is required to perform the analysis. The road network allows for the creation of the individual response coverage areas that in turn allows the modeling of all apparatus and alarm configuration response capabilities. With the components necessary for the response service area polygon generation, the time-based response coverage areas are generated from the ArcGIS 9.2 Network Analyst Service Area tool. Actual travel speeds and routing characteristics are derived from a national road database. The average road speeds throughout the fire response district are collected as supplemental information, during the initial fire department data acquisition phase. Detailed information about the national road database will be explained in the GIS data section below.

### **Additional Information**

In addition to fire department operational resource data, it is also important to obtain detailed information about the specific services the fire department provides and how they are administered. These services include, Fire Suppression, Fire Prevention & Fire Investigation, Emergency Medical Services, and Special Operations such as Domestic preparedness, technical rescue, hazardous materials response, and urban search and rescue.

### **GIS Data**

#### **Data conversion**

To perform this fire response capabilities analysis all the collected fire department data must exist in a format compatible to the GIS. Occasionally, a portion of the data received from the fire departments is already in GIS compatible files. All data that does not currently exist in a GIS compatible format must be created or converted into a GIS compatible format. When acquiring the fire department data, a GIS file is always preferred. If a GIS shapefile is not available the location information drawn on the submitted paper map can be converted to a GIS compatible shapefile. If a GIS compatible file is submitted, the local geographic projection information must be submitted for projection purposes. All of the road length calculations are done in local projected coordinates, but the geographic processing is performed in an un-projected coordinate system, the World Geodetic System 1984 (WGS84). The use of the WGS84 projection provides ease of geo-processing. Additionally, by using the WGS84 projection total processing time is significantly reduced and inherent projection compatibility is achieved with the road network dataset.

### **Fire Stations**

If the fire station locations are not provided in geographic file, they must be converted to a GIS compatible file, for which three manual conversion options are available. The first option is to create a shapefile using the referenced locations from the hand drawn map to a point shapefile. The second option is to import a list or digital file of the latitude and longitude (X-Y) coordinates to create a GIS point file. The third option is to geocode the fire station location, a process used to geographically reference a physical street address and

zipcode data along attributes of a road centerline. The fire station location can be verified by locating the cross street intersections.

### **Fire Response District Boundary**

If the fire response district boundary is not provided in geographic format, a GIS compatible file must be created. The detailed fire response district boundaries must be created from referenced locations on the acquired paper map or compiled from existing GIS data. The national commercial GIS file vendor provides various politically based jurisdictional boundaries that can be utilized to create the fire response district boundary.

### **Road Centerlines**

The road data utilized in this analysis is either obtained from a national commercial dataset or from a road centerline file provided by the fire department. The road centerline file selected for this analysis, to create the individual fire response coverage areas, is based on overall quality of the routing attributes. A more robust set of routing attributes provides a more accurate model of real world driving conditions and in turn models more accurate fire response capabilities. Typically the national road centerline dataset is utilized. The national road centerline dataset has a very good temporal update process and the amount of included routing attributes, generally surpasses the capabilities of a local GIS department. When using a road centerline file provided by a local jurisdiction with no routing attributes, routing can be performed with either road segment length or travel time, based on a generalized speed limits set across the entire fire response district, to calculate base line travel costs.

During the set up process many physical characteristics of the local jurisdiction, in addition to the fire department configuration, must be taken into account before the analysis is performed. These physical characteristics are associated with impact of the jurisdictional physical geography on transportation, in GIS terms the road network. The attributes of the street network must be able to model and compensate as closely as possible the physical characteristics of the fire department response area.

The commercial road centerline dataset has preset network routing attributes and the fire department provided road centerline dataset may or may not have encoded routing attributes. When using the national commercial encoded road centerline file with preset travel costs and turn restrictions, modeling travel along the fire response districts road is more accurate. The turn restriction attributes included in the national commercial road centerline file include the locations of underpasses and overpasses, models multi-level legal turns, and locations of restricted left turns and u-turns, as well as one-way streets. In addition to the turn restrictions, speed limit is a very important component to routing along a road network. The speed limit feature class in the national road centerline dataset is based upon the attribute table item, Feature Classification Code (FCC), based on road type, as assigned by the U.S. Census Bureau. In this study the response coverage areas are based on length of travel time. The travel time for each line segment is included in the data table.

## **GIS Methodology/Analysis**

### **Street Network Creation**

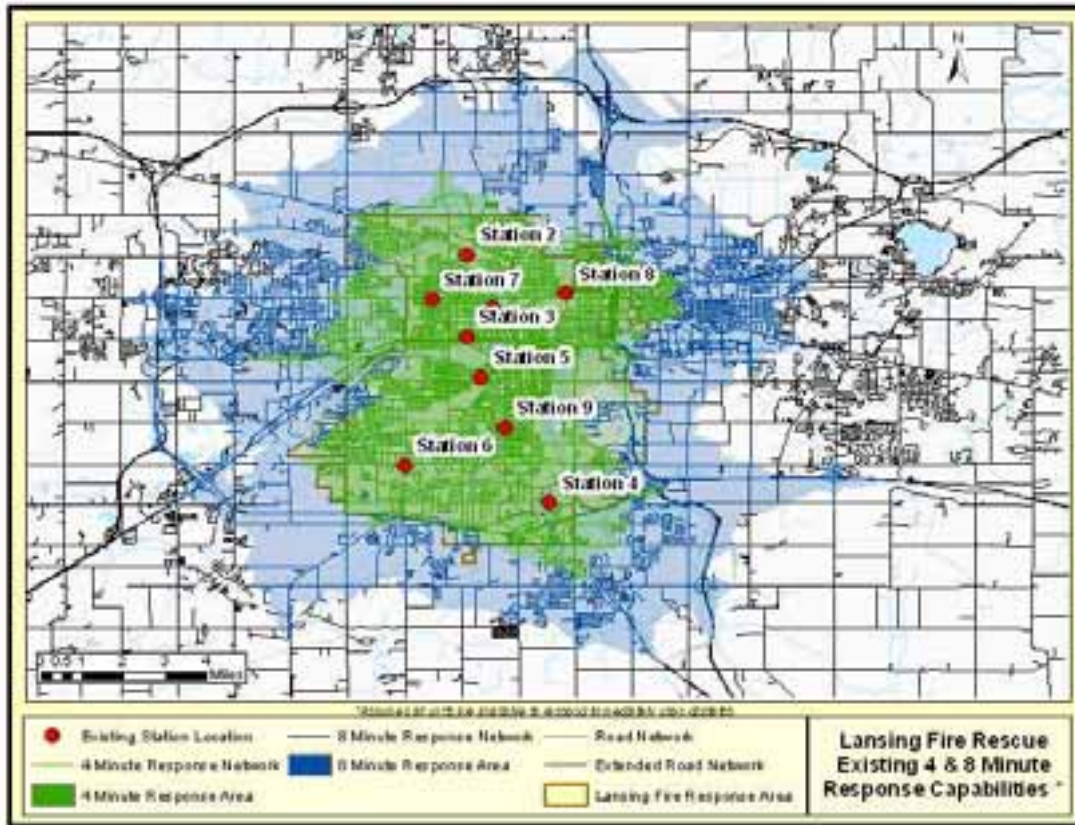
The creation of a network dataset, in ArcGIS ArcCatalog 9.2, derived from the road centerline file is necessary to create the response coverage areas in the ArcGIS ArcView 9.2 Network Analysis extension. The network dataset takes into account and contains all of the routing attributes and travel costs within the national commercial road centerline file. For the purpose of this analysis the network dataset contains travel costs in minutes and all applicable impedances including one-way streets and road class.

### **ArcGIS 9.2 Network Analyst – Service Area Generation**

Once the fire department data layers necessary for this analysis are in a GIS compatible format, and prepared for routing, the GIS processing can begin. With the fire department data components, fire station locations and the road centerlines, necessary for the response service area generation, the time-based response coverage areas are generated from ArcGIS 9.2 Network Analyst. The generated time-based response service areas represent the individual response capabilities of each fire station and associated roads within the fire response district. The individual fire station response coverage areas provide all of the necessary geographic components to determine the response capabilities of the apparatus companies and alarm configurations throughout the rest of this analysis.

The Network Analyst Service Area wizard, as seen in Figure 1 below, contains all the necessary options to create the individual 4 and 8-minute fire station response service coverage areas from a routable network dataset and fire station locations, facilities. The Network Analyst generated service area polygons represent the fire station response service areas calculated travel time from each fire station location within 4 minutes or 8 minutes. The Network Analyst generated service area lines represent the road centerlines a fire station can respond to within 4 or 8 minutes. The analysis settings for the service areas created are impedance cost in minutes, default breaks at 4 and 8-minute intervals. The individual polygon generated are generalized which overlap in disk format. The 4-minute and 8-minute response time service areas appear in the map below.

## MAP 1



Once the 4 and 8-minute response service area polygons and lines are generated and saved, each individual fire station service area polygon and line is saved in a separate shapefile. A comparison of the individual fire station service area polygons are compared to the associated fire station service area lines to determine whether or not the polygons have to be edited. More than likely the polygon has to be edited. The Network Analyst Service Area generation tool does not create service area polygon features that exactly match the service area line features. Typically there are portions of the individual fire station service area lines excluded or included from the geographic extent of the fire station service area polygons. The following map depicts the discrepancy between the geographic extents between the fire station service area polygon and of the fire station service area lines.



**MAP 2**



The following map depicts the modifications made to the fire station service area polygon so that the associated fire station service area lines are geographically coincident to the fire station service area polygon.

**MAP 3**



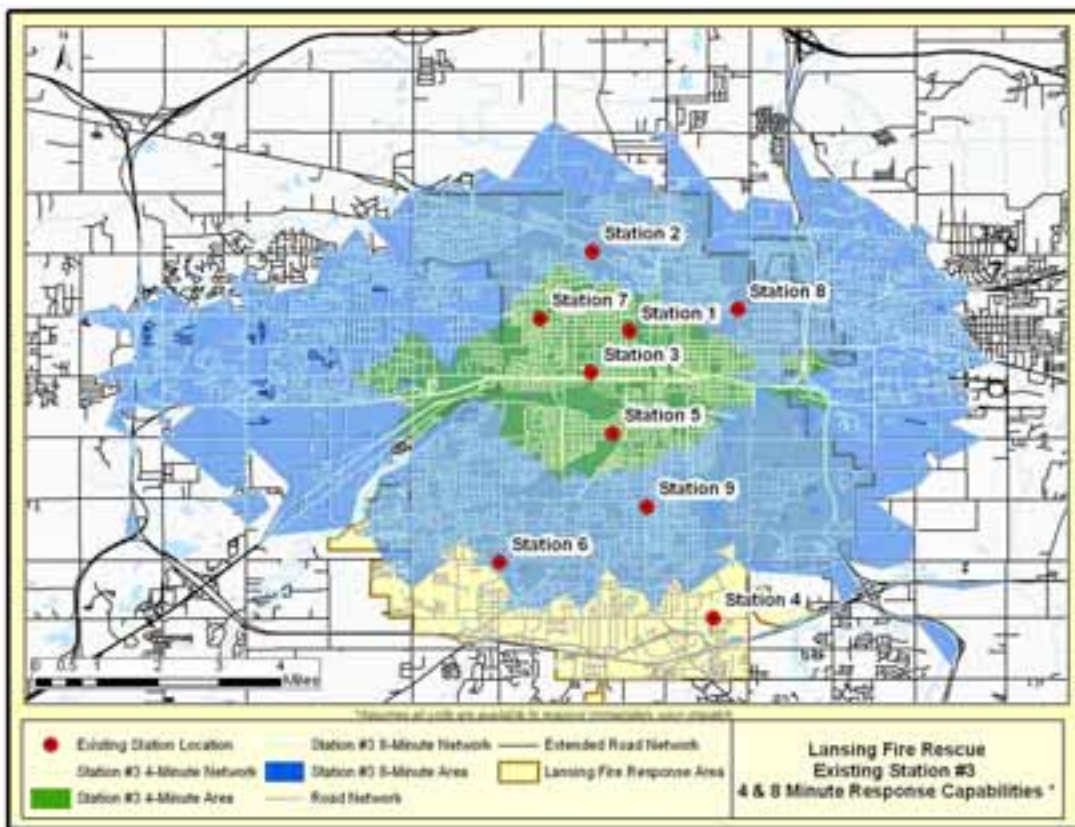
The utilization of the generalized polygon generation option within the Network Analyst provides the most appropriate generated polygons for the desired results. Using the detailed polygon generation option does not produce the desired results, and entailed extensive editing.

The Network Analyst Service Areas tool can also determine travel distance areas for fire service evaluation. A travel distance evaluation supports ISO standards fire apparatus

placement. The ISO standard defines the effective response distance for an engine company to be 1.5 miles and the effective response distance of a ladder company to be 2.5 miles. The ISO standards are based on travel distance instead of travel time; therefore, when using Network Analyst to generate the effective service response areas, length is selected instead of cost in time (minutes).

Once the calculated 4-minute and 8-minute response areas are saved, both the individual 4 and 8-minute fire station response areas are separated out by station. A total of 4 shapefiles comprises the total file complement for each fire station location. There are two polygon files and two service area network files for each time-based fire station service area. For example, the two files for the 4-minute fire station response service area are the 4-minute service area polygon and the 4-minute service area lines. The same files are copied out of the 8-minute service area file as well for the station. Map 4 below displays the 4-minute and 8-minute response area polygons and associated street network lines for Station #3 in the Lansing Fire Department.

MAP 4



The manipulation and analysis these individual fire station travel-time response coverage area polygons allows for the identification of the area covered by an individual apparatus from specific fire station within 4 and 8 minutes. With the individual 4 and 8-minute response coverage area polygons available, the response capability for each of the apparatus

companies as well as all the alarm configurations is possible. The response coverage areas aid in the identification of the existing response deficiencies within the fire department.

### **Fire GIS Modeling Assumptions**

Clarification of three influential factors, related to the ability of a GIS to accurately model fire service response capabilities, is necessary. These three factors include emergency call time stamp interpretation, routing impedances, and fire department specific factors. The first of these three influencing factor is the interpretation of emergency call time stamps. When attempting to analyze the temporal response capabilities of a fire department, it is important to specify the criteria for each individual component of response time. Each of the following emergency response time components needs to be taken into consideration before any apparatus or alarm configuration response analysis can be measured. The following table details the list of temporal call criteria components associated with emergency response.

**Table 4. Fire Response Time Components**

<b>Alarm Time</b>	“The point of receipt of the emergency alarm at the public safety answering point to the point where sufficient information is known to the dispatcher to deploy applicable units to the emergency.” (NFPA 1710, §3.3.37.1)
<b>Dispatch Time</b>	“The point of receipt of the emergency alarm at the public safety answering point to the point where sufficient information is known to the dispatcher and applicable units are notified of the emergency.” (NFPA 1710, §3.3.37.3)
<b>Turnout Time</b>	“The time beginning when units acknowledge notification of the emergency to the beginning point of response time.” (NFPA 1710, §3.3.37.5) Per NFPA 1710, turnout time should not exceed one minute. (NFPA 1710, §4.1.2.1)
<b>Response Time</b>	“The time that begins when units are en route to the emergency incident and ends when units arrive at the scene.” (NFPA 1710, §3.3.37.4)

### **Routing Assumptions**

In addition to the response time components many routing assumptions also have to be taken into consideration. When using an encoded road centerline file for routing purposes several assumptions need to be taken into consideration before any response measuring conclusions can be drawn. Clarification on the many routing variables and limitations embedded in the routing data are important as well. First and foremost, the travel speeds used to create the travel costs are modeled on posted road speeds. The physical limitations of the various vehicles responding are a factor. For example, a Battalion Chief can respond at much higher rate than an engine full of water. Traffic conditions as well are a factor and typically unpredictable and fluctuate throughout the day. The capabilities of the current routing software provide a snapshot of a single routing condition, a static model of the real world.

To dynamically model the real world, multiple scenarios are necessary and many other variables must be incorporated. Table 5 details the unpredictable routing impedances not incorporated into this routing evolution.

**Table 5. Unpredictable Routing Impedances (IAFF Report)**

<b>Traffic Incidents</b>	Collisions and vehicle breakdowns causing lane blockages and driver distractions
<b>Work Zones</b>	Construction and maintenance activity that can cause added travel time in locations and times where congestion is not normally present
<b>Weather</b>	Reduced visibility, road surface problems and uncertain waiting conditions result in extra travel time and altered trip patterns.
<b>Demand Changes</b>	Traffic volume varies from hour-to-hour and day-to-day and this causes travel time, crowding and congestion patterns to disappear or to significantly worsen for no apparent reason in some locations.
<b>Special Events</b>	Identifiable case of demand changes where the volume and pattern of the change can frequently be predicted or anticipated.
<b>Traffic Control Devices</b>	Poorly timed or inoperable traffic signals, drawbridges, railroad grade crossing signals or traveler information systems contribute to irregularities in travel time.
<b>Inadequate Road or Transit Capacity</b>	The interaction of capacity problems with the aforementioned sources causes travel time to expand much faster than demand. (Shrank & Lomax)

**Fire Service Response Factors (IAFF Report)**

In addition to the response time components and unpredictable routing impedances, fire service variables must be taken into consideration as well. The fire service variables include the availability of emergency response resources. For example, modeling the response time of call back personnel to arrive at a fire station or respond with private vehicles is a dynamic factor. The variability of other factors such as dispatch time, unit availability, and staffing cannot be modeled either. This analysis assumes that the emergency fire response apparatus are always ready and fully staffed in their fire stations when dispatched. This analysis cannot compensate for additional response times due to the inaccessibility of a specific fire location. These factors cannot be taken into consideration when predicting emergency response capabilities in this analysis. The results of this analysis are based solely on the quality and completeness of the geographic data provided.

**Response Capability Evaluation**

A comprehensive understanding of a fire department’s resources including overall shift staffing, apparatus, and alarm configurations. The comprehensive understanding of fire department resources allows for the proper modeling of a fire departments standards of response coverage. Defined as the “written procedures that determine distribution and concentration of fixed and mobile resources”, the Standards of Response Cover (SORC)

model provides the basis for evaluating fire department system performance (Moore). The two main components of the SORC are the distribution and concentration of fire department resources. Determination of the standards of response cover for a fire department, incorporating the above assumptions, involves the evaluation of the individual fire station response service areas and deployment data.

The individual fire station and apparatus company response capabilities allow for the identification of the existing response coverage deficiencies, within the apparatus company and the current fire department configurations, as well as in the overall fire department configuration response capabilities. The individual apparatus company response capabilities and deficiencies provide the basic components for system wide performance evaluations and identifying their roles in structural fire fighting response operations and emergency medical services. The individual apparatus company response capability provides the necessary structure to determine the capabilities of the alarm configurations.

This study evaluates the 4-minute and 8-minute response capabilities of all staffed apparatus companies, the alarm configurations, and measures the level of compliance with NFPA 1500 OHSA “2 In/ 2 Out” and NFPA 1710 response and staffing standards, based on fire department configurations. The fire department data utilized in this analysis consists of the distribution and allocation of fire department operational resources. The response coverage areas are derived from the station locations, apparatus allocation and staffing, local road networks, and alarm configuration data obtained from the fire department. The Lansing, Michigan Fire Department configuration data, released by Local 421 of the International Association of Fire Fighters (IAFF), Lansing Fire Fighters Association, provides a real world demonstration of SORC measurement capabilities within this analysis.

The 4-minute response capabilities of an apparatus company are calculated by merging and dissolving all the individual 4-minute response area polygons for the individual fire stations, that house and staff a specific apparatus type. Once the polygon representing the total service response coverage area is calculated all of the coincident road network lines are identified and measured against the total length of roads within the fire response district, by percentage. For example, the individual 4-minute service response polygons for the Lansing Fire Department stations that deploy staffed Medic Units will be used. In the Lansing Fire Department fire stations, #1, #6, and #9, deploy staffed Medic Units. Map 5 is an example of the 4-minute Medic Unit response coverage area, representing the response capabilities, for the Medic Units within the Lansing, Michigan Fire Department.

## MAP 5



The Lansing Fire Department Medic Units are capable of responding to 65.07% of all roads located within the Lansing Fire District in 4 minutes or less, assuming the units are available to respond immediately upon dispatch. The individual apparatus company response capabilities identify the existing response coverage deficiencies for an apparatus company, within the current fire department configuration. The individual apparatus company response capabilities and deficiencies are important in identifying their roles in structural fire fighting response operations and emergency medical services.

The importance of the 4-minute Company response in structural fire fighting operations is enormous. The NFPA 1710 Standard recognizes the criticality of rapid fire department response, by stating the response time objective as “4 minutes or less for the arrival of the first arriving engine company at a fire suppression incident.”(NFPA 1710, §4.1.2.1 (2)) Section 5.2.2.1 of the NFPA 1710 states that fire suppression personnel shall be comprised of the numbers necessary for fire-fighting performance relative to the expected fire-fighting conditions. “These numbers shall be determined through task analyses that take the following factors into consideration:

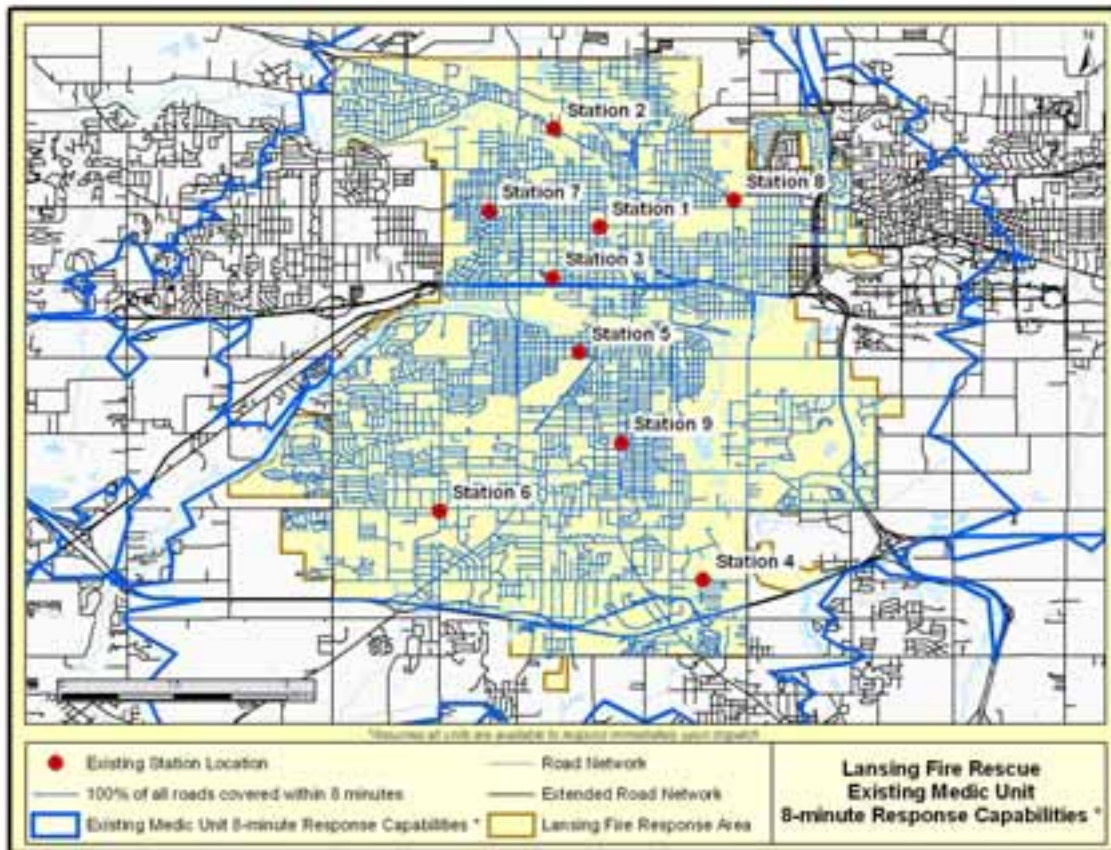
**Table 6. Staffing Factors (NFPA 1710, §5.2.2.1)**

Life hazard to the populace protected
Provisions of safe and effective fire-fighting performance conditions for the fire fighters
Potential property loss
Nature, configuration, hazards, and internal protection of the properties involved
Types of fire ground tactics and evolutions employed as standard procedure, type of apparatus used, and results expected to be attained at the fire scene.”

NFPA 1710 Standard also stresses the importance of the 4-minute Company response in the provision of Emergency Medical Services by stating a “fire department shall establish the response time objectives of 4 minutes or less for the arrival of a unit with first responder or higher capability at an emergency medical incident”(NFPA 1710, §4.1.2.1 (3)). In compliance with NFPA Standard 1710, Section 4.3.2, details that “The fire department... shall ensure that the fire department's emergency medical response capability includes personnel, equipment, and resources to deploy at the first responder level with automatic external defibrillator (AED) or higher treatment level” (NFPA 1710, §4.3.2).

The same analytical geographic process utilized to determine the 4-minutes service response capabilities, is employed to determine the 8-minute service response capabilities for the apparatus groups within a fire department. The following map is an example of 8-minute response capabilities for a Lansing Fire Department apparatus group, the Medic Units.




MAP 6



The Lansing Fire Department Medic Units are capable of responding to 100% of all roads located within the Lansing Fire District in 8 minutes or less, assuming the units are available to respond immediately upon dispatch. The details regarding the importance of the 8-minute Company response capabilities in the providing Emergency Medical Services, appears in the Eisenberg Model for Cardiac Arrest Survival Prediction. The Eisenberg Model supports Journal of the American Medical Association findings concluding “two-tier systems in which the first responders are trained in early defibrillation are most effective in providing rapid Advanced Cardiac Life Support” (JAMA). Table 7 below detail the effect of emergency response on patient survival.



**TABLE 7:  
“EFFECT OF EMERGENCY CARE RESPONSE TIMES ON  
CARDIAC PATIENT SURVIVAL RATES” (LARSEN)**

<b>Fire Dep't. Response Time</b>	<b>Initiation of CPR</b> 	<b>Time to Defibrillation</b> 	<b>Time to Advanced Cardiac Life Support (ACLS)</b> 	<b>Predicted Survival Rate/ All Cardiac Arrest (percentages)</b>
9 minutes	10 minutes	11 minutes	13 minutes	4.6%
4 minutes	F.D. EMT: 5 minutes	11 minutes	12 minutes	18.2%
4 minutes	F.D. EMT: 5 minutes	F.D. EMT-D: 6 minutes	11 minutes	25.8%
<b>4 minutes</b>	<b>F.D. EMT: 5 minutes</b>	<b>F.D. EMT-D: 6 minutes</b>	<b>F.D. Paramedic: 7 minutes</b>	<b>34.3%</b>

The importance of the 8-minute Engine Company response capabilities in structural fire fighting operations is limited to “flashover”, (the very rapid spreading of the fire due to super heating of room contents and other combustibles, generally occurs in less than 10 minutes (IAFF). To provide swift response the NFPA 1710 standard states that “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” (NFPA 1710, §5.2.3.2 and §5.2.3.2.1).

The response capabilities of the individual apparatus companies form the basis from which each fire department alarm configuration is determined. Two types of alarm configurations included in this study are unique fire department specific emergency response alarm configurations and alarm configuration detailed within the NFPA 1710 Standard.

**The Role of the National Fire Protection Association (IAFF)**

“The recommendations and analysis contained in this study are guided by NFPA standards for two important reasons. First, NFPA standards provide fire departments with a measure of “interoperability.” Interoperability enables fire service personnel in the chain of command to speak the same language and conform to the same operational guidelines. NFPA standards provide the fire service with a common language, common definitions, and common requirements that are meant to foster the safe and effective delivery of fire suppression, rescue, EMS, and special services to a given community. Second, NFPA standards are formulated via consensus development. Development of NFPA standards are the result of scientific research, empirical studies, and consensus among technical experts and the organizations they are affiliated with. Combined, these factors legitimate NFPA standards as the yardstick by which fire departments are measured internationally”.

The purpose of NFPA 1710, Standard for the Organization and Deployment of Fire Suppression Operations, Emergency Medical Operations and Special Operations to the Public by Career Fire Departments, is “to specify the minimum criteria addressing the effectiveness and efficiency of the career public fire suppression operations, emergency medical service, and special operations delivery in protecting the public of the jurisdiction and the occupational safety and health of fire department employees” (NFPA 1710, § 1.2.1).

#### **NFPA 1710 and GIS Analysis (IAFF)**

“The NFPA 1710 Standard is important because it applies the documented and proven science of fire behavior and emergency medicine to the basic resource requirements for effective fire and emergency service deployment. Coupled with GIS analysis, this application allows a community to determine if the resources allocated for the different types of fires, emergencies, medical calls and other incidents are sufficient to effectively control the incident and protect lives and property. NFPA 1710 sets forth in concise terms the recommended resource requirements for fires, emergencies and other incidents. The standard requires, and GIS analysis facilitates, the emergency response organization to evaluate its performance and report it to the authority having jurisdiction. The approach embodied by NFPA 1710, and supported by GIS analysis, makes communities and fire fighters safer and responders more effective and enhances efficiency.”

The NFPA alarm configurations calculated and evaluated in this study are included from two different Standards, 1500 and 1710, and one alarm configuration from the NFPA Fire Protection Handbook for incident response and staffing. The alarm configuration evaluated from the NFPA 1500 Standard is an interpretation of the OSHA “2 In/2 Out” regulation. The alarm configurations from the NFPA 1710 Standard evaluate the capability of a fire department to respond to an “Initial Full Alarm” with fifteen or seventeen fire fighters. The alarm configuration from the NFPA Fire Protection Handbook, the NFPA Initial Attack Alarm evaluates the capabilities of a fire department to respond with a total complement of twenty-six fire fighters, for high-risk occupancies.

To initiate a safe attack on a fire, a total of four fire fighters are necessary. The allocation of the four fire fighters provides the proper resources for two fire fighters inside the structure and two fire fighters available to provide necessary backup. The four fire fighter configuration mentioned is known as the “2 In/2 Out” regulation, derived from OSHA CFR 1910.134.

The description of the OSHA “2 In/2 Out” regulation as quoted from the IAFF GIS Report is:

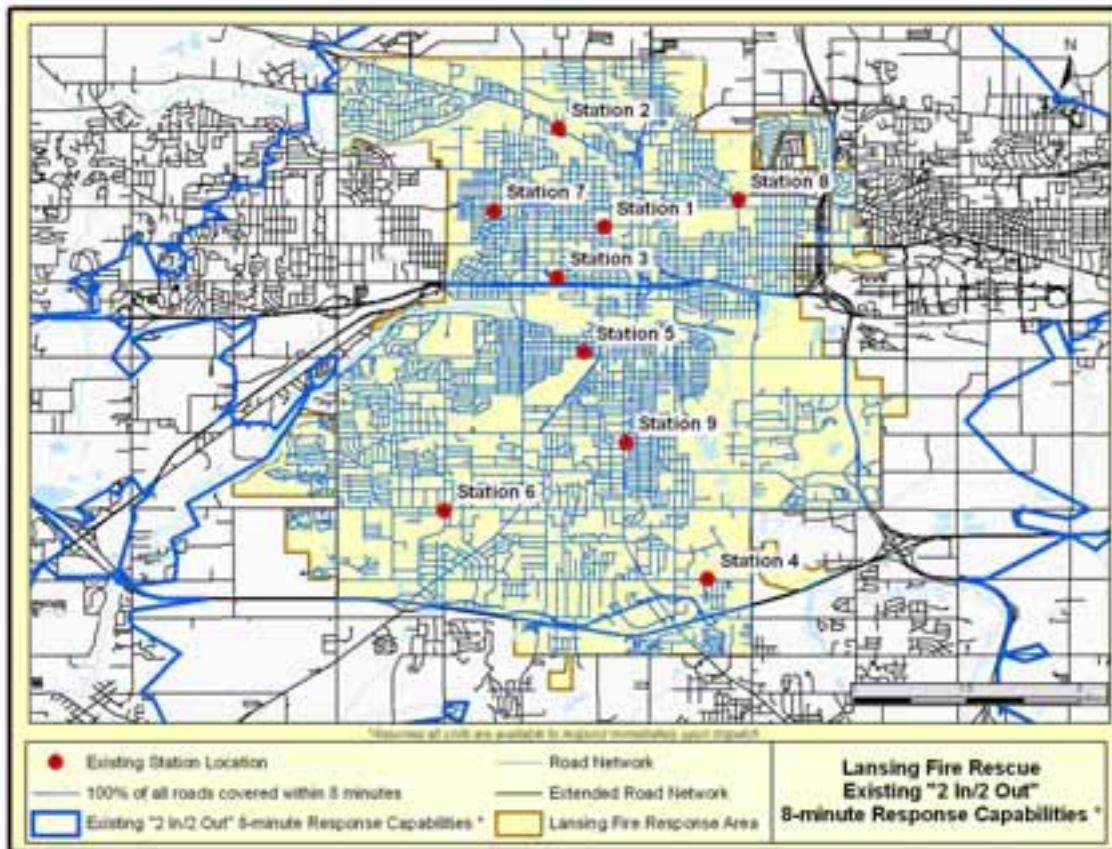
“The “2 In/2 Out” regulation requires that, at a minimum, a crew of four is required to make a safe initial attack on a fire, with a crew of two working inside the burning structure and a backup crew of two standing by to assist as necessary. On the scene of a fire the driver/operator of a ladder truck must remain with the apparatus to safely operate the aerial device. The remaining crew a ladder company is responsible for attacking the fire and/or complete

search and rescue activities. Therefore, a truck company activities initiated by a short staffed single ladder company would not be in compliance with the “2 In/2 Out” regulation until a second fire suppression company arrives and is available to assist the first company in the event of an unexpected emergency.” (OSHA, IAFF).

NFPA 1500 states, “while members can be assigned and arrive at the scene of an incident in many different ways, it is strongly recommended that interior fire fighting operations not be conducted without an adequate number of qualified firefighters operating in companies under the supervision of company officers. It is recommended that a minimum acceptable fire company staffing level should be four members responding on or arriving with each engine and each ladder company responding to any type of fire.”

The following map is an example of the capability of the Lansing Fire Department to initiate safe and effective fire suppression and rescue operations in accordance with the “2 In/2 Out” regulation within 8-minutes.

MAP 7

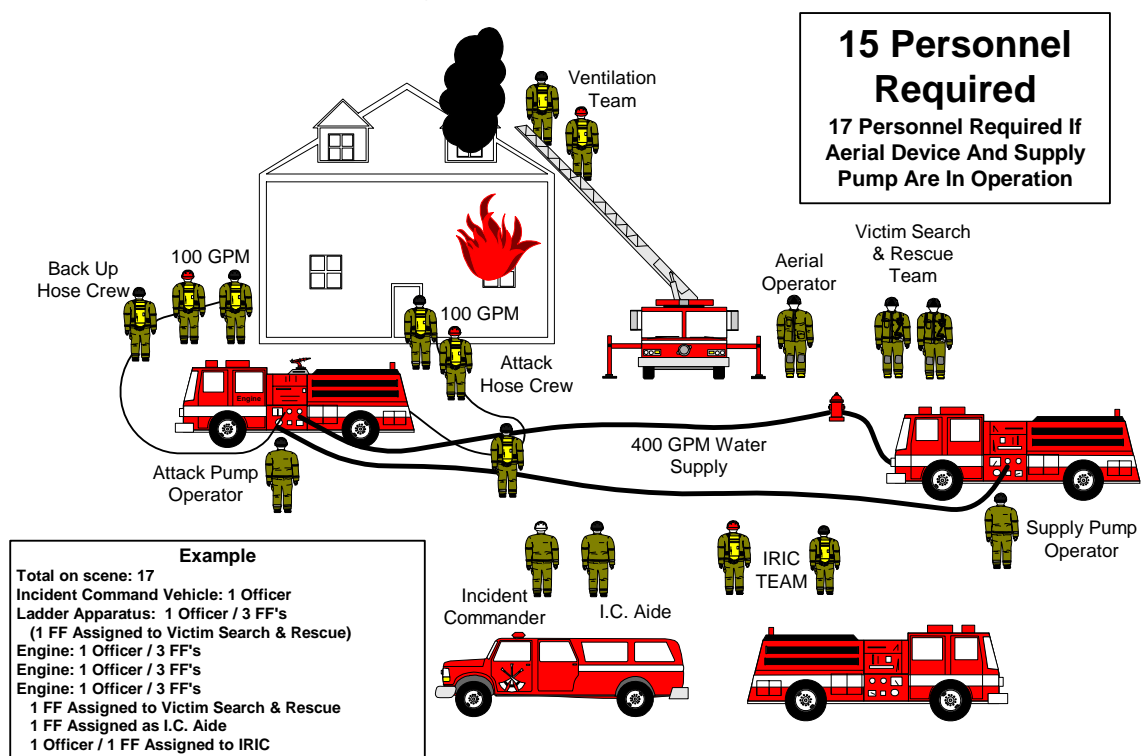


Under these conditions, when fire department units are responding from their assigned fire stations, it is predicted that the Lansing Fire Department is capable of initiating fire suppression and rescue operations in accordance with the “2 In/2 Out” regulations on 100%

of all Fire District roads within 8 minutes, assuming the units are available to respond immediately upon dispatch.

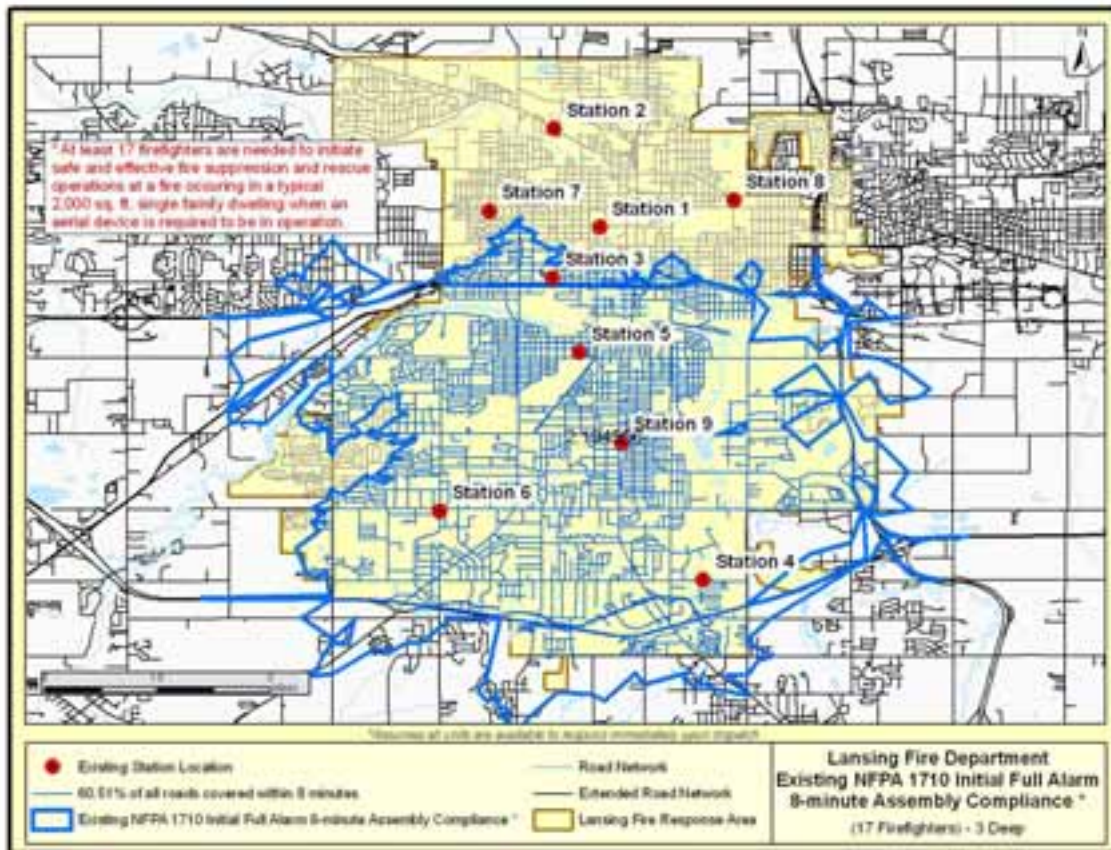
The “Initial Full Alarm” Assignment Capability detailed in the NFPA Standard 1710 sections 5.2.4.2.1 and 5.2.4.2.2 requires a minimum staffing of fifteen fire suppression personnel, within 8 minutes of receiving the alarm to arrive at the scene of a structure fire. Figure 1 below illustrates the “Initial Full Alarm” Assignment staffing as required in section 5.2.3.2.2 of the NFPA 1710 Standard.

**Figure 1 (IAFF Fire & EMS Operations/EMS Department)**  
**5.2.3.2.2 Initial Full Alarm Assignment Capability**  
**Deployed Within 8 Minutes**



The NFPA 1710 “Initial Full Alarm” configuration for the Lansing Fire Department is calculated with all fire department staffed response apparatus resources. The alarm configuration is derived by intersecting the all individual fire station response service areas, attributed with the total number of available fire fighters, until a total of seventeen fire fighters can be assembled. Map 8 is an example of NFPA 1710 “Initial Full Alarm”, when an aerial device is needed, calculating service response capabilities of the Lansing Fire Department when responded with all personnel, when responding with seventeen fire fighters.

## MAP 8



Utilizing all apparatus and personnel in all stations, it is predicted that 60.51% of all Lansing Fire District roads currently receive a sufficient number of fire suppression personnel within 8 minutes of receiving an alarm to comply with NFPA Standard 1710, assuming all units are fully staffed at existing staffing levels and available to respond immediately upon dispatch. NFPA 1710 states that “the fire department’s fire suppression resources shall be deployed to provide for the arrival of an engine company within a 4-minute response time and/or the initial full alarm assignment within an 8-minute response time to 90% of the incidents.”

In addition to Initial Full Alarm Assignment Capability, as outlined in NFPA Standard 1710, the NFPA also outlines the ‘Typical Initial Attack Response Capabilities Assuming Interior Attack and Operations Command Capabilities.’ Figure 2 details the parameters, such as recommended apparatus and personnel, for various occupancy types related to the ‘Typical Initial Attack Response Capabilities Assuming Interior Attack and Operations Command Capabilities’ from the NFPA Fire Protection Handbook.

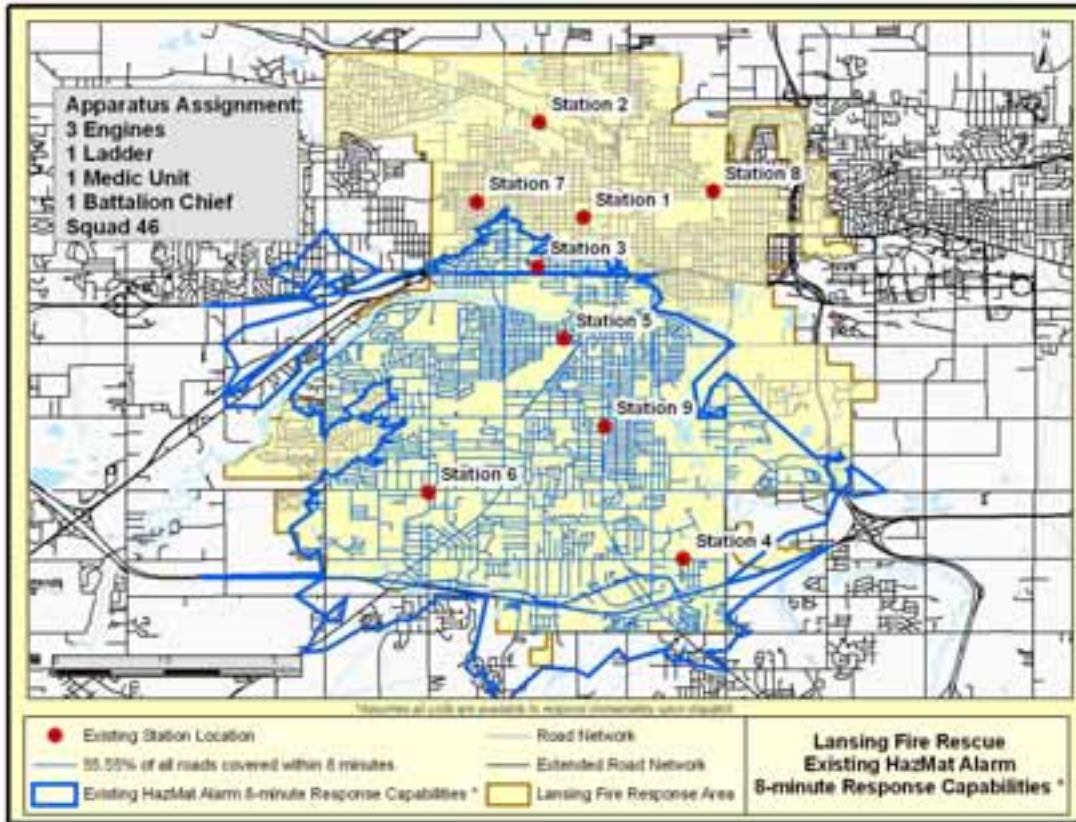
**FIGURE 2: (NFPA)  
 “Typical Initial Attack Response Capabilities Assuming Interior Attack and  
 Operations Command Capabilities”**

<p><b>High-hazard</b></p> <p><b>Type of Occupancy</b></p> <ul style="list-style-type: none"> <li>• Schools</li> <li>• Hospitals</li> <li>• Nursing Homes</li> <li>• Explosives Plants</li> <li>• Refineries</li> <li>• High-Rise Buildings</li> <li>• Other high life hazard or large fire potential occupancies.</li> </ul> <p><b>Apparatus Needed</b></p> <ul style="list-style-type: none"> <li>• 4 Pumpers</li> <li>• 2 Ladder Trucks (or combination apparatus with equivalent capabilities)</li> <li>• 2 Chief Officers</li> <li>• Other Specialized Apparatus as may be needed to cope with the combustible involved.</li> </ul> <p><b>Personnel</b></p> <ul style="list-style-type: none"> <li>• 24 Fire Fighters, no fewer</li> <li>• 2 Chief Officers</li> </ul>
<p><b>Medium-hazard</b></p> <p><b>Type of Occupancy</b></p> <ul style="list-style-type: none"> <li>• Apartments</li> <li>• Offices</li> <li>• Mercantile and Industrial</li> </ul> <p><b>Apparatus Needed</b></p> <ul style="list-style-type: none"> <li>• 3 Pumpers</li> <li>• 1 Ladder Trucks (or combination apparatus with equivalent capabilities)</li> <li>• 1 Chief Officer</li> <li>• Other Specialized Apparatus as may be needed to cope with the combustible involved.</li> </ul> <p><b>Personnel</b></p> <ul style="list-style-type: none"> <li>• 16 Fire Fighters, no fewer</li> <li>• 1 Chief Officer</li> </ul>
<p><b>Low-hazard</b></p> <p><b>Type of Occupancy</b></p> <ul style="list-style-type: none"> <li>• One, two, or three-family dwellings</li> <li>• Small Business</li> <li>• Small Industrial Occupancies</li> </ul> <p><b>Apparatus Needed</b></p> <ul style="list-style-type: none"> <li>• 2 Pumpers</li> <li>• 1 Ladder Truck (or combination apparatus with equivalent capabilities)</li> <li>• 1 Chief Officer</li> <li>• Other Specialized Apparatus as may be needed to cope with the combustible involved.</li> </ul> <p><b>Personnel</b></p> <ul style="list-style-type: none"> <li>• 12 Fire Fighters, no fewer</li> <li>• 1 Chief Officer</li> </ul>

The NFPA “Initial Attack” alarm configuration for the Lansing Fire Department is calculated with all fire department staffed response apparatus resources. The alarm configuration is calculated by intersecting the each individual fire station response service (polygons) areas, attributed with the total number of available fire fighters, until a total of twenty-six fire fighters can be assembled.

Unique alarms are also included in this study. A unique alarm for the Lansing Fire Department is the Hazardous Materials Alarm with a unique complement of response apparatus. The total response apparatus complement includes three engine companies, one ladder company, one medic unit, one battalion chief, and Squad 46. The alarm configuration is calculated by intersecting the appropriate combination of individual apparatus group response service areas (polygons). Map 10 is an example of Hazardous Materials alarm in the Lansing Fire Department.

MAP 10



Under these conditions, when fire department units are responding from assigned fire stations, it is predicted that the Lansing Fire Department is capable of responding to a Hazardous Materials Alarm on 55.55% of all Fire District roads within 8 minutes, assuming the units are available to respond immediately upon dispatch.

### IAFF Suggested Enhancements

In addition to the existing configuration of the fire department, an IAFF suggested configuration is included as well, and potentially a set of proposed scenarios, resulting from either fire department or local government suggested modifications. The IAFF suggested configuration calculates the response capabilities of the fire department with all apparatus and fire stations staffing at NFPA Standard 1710 levels. Typically all apparatus staffing is increased. The following section details the staffing levels required by the NFPA Standard 1710.

## **NFPA Staffing Requirements**

The National Fire Protection Association (NFPA) provides organizational and operating standards for the fire service. These standards in NFPA 1710 Standard recommend organizational and operating benchmarks for fire departments. NFPA 1710, Standard for the Organization and Deployment of Fire Suppression Operations, Emergency Medical Operations, and Special Operations to the Public by Career Fire Department has specific recommendations for staffing applicable to this analysis. The several aspects of the NFPA 1710 standard are incorporated into the IAFF suggestions used to determine appropriate staffing levels. The following staffing recommendations are derived from the NFPA 1710 Standard.

### ➤ **Engine & Trucks**

When making recommendations for minimum engine staffing the NFPA Standard 1710 recommends “fire companies, whose primary functions are to pump and deliver water and perform basic fire fighting at fires, including search and rescue... shall be staffed with a minimum of four on-duty personnel” (NFPA 1710, §5.2.3.1 and §5.2.3.1.1).

### ➤ **Truck**

When making recommendations for minimum truck staffing the NFPA Standard 1710 recommends “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 personnel” (NFPA 1710, §5.2.3.2 and §5.2.3.2.1).

### ➤ **Quint**

When making recommendations for minimum quint staffing the NFPA Standard 1710 recommends “fire companies that deploy with quint apparatus designed to act as either an engine company and/or a ladder company shall be staffed as specified in 5.2.3.4. 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 safely, effectively, and efficiently” (NFPA 1710, §3.3.5.2 and §5.2.3.4.2).

### ➤ **Supervisory Chief Officers**

When making recommendations for minimum supervisory chief vehicle staffing the NFPA Standard 1710 recommends, “supervisory chief officers shall be dispatched or notified to respond to all full alarm assignments. The supervisory chief officer shall ensure that the incident management system is established as required in Section 6.2” (NFPA 1710, §5.7.4.2.4 and § 5.7.4.2.3). NFPA Standard 1710, Section 5.2.2.2.5, states that, “supervisory chief officers shall have staff aides deployed to them for purposes of incident management and accountability at emergency incidents.”

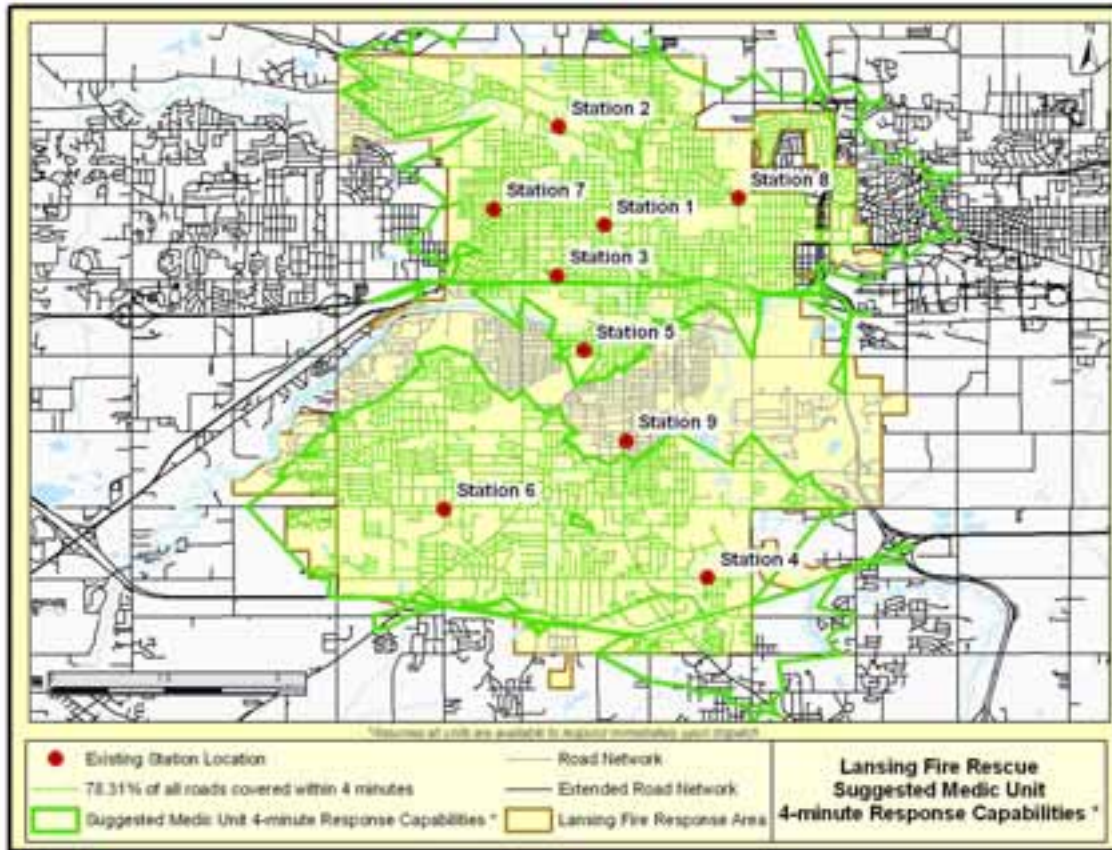
“The unavailability of fire department units, or inadequate staffing levels on those units, exposes citizens to increased risk, drains limited fire department resources, and stresses the emergency response system by requiring additional apparatus to respond with an additional number of personnel. Independent



studies performed by private consultants, industry trade groups, emergency service associations and individual fire departments across the United States and Canada all validate similar findings: adequately staffed fire suppression companies responding in a timely fashion are able to initiate and perform emergency scene operations more safely, more effectively, and with greater success than under-staffed companies” (IAFF).

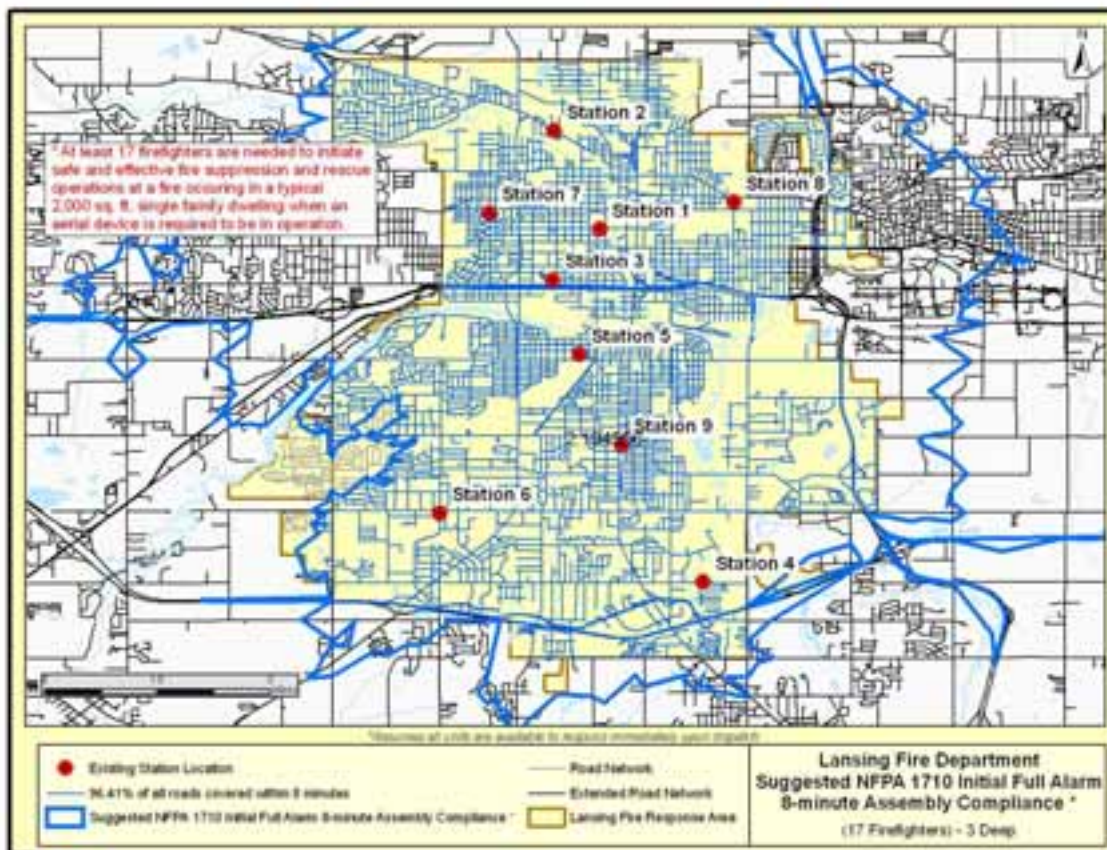
Map 11 is an example of the increased response capabilities of the Medic Units within the Lansing Fire Department after the implementation of NFPA Standard 1710 required staffing.

MAP 11



Map 12 is an example of the increased response capabilities of the NFPA “Initial Full Alarm” within the Lansing Fire Department after the implementation of NFPA Standard 1710 required staffing.

## MAP 12



### Enhancement Conclusions (IAFF)

Even by increasing staffing to industry standards, improving overall response capabilities within the fire department and across the fire district, the response coverage could still be improved upon. Additional apparatus and staffing would help improve emergency response capabilities, and these additions are necessary to facilitate an increase in the “2 In/ 2 Out”, 8-minute Initial Full Alarm, NFPA 1710 staffing 15 + 17 response capabilities.

While it is impossible to predict where most of a jurisdiction’s fire and medical emergencies will occur, a fire department should examine where emergencies have typically occurred in the past and make efforts to ensure these areas continue to enjoy the same level of coverage, while adjusting resources and deployment in an effort to achieve complete compliance with NFPA Standard 1710. Areas with accelerated development and 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.

In addition, a fire department should be designed to adequately respond to a number of emergencies occurring at once in a fashion that aims to minimize the loss of life and the loss of property that the fire department is charged with protecting. Any proposed changes in staffing, deployment and fire 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 national 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.

The business of providing emergency services has always been labor intensive, and remains so to this day. Although new technology has improved firefighting equipment and protective gear, and has led to advances in modern medicine, it is the fire fighters who still perform the critical tasks necessary to contain and extinguish fires, rescue trapped occupants from a burning structure, and provide emergency medical and rescue services. When staffing falls below minimum acceptable levels so does service; at this point, the goals and expectations set by the community are essentially abandoned. The staffing deficiencies that prevail within a fire department are illustrative of this condition.

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

The ramifications of staffing reductions as they pertain to the loss of life and property within a community are essential when considering modifications to a fire department's deployment configuration. While it is impossible to predict where most of a jurisdiction's fire and medical emergencies will occur, the fire department should examine where emergencies have typically occurred in the past and make efforts to ensure these areas continue to enjoy the same level of coverage, while adjusting resources and deployment in an effort to achieve complete compliance with NFPA Standard 1710. Areas with accelerated development and 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.

In addition, a fire department should be designed to adequately respond to a number of emergencies occurring at once in a fashion that aims to minimize the loss of life and the loss of property that the fire department is charged with protecting. Any proposed changes in staffing, deployment and fire 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 national 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.

In this manner, GIS allows public safety personnel to effectively plan for emergency response, determine mitigation priorities, analyze historical events, and predict future events. GIS can also be used to provide critical information to emergency responders upon dispatch or while en route to an incident to assist in tactical planning.

The deliverable report produced combines the data received from the fire department, software created response capability maps, references to accepted fire fighting practices, and national standards, including NFPA 1710. The results of the analysis allows public safety personnel to effectively plan for emergency response, determine mitigation priorities, analyze historical events, predict future events, and provide critical information to emergency responders.

### **Acknowledgements:**

The entire IAFF Fire & EMS Operations/GIS for compiling the content of Geographic Information System (GIS) Fire Suppression and Emergency Medical Services Response Capabilities Analysis report.

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