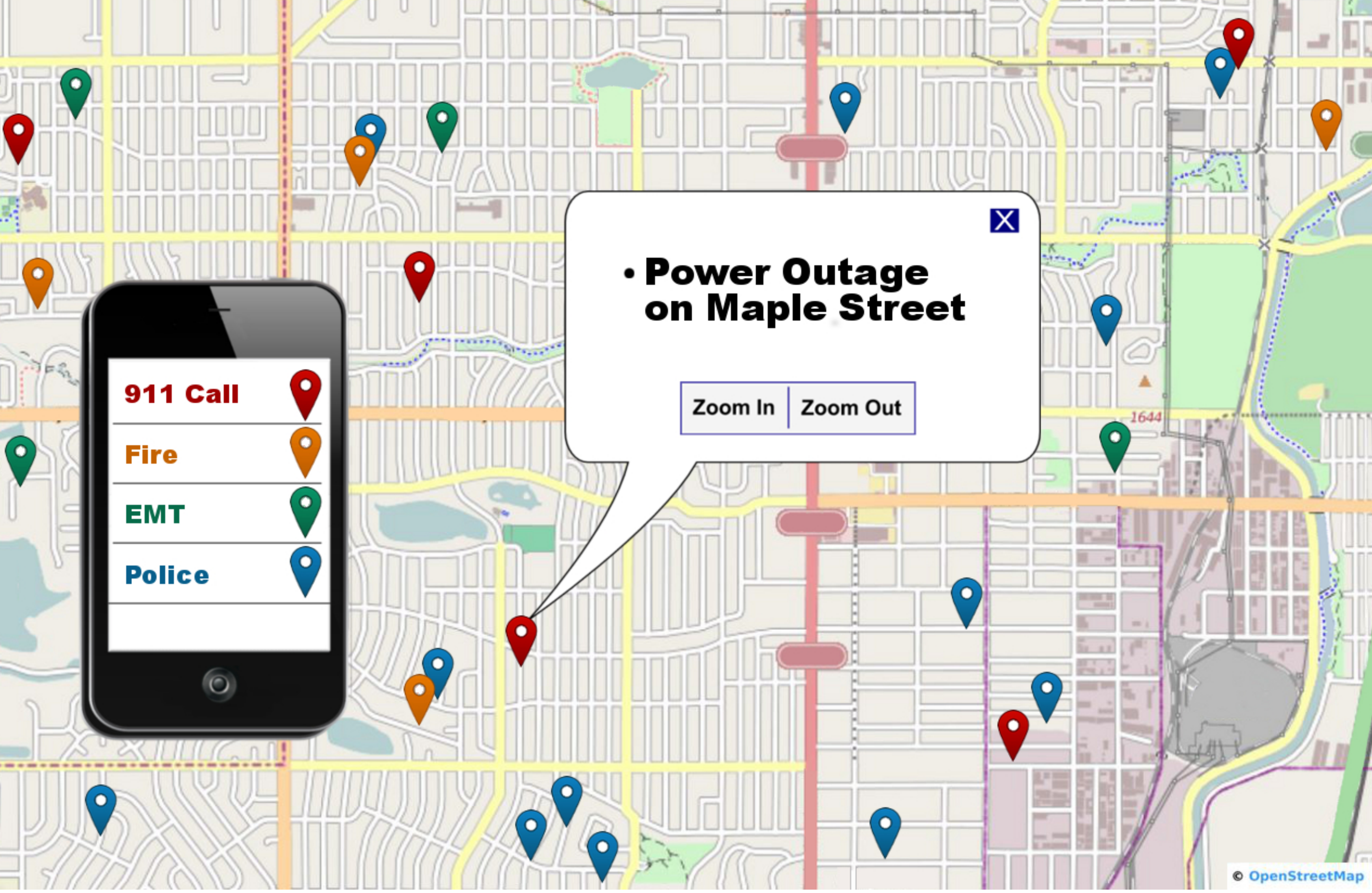


*System Assessment and Validation for Emergency Responders (SAVER)*

# Geographic Information System Software Selection Guide

*July 2013*

Homeland Security
Science and Technology

U.S. Department of Homeland Security
SAVER
System Assessment and Validation for Emergency Responders

*Prepared by Space and Naval Warfare Systems Center Atlantic*

The *Geographic Information System Software Selection Guide* was funded under Interagency Agreement No. HSHQPM-12-X-00031 from the U.S. Department of Homeland Security, Science and Technology Directorate.

# FOREWORD

The U.S. Department of Homeland Security (DHS) established the System Assessment and Validation for Emergency Responders (SAVER) Program to assist emergency responders making procurement decisions. Located within the Science and Technology Directorate (S&T) of DHS, the SAVER Program conducts objective assessments and validations on commercial equipment and systems and provides those results along with other relevant equipment information to the emergency response community in an operationally useful form. SAVER provides information on equipment that falls within the categories listed in the DHS Authorized Equipment List (AEL). The SAVER Program mission includes:

- Conducting impartial, practitioner-relevant, operationally oriented assessments and validations of emergency responder equipment; and
- Providing information, in the form of knowledge products, that enables decision-makers and responders to better select, procure, use, and maintain emergency responder equipment.

Information provided by the SAVER Program will be shared nationally with the responder community, providing a life- and cost-saving asset to DHS, as well as to Federal, state, and local responders.

The SAVER Program is supported by a network of Technical Agents who perform assessment and validation activities. Further, SAVER focuses primarily on two main questions for the emergency responder community: "What equipment is available?" and "How does it perform?"

As a SAVER Program Technical Agent, the Space and Naval Warfare Systems Center (SPAWARSYSCEN) Atlantic has been tasked to provide expertise and analysis on key subject areas, including communications, sensors, security, weapon detection, and surveillance, among others. In support of this tasking, SPAWARSYSCEN Atlantic developed this selection guide for geographic information system software, which falls under AEL reference 04AP-03-GISS System: Geospatial Information (GIS).

Visit the SAVER section of the Responder Knowledge Base (RKB) website at https://www.rkb.us/saver for more information on the SAVER Program or to view additional reports on GIS software or other technologies.

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# EXECUTIVE SUMMARY


Geographic information system (GIS) software tools enable crisis managers and emergency responders to improve situational awareness and enhance decision making. These tools display, store, manage, and analyze geospatial data; offer robust visualization capabilities at various geographic scales; and provide the user with multiple-layer mapping, spatial analysis, and pattern modeling capabilities. Before implementing these capabilities, emergency response agencies need to evaluate multiple GIS software products and select options that support mission requirements, improve operational practices, and enhance knowledge sharing within their communities.

This guide describes a comparative evaluation process that is divided into five activities:

- Needs analysis;
- Requirements definition;
- Product identification;
- Product selection; and
- Product assessment.

Critical components used in the software selection process are listed in the feature comparison matrix and the product comparison matrix.

The feature comparison matrix uses vendor responses to identify software products that support the criteria identified by the stakeholders. The vendor responses for each product will be compared to each criterion and scored based on whether the product is reported to meet the capabilities specified by the stakeholders. A completely populated matrix will reflect the functions, features, and requirements supported by each product.

The product comparison matrix will be used to generate product rankings (highest to lowest) relative to criteria that have been weighted by identified stakeholders. This type of analysis uses normalized weighting for each criterion and results in a score for each criterion and for each product. The scores are then summed and result in a ranking for each product. The products with higher scores are then considered for final product assessment.

An assessment may focus on the operational environment, interoperability, and functional capabilities required for satisfactory user operation. The assessment process may require the development of a standardized environment so that all products can be evaluated equally under the same conditions using the same data.

This software selection approach should not be construed as an endorsement or recommendation by the U.S. Government of any particular software application.

# 1. INTRODUCTION

Geographic information systems (GIS) use hardware and software tools to collect, display, analyze, manage, and store geographic data. These tools offer robust visualization features at various geographic scales; give users multiple layer mapping, spatial analysis, and pattern modeling capabilities; and often provide customization features that support unique, agency-specific GIS solutions.

Emergency response agencies intending to procure a GIS solution will be faced with the task of evaluating multiple products with similar capabilities and levels of complexity. This guide presents a selection process that can be used to evaluate GIS software tools. The process involves performing a needs analysis, developing requirements, researching available products, and conducting a product assessment. By using this approach, agencies will be better able to identify and select GIS solutions that best meet their current and future operational needs.

# 2. GIS OVERVIEW

Mapping tools are essential to crisis managers and emergency responders; however, many agencies still use printed resources, such as map books, which are not always current or organized for quick reference. Moreover, command centers often have access to a wide range of data but with limited ways for responders to view that information.

A GIS solution can help solve these problems by providing emergency response teams with rapid access to a more comprehensive tactical picture, which can reduce response times and increase operational efficiency. An agency needs to consider standards, procedures, and work processes as well as trained personnel when selecting a GIS.

Computer applications such as spreadsheets, statistical software, or computer-aided drafting packages can process simple geographic or spatial data, but this does not necessarily comprise a GIS. A GIS has the following capabilities:

- Links spatial data (e.g., features such as a fire hydrant) to a specific location on a map;
- Incorporates individual data layers (e.g., roads, hospitals, and schools);
- Incorporates database management systems; and
- Incorporates tools for data compilation, geographic query, spatial analysis and geoprocessing, image visualization, and cartographic representation.

GIS has a wide variety of uses including resource management, development planning, and calculating emergency response times. The information derived from these and other applications of GIS can be distributed over the Internet or other LANs/WANs.

## 2.1 GIS Software Types

Several types of GIS software products are available in the market and worth consideration during the software selection process. The following list, compiled from the Environmental Systems Research Institute’s (ESRI’s) GIS dictionary, describes the most common types of software. The use of ESRI information in this handbook is not intended to indicate an endorsement of the company or their products.

- **Add-ons/Extensions:** Refers to optional software modules that add specialized tools and functionality to an existing core software application;
- **Computer-aided design (CAD):** Refers to software that provides the ability to design, draft, and display graphical and geographic information;
- **Desktop mapping:** Refers to software for personal computers, ranging from systems that can only display data to full data manipulation and analysis capabilities;
- **Global positioning system (GPS):** Refers to a collection of hardware, software, and data that provides the ability to view, collect, and edit geographic data and base maps in the field with or without a GPS receiver;
- **Image processing:** Refers to software that manipulates remotely-sensed data (e.g., aerial photographs, satellite imagery) to improve the interpretation and thematic classification of the image;
- **Internet mapping:** Refers to software that provides the ability to deliver dynamic maps, data, and basic spatial functions over the Internet;
- **Mobile GIS:** Refers to software that provides mapping, GIS, and GPS integration to field users through handheld and mobile wireless devices;
- **Photogrammetry:** Refers to software that extracts useful information (e.g., distance between two objects) from photographic images, particularly for the creation of accurate maps;
- **Routing/Delivery GIS:** Refers to software that plans and adjusts optimal delivery routes;
- **Spatial database:** Refers to software that edits and organizes spatial data and its related descriptive data for efficient storage and retrieval; and
- **Web service:** Refers to software that is not dependent on the operating system of a hardware platform but is accessible over the Internet for use in a wide range of other applications.

## 2.2 GIS Resources

A GIS solution is a complex system requiring the following resources for operation: hardware, software, data, and personnel. All of these resources, as described below, need to be considered during the GIS software selection process.

### 2.2.1 Hardware

A wide range of hardware types can support a GIS solution including centralized servers, desktop computers, laptops, and handheld devices. Examining the agency’s current and future computing resources is necessary to ensure sufficient capability will exist to support GIS software and system operation. Some GIS applications will require robust servers, workstations, and network bandwidth for extensive data acquisition, geoprocessing, data analysis, and management operations. Conversely, other applications will only require terminals linked to a distributed network for application access, data display, and spatial querying.

### 2.2.2 Software

GIS software provides the functions and tools necessary to conduct analyses and develop data and information products. This software includes the agency's primary GIS software package as well as extensions that perform spatial analysis, image processing, and thematic mapping. GIS software may require updates, subscription service fees, and technical support contracts. Many GIS packages offer the following key components and capabilities:

- A database management system (DBMS);
- Tools for the input and manipulation of geographic information;
- Tools that support geographic query, analysis, and visualization; and
- A graphical user interface (GUI) for easy access to tools and scripts.

### 2.2.3 Spatial Data

Spatial data consists of vector and raster features. Vector, or linear, features include points, lines, and polygons with attributes such as size, type, length, area, and volume. Raster, or grid, features consist of identically sized square cells, or pixels, with a unique value assigned to each cell. Typical vector data sets include roads, landmark locations, and building footprints. Typical raster data sets include thematic classifications, topographic elevations, and aerial photographs. Spatial data is often presented in tabular form to compare data or consolidate information.

Many GIS solutions employ a DBMS to help organize, manage, and document data. This data may include various types of spatial data such as vector, raster, and tabular as well as non-spatial data such as photographs, law enforcement records, and metadata. Data standards are important to ensure maximum utility and interoperability of dissimilar data sets and sources.

GIS data becomes outdated quickly and therefore needs to be updated on a regular basis. Some vendors require a subscription to routinely update this data.

### 2.2.4 Personnel

GIS technology is of limited value without trained personnel to operate and manage the system. Developing specific GIS functional requirements will help identify the skilled personnel needed to run a particular system. These personnel may include technical specialists and database programmers, who design and maintain the system, as well as analysts, who perform spatial operations and data development activities. It is recommended that agencies include skilled personnel in the conceptual design, physical design, implementation stages, and subsequent long-term operation of the GIS.

## 2.3 GIS Functional Capabilities

GIS software functional capabilities can be grouped into two general categories, basic and advanced. Table 2-1 and Table 2-2 present a representative sample of these capabilities. For definitions of terminology, see the glossary in Appendix A.

**Table 2-1. Basic GIS Functional Capabilities**

| Input Capabilities | Output Capabilities |
|---|---|
| Digitization of maps, images, etc. | Create/manage database |
| Scanning of text, images, etc. | Symbolize features |
| Keyboard entry | Plot data |
| File input/transfer | Update data |
| Raster to vector/vector to raster conversion | Browse data |
| Topology rules | Suppress data |
| Attributes | Generate reports |
| Reformatting digital data | Web mapping applications |

**Table 2-2. Advanced GIS Functional Capabilities**

| Capability | Description |
|---|---|
| Query | • Spatial or attribute query |
| Generate Features, Views, and Graphs | • Generate features, buffers, viewshed, perspective view, elevation cross-section, and graphs |
| Manipulate Features | • Classify attributes<br>• Dissolve and merge<br>• Clip features<br>• Scale change<br>• Rubber sheet stretch of datasets<br>• Conflate<br>• Subdivide area |
| Address Locations | • Address match or address geocode |
| Measurement | • Measure length, perimeter, area, volume |
| Spatial Analysis | • Graphic overplot<br>• Topological overlay<br>• Adjacency analysis<br>• Connectivity analysis<br>• Nearest neighbor search<br>• Correlation analysis<br>• Linear referencing |
| Surface Interpolation | • Interpolate spot height, spot heights along a line, isoline (contour), and watershed boundaries |

| Capability | Description |
|---|---|
| Visibility Analysis | • Line of sight • Generate viewshed |
| Modeling | • Arithmetic or weighted modeling |
| Network Analysis | • Shortest route • Defining service coverage |

By implementing GIS capabilities, emergency response agencies can realize significant benefits. Some examples of these benefits are described below.

**Spatial Analysis:** Using readily available GIS census data, emergency responders can perform buffer analyses to identify key demographic features for particular areas. During a chemical spill, for example, an emergency responder could create a buffer that extends 20 miles and clip the census data to estimate the number of people in the area who may be impacted during an evacuation. A web-based mapping application could then be used to post the results, which will help decision-makers formulate informed response strategies.

**Data Layering:** Emergency responders can use GIS tools to create accurate area maps with numerous layers of critical information such as roads, airports, hospitals, schools, water distribution, electric grids, underground cables, sewers, mass transit, etc. In addition, topography can be used where terrain elevation is a consideration, and aerial and satellite images can be used to provide an actual view of a desired area.

**Data Reprojection:** Reprojection facilitates data sharing by automatically converting the data formats and attributes of different sources into a single standard map view. Having the ability to read multiple GIS data formats and then reproject the data is very important. For example, during a natural disaster that encompasses multiple jurisdictions, agencies often share GIS data that was created in different formats and projections.

**Replication:** Replication synchronizes data entered in the field to a master database; thereby enabling all personnel accessing the system to share and maintain the same information. This technology is particularly useful for emergency responders lacking network connectivity since it allows GIS data entered offline to be automatically updated in a master database once a connection to the network can be reestablished. Additionally, GIS software applications running on mobile computers, laptops, and handheld devices (i.e., tablets and smartphones) enable emergency responders to enhance their situational awareness before, during, and after an event. For example, during Hurricane Katrina emergency responders needed to keep track of houses that had been searched in order to prevent duplication of effort. Using GPS-enabled handheld devices, the responders were able to edit the GIS data in the field and then synchronize the data they collected with the master database after returning to their base of operation. This data was then uploaded to the Internet, where all personnel could see the areas that had been canvassed and those that still needed to be canvassed.

## 2.4 Data Models

Data models describe how geographic data will be displayed and stored by the system. The selection of a data model that simplifies information to a useful form without oversimplifying it to the point that features are misrepresented is essential. The process of data modeling involves three phases: conceptual, logical, and physical.

**Conceptual Data Modeling:** Defines in broad and generic terms the scope and requirements of the database such as a collection of roads and buildings.

**Logical Data Modeling:** Specifies the user's view of the database with a clear definition of attributes—e.g., road types, road names, building addresses, year of construction—and their relationships. Logical data models are system-independent models used by developers as guidelines in creating the operational database.

**Physical Data Modeling:** Specifies the file organization of the database (e.g., where the conceptual and logical data pertaining to roads and buildings resides in the database).

### 2.5 Geographic Data Models

A geographic data model is "an abstraction of the real world that incorporates only those properties thought to be relevant to the application at hand [that] defines specific groups of entities, their attributes, and the relationships between these entities" (University of Texas at Austin, 2013). Examples of geographic data models include the following:

- **Cartographic data model:** Points, lines, and polygons (topologically encoded) with one, or only a few, attached attributes, such as a land use layer represented as polygons with associated land use code.
- **Extended attribute geographic data model:** Geometric objects such as points, lines, and polygons, but with many attributes, such as census tract data sets.
- **Conceptual object/spatial data model:** Explicit recognition of user defined objects, associated spatial objects, and sets of attributes for each defined object such as the following:
    - User objects such as land parcels, buildings, and occupants, each having its own set of attributes but with different associated spatial objects;
    - Polygon for land parcel; and
    - Footprint for building.
- **Conceptual objects/complex spatial objects model:** Multiple objects and multiple associated spatial objects such as the following:
    - A street network with street segments having spatial representations of both line and polygon type; and
    - Street intersections having spatial representations of both point and polygon type.

## 3. SOFTWARE SELECTION PROCESS

Selecting the right GIS software solution can be challenging for an agency due to the number of available products that have similar capabilities and levels of complexity and yet must support multiple stakeholders with varying objectives. To address these challenges, a thorough software selection method is required.

Described below is a comparative evaluation process, a weight-based criteria model that leverages inputs from subject matter experts. This process will help agencies identify, assess, and validate commercial off-the-shelf (COTS) and government off-the-shelf (GOTS) products as well as freeware and custom software products. However, with many methods available, and no current standards, alternative processes need to be reviewed to determine the best solutions for an agency.

The comparative evaluation process is organized into five general activities. Table 3-1 defines these activities. Not all process activities or steps may be necessary, but all are mentioned to cover the range of information that may need to be considered when choosing a software solution.

**Table 3-1. GIS Software Selection Process**

| Activities | Process Steps |
|---|---|
| **Needs Analysis** | Identify stakeholders<br>Determine geographic information system (GIS) uses and applications<br>Examine existing practices<br>Identify GIS functions<br>Identify GIS data and information |
| **Requirements Definition** | Collect information<br>Identify standards<br>Identify business policies<br>Define data requirements<br>Validate requirements |
| **Product Identification** | Conduct Internet research<br>Issue Request for Information (RFI) |
| **Product Selection** | Consider implementation factors<br>Consider cost factors<br>Consider software requirements factors<br>Establish requirements priorities<br>Conduct vendor surveys<br>Compile feature comparison matrix<br>Compile product comparison matrix<br>Conduct product comparison matrix analysis |

| | |
|---|---|
| **Product Assessment** | Develop test bed<br>Develop work processes/scenarios<br>Select assessment personnel<br>Conduct assessment<br>Analyze results |

## 3.1 Needs Analysis

A needs analysis determines what the user community will require from a system or GIS software product in order to meet organizational goals. It defines the scope, anticipated functions, and initial data critical to the rest of the selection process. The analysis provides specific answers about organizational needs, capability requirements, operational environment, technology applications, user community definition, and required staff. This is critical in the initial stages of the software selection process as it lays the foundation for requirements-based software selection and ensures organizational support for the activity. The analysis also provides the information necessary for planning the deployment or implementation of the GIS software or capabilities.

The needs analysis process is composed of two parts: 1) documenting potential GIS needs in a functions list that identifies desired tasks such as the ability for the users to create, edit, import, and export various types of data and 2) creating a general data list that includes elements such as roads, hospitals, political boundaries, and population. These two lists are used to develop the comprehensive master requirements list (MRL) of GIS functions and capabilities.

### 3.1.1 Identify Stakeholders

An effective needs analysis requires the involvement of a variety of agency personnel, in addition to potential users, to ensure all perspectives and requirements have been considered. Detailed interviews conducted individually or in groups, can aid in the collection of information on desired uses and processes for GIS, desired functions and outputs, and existing practices.

Potential stakeholders and the scope of information they may provide are listed below:

- **Senior managers:** Identify the software implementation scope, management reporting and approval requirements, available resources (e.g., budget, personnel, facilities), potential user community, and external participation;
- **Information technology (IT)/security managers:** Identify existing agency policies, IT equipment, facility layouts, communication and computer networks, network performance requirements, security requirements (e.g., physical, logical, and archival), and network architecture design options;
- **Program analysts:** Identify current agency operations, business processes, work practices, and improved work processes from the GIS software implementation;
- **GIS program managers:** Identify the software implementation planning process, geospatial network design, output products (e.g., maps, charts, graphs, reports), software licensing levels, and data sharing agreements;

- **Spatial/data analysts:** Identify the geospatial hardware and network operations, application programming activities, database administration actions, data translation/maintenance procedures, and spatial query/analysis requirements; and
- **GIS users (internal or external):** Identify the desired software capabilities or output products that would make the agency data more useful in work activities or decision-making processes.

### 3.1.2 Determine GIS Uses and Applications

The needs analysis will explore how the GIS will be used, existing and desired data, procedures for data management, and required capabilities. Required capabilities can be designated either as basic (e.g., query, display) or advanced (e.g., routing, geocoding, buffering).

The process also requires an exploration of whether the software will be applied to data stored locally within an agency or to wider scope efforts such as an organizational or community system. With any of these configurations, an agency may consider the range of data and data communications necessary to support the needed capabilities and produce the desired outputs. As an agency expands its efforts and moves from a local to a community GIS, the software selection process becomes more complex and may require a consultant in addition to involvement from various groups within the agency. Appendix B contains examples of GIS architectures.

The designated stakeholders within an agency need to consider a variety of factors in order to ensure that all aspects of the software implementation are addressed during the needs analysis. General discussions may include identifying the following topics:

- Reason(s) to use or upgrade the GIS software in the agency;
- Potential primary functions in order to designate roles and responsibilities throughout the selection process;
- Where the GIS will be deployed in the agency (to support internal and external customers or partners);
- Trained personnel needed to effectively operate GIS software;
- Type of data (e.g., vector, raster, databases, records, maps) that will be used to produce the desired results and products and whether that data is already maintained by state, county, or municipal GIS offices;
- Costs of deploying GIS software and supporting applications; and
- IT security requirements or technical constraints within the agency or partnering agencies.

After determining the required GIS capabilities, existing practices within an agency must be examined to determine how the GIS software will be used. This involves researching and referencing agency policies and practices to understand compatibility with current computer networks, hardware, software, data, and supporting applications.

Having an understanding of current business methodologies will help shape discussions about how a GIS can improve current practices with better and simpler processes. Integrating GIS

software into current practices will likely result in new interactions across departments. These interactions may result in improved user workflows, identification of new information technologies, and ultimately enhance productivity and knowledge sharing.

The identification of specific software functional capabilities for an agency depends on organizational needs, business priorities, desired information products, information technology infrastructure, database structure, personnel composition, and knowledge sharing or collaboration processes. Table 3-2 provides a sample of GIS software functionality that may be considered.

**Table 3-2. Sample GIS Software Functionality Considerations**

| Software Functionality Consideration | Key Factors |
|---|---|
| **Data Access** | Can the software perform a direct read of various raster and vector data? |
| **Data Development** | Can users create, edit, import, and export various types of data including imagery, grids, and tables?<br>Can the software geocode addresses and locations?<br>Can multiple users create and edit a spatial database independently of other users?<br>Can users create and edit domains?<br>Can users attach files to geographic information system (GIS) features?<br>Does the software provide metadata tools? |
| **Editing** | Does the software provide basic editing capabilities?<br>Can users interactively move, scale, and rotate GIS features?<br>Can users align images to real-world coordinates?<br>Can users edit when disconnected from the database and later synchronize edits when reconnected to the database?<br>Can users manipulate data using geoprocessing tools such as scaling, merging, and buffering?<br>Does the software provide mobile integration tools? |
| **Labeling and Symbology** | Can users label GIS features?<br>Can users symbolize GIS features |
| **Product Customization** | Can users customize tools/toolbars?<br>Can users create new tools/toolbars and store customized functionality? |

| Software Functionality Consideration | Key Factors |
|---|---|
| **Analysis and Display** | Can users create various types of reports?<br>Does the software perform on-the-fly reprojection of data to align different coordinate systems?<br>Can the software measure distances, areas, and perimeters?<br>Does the software provide customizable page layout and printing functions? |

Identifying an agency's GIS data needs begins with the creation of a general data list, which includes a variety of inputs such as roads, buildings and critical infrastructure, political boundaries, and population by area. The agency may then define the information products, such as those shown in Figure 3-1, that are the anticipated outputs of the GIS. These outputs may include printed or electronic versions of maps, graphs, reports, lists, or a combination of these outputs.

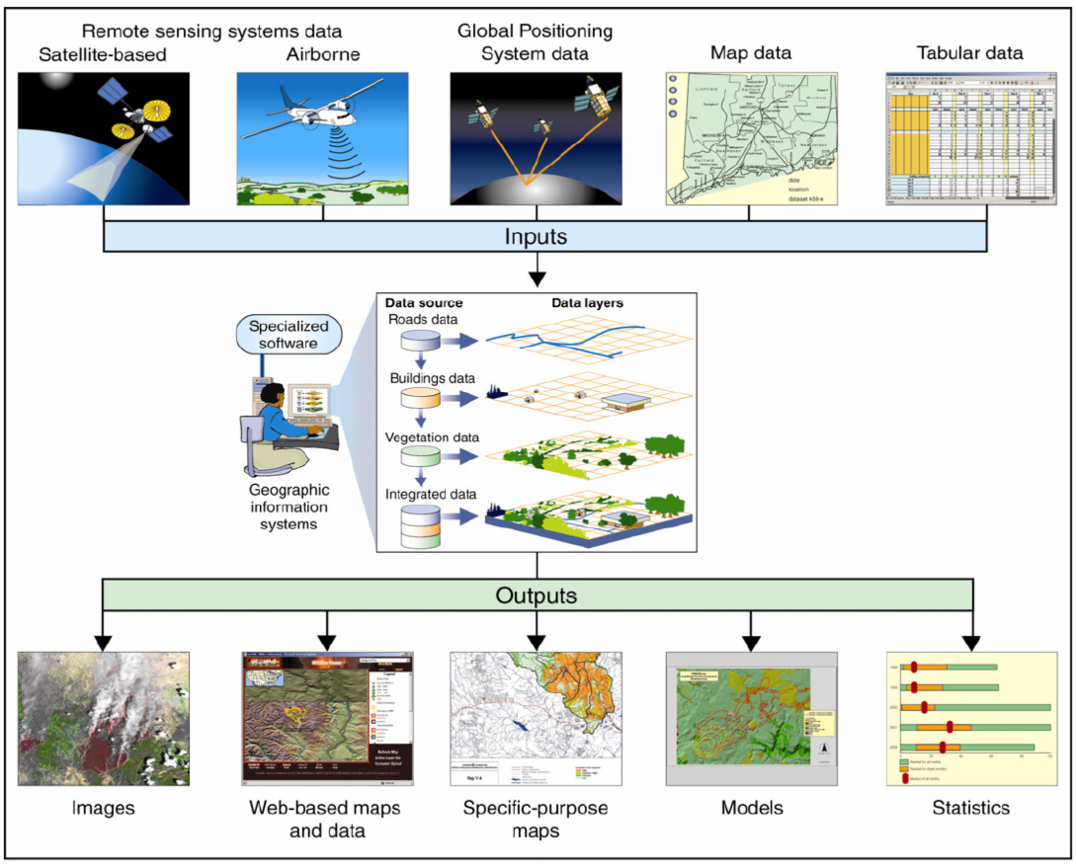



**Figure 3-1. GIS Data and Information Flow**

*Image courtesy of DHS Systems Support Division*

## 3.2 Requirements Definition

Requirements are typically defined by personnel or agencies at the mission or tactical level. Accordingly, requirements for GIS software are determined by those who will actually use or benefit from the software selection.

Defining requirements involves collecting information from user or practitioner interviews, surveys, focus groups, or workshops. Subject matter experts (SMEs) and technical staff need to be involved to identify the range of functional capabilities that the GIS software will be able to perform for the organization. Data needs will vary greatly from agency to agency. After creating a general data list during the needs analysis, an agency defines the required vector, raster, and raw data sources to be used in daily operations.

The information to be collected during the requirements definition process also includes agency, technology, and data standards; data interoperability; business policies relating to the use of the GIS solution; and data needs.

Once requirements are defined, they are compiled into an MRL, which documents each function, feature, capability, and specification derived through the needs analysis and requirements definition processes. The MRL is tailored to meet the specific needs of an agency and is then referenced when making inquiries to vendors regarding their software products.

### 3.2.1 Collecting Information

In defining GIS requirements, agencies may find it beneficial to collect information from various sources including those described below.

#### 3.2.1.1 User Interviews

User interviews can help provide valuable information for scoping and shaping the information collected during the requirements definition process. They help to identify initial software applications and functions so that the potential users can see how the GIS software will support the organizational workflow. These interviews can be conducted on either an individual or group basis. Input from the range of potential users will provide insight as to how the software product may be used across the agency and possibly identify additional items for consideration in the various surveys described in the following section. These interviews provide insight into operational activities and implementation considerations. This ensures that selection and integration of a software product will achieve the maximum utility.

#### 3.2.1.2 Surveys

Surveys can be used to gather information from various members of the agency, addressing the necessary elements for software selection. The survey responses are used as inputs when compiling the MRL, which becomes the basis of the future vendor survey. Typical surveys would cover the areas of standards, software system environment, software functions, and software support.

#### 3.2.1.3 Focus Groups and Workshops

Focus groups and workshops help identify the needs and requirements that will support the mission priorities of an agency. These group discussions focus on software functions, capabilities, necessary data, potential data sources, work processes, and possible scenarios for

feature or function validation. Each focus group includes SMEs or technical staff that will operate or apply the software. It may also be beneficial to populate a workshop or focus group with those from a representative cross-section of the user community (e.g., law enforcement, public safety, emergency management) outside the agency to ensure that the collected requirements are comprehensive.

### 3.2.2 Standards

In defining GIS requirements, agencies need to identify both their organizational and data standards. Agency standards can be considered in the requirements definition process. If an agency or parent organization has already developed a software selection strategy, strong justification for undertaking this formalized process in part or in entirety may be required. The agency may have additional requirements that are not being met by the existing software standard or other compelling reasons for choosing a new software acquisition approach. It is critical that top management at the agency support this process including implementation costs, staff requirements, and training. Other agency or industry policies may need to be considered including network standards, software standards, security standards, and database standards.

In implementing a GIS solution, agencies need to develop and maintain internal data standards and address the critical task of ensuring data interoperability.

> When data is generated outside of an organization, measures must be taken to ensure that it can be integrated into the existing infrastructure. Industry standards have been developed by large scale data producers, data users, and government commissions over the years to maintain quality and insure data interoperability. (Mine Action Information Center, 2013)

A detailed explanation of the most prominent GIS data standards is included in Appendix C. Data standards are usually considered during the needs analysis and requirements definition process in order to enhance data interoperability.

### 3.2.3 Business Policies

A successful GIS must operate according to well-designed methods, processes, business rules, or policies, which may be unique to each agency. Established processes document the way practitioners accomplish their work and interact with others, and process documents can be used to describe the changes required to adopt the GIS technology, implement a new or expanded GIS, and encourage acceptance across an organization. These processes may also prompt the development of a transition plan from current operations to a new operational approach as well as the transition or integration of legacy systems with the new GIS.

### 3.2.4 Requirements Validation Activities

After collecting the requirements, the agency can compile an initial MRL, which can then be distributed to all the participating SMEs and technical staff for review and validation. Each of the SMEs can annotate the requirements they believe to be necessary based on their specific responsibilities, requirements, and workflows. Individual SMEs may not consider every listed requirement necessary and varying responses are expected, which shows that the software may be used for different purposes or applications across an agency.

## 3.3 Product Identification

Product identification and selection involves researching available GIS software products that may be evaluated based on the information obtained through the needs analysis and requirements definition process. Products can also be identified before and during requirements definition. The information gathered from this research may enhance the agency's familiarity with the technology and help refine requirements for capabilities that were not well known or understood.

Market research will identify COTS, GOTS, freeware, or custom GIS software applications that can potentially perform one or many of the functional requirements. Market research can consist of Internet searches, reviews of periodicals and websites, and Requests for Information (RFIs) from industry. Contacting similar agencies (e.g., police and fire) will help to determine the tools being used to support local mission requirements.

Each product identified through market research can then be reviewed, and the following information documented: product type, capabilities, features, system interoperability, data and file formats, training and support options, installation parameters, IT models, and current users. The collected information may help identify initial products based on the operating system platform, interoperability needs, product support, or training options. See Appendix D for a sample product information summary sheet.

### 3.3.1 Internet Research and Literature Review

Internet searches are particularly useful in identifying GIS capabilities and features. Some typical search terms include "geographic information systems," "web mapping," and "spatial analysis." Moreover, a literature review of GIS periodicals and websites, such as those shown in Table 3-3, may be helpful for identifying products that meet an agency's needs.

**Table 3-3. Sample GIS Websites**

| Name | Website |
|---|---|
| ASPRS Journal | http://www.asprs.org |
| Directions Magazine | http://www.directionsmag.com |
| Esri | http://www.esri.com |
| Federal Geographic Data Committee | http://www.fgdc.gov |
| GIS Lounge | http://www.gislounge.com |
| GeoWorld | http://www.geoplace.com |
| Imaging Notes | http://www.imagingnotes.com |
| Open Geospatial Consortium | http://www.opengeospatial.org |
| Pathfinder | http://www1.nga.mil |

| Name | Website |
|---|---|
| Professional Surveyor Magazine | http://www.profsurv.com |
| Spatial Media, LLC | http://www.gisuser.com |
| U.S. Geological Survey (USGS) | http://www.nationalmap.gov |

### 3.3.2 Requests for Information

Agencies may want to issue an RFI to further identify software products that can benefit the user community. These formal requests are used to gather information on potential vendors as well as key product considerations such as specifications, maintenance, support, training, and cost. RFIs are typically posted on Federal, state, and local agency sites and can be followed up with a request for proposal (RFP) or a request for quotation (RFQ), both of which allow vendors to present their qualifications and terms for supplying the product to the agency.

## 3.4 Product Selection

The product selection process involves evaluating software against implementation, cost, and requirement factors as well as conducting a comparative analysis of operational and functional considerations. The criteria used to evaluate software products will be objective and subjective and must be defined as much as possible before communicating with software vendors. This will provide a better understanding of how each identified GIS software product may support the feature, function, and capability requirements.

### 3.4.1 Implementation Factors

Consideration must be given to how the software will be implemented within the agency. Each GIS configuration has different implementation considerations, potentially requiring differing network architectures and infrastructure, hardware, and personnel. In addition, the complexity of implementing a GIS solution may require that the software application be phased in over time to support core users without disrupting ongoing operational or production activities. See Appendix B for examples of GIS architectures.

### 3.4.2 Cost Factors

Cost must be considered during the selection process and involves a review of vendor-related costs such as initial license fees, annual license maintenance fees, media fees, support fees, installation fees, customization costs, consulting fees, and initial training costs. Moreover, agencies need to consider other potential life cycle costs relating to factors such as additional staffing and training, computer and network upgrades, and future infrastructure.

The cost of data may also require a significant investment over the life cycle of the software. The initial and recurring costs of data acquisition can be substantial and therefore must be considered during the software selection process. Anticipated data costs may lead to a phased implementation approach or creative software licensing strategies to ensure any budget constraints can be maintained while meeting agency requirements.

### 3.4.3 Software Requirements

In selecting a GIS solution, emergency response agencies should consider the software function list derived from the needs analysis. This process will ensure that the product under assessment meets all the identified requirements. In addition, it is recommended that emergency response agencies consider the various system requirements relating to software integration, administration, and security. These considerations will guide decision-making about client/server infrastructure, network infrastructure, and security architecture and will be useful in determining:

- Which software packages are desirable given the current and future client/server architecture or infrastructure;
- Which software upgrades might be necessary to support the desired software functionality;
- Whether the network is capable of supporting planned GIS activities; and
- Whether the current security architecture is sufficient and/or compatible with planned GIS activities.

Emergency response agencies seeking to purchase GIS software also need to consider the training and support requirements. An examination of factors such as those presented in Table 3-4 will help guide agencies in choosing GIS software products that best meet their current and future needs.

**Table 3-4. Sample GIS Software Support Considerations**

| Support Consideration | Key Factors |
|---|---|
| Licensing fees | Are licensing fees applied and how are they assessed?<br>Are discounts available when purchasing multiple licenses?<br>Are discounts available for government agencies? |
| Service Agreements | Are tiered service agreements offered?<br>Are annual fees required to maintain the service agreement? |
| Upgrades | How often are upgrades provided?<br>How much do major and minor upgrades cost? |
| Training | Does the vendor provide on-site support for product installation and configuration?<br>Does the vendor provide computer-based training?<br>Does the vendor provide web-based training?<br>Does the vendor provide instructor-led local or remote training? |

| Support Consideration | Key Factors |
|---|---|
| Help Desk | What are the hours of operation?<br>Is toll-free telephone support offered?<br>Is web-based support offered?<br>Is e-mail support offered? |
| User Groups | Is support available via a user group forum? |

### 3.4.4 Requirements Priorities

The MRL may be extensive and present challenges in conducting a product assessment if all requirements receive equal consideration with no assignment of relative importance. Consequently, an agency may need to prioritize all or parts of the MRL so that essential functions, features, and capabilities receive greater consideration during the product assessment process. This prioritization will ensure the presence of critical functionality in the final software selection while reducing the complexity of the product assessment process.

One way to prioritize requirements is to assign weights based upon the SME or technical staff responses. The following is a simple example with four SMEs:

- If four out of four SMEs specify a particular requirement (i.e., function, feature, or capability) is essential, then a weight of 1 (4/4) is assigned to that requirement;
- If three out of four SMEs specify a particular requirement is essential, then a weight of 0.75 (3/4) is assigned to that requirement;
- If two out of four SMEs specify a particular requirement is essential, then a weight of 0.5 (2/4) is assigned to that requirement;
- If one out of four SMEs specify a particular requirement is essential, then a weight of 0.25 (1/4) is assigned to that requirement; and
- If none of the SMEs specify a particular requirement, then a weight of 0 (0/4) is assigned to that requirement.

These weights are assigned to every requirement in the MRL. The derived weight for each requirement can then be used in the future analysis on a product-by-product basis to determine how well each product supports the agency's needs. Table 3-5 presents an example of derived weights based on SME requirements.

**Table 3-5. SME Requirements with Derived Weights–Example**

| Geographic Information System Software Feature, Function, or Capability Requirements | | | SME #1 | SME #2 | SME #3 | SME #4 | Weight |
|---|---|---|---|---|---|---|---|
| **1.0** | **Application Framework** | | | | | | |
| **1.1** | **The product is structured to support various system architectures.** | | | | | | |
| | a. | The product can be standalone. | X | X | X | X | 1.0 |
| | b. | The product can be web-based. | X | X | X | | 0.75 |
| | c. | The product can be network-based. | X | X | X | | 0.75 |
| **1.2** | **The product is structured to support various operating systems (OS).** | | | | | | |
| | a. | The product supports Windows® OS. | X | X | X | X | 1.0 |
| | b. | The product supports Unix® OS. | X | | | X | 0.5 |
| | c. | The product supports Linux OS. | | X | | X | 0.5 |
| | d. | The product supports Android™ OS. | | X | | X | 0.5 |
| | e. | The product supports iOS®. | | X | | X | 0.5 |
| **2.0** | **Data Creation and Conversion** | | | | | | |
| **2.1** | **The product can create and edit various types of data.** | | | | | | |
| | a. | The ability to create shapefiles. | X | X | X | X | 1.0 |
| | b. | The ability to edit shapefiles. | X | X | X | X | 1.0 |
| | c. | The ability to create database files (DBFs). | X | X | X | X | 1.0 |
| | d. | The ability to edit DBFs. | | X | X | X | 0.75 |
| | e. | The ability to create Tagged Image File Format (TIFF) files. | X | | X | X | 0.75 |
| | f. | The ability to edit TIFFs. | X | | X | X | 0.75 |
| **2.2** | **The product can import to a raster.** | | | | | | |
| | a. | The ability to import a line feature to a grid. | X | | X | X | 0.75 |
| | b. | The ability to import a point feature to a grid. | X | | X | X | 0.75 |
| | c. | The ability to import a polygon feature to a grid. | X | | X | X | 0.75 |
| **2.3** | **The product can import to a table.** | | | | | | |
| | a. | The ability to import database to Microsoft Excel | X | X | X | | 0.75 |
| | b. | The ability to import database management system (DBMS) to comma separated value (CSV) files | X | X | X | | 0.75 |
| **2.4** | **The product can import to a vector.** | | | | | | |
| | a. | The ability to import digital line graph (DLG) data to a feature. | | | X | X | 0.5 |
| | b. | The ability to import drawing exchange format (DXF) data to a feature. | | | X | X | 0.5 |
| | c. | The ability to import drawing (DWG) data to a feature. | | | X | X | 0.5 |
| | d. | The ability to import shapefile to a feature. | X | | X | X | 0.75 |
| | e. | The ability to import MapInfo file to a feature. | X | | | X | 0.5 |

### 3.4.5 Vendor Surveys

Once an agency develops an assessment approach, the vendors can be engaged to gather the product information necessary to conduct the assessment. At this time, the MRL is reformatted to a yes or no questionnaire survey and sent to software vendors that have products for consideration. Those vendors would be asked to voluntarily complete the survey, which includes all or subsets of the MRL in the areas of system environment, product functions, product support, and pricing models. During the product assessment, it may become necessary to reduce the number of requirements and place an emphasis on the highest priority functions and capabilities. Since product information has been provided for the comprehensive list, the subset of requirements under consideration can be easily extracted.

### 3.4.6 Feature Comparison Matrix

The vendor survey responses are compiled into a feature comparison matrix on a product-by-product basis. This matrix captures whether the software supports the requested capability or specification.

If the software fully supports the requirement, then the vendor would respond with a yes, which would be assigned a value of 1 for future analysis. If the software does not fully support the requirement, then the vendor would respond with a no, which would be assigned a value of 0 for future analysis. These values, 1 or 0, would be populated in the feature comparison matrix in anticipation of future analysis across all products. The resulting populated matrix then reflects the functions, features, and requirements supported by the product.

### 3.4.7 Product Comparison Matrix

Once all the vendor survey responses are compiled individually into a feature comparison matrix, the matrices for each product are then combined into a product comparison matrix.

All products can now be reviewed collectively on a requirement-by-requirement basis for their ability to support any necessary function or capability. The product comparison matrix allows the evaluating agency to begin examination of product capabilities across all products based on requirements, features, and functions. This initial analysis provides insight into the breadth and depth of capabilities of those products matching an agency's criteria. Table 3-6 presents an example of a product comparison matrix vendor response.

**Table 3-6. Product Comparison Matrix Vendor Response Example**

| Geographic Information System Software Feature, Function, or Capability | Vendor #1 Response | Vendor #1 Value | Vendor #2 Response | Vendor #2 Value | Vendor #3 Response | Vendor #3 Value | Vendor #4 Response | Vendor #4 Value |
|---|---|---|---|---|---|---|---|---|
| **1.0 Application Framework** | | | | | | | | |
| **1.1 The product is structured to support various system architecture.** | | | | | | | | |
| a. The product can be standalone. | Yes | 1 | Yes | 1 | No | 0 | Yes | 1 |
| b. The product can be web-based. | Yes | 1 | No | 0 | No | 0 | Yes | 1 |
| c. The product can be network-based. | Yes | 1 | Yes | 1 | No | 0 | Yes | 1 |

| Geographic Information System Software Feature, Function, or Capability | Vendor #1 Response | Vendor #1 Value | Vendor #2 Response | Vendor #2 Value | Vendor #3 Response | Vendor #3 Value | Vendor #4 Response | Vendor #4 Value |
|---|---|---|---|---|---|---|---|---|
| **1.2 The product is structured to support various operating systems (OS).** | | | | | | | | |
| a. The product supports Windows® OS. | Yes | 1 | Yes | 1 | No | 0 | Yes | 1 |
| b. The product supports Unix® OS. | Yes | 1 | No | 0 | No | 0 | Yes | 1 |
| c. The product supports Linux OS. | Yes | 1 | No | 0 | No | 0 | No | 0 |
| d. The product supports Android™ OS. | Yes | 1 | Yes | 1 | No | 0 | Yes | 1 |
| e. The product supports iOS®. | Yes | 1 | Yes | 1 | No | 0 | Yes | 1 |
| **2.0 Data Creation and Conversion** | | | | | | | | |
| **2.1 The product can create and edit various types of data.** | | | | | | | | |
| a. The ability to create shapefiles. | Yes | 1 | Yes | 1 | Yes | 1 | Yes | 1 |
| b. The ability to edit shapefiles. | Yes | 1 | Yes | 1 | Yes | 1 | Yes | 1 |
| c. The ability to create DBFs. | Yes | 1 | Yes | 1 | Yes | 1 | Yes | 1 |
| d. The ability to edit DBFs. | Yes | 1 | Yes | 1 | Yes | 1 | Yes | 1 |
| e. The ability to create TIFFs. | Yes | 1 | Yes | 1 | Yes | 1 | Yes | 1 |
| f. The ability to edit TIFFs. | Yes | 1 | Yes | 1 | Yes | 1 | Yes | 1 |
| **2.2 The product can import to a raster.** | | | | | | | | |
| a. The ability to import a line feature to a grid. | Yes | 1 | No | 0 | Yes | 1 | Yes | 1 |
| b. The ability to import a point feature to a grid. | Yes | 1 | No | 0 | Yes | 1 | Yes | 1 |
| c. The ability to import a polygon feature to a grid. | Yes | 1 | No | 0 | No | 0 | Yes | 1 |
| **2.3 The product can import to a table.** | | | | | | | | |
| a. The ability to import dbase to INFO. | Yes | 1 | No | 0 | No | 0 | Yes | 1 |
| b. The ability to import DBMS to INFO. | Yes | 1 | No | 0 | No | 0 | Yes | 1 |
| **2.4 The product can import to a vector.** | | | | | | | | |
| a. The ability to import DLG to a feature. | Yes | 1 | No | 0 | No | 0 | Yes | 1 |
| b. The ability to import DXF to a feature. | Yes | 1 | Yes | 1 | Yes | 1 | Yes | 1 |
| c. The ability to import DWG to a feature. | Yes | 1 | Yes | 1 | Yes | 1 | Yes | 1 |
| d. The ability to import shapefile to a feature. | Yes | 1 | Yes | 1 | Yes | 1 | No | 0 |
| e. The ability to import MapInfo file to a feature. | Yes | 1 | Yes | 1 | No | 0 | Yes | 1 |

### 3.4.8 Product Comparison Matrix Analysis

Product comparison matrix analysis is a mathematical approach used to generate product rankings (highest to lowest) based on vendor claims of software capabilities relative to weighted agency criteria such as requirements and features. This type of analysis applies normalized

weights to each criterion on a product-by-product basis and scores them. The scores are then summed for each product and are used to derive rankings as shown in the example in Table 3-7.

The products with higher scores are then considered for final product assessment. The number of products for assessment may be dependent on the resources available (e.g., time, funding, personnel, and hardware).

**Table 3-7. Product Comparison Matrix Analysis with Product Rankings Example**

| GIS Software Feature, Function, or Capability | SME Weight | Product #1 Value | Product #1 Score | Product #2 Value | Product #2 Score | Product #3 Value | Product #3 Score | Product #4 Value | Product #4 Score |
|---|---|---|---|---|---|---|---|---|---|
| **1.0 Application Framework** | | | | | | | | | |
| **1.1 The product is structured to support various system architectures.** | | | | | | | | | |
| a. The product can be standalone. | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 |
| b. The product can be web-based. | 0.75 | 1 | 0.75 | 0 | 0 | 0 | 0 | 1 | 0.75 |
| c. The product can be network-based. | 0.75 | 1 | 0.75 | 1 | 0.75 | 0 | 0 | 1 | 0.75 |
| **1.2 The product is structured to support various operating systems (OS).** | | | | | | | | | |
| a. The product supports Windows® OS. | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 |
| b. The product supports Unix® OS. | 0.5 | 1 | 0.5 | 0 | 0 | 0 | 0 | 1 | 0.5 |
| c. The product supports Linux OS. | 0.5 | 1 | 0.5 | 0 | 0 | 0 | 0 | 0 | 0 |
| d. The product supports Android™. | 0.5 | 1 | 0.5 | 0 | 0 | 0 | 0 | 1 | 0.5 |
| e. The product supports iOS®. | 0.5 | 1 | 0.5 | 0 | 0 | 0 | 0 | 0 | 0 |
| **2.0 Data Creation and Conversion** | | | | | | | | | |
| **2.1 The product can create and edit various types of data.** | | | | | | | | | |
| a. The ability to create shapefiles. | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| b. The ability to edit shapefiles. | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| c. The ability to create DBFs. | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| d. The ability to edit DBFs. | 0.75 | 1 | 0.75 | 1 | 0.75 | 1 | 0.75 | 1 | 0.75 |
| e. The ability to create TIFFs. | 0.75 | 1 | 0.75 | 1 | 0.75 | 1 | 0.75 | 1 | 0.75 |
| f. The ability to edit TIFFs. | 0.75 | 1 | 0.75 | 1 | 0.75 | 1 | 0.75 | 1 | 0.75 |
| **2.2 The product can import to a raster.** | | | | | | | | | |
| a. The ability to import a line feature to a grid. | 0.75 | 1 | 0.75 | 0 | 0 | 1 | 0.75 | 1 | 0.75 |
| b. The ability to import a point feature to a grid. | 0.75 | 1 | 0.75 | 0 | 0 | 1 | 0.75 | 1 | 0.75 |
| c. The ability to import a polygon feature to a grid. | 0.75 | 1 | 0.75 | 0 | 0 | 0 | 0 | 1 | 0.75 |
| **2.3 The product can import to a table.** | | | | | | | | | |
| a. The ability to import dbase to INFO. | 0.75 | 1 | 0.75 | 0 | 0 | 0 | 0 | 1 | 0.75 |
| b. The ability to import DBMS to INFO. | 0.75 | 1 | 0.75 | 0 | 0 | 0 | 0 | 1 | 0.75 |
| **2.4 The product can import to a vector.** | | | | | | | | | |
| a. The ability to import DLG to a feature. | 0.5 | 1 | 0.5 | 0 | 0 | 0 | 0 | 1 | 0.5 |
| b. The ability to import DXF to a feature. | 0.5 | 1 | 0.5 | 1 | 0.5 | 1 | 0.5 | 1 | 0.5 |

| GIS Software Feature, Function, or Capability | SME Weight | Product #1 Value | Product #1 Score | Product #2 Value | Product #2 Score | Product #3 Value | Product #3 Score | Product #4 Value | Product #4 Score |
|---|---|---|---|---|---|---|---|---|---|
| c. The ability to import DWG to a feature. | 0.5 | 1 | 0.5 | 1 | 0.5 | 1 | 0.5 | 1 | 0.5 |
| d. The ability to import Shapefile to a feature. | 0.75 | 1 | 0.75 | 1 | 0.75 | 1 | 0.75 | 0 | 0 |
| e. The ability to import MapInfo file to a feature. | 0.5 | 1 | 0.5 | 1 | 0.5 | 0 | 0 | 1 | 0.5 |
| **Product Score** | | | **16.25** | | **10.25** | | **8.5** | | **15** |
| **Product Ranking** | | | **1** | | **3** | | **4** | | **2** |

## 3.5 Product Assessment

After conducting the product comparison matrix analysis and identifying a reasonable number of products for consideration, an agency can contact the vendors of the products identified as providing viable solutions for detailed discussions on the product's potential to meet organizational requirements. The agency can ask the vendor to conduct an on-site demonstration focusing on specific software functions or features, or the agency can conduct a more formal assessment. The criteria used to develop the SME requirements can also be used during the assessment process.

An assessment may focus on the system environment, interoperability, and functional capabilities required for satisfactory user operation. The assessment process may require the development of a standardized environment so that any down-selected products can be evaluated equally under the same conditions using the same data.

The major activities associated with conducting a formal assessment may include the following:

- Developing the assessment laboratory/facility/test beds:
  - Servers, clients, networks, and data.
- Creating the assessment work processes/scenarios:
  - Relevant and realistic to the agency's workflow; and
  - Important or required exercise-level software functions.
- Selecting assessment personnel:
  - Training, experience, and availability to conduct assessment.
- Conducting the assessment:
  - Perform work processes/scenarios; and
  - Monitor and record software performance.

- Analyzing assessment results:
    - Functions/capabilities performance;
    - Usability of the software; and
    - Software performance within system environment.

## 4. SUMMARY

GIS software tools have become a valuable resource within the emergency response community because they enhance the ability of practitioners to visualize and analyze mission-critical data and formulate efficient response plans in a timely manner. This *GIS Software Selection Guide* describes a structured process for identifying and selecting a GIS software solution that best meets an agency's needs. The process includes the following steps:

- Needs Assessment: Identifies the capabilities a GIS must provide and includes stakeholders at all levels within an agency;
- Requirements Definition: Identifies the functionality the GIS software solution must provide;
- Product Identification: Identifies currently available GIS software solutions and the capabilities they provide;
- Product Selection: Uses market research results to select GIS software solutions for assessment; and
- Product Assessment: Compares and ranks the features of the GIS software solutions under consideration against implementation, cost, and software requirement factors.

Agencies intending to purchase a GIS will benefit greatly from using a formal software selection process. The approach presented in this guide can be tailored to meet unique organizational requirements and will assist an agency's decision makers in finding the right GIS software solution for integration into existing and future operations.

# APPENDIX A. GLOSSARY OF TERMS

This glossary was derived from sources listed in Appendix E.

**Abstract data types.** A mathematical model of data structures that are similar or have a similar behavior.

**Accuracy.** Conformity with a standard or correctness in measurement. Accuracy relates to the quality of a result and is distinguished from precision, which relates to the quality of the operation by which the result is obtained.

**Aspect.** The compass direction in which a topographic slope faces, usually expressed in terms of degrees from the north. Aspect can be generated from continuous elevation surfaces. The aspect recorded for a triangulated irregular network (TIN) face is the steepest downslope direction of the face. The aspect of a cell in a raster is the steepest downslope direction of a plane defined by the cell and its eight surrounding neighbors. Alternately, aspect can be the conceptual center of a projection system.

**Attribute.** Descriptive information about features or elements of a database. For a database feature like census tract, attributes might include many demographic facts such as total population, average income, and age. In statistical terms, an attribute is a variable whereas the database feature represents an observation of the variable.

**Bearing.** The situation or horizontal direction of a fixed point with respect to another or to the compass, expressed as an angle from a known direction, usually north, and usually measured from 0 degrees at the reference direction clockwise through 360 degrees. Bearings are called true bearings, magnetic bearings, or assumed bearings, depending on whether the reference meridian is true, magnetic, or assumed.

**Buffer.** A zone around a map feature measured in units of distance or time. A buffer is useful for proximity analysis. A polygon enclosing a point, line, or polygon at a specified distance.

**Centroid.** The geometric center of an object. For a line, it is the midpoint; for a polygon, it is the center of the area; for a three-dimensional figure, it is the center of volume.

**Client/Server.** A common form of distributed system in which software is split between server tasks and user or client tasks. A client sends requests to a server asking for information or action, and the server responds. There may be either one centralized server or several distributed ones.

**Clip.** A command that extracts features from one feature class that reside entirely within a boundary defined by features in another feature class.

**Conflate.** The aligning of the features of two geographic data layers and then transferring the attributes of one to the other.

**Coordinate system.** A particular kind of reference frame or system, such as plane rectangular coordinates or spherical coordinates, which use linear or angular quantities to designate the relative position of points within that particular reference frame or system.

**Cost-benefit analysis.** A comparison of the costs and benefits of the current system or processes versus a proposed geographic information system (GIS). A cost-benefit analysis is developed to assist with making an acquisition decision.

**Data.** Facts about real-world entities that are organized for analysis. This would include attribute information that describes the geographical information about the relative position of the entity, qualitative information on characteristics, variables, and values of the entity, and temporal information that describes the instant or period of time during which the entity is at a defined location or in an observed state or condition.

**Data dictionary.** A directory of all data items, giving the name and structure of each. It does not contain the actual data. The contents of a data dictionary are sometimes called metadata.

**Data mart.** A repository of information on a specific subject that can be independently accessed and applied by different user groups.

**Data model.** The conceptual organization of a database. It can be thought of as the style of structuring, describing, and manipulating the data in a database.

**Data quality.** The degree of excellence exhibited by the data in relation to a correct portrayal of the actual phenomena.

**Data standardization.** The process of achieving agreement on common data definitions, representation, and structures to which all data layers and items must conform.

**Database.** A logical collection of files managed as a unit. A GIS database includes data about both the position and the attributes of geographic features.

**Database management system (DBMS).** A systematic approach to maintaining, accessing, reporting, and analyzing attribute data. GIS packages may use a DBMS to handle some data management tasks.

**Database structure.** The physical organization of data elements assigned to files and relationships among files.

**Datum.** A base or reference elevation used as the origin to define subsequent elevations. Often refers to mean sea level.

**Digitize.** The process of converting the geographic features on an analog map into digital format using a digitizing tablet, or digitizer, which is connected to a computer. Features on a paper map are traced with a digitizer puck, a device similar to a mouse, and the x, y coordinates of these features are automatically recorded and stored as spatial data.

**Ellipsoid.** A three-dimensional ellipse.

**Features**. A set of points, lines, or polygons in a spatial database that represent a real-world entity. The terms feature and object are often used synonymously.

**Freeware/Open Source Software.** Software, which is freely available, often with source code. There is a wide variety of such software to be found. There are tradeoffs involved in using such software. For mission-critical applications, it is often better to have commercial support. However, some freeware/open source software is supported by commercial entities. Although there is cost involved in that case, there are still some advantages in having source code available, and no per-machine licenses. This type of software may be most attractive to organizations with software development staff, or with heavy customization requirements.

**Generalization.** Simplification of map information so that information remains clear and uncluttered when map scale is reduced. Usually involves a reduction in detail, a resampling to a larger spacing, or reduction in the number of points on a line.

**Geocode.** The process of assigning alphanumeric codes or coordinates to geographic reference data provided in a textual format such as two letter country codes and coordinates computed from addresses.

**Geographic coordinates.** Values specifying the location of features in a standard, absolute worldwide coordinate system (e.g., latitude/longitude, state plane coordinates, universal transverse Mercator).

**Geographic data.** Data that convey the locations and descriptions of geographic features.

**Geographic information system (GIS).** System of computer hardware, software, and procedures designed to support compiling, storing, retrieving, analyzing, and displaying data related to positions on the Earth's surface. A GIS is typically used for handling maps of one kind or another. These might be represented as several different layers where each layer holds data about a particular kind of feature. Each feature is linked to a position on the graphical image of a map.

**Geography network**. An Internet resource used to locate, access, and share GIS data and services.

**Geoid.** An imaginary shape for the Earth defined by mean sea level and its imagined continuation under the continents at the same level of gravitational potential.

**Geoprocessing.** The automated manipulation and/or analysis of geographic data.

**Georeferencing**. The process of taking an image and assigning it geographic coordinates.

**Global positioning system (GPS).** A satellite-based navigational system allowing the determination of any point on the Earth's surface with a high degree of accuracy given a suitable GPS receiver. The network of satellites is owned by the U.S. Department of Defense. Errors in the accuracy of GPS derived positions can be introduced through the nature of local conditions. These errors can be greatly reduced using a technique known as differential GPS.

**Image processing.** The use of data processing systems to analyze, enhance, interpret, or display digital images.

**Isoline.** A line connecting points on a surface of equal value or a map of such lines.

**Large scale.** A map scale that covers a relatively small area on the ground and has a high level of detail. A small area of the Earth's surface on one page is a large-scale map (i.e., a 1:500 map where 1 map unit equals 500 ground units is large scale compared with a 1:1,000,000 map). Contrast with small scale.

**Latitude.** A system of referencing relative north-south locations on the Earth's surface. It is measured in degrees, minutes, and seconds north or south of the equator to the poles.

**Layer.** A logical separation of mapped information representing a theme (e.g., roads, soils, vegetative cover). Layers are registered to each other by control points and the common coordinate system of the database.

**Line.** A set of ordered coordinates that represent the shape of a linear geographic feature. It has a length and direction but no area. Examples include streams, roads, and telecommunication lines.

**Linear referencing.** A mechanism for finding and stating the location of any point along a network by referencing it to a known point so that each point along a network can be identified uniquely by specifying the direction and distance from any known point on the network.

**Longitude.** A system of referencing relative east-west locations on the Earth's surface. It is measured in degrees, minutes, and seconds east or west of the Prime Meridian.

**Map.** A two-dimensional abstract graphical representation of the Earth's surface that displays spatial relationships among features, generalizes their appearance to simplify them for the purpose of communication, and applies symbols to aid in interpretation.

**Metadata.** Data about data and proper usage aspects of it. This information usually includes what it is about, where it is to be found, how to get it, how much it costs, who can access it, in what format it is available, what is the quality of the data for a specified purpose, what spatial location does it cover and over what time period, when and where the data were collected and by whom, and what purposes the data have been used for, by whom and what related data sets are available, etc.

**Model.** A set of rules and procedures that represent a view of reality for conducting spatial analysis to generate a result.

**Needs analysis.** A strategic planning approach for implementing a GIS, which includes a comprehensive assessment of the analytical capabilities, data, and products required by potential users leading to development of software requirements.

**Network analysis.** A data processing method using topologically linked data such as street maps or river networks with the purpose of determining routes between geographic locations, and other analyses requiring the consideration of path and direction. Such analyses might include finding the most efficient travel route, generating directions, or defining service coverage based on travel time.

**Output.** Anything that comes out of a computer to any other device. With a GIS, output may come in the form of a printed map, screen displays, a tabular data summary, or a data file.

**Pixel.** A contraction of the words picture element. Pixel refers to the smallest unit of information available in an image or raster map that can be independently assigned attributes such as color and intensity.

**Point.** A single x, y coordinate that represents a geographic feature that is too small to be displayed as a line or a polygon at a particular scale. Map examples include wells, weather stations, and navigational lights.

**Polygon.** A two-dimensional figure with three or more sides intersecting at a like number of points. It is defined or bounded by a closed line or arc and has attributes that describe its geographic features.

**Precision.** (1) The degree of discrimination with which a quantity is stated. For example, a three-digit number discriminates among 1,000 possibilities. (2) Statistical measure of

repeatability, usually expressed as variance or standard deviation of repeated measurements about the mean.

**Projection (map projection).** A mathematical model that transforms the locations of features on the Earth's surface to locations on a two-dimensional map surface. Some map projections minimize distortion of the feature's shape; others minimize distortion of area, distance, or direction. There are a variety of map projections, but all are generally of three basic types; these are the azimuthal, cylindrical, and conical projections. For example, the Transverse Mercator Projection is a variant of the cylindrical projection.

**Query.** A statement, usually in a standardized language—e.g., Structured Query Language (SQL)—expressing a set of conditions that forms the basis for the retrieval of information from a database.

**Raster data.** Cell data arranged in a regular grid pattern in which each unit (pixel or cell) in the grid is assigned an identifying value based on its characteristics.

**Reference ellipsoid.** A geometric model of the Earth, required for accurate range and bearing calculations over long distances. Ellipsoidal models define an ellipsoid with an equatorial radius and a polar radius. The best of these models can represent the shape of the Earth over the smoothed, averaged sea-surface to within about one-hundred meters.

**Relational database.** A method of structuring data in the form of records so that relations between different entities and attributes can be used for data access and transformation.

**Resolution.** The minimum distance between two objects that can be distinguished by a sensor. While most often it is a synonym for spatial resolution, it also applies to spectral and temporal aspects of remote sensing imaging systems.

**Rubber sheet stretch.** The ability to adjust one dataset to match another dataset.

**Scale.** The ratio or fraction between the size of an object on a map and its size in the real world.

**Scan.** An analogue map digitized by scanning with a resulting raster data structure.

**Server.** A computer, which provides service for other computers connected to it via a network. The most common example is a file server, which has a local disk and services requests from remote clients to read and write files on that disk using the Network File System (NFS) protocol or network operating system software.

**Slope.** A measure of change in surface value over distance expressed in either degrees or percentage. Slope refers to an inclined surface, which can be concave, straight, convex, or a combination of all three.

**Small scale.** A map scale that covers a relatively large area and has generalized labels. A large area of the Earth's surface on one page is a small-scale map (i.e., a 1:1,000,000 map where 1 map unit equals 1,000,000 ground units is small scale compared with a 1:500 map). Contrast with large scale.

**Spatial.** Refers to phenomena distributed in space and therefore having physical dimensions and geography.

**Spatial analysis.** Analytical techniques associated with the study of the location of geographical entities together with their spatial dimensions.

**Spatial data.** Data pertaining to the location, shape, and relationships among geographical features. These can be classified and stored as point, line, area, polygon, grid cell, or object.

**Spheroid.** A solid that resembles a sphere in geometry. One of the terms used to describe the shape of the Earth.

**Spot height.** Computation of height above sea level for a particular spot on the earth's surface.

**Symbology.** Methodology for describing symbols and mapping of the schema to an application schema.

**Standards.** See data standardization.

**Tabular data.** Data (usually an attribute) organized into logical tables. Tables contain items and records in rows and columns.

**Thematic map.** A map related to a topic, theme, or subject of discourse. Also called topical, geographic, special purpose, distribution, parametric, or planimetric maps. Thematic maps emphasize a single topic such as vegetation, geology, or land ownership. Contrast with base map.

**Tool.** A computer program provided within a GIS to allow the user to perform a specific set of operations on map and attribute data. Examples of spatial analysis tools include overlay, window, proximity and network analysis, and map algebra.

**Topology.** The relative location of geographic phenomena independent of their exact position. In digital data, topological relationships such as connectivity, adjacency, and relative position are usually expressed as relationships between nodes, links, and polygons. Topology is useful in GIS because many spatial modeling operations do not require coordinates, only topological information. For example, to find an optimal path between two points requires a list of the lines or arcs that connect to each other and the cost to traverse each line in each direction. Coordinates are only needed for drawing the path after it is calculated.

**Transformation.** A computational process of converting an image or map from one coordinate system to another. Transformation is also known as rectification and usually involves rotation or scaling of grid cells requiring resampling of values.

**Vector data.** Data comprised of x, y coordinate representations of locations that take the form of single points, strings of points (lines or arcs), or closed lines (polygons).

**Viewshed.** Areas obscured from a particular vantage point (i.e., line of sight) for a particular visual surveillance or communication device.

**Workstation.** A computer that consists of a graphic terminal, central processor, digitizer, graphics tablet (optional), and a mouse (optional). It may also be a standalone central processing unit (CPU) and its peripheral devices. It is often linked to other computers through a network.

# APPENDIX B. EXAMPLE GIS ARCHITECTURES

As geographic information system (GIS) deployments have grown in size and complexity, various system architectures are possible to support different distributed computing and data access configurations. The following are examples of possible GIS architectures to support local, department, and community user needs.

## B.1 Local GIS

A local GIS, as shown in Figure B-1, involves operations occurring on user desktops with data stored locally or accessed remotely from the World Wide Web (WWW). This configuration is easy to establish since it does not have extensive equipment infrastructure.


**Figure B-1. Local GIS**

## B.2 Department GIS

A department GIS, as shown in Figure B-2, supports operations through multiple, networked workstations sharing information between department-level file servers. This configuration requires a more significant commitment in staffing and infrastructure and can be managed across cooperating departments to accomplish necessary updates and integration activities.

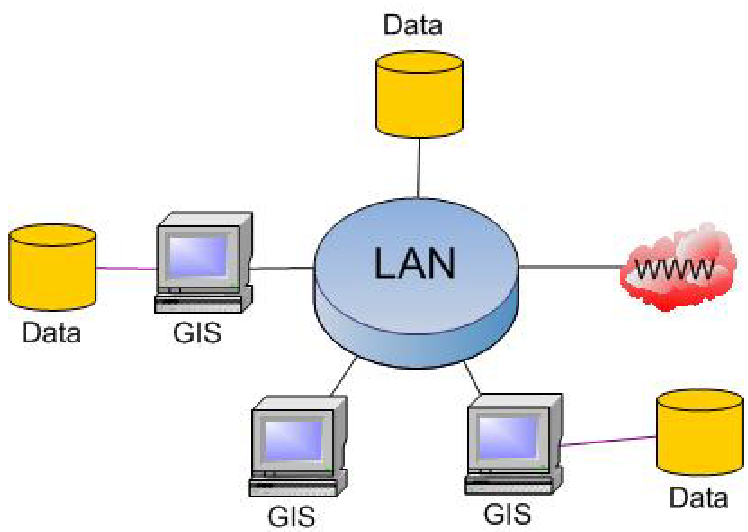



**Figure B-2. Department GIS**

## B.3 Organizational GIS

An organizational GIS supports operations across several departments and may include local GIS operations, which require data resources from other departments within the agency. The WAN supports sharing data between department-level file servers. This configuration requires a higher commitment in staffing and infrastructure and must be managed across all participating departments to deal with data sharing, integrity, exchange, metadata, and standards issues. An example of an organizational GIS examples is shown in Figure B-3.

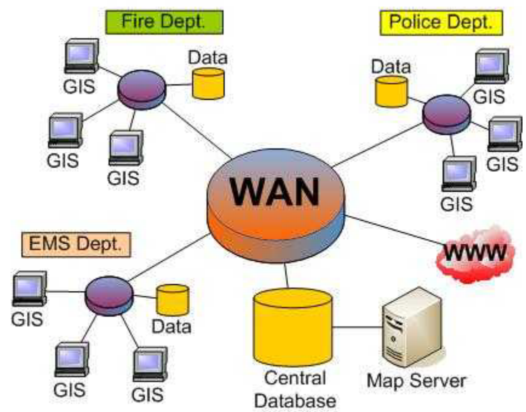



**Figure B-3. Organizational GIS**

## B.4 Community GIS

A community GIS supports the ability to share data and services between organizations. The WAN supports sharing data between organizational-level file servers and distributed client/server networks. This configuration requires a much higher and long-term commitment in staffing and infrastructure and must be managed across all participating agencies to deal with data sharing, integrity, exchange, metadata, technology, and standards issues. An example of a community GIS is shown in Figure B-4. This architecture includes external resources such as a GIS data mart and geography network.

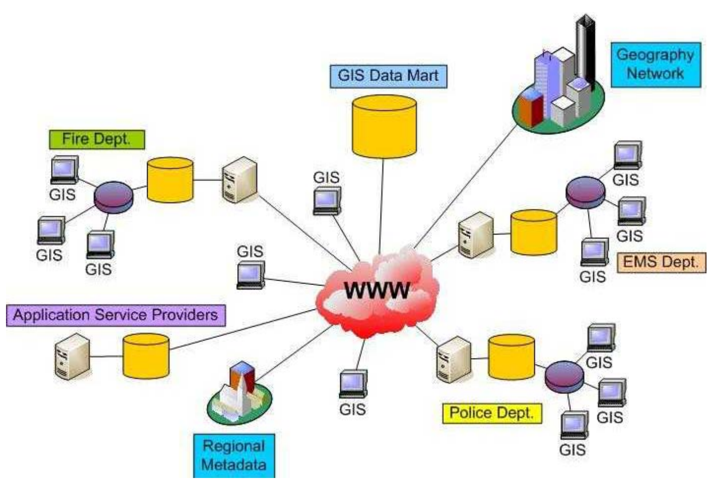



**Figure B-4. Community GIS**

# APPENDIX C. GIS DATA STANDARDS

These are descriptions of the more prominent geographic information system (GIS) Data standards that are to be considered during the software selection process to enhance data interoperability.

## C.1 Coordinate Systems

A coordinate system is used to define a location. It is created in association with a map projection, datum, and reference ellipsoid and describes locations in terms of distances or angles from a fixed reference point. The system may be either a Cartesian system, with coordinates based on orthogonal or 90-degree angles, or it may be polar, based on angles measured from a point such as the center of the Earth. For example, in the latitude/longitude system, positions are described based on angular measurements north or south of the equator and east or west of the Prime Meridian, which runs through Greenwich, England. This is considered a polar system (see Figure C-1).

Coordinates are used to describe positions in two- or three-dimensional space and specify a particular location. A two-dimensional system uses a coordinate pair, typically referred to as x and y, to describe a horizontal position. A three-dimensional system adds the height or elevation to create an x, y, z position.

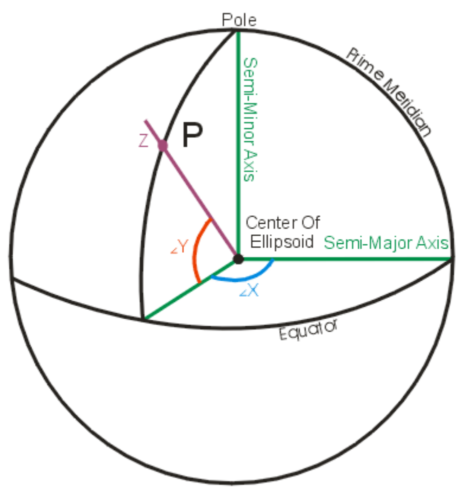



**Figure C-1. Example of Polar System (MAIC, 2013)**

Some coordinate systems extend over the entire globe, while others are used exclusively for specific regions. Examples of global coordinate systems include latitude/longitude, Universal Transverse Mercator (UTM), World Geographic Reference System (WGRS), and various military grid reference systems. Examples of local coordinate systems include numerous national grid systems, as well as Universal Polar Stereographic, which is used for the polar regions of the globe (Mine Action Information Center [MAIC], 2013).

## C.2 Projection

A map projection is a mathematical model for conversion of locations from a three-dimensional to a two-dimensional map representation. This conversion necessarily distorts some aspect of the surface, such as area, shape, distance, or direction. Projection types are based on the geometric form used in the transfer from the spherical Earth to a flat surface. Several examples are listed below and shown in Figure C-2:

- Azimuthal (or Planar);
- Cylindrical; and
- Conic.

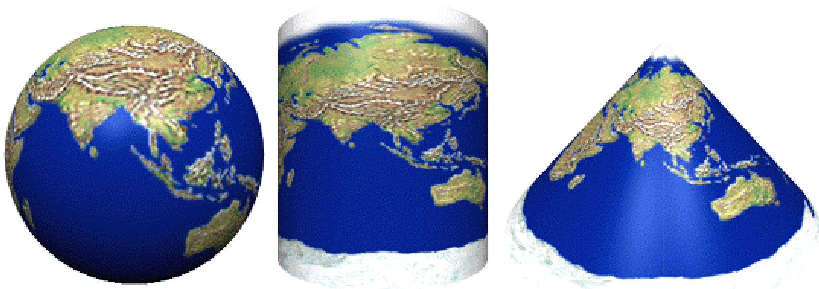


**Figure C-2. Planar, Cylindrical, and Conic Projections**

Different types of projections are used for specific areas and minimize the distortions for that part of the globe. Some of these projections include Mercator, Robinson, Transverse Mercator, Eckert, and Lambert Conformal Conic (MAIC, 2013).

Map projections are very important when more than one data source is used. For example, if a base map is in the Mercator projection and a data set of cities is in the Robinson projection, the cities will not be displayed in the correct location relative to the base map.

## C.3 Datum

A datum is a mathematical model used to calculate the coordinates on a map, chart, or survey system. This includes a set of defining parameters, which forms the basis for computing positions on the surface of the Earth. These parameters include the dimensions of a reference ellipsoid and the coordinates of a point of origin. Most datums are created for use only in specific areas, but the World Geodetic Systems (WGS) can be used globally.

Datums are important because, to accurately represent horizontal positions on maps and charts, we need a mathematical model that takes into consideration the size and shape of the Earth. It is important to know which datum is being used on a map because the coordinates for a point on the surface in one datum will not match the coordinates from another datum for that same point. These different systems can be translated into each other very rapidly using sophisticated computer algorithms (MAIC, 2013).

## C.4 Ellipsoid

Because the Earth is not a perfect sphere (it is wider at the equator than at the poles), an ellipsoid is often used to model its shape. The reference ellipsoid is defined by its dimensions for the major and minor axes and the amount of flattening at the poles (see Figure C-3). Ellipsoids that model the Earth are very near to being spherical, so close that they can be considered a spheroid. Since the flattening occurs at the north and south poles due to the centrifugal force of the rotation, the figure may be further defined as an oblate spheroid.

Specific ellipsoids are better suited for specific situations. For a relatively small area such as a county, the Earth's surface can be thought of as a plane (or flat surface). On the other hand, when high accuracy of large areas is needed, it is necessary to use a more accurate and reliable model of the Earth such as an ellipsoid or geoid (Maling, 1989). When combining or integrating data in a GIS, the various themes (inputs) should share the same projection, datum, and ellipsoid in order to ensure that all of the features will be aligned when viewed together.

Another description of the Earth is a geoid. The geoid is a representation of the Earth's gravity field. Essentially, a geoid is a representation of the surface of the Earth in terms of sea level for every position on Earth, in a more complex manner than an ellipsoid.

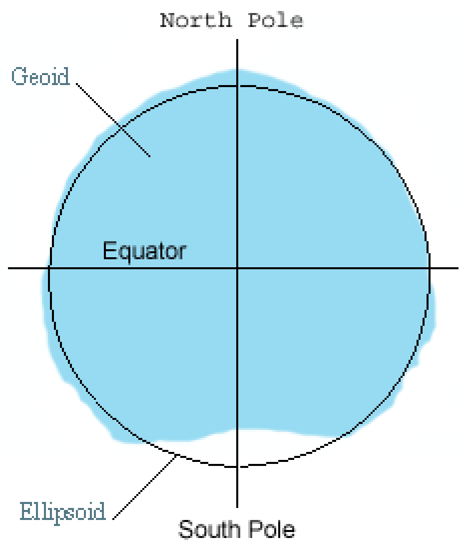



**Figure C-3. Illustration of a Geoid (National Geodetic Survey, 2012)**

When combining or integrating data in a GIS, the various themes (inputs) should share the same projection, datum, and ellipsoid in order to ensure that all of the features will be aligned when viewed together (MAIC, 2013).

## C.5 Map Scale

Scale refers to the relationship or ratio between a distance between two points on a map and the distance between the same two points on the Earth it represents. Maps should display accurate distances and locations and should be in a convenient and usable size. To accomplish this, maps need to show information proportionately smaller than the real-world objects they represent. This proportion is referred to as a map scale, or the relationship between distances on the map and distances in the real world (MAIC, 2013).

Map scales are generally expressed in one of three formats:

- Representative fraction;
- Graphical scale; and
- Verbal-style scale.

In a representative fraction or ratio (e.g., 1:100,000 or 1/100,000), the number to the left of the colon (the denominator) represents a distance on the map, and the larger number to the right (the numerator) represents the actual distance on the Earth's surface. The units of distance are not included because they are the same on the map and in the real-world, regardless of what they may be (e.g., inches, centimeters, etc.). The advantage of a representative fraction or ratio is that any unit of measurement can be used.

On a graphical or bar scale, the length of the scale represents a certain length of the Earth. The units of measurement are provided. In this example, metric and English units are both given (see Figure C-4). The advantage of a bar scale on a map is that it can be easily enlarged or reduced without affecting the accuracy of the scale, assuming the reproduction is enlarged or reduced by the same factor in both horizontal and vertical directions.

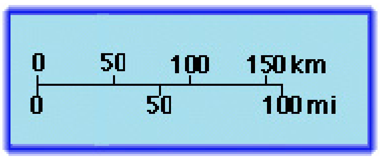


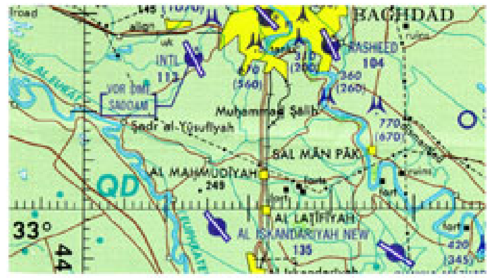

**Figure C-4. Graphic Scale**

Verbal scales are a simple translation to a usable unit of measurement and can be as simple as "1 inch on the map is equal to 2000 feet on the ground." This type of scale is rarely used on maps, yet many maps are designed in such a way that one commonly used unit on the map will equate to another commonly used or easily estimated unit on the ground (Monmonier and Schnell, 1988).

### C.5.1 Large Scale vs. Small Scale

Given a map scale ratio or fraction, the larger the second number, the smaller the scale (or less detail in the map) (see Figure C-5 and Table C-1). A map of scale 1:50,000 is of larger scale than a map of scale 1:1,000,000. In other words, a map which has a larger scale will represent features on the map larger. When choosing a map scale, one must sacrifice the amount of area displayed in order to obtain greater details.


DMA: Saigon, Vietnam, 1968
City Map, Series L909
Scale 1:15,000




DMA: ONC G-4, 1986
Operational Navigation Chart
Scale 1:1,000,000

**Figure C-5. Illustration of Large Versus Small Scale**

**Table C-1. Representative Distances for Map Scales**

| Scale | 1 inch on map represents: | 1 centimeter on map represents: |
|---|---|---|
| 1:24,000 | 2,000 feet | 240 meters |
| 1:50,000 | 4,166 feet | 500 meters |
| 1:63,360 | 1 mile | 633.6 meters |
| 1:100,000 | 1.6 miles | 1 kilometer |
| 1:250,000 | 4 miles | 2.5 kilometers |
| 1:500,000 | 8 miles | 5 kilometers |
| 1:1,000,000 | 16 miles | 10 kilometers |

GIS does not use a specific scale as such, because its maps can be enlarged, reduced, and plotted at many different scales other than the scale of the original data. However, all maps in a GIS may need to be projected on-the-fly or converted to the same scale in order to be layered (MAIC, 2013).

## C.6 Metadata

Metadata is data about data. Specifically, it is information about GIS data with the primary purpose of facilitating and enhancing the retrieval and sharing of spatial information. It can be stored in many formats such as a text file, extensible markup language (XML), or a database record (ESRI White Paper J-8953, 2002). It consists of information that describes spatial data and is used to provide documentation for data products. For example, metadata may describe the format, geographic boundary, projection, coordinate system, availability and cost of a spatial

data set (i.e., road network data, political boundary data, and satellite imagery). Simply put, metadata is the who, what, when, where, why, and how of spatial data (MAIC, 2013).

Metadata provides an easy way to organize, track, and maintain spatial data within an agency. Metadata not only helps find data but also tells how to interpret and use the data. Published metadata facilitates data sharing by providing data documentation, describing data set content, and listing appropriate data uses. Metadata also provides records to resolve potential legal issues, supports budgeting decisions on whether to update or repurchase data, and documents historical changes to the data set (e.g., projection, attribute editing, topology, file format, etc.) which may ultimately affect data quality (ESRI White Paper J-8953).

### C.6.1 Metadata Standards

There are several national and international metadata standards currently being implemented. The U.S. Federal Geographic Data Committee (FGDC) has adopted the content standard for digital geospatial metadata (CSDGM), Australia has a standard implemented by the Australia New Zealand Land Information Council (ANZLIC), and the European Union (EU) is working to implement a European geographic information infrastructure (EGII). Currently, the international organization for standardization (ISO) is developing geospatial metadata standards.

### C.6.2 Data Standards Organizations

In the mid-1990s, new technology emerged that enabled spatial data to be stored in a relational database. These databases enabled organizations to take the first steps toward an enterprise GIS. The open GIS movement was spawned after a short time. Standards organizations, such as the Open Geospatial Consortium (OGC), ISO, and the FGDC, began promoting the idea of GIS standards. The early work of these organizations focused on sharing simple spatial data via relational databases, thus allowing the data to be shared among different GIS packages.

The FGDC (http://www.fgdc.gov) is a 19 member interagency committee composed of representatives from the Executive Office of the President, the Cabinet, and independent agencies. The FGDC is developing the National Spatial Data Infrastructure (NSDI) in cooperation with organizations from state and local governments, the academic community, and the private sector. The NSDI encompasses policies, standards, and procedures for organizations to cooperatively produce and share spatial data. The FGDC has five types of standards. Data classification standards provide groups or categories of data that serve an application; they are the attributes common to elements of a group. Data content standards provide semantic definitions of a set of objects, and may be organized in a data model. Data symbology or presentation standards define graphic symbols. Data transfer standards are independent of technology and facilitate moving data among different GIS applications, without prior specification of the intended end use of the data. The Spatial Data Transfer Standard (SDTS) is an example of a data transfer standard. Finally, data usability standards describe how to express the applicability, or essence of a data set or data element and include data quality, assessment, accuracy, and reporting. The FGDC CSDGM Standard is an example (FGDC, 2013).

The OGC (http://www.opengeospatial.org) is a non-profit, international, voluntary consensus standards organization that is leading the development of standards for geospatial and location-based services. Through the member driven consensus programs, OGC operates over 230 governments, private industry, and academia to create open and extensible software application programming interfaces for GIS and other mainstream technologies. The OGC

mission is to deliver spatial interface specifications that are openly available for global use. The OGC maintains a compliance testing program to permit vendors and users to take advantage of the standards that OGC has created (OGC, 2013).

The ISO (www.iso.org) is developing several GIS standards, though many are still under development. One of the larger standards under development is the Geographic Information Reference Model (GIRM). This standard will describe a total reference model to ensure an integrated and consistent approach to a comprehensive standardization effort. This will promote the widest possible interoperability among geographic information applications and allow these applications to be integrated with the widest possible array of information technology services. Some of the other standards the ISO is working on include adoption of a conceptual schema language, conformance and testing standards, spatial schema standards, and many others far too numerous to list (ISO, 2013).

The Defense Installation Spatial Data Infrastructure (DISDI) Group (http://www.sdsfie.org) is another group working on GIS standards. This organization has developed several tools to assist in the development of graphic and non-graphic standards for GIS implementation. This group of tools is known as the spatial data standards for facilities, infrastructure, and environment (SDSFIE). The SDSFIE provides a standardized grouping of geographically referenced features. Each geospatial feature has an "attached" attribute table containing relevant data about the geospatial feature. The SDSFIE is the only non-proprietary GIS data content standard designed for use with the predominant COTS GIS (e.g., ESRI ArcGIS, Intergraph MGE, and GeoMedia), CAD (e.g., Autodesk AutoCAD/AutoMap, Bentley Microstation, and GeoGraphics), and relational database software (e.g., Oracle and Microsoft Access). This nonproprietary design, in conjunction with its universal coverage, has resulted in the SDSFIE being adopted as the standard for GIS implementations throughout the Department of Defense (DoD), as well as the de facto standard for GIS implementation in other Federal, state, and local government organizations; public utilities; and private industry throughout the U.S. and the world.

There are many geographic standards, which range from organizational standards, to state standards, to world standards. The choice of specific standards will depend on the type of data, the organization that is maintaining the data, how the data will be used, and who will be using it.

Other organizations that are responsible for standards considered important to GIS technology are listed below:

- ANSI: American National Standards Institute (http://www.ansi.org);
- CEN: European Committee for Standardization (http://www.cenorm.be);
- DGIWG: Digital Geographic Information Working Group (http://metadata.dgiwg.org);
- GSDI: Global Spatial Data Infrastructure (http://www.gsdi.org);
- IHO: International Hydrographic Organization (http://www.iho.shom.fr);
- LIF: Location Interoperability Forum (http://www.openmobilealliance.org);
- WS-I: Web Services Interoperability Organization (http://www.ws-i.org); and
- W3C: World Wide Web Consortium (http://www.w3.org).

# APPENDIX D. SAMPLE PRODUCT INFORMATION SUMMARY

## Geographic Information System Software Product Name

| | | | |
|---|---|---|---|
| **Company:** | | **Point of Contact:** | |
| **Mailing Address:** | | **Phone:** | |
| **Developer/Publisher:** | | **Fax:** | |
| **URL:** | | **E-mail:** | |

| **Type of Product** | | **Current Users** | | |
|---|---|---|---|---|
| | ☐ COTS<br>☐ GOTS<br>☐ Custom<br>☐ Freeware | | ☐ Emergency Operations Center<br>☐ Law Enforcement Operations Center<br>☐ Emergency Medical Services<br>☐ Maritime Operation Centers<br>☐ Transportation Agencies | ☐ Public Safety Agencies<br>☐ Fire Operations and Planning Centers<br>☐ Search and Rescue Agencies<br>☐ Hazmat Operations/Planning Centers<br>☐ Other: |

### System Interoperability

| Standards | Programming Languages | | Scripting Languages | DBMS | |
|---|---|---|---|---|---|
| ☐ FGDC metadata compliant<br>☐ OGC compliant<br>☐ XML<br>☐ TCP/IP<br>☐ UML<br>☐ Other: | ☐ Java<br>☐ Visual C++<br>☐ Delphi<br>☐ C<br>☐ C ++<br>☐ Other: | ☐ XML<br>☐ Vision C#<br>☐ .NET<br>☐ JavaScript<br>☐ ASP/ISP | ☐ VBScript<br>☐ Python<br>☐ J script<br>☐ Other: | ☐ Oracle<br>☐ MS Access<br>☐ MS SQL<br>☐ Java Objects<br>☐ SQL Server<br>☐ DB2<br>☐ Other: | ☐ FoxPro<br>☐ Informix<br>☐ Ingres<br>☐ ODBC<br>☐ Sybase<br>☐ dBase |

### File Formats

**Raster Formats**

- ☐ Compressed ARC Digitized Raster Graphics (ADRG)
- ☐ ASCII grid data format (ASC)
- ☐ Band Interleaved by Line/Pixel (BIL/BIP)
- ☐ Band Sequential (BSQ)
- ☐ Controlled Image Base (CIB)
- ☐ DEM ArcInfo (DEM & HDR)
- ☐ DTED (levels 1 and 2)
- ☐ ER Mapper (ERS)
- ☐ ER Mapper Enhanced Compressed Wavelet (ECW)
- ☐ ERDAS Image file format (GIS/LAN)
- ☐ ERDAS Raw (RAW)
- ☐ National Image Transfer Format v2.0 and 2.1 (NITF, NTF)
- ☐ Graphics Interchange Format (GIF)
- ☐ JPEG File Interchange Format (JFIF) including JPEG 2000
- ☐ LizardTech MrSID (SID) including generation 3
- ☐ Portable Network Graphics (PNG)
- ☐ Standard JPEG format (JPG)
- ☐ Tagged Image File Format (TIFF)
- ☐ Windows Bitmap format (BMP)
- ☐ Other:

**Vector Formats**

- ☐ ArcInfo Interchange format (e00)
- ☐ Autodesk Drawing eXchange Format (DXF)
- ☐ Autodesk Drawing files (DWG)
- ☐ Digital Line Graphs (DLG)
- ☐ ESRI Generate Line (ARC)
- ☐ ESRI Shapefiles (SHP)
- ☐ Geography Markup Language (GML)
- ☐ MapInfo Interchange Format (MIF & MID)
- ☐ Microsoft Windows Metafile (WMF)
- ☐ MicroStation Design files (DGN)
- ☐ MOSS files (MOS)
- ☐ Scalable Vector Graphics (SVG)
- ☐ Spatial Data Transfer System (SDTS)
- ☐ Topologically Integrated Geographic Encoding & Referencing Files (TIGER)
- ☐ Vector Product Format (VPF)
- ☐ Other:

### Installation Information

| Operating System | IT Models | Browsers | Components |
|---|---|---|---|
| ☐ Windows<br>Specify OS: ________________<br>☐ Unix<br>Specify OS: ________________<br>☐ Macintosh<br>Specify OS: ________________<br>☐ Other OS<br>Specify OS: ________________ | ☐ Client/server<br>☐ Standalone<br>☐ Network-based<br>☐ Web-based<br>☐ Other: _________ | ☐ Internet Explorer<br>☐ Firefox<br>☐ Chrome<br>☐ Other: __________ | Minimum recommended CPU Speed (MHz): ______________________<br>Minimum recommended RAM (Mb): ______________________<br>Minimum recommended Disk Storage (Mb): ______________________ |

| Support Options | Training Options |
|---|---|
| ☐ Web-based support<br>☐ Phone support (business hours)<br>☐ Phone support (24/7)<br>☐ E-mail support<br>☐ Fax support | ☐ Computer-based<br>☐ Web-based<br>☐ Instructor-led (local)<br>☐ Instructor-led (remote) |

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