GIS for the Fire Service

An Esri® White Paper
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Introduction

The fire service mission requirements of saving life and protecting property have become increasingly complex in the twenty-first century. Fire professionals are finding that they need to be more strategic in the use of technology to successfully overcome challenges. Geographic information systems (GIS) have surfaced as a pivotal technology that enables better planning and action for both strategic and tactical needs.

For more than a decade, GIS has helped fire departments reduce risk, increase efficiency, and improve outcomes. Now, more than ever before, fire service executives and information technology professionals are discovering new and creative ways to apply this proven technology to solve ever-increasing fire service demands.

GIS is a powerful information management system with a unique ability to collect, analyze, and visualize information based on location. Because so much of the fire service mission is location dependent (emergencies always happen at a place or location), GIS has emerged as an important component of information platforms built to support fire service organizations.

This white paper explains key characteristics of GIS, describes how GIS applies to the fire service, and provides guidance on the most important aspects of a successful GIS implementation.

More Than a Map: GIS Fundamentals

Many people think of GIS as a mapmaking software tool. GIS is certainly used for map production. However, GIS is a scalable, standards-based technology platform. GIS technology works on desktop computers, in server environments, on mobile devices, and in the cloud. GIS provides powerful spatial analysis that enables the user to effectively solve problems and make better decisions. For the fire service, it is used to help meet mission requirements at every level of the organization, from frontline responders to midlevel and senior-level commanders to fire chiefs.

Today, GIS has the ability to retrieve large amounts of data maintained by agencies and organizations outside the fire service. GIS allows fire staff to access and integrate diverse datasets maintained by outside organizations. This enables personnel to access and fuse these datasets with existing preplanning, incident, and other fire data. Complex analysis and modeling can be performed to predict, monitor, and model service delivery based on call history. This information can also be shared with other stakeholders through various means of data sharing.

Two key principles make GIS a technology platform uniquely well suited to public safety:

- GIS is layer-centric.
- Geography is key.

GIS Is Layer-Centric

GIS provides the ability to take a layer-centric approach to managing, creating, analyzing, and visualizing data. A GIS creates a map by stacking layers of different information—aerial imagery, streets and highways, fire districts and station locations—on top of one another like acetate map sheets. This creates an accurate information picture and an analytical framework for an area of interest. Any digital map is actually a collection of these layers. The first layers on a map are almost always things like political boundaries, large natural features like water and mountains, and common infrastructure features like roads. These collections of data are called basemaps; they are frequently referred to by descriptive names, like *street maps* or *topographic maps*.

GIS technicians often design and compile these basemaps for others. Basemaps are the foundation for other layers containing information about *features*, such as fire stations, vehicles, hydrants, or hazardous material locations. GIS can then represent all the features that exist in a specific area of interest in layouts designed for different purposes and people. It provides the members of the fire service with a visual or mapcentric approach to bringing information together for situational awareness or other specific needs. It supplies a map view of real-time data in the vehicle, on a mobile device, or in the command center, enabling users to make quick assessments and act with the best available information. It also provides a complete map-based analysis framework that enables users to ask complex questions of the data.

Geography Is Key

GIS has the ability to manage physical features that are geographically referenced, such as those that have a physical address or a latitude-longitude grid reference. This ability to store the data's physical geography gives GIS the unique ability to index and sort otherwise disparate data.

GIS combines the geocentric layering described above with the power of a traditional database. Fire personnel can use GIS to query an unlimited number of characteristics, or *attributes*, in the data. With GIS, the layers of data all stay attached to the original tabular data maintained in and accessed from the database. Much like the columns of data in a spreadsheet, GIS allows people to add any attribute to any feature. For example, the way to track inspection dates on fire hydrants is simply to include a field, or an attribute, called "inspection date" in the database. Combined with the first two principles (layering and geographic referencing), this ability to query unlimited attributes provides a powerful construct for modeling or accessing very detailed data about a feature on the map.

Powerful Tools for Fire

Geography makes it possible to focus on an area of interest. Relationships between layers of information within an area of interest quickly reveal patterns. These two features make GIS well suited for the public safety mission. Two common fire service uses of GIS demonstrate this well: map production and response time analysis.

Map Products: Wall Maps, Run Books, and Preplans

GIS improves the ability to create maps through its cartographic tools and data integration capabilities. Wall maps, run book series, and preplans are all examples of map products that can be produced and updated quickly and accurately using GIS.

To create a large-format wall map, fire department staff starts with basemap data showing jurisdictional boundaries, streets, and bodies of water. GIS technicians can add any specialized or detailed local information based on need or task. Depending on the size of the community and the purpose of the map, additional information layers, such as parcel boundaries, hydrants, school and fire station locations, and reference grids, can be easily

added. Next, many fire departments customize their large-format maps with logos and credits for agencies providing data or other support. Finally, the designer applies cartographic finishing touches, such as appropriate colors, symbols, and sizes, for visual appeal and clarity. These map products can then be printed or converted into digital formats like PDF.

To produce a run book with a GIS, the same data layers are reused and segmented into smaller areas. More detailed information like alleys, driveways, and building footprints can be added as required. For this type of map product, an index can be added, with street names and an inset map providing a page-by-page overview of the more detailed data contained within each of the run book pages.

Fire preplan documents often contain the same street, hydrant, and building footprint data elements used for wall maps and run books. But these map products require an additional level of detail. With mobile GIS, station crews can collect data during preincident surveys to capture information such as the locations of building features like fire department connections (FDC), stairwell entrances, and lockboxes or perhaps notes about dangerous construction features. These new datasets are added to the existing database, and through the use of different map layouts, accurate, detailed, individual preincident plans can be produced. Because the same layers of data are being reused, and each map product is referenced to a common geography, agencies can leverage work from one map product to another.

In a modern GIS, these different map products, once created, can be published many different ways. Like books and articles, maps can be printed; viewed digitally on a handheld or mobile device; or made available, shared, and edited over the web.

Spatial Analysis: Response Time Analysis

Response time analysis provides one good example of how many fire departments use the attribute data attached to the layers in a GIS to perform spatial analysis. Response times for service calls are critical. They can mean the difference between life and death and between the protection of property and damage or loss. GIS permits the powerful, yet intuitive, analysis of response times. This allows fire service leadership to ensure that response goals are being met, and, if not, to make appropriate adjustments. GIS provides a representation of response time capabilities that is easy to understand and can be shared with staff or other stakeholders.

In performing a response time analysis, GIS builds a street network of connected lines with descriptive attribute data for all the lines and line segments. Attributes for street network data can be things like "speed limit," "daytime average speed," "one way," "road surface type," "height restrictions," or "weight restriction." Any of these attributes can be factored into the equation when the GIS analyst asks the question, If my fire station is at point A, how far can I travel in any direction, on any road connected to that station, in five minutes?

The result of this analysis is a polygon representing the area—sometimes called a service area—where a vehicle could travel within the allotted time period, given whatever conditions the analyst built into the query based on available attributes in the data. This type of analysis can be run for multiple stations within a jurisdiction simultaneously. In this case, the resultant map is often referred to as a coverage area.

Map production and response time analysis provide two good examples of how fire departments use GIS to combine layers of data with geography. There are many benefits of using GIS to perform these tasks:

- GIS can derive map products from a common data source. Collecting data once and using it for multiple products and projects results in optimal accuracy and currency.
- GIS maps can be customized with department logos, standardized with style templates, and sized to fit specific purposes. Using consistent map layouts makes it easier for fire personnel to recognize key features and hazards.
- GIS combines the analytical capacity of a database with the visual benefits of a map. Leveraging the geography inherent within data uncovers important patterns and provides powerful insights that can result in better decisions, increased efficiency, and improved outcomes throughout the organization.

In addition to map production and response time analysis, many other fire and rescue mission requirements can be effectively supported by GIS technology. These factors contribute to the emergence of GIS as an important component of information platforms built to support fire service organizations.

GIS for Every Mission Requirement

Every fire and emergency service mission requirement can be effectively supported and enhanced by GIS technology. Because GIS is a fully integrated and scalable platform that works in desktop, server, mobile, and web environments, its benefits can be realized in all phases of the mission: planning, response, recovery, and administration. It empowers fire fighters, first responders, captains, fire chiefs, and IT staff with better information for improved decision making. It can also be used for sharing vital information to the public and to outside agencies and government entities. Below are some examples.

Preparedness

Planning is essential for developing effective prevention, protection, and mitigation strategies. GIS allows fire service staff to perform comprehensive analysis to support the development of all types of plans. These plans are based on a more accurate understanding of vulnerabilities, potential events, and deployment requirements.

Vulnerability Analysis

A community with a clear understanding of its vulnerabilities is able to make priority decisions about how to manage risk through a prescriptive approach using various fire resources and programs. GIS enables a community to perform vulnerability analysis by following the steps described below.

Identifying Values

A value in this context is defined as anything required to sustain the economic and social viability of a community. The values in a community can include population density, critical infrastructure, cultural icons, and natural resources. Once the values have been identified, they can be characterized and visualized within a GIS.

Identifying Hazards

Hazards are known conditions or physical features that have the potential to cause negative impacts to life, property, or natural resources. Examples of common hazards in a community are unstable, vacant, or highly combustible structures; chemical, biological, radiological, or nuclear (CBRN) material; natural hazards such as highly flammable vegetation; and other potentially dangerous infrastructure.

Calculating Risk

Risk is a chance of exposure to, or having an influence on, the conditions (hazards) that create harm or damage to people, property, or the environment. Using GIS to identify community hazards will provide accurate and accessible data with which to calculate risk. Hazard data modeled against the variables that influence the potential for harm provides the risk equation. Variables from which risk is derived should include such factors as the concentrations, distributions, frequencies, and potential impact of incidents. The analysis should also include threat variables, which factor in the potential for human-caused incidents resulting from intentional actions.

Assessing Community Vulnerability

Once the locations of values and hazards are identified and the potential for harm (risk) has been calculated, the overall landscape of a community's vulnerability can be assessed. GIS clearly reveals the vulnerability to the values to be protected.

The robust analytic capabilities of GIS allow users to identify spatial patterns in the data, determine causes of negative trends, and perform modeling to predict scenarios. They can also be available for decision support and for incident response to enhance fire fighter safety. They also pave the way for compliance with Department of Homeland Security (DHS) and other grant application requirements.

Mitigation and Protection

Analysis precedes good planning. With GIS, the results of an integrated community risk assessment are immediately available to help determine mitigation strategies and protection priorities. The data derived from the analysis performed during the risk assessment is used to support decision making for resource requirements, staffing, fire prevention measures, mitigation programs, training, and more. GIS facilitates efforts for creating sustainable communities, adopting building and safety codes, and encouraging citizens to advocate for and implement safer construction for new housing.

Vulnerabilities identified during the risk assessment process become the target for mitigation activities such as fire prevention education programs, increased inspections, building code modifications, weed abatement, prescribed burning and fuel reduction, hydrant inspections, and preplanning for incident response. GIS supports all these programs by identifying geographic target areas, improving routing and scheduling efficiency, and disseminating public information using relevant web maps.

Deployment Planning

A GIS-supported deployment analysis helps decision makers determine where to move, add, remove, or restructure resources to maximize the potential for achieving desired levels of protection. Information from the risk assessment is used to determine acceptable levels of risk with a clear understanding of protection priorities and levels.

Training and Exercises

Training and drills are an ongoing requirement for the fire service. GIS is an effective technology for developing training scenarios based on likely events identified through the vulnerability assessment.

Prevention and Education

Code Enforcement

With GIS, inspections data can be collected with accurate locational references. When this data is stored and made accessible for integration with other information systems, permits can be processed quickly, field inspector routes can be optimized, and inspection

metrics can be analyzed for reporting trends and programs. This data can be used to generate map-based reports to show inspection progress, violation trends in conjunction with demographics, zoning, and so forth.

Prevention Programs

All the planning previously described can help target prevention programs to reduce preventable emergencies. Home safety checks, safety education programs, and disaster preparedness activities can be focused geographically to target vulnerable populations. Programs can be designed with a better understanding of demographics and lifestyle characteristics to produce more positive outcomes and improve effectiveness.

Threat and Hazard Identification

The Department of Homeland Security began requiring jurisdictions to perform a Threat and Hazard Identification and Risk Assessment (THIRA) beginning with the 2013 grant cycle. When GIS is used to perform vulnerability analysis, the mitigation programs and protection activities described above will assist in providing the data necessary to satisfy the five-step THIRA process described in the Comprehensive Preparedness Guide (CPG) 201 released by DHS in April 2012.

Response

When an emergency occurs, digital data becomes an important backdrop to the entire sequence of events. From the moment a 911 call is received, an accurate incident location is the one attribute that ties together and sifts through all the other information available to support a successful outcome. When that location is stored in a modern, standards-based enterprise GIS, it provides the foundation to everything else that follows:

- Call takers can confirm the accurate location of the incident.
- Station personnel can quickly reference the location on a large paper wall map on their way out the door.
- Digital route maps with standard symbology can augment the driver's mental image.
- Accurate hazard and hydrant locations support the scene size-up scenario forming in the company officer's mind.
- Preplan layouts in scalable formats provide lifesaving detail for search operations and attack strategies.

Information available at the right time to the right person can make the difference between life and death. Call location, initial incident description, routes, locations of responding vehicles, water sources, exposures, hazards, access and egress—all are crucial, all are about geography, and all need to be right.

When fire personnel are dispatched, the response results in their arriving at the scene quickly and with adequate resources and information to mount a safe and effective attack. GIS provides first responders with a mission-critical tool for rapid response, enhanced fire fighter safety, and better decision support during an emergency.

Recovery

GIS is an ideal tool for streamlining recovery operations. Recovery is difficult, time-consuming, and essential to determine overall damage, costs, and reimbursement.

Mobile GIS applications enable recovery personnel to identify damage status and rapidly report it to a central location. Regardless of the extent of the incident, recovery operations benefit from GIS.

Many specific GIS functions can support a recovery operation. A partial list includes enabling responders to do the following:

- Assess damage costs and prioritize reconstruction efforts
- Create summary reports of damages and loss
- Determine resource and housing needs
- Identify optimum locations for public assistance
- Identify alternative transportation routes, enabling operations to resume for private-sector businesses, government operations, and residential communities
- Plan and organize restoration activities

Administration

Fire department administration involves working with elected officials, the community, and department personnel, as well as supporting department operations and safety. Whether it is used for presenting budget requirements to the city council or debriefing the community, GIS has the unique ability to provide a visual map context for all operations that is easy to assimilate and understand.

Executive Dashboard

A GIS platform can be configured to provide a view into all fire department operations. This enables decision makers to maintain an overview of existing operations and obtain the status of key metrics of importance to chief and staff. The integration of multiple sources of data provides managers with a picture of operations that is easy to understand, act on, and make adjustments to. For example, daily response performance, incident trends, equipment locations, units out of service, specific staffing for each apparatus, traffic status, weather impacts, and other reports and tabular data can be delivered through a GIS-powered executive dashboard to help track outcomes and achieve performance improvement objectives.

Public Information

Information can be published in the form of maps to facilitate transparency, encourage communications, and engage the public and other government organizations in the progress, activity, and performance of the department. Web maps that illustrate emergency incident locations over specified periods of time (daily, weekly, monthly), station locations, hazardous material sites, hazardous wildfire areas, permitted activities, current incidents, planned community/fire department activities, and so forth, can be provided through GIS.

Specialized Applications

Situational Awareness

GIS has the capacity to aggregate, analyze, query, and visualize unlimited amounts of information from local and distributed sources. This enables trained GIS analysts to

support the incident commander (IC) by providing current, accurate, relevant, and actionable information throughout the emergency. At the IC's discretion, appropriate information can be delivered to satisfy the unique knowledge needs of the entire command staff, field personnel, executive management, and political stakeholders. With an enterprise GIS, this information will be based on the same data source, customized on the fly, and delivered in a format each recipient can absorb.

Incident Command

During large-scale emergencies, incident command staff use GIS for enhanced situational awareness, analysis capabilities, and map production to manage vast amounts of information and support collaborative decision making. This is especially critical during long-term events requiring multiagency and multijurisdictional coordination.

GIS can be used to visualize the incident perimeter, understand the potential impact of the emergency to populations and critical infrastructure, and assess the highest-priority objectives across multiple jurisdictions.

ICS Map Products

During a large-scale emergency or disaster, each operational period (typically 12 hours) is supported through an incident action plan (IAP), which consists of maps that are continually updated. Some of the most common standardized map products for incident command systems (ICS) include those listed below:

- Operations maps showing incident geographic area segments (branches, divisions, sectors), grid area assignments, and so forth
- Logistics and transportation maps showing transportation plans, staging areas, supply points, helibases, heliports, fueling areas, and so forth
- Briefing maps
- Public information maps
- Incident prediction maps

Logistics

GIS facilitates the effective allocation of personnel, equipment, and other resources by identifying the locations of available support resources and helping determine how to get them to the right place to support critical operations.

Damage Assessment

When an area is devastated by a large-scale event, GIS can be used to support rescue logistics, data collection, and status updates and reporting. With GIS and GPS, emergency workers can see exactly where they are and what was in that location before the emergency. Using mobile devices, they can collect data, including photographs of damage and debris. All this can be transmitted to a synchronized GIS server when connections are available, permitting the efficient reassignment of emergency crews and the accurate reporting of early damage estimates to all stakeholders.

Search and Rescue

Geospatial information is an integral part of planning and conducting search and rescue (SAR). SAR has several subspecialties, and searches are conducted in a wide variety of environments, including urban (out of doors, inside buildings, and inside collapsed structures), wilderness, and marine, to name the most common. Regardless of the

environment, GIS can be used to deploy search teams; analyze data to focus search strategies; and manage clues, team status, and other important data about the search operation.

Planning: The Steps in Implementing GIS

The single most important factor in successfully implementing technology within any organization is proper project planning and management. This is particularly true when implementing GIS for fire and rescue. Technical projects often fail from lack of consensus, careless governance, poor budget planning, and inadequate communication. Failure rarely stems from the technology. It is essential to have a clear understanding of program requirements and priority workflows. All technical solutions should be standards based and interoperable. Broad stakeholder engagement will ensure that the system is designed to consider the full realm of potential users.

A well-guided planning process should be conducted in alignment with the National Fire Protection Association (NFPA) 950 and should include the four steps below:

1. Assessment
2. Planning
3. Use
4. Management

Assessment

The first step in building a successful GIS includes assessing needs and understanding how technology can address them. This involves looking at what technology is in place and what technology is available; the latter assessment should be based on a number of criteria, including budget and organizational buy-in. Input can be solicited from other agencies using GIS to learn how they use it, what supporting workflows help staff get what they need when they need it, and what best practices can be applied to ensure success. Understanding the options available helps determine the GIS uses most relevant to the agency's planning and operations.

Some fire departments implement GIS by acquiring a single software application to address a specific need such as creating map books, analyzing response zones, preplanning, or managing inspections. Other departments begin building a GIS by identifying the key datasets needed to support major projects like strategic planning, the accreditation process, or an integrated community risk assessment. The important step is to understand short- and long-range needs and available resources.

Planning

Begin the planning process by identifying stakeholders. Some fire service agencies create their own planning committees; some fit into a larger, decentralized GIS planning and organizational structure at the city or county level.

Coordinating with other stakeholders outside the fire agency, as well as the local government agency GIS department, if one exists in the area, will help avoid duplication and create better communications. Three groups within the fire department need to have active representation and participation in the planning process. The executive lead and the technical lead should guide the process. The end users need to be consulted at all steps along the way. In addition to these core members of the planning team and organizational structure, be sure to reach out to other GIS stakeholders in other agencies, and to the GIS department in the community.

Part of the planning process is a data survey. Access to data requires someone to acquire, create, organize, store, and maintain such data. Time invested at the beginning in identifying needs and researching existing data sources will save time and effort later. In fact, although it is often overlooked, a good data survey might be the most important step in the entire planning process.

There are a myriad of free data sources. Moreover, now more than ever, city, county, state, and federal GIS groups are in place, and they make their GIS data available to others. More than 80 percent of local government agencies have a GIS in place today. This means that most fire departments have full-time GIS departments they can leverage as part of their own GIS work. One of the first steps should be to learn what data is already available from city, county, and state GIS departments. Develop relationships with GIS technicians in other agencies, and wherever possible, use resources that already exist.

Use

Using the information gathered during the earlier steps, determine initial program/implementation objectives. Include detailed tasks and timelines for tasks in the near term. These first GIS applications should be designed to generate immediate success. This will ensure immediate buy-in and continued support. The closer the uses of the GIS align with a solid business case, the more likely it is that the technology will begin achieving results.

As in a construction project, investing in a solid and reliable foundation is required to build a sustainable structure. The GIS foundation is the platform that provides GIS data services and analytics to users across the department. An *enterprise system* is defined as a computing system that (1) offers a high quality of service, (2) deals with large volumes of data, and (3) is capable of supporting an entire organization (an enterprise). Access to an enterprise GIS will increase the ability of fire department personnel to use maps and analyses to support their work.

Management

The key to properly managing GIS at any level—whether it's a single use of GIS or an enterprise installation linking multiple users and departments—is incorporating GIS deployment into the overall IT strategy. That means continuously evaluating the success of the GIS and assessing the evolving needs of the entire organization. While many fire service agencies may begin with a department- or application-centric approach to GIS, most will grow their GIS use based on the technology's native ease of use and scalability. Constantly evaluating the success of the GIS and applying GIS to new opportunities will ensure maximum benefits.

Summary

The public safety mission is complex, as is the information technology environment in which the public safety community operates. GIS has emerged as a mission-critical technology to assist fire professionals in meeting mission requirements.

This paper has identified what GIS is, described how it is used in the fire and emergency services, and provided the fundamental steps in getting started. GIS can be deployed with an overall vision of what the GIS platform is intended to support with small steps and deployments along the way.

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When properly deployed, GIS provides an immeasurable return on the investment. GIS can provide the following:

- A comprehensive understanding of the community and its vulnerabilities
- Integration with and access to all types of fire department reports and data
- Better placement, deployment, training, and utilization of resources
- Safer, quicker, and more intelligent response and deployment
- Real-time situational awareness, resource tracking, and departmental performance monitoring
- Better public information and public engagement

The fire service now has a powerful platform in GIS to better optimize resources, improve service delivery, reduce losses, and improve fire fighter safety. It can be deployed in small steps or through a departmental enterprise approach. However an organization chooses to proceed, having a well-thought-out strategy or long-term goal will enable it to scale and grow as needed.

Esri inspires and enables people to positively impact their future through a deeper, geographic understanding of the changing world around them.

Governments, industry leaders, academics, and nongovernmental organizations trust us to connect them with the analytic knowledge they need to make the critical decisions that shape the planet. For more than 40 years, Esri has cultivated collaborative relationships with partners who share our commitment to solving earth's most pressing challenges with geographic expertise and rational resolve. Today, we believe that geography is at the heart of a more resilient and sustainable future. Creating responsible products and solutions drives our passion for improving quality of life everywhere.

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