

GIS DEVELOPMENT GUIDE

Volume III

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GIS DEVELOPMENT GUIDE: ACQUISITION OF HARDWARE AND SOFTWARE

1 INTRODUCTION

This guide begins the description of the first of four steps of the GIS Development process (figure 1) which deal with the actual assembly of the GIS and its subsequent operation.

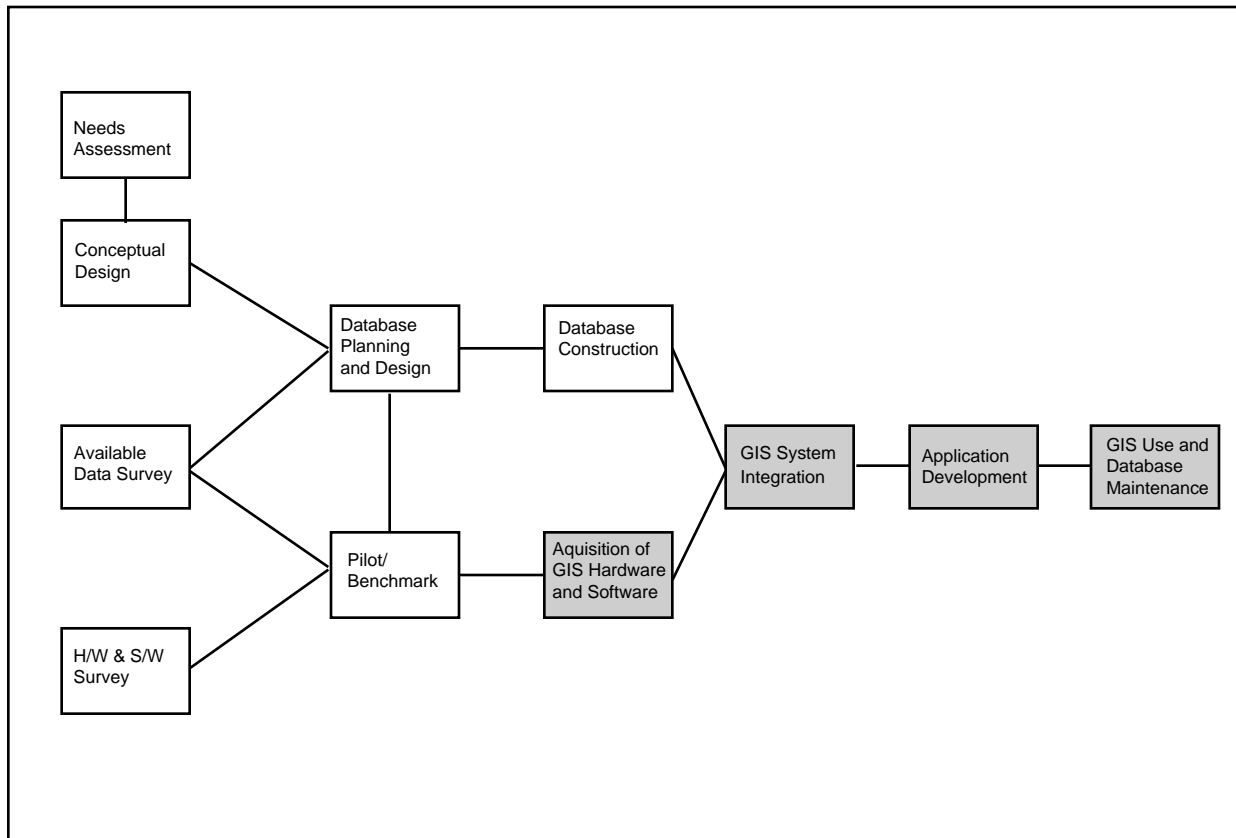


Figure 1 - GIS Development Process

All of the necessary planning, design and testing should have been completed during the execution of the previous seven steps of the GIS development process. The remaining steps and their main purpose are as follows:

- GIS Hardware and Software Acquisition - includes the final selection of the hardware and software (by competitive bid in response to a Request for Proposals - RFP, as necessary); the delivery and installation of the hardware and software; and all necessary renovation of space, wiring, and environmental remodeling.
- GIS System Integration - bringing the final database and the hardware and software together and testing their combined operation.

- GIS Application Development - preparing applications identified in the Needs Assessment which require additional programming using the GIS macro language or other supporting programming languages.
- GIS Use and Maintenance - starting use of the GIS and institution of database, hardware and software maintenance programs. Further application development and user training are also continuing needs.

2 GIS HARDWARE AND SOFTWARE ACQUISITION

This step is the actual purchase of the GIS - hardware and software. The GIS to be acquired is usually subject to competitive bid by the interested vendors. The single most critical part of this process is the preparation of an adequate (and detailed) Request for proposals (RFP).

Acquiring the components for your GIS is an important step. Use all of the information you have gathered up to this point to produce a document telling prospective bidders what you need. The document should clearly communicate your needs and how bidders should respond to the RFP.

During this phase remain objective. Keep as much of the “politicking” out of the selection process. You should be looking for the best value for your money, not the lowest cost.

3 STEPS IN THE GIS ACQUISITION PROCESS

Evaluation Team

The evaluation team should be made up of interested staff from departments involved in implementing GIS within the local government. These individuals need to be objective and not have pre-defined ideas of what system they want. They need to be action oriented and willing to put in the time to do the job right. A successful RFP process involves a great deal of hard work and coordination. You will need to have people on the committee to help accomplish this.

Once a draft RFP has been developed, have an objective 3rd party look at it. You want it as complete and readable as possible. This can be another local government (maybe one of the ones who supplied you a copy of theirs) or a consultant helping you with the RFP process (make sure the consultant is not planning on bidding on the project).

Preparation of Request for Proposal (RFP)

The RFP document is used to communicate your needs to potential bidders. It will also tell bidders how you want them to respond to the RFP.

Be as specific as possible in defining what you need for your GIS. Provide detailed descriptions of the functionality, services and support you are looking for. It is recommended that you do not use specific brand names of software and hardware products in your RFP specifications. This will limit the number of potential bidders you can choose. There will be situations where specific

products are needed. An example is when your organization has a policy in place for using a type of operating system or has already standardized and developed data sets for use in a particular software package. Focus more on what you want the system to do. You will not get what you need unless you specify it clearly in the RFP.

In your RFP, tell the bidders how you want them to respond. Provide examples of what you want: define how pricing should be structured, use standardized forms if appropriate, clearly state criteria for evaluating the responses. You will receive responses that are more consistent and easier to evaluate if you define the response guidelines in the RFP.

To get started, contact other local governments who have recently developed similar RFPs. Use these as a guide. It would be a good idea to contact the person responsible for evaluating the responses. Ask them what worked and what didn't work with the RFP. Adjust your RFP accordingly. Also adjust the scope of your RFP to fit your needs. If you are a small village, don't use a RFP developed by a larger city (or visa-verse) you will not get what you need and the potential bidders will be confused or mis-directed.

Distribution of RFP

You will want your RFP to go to qualified bidders. The best source for this is to go to trade shows or GIS user group meetings and ask around. Again, try to stay objective. Don't get mis-lead by flashy demos or excessive hype. Talk to other local governments and get recommendations of companies they think are qualified to respond to your RFP.

Another method might be to post a notice in GIS trade journals (both regional and national). Be prepared for a large amount of companies inquiring about your project. This method is better used for large, expensive projects.

Bidder's Meeting

A bidder's meeting should be scheduled within a week or two of the RFP be sent out. Make sure the time and location is in the RFP. This meeting is used to get feedback from the bidders and to clarify anything not clearly stated in the RFP. It is always an interesting experience to have number of competitors gathered together in one room. There will be a reluctance by the bidders to ask any questions that might give away their bidding strategy to their competitors. Do not be surprised if there are not many questions raised at the meeting. To get things going, have a short prepared statement or presentation that outlines the history of the project and the requirements of the RFP.

It is important to ask the bidders to submit written questions to you in a specified period of time. It is also recommended that all written questions and your responses be compiled and sent back to all bidders. This will provide consistency and fairness in the process.

The purpose of this meeting is to communicate to all bidders what you need and how you want them to respond.

Answering questions

In addition to the written responses from the bidder's meeting, you will need to provide some mechanism for answering ad-hoc questions from bidders. The best way to do this is to require that all questions be faxed or e-mailed to a specific person and provide a response within 24 hours. It would be impractical for your organization to provide these ad-hoc questions and answers to all bidders. It would be a good policy to take questions up to the submission date for proposals. After that date no correspondence between a bidder and people involved with the selection process should be allowed.

Deadline for submission

Establish a deadline for submission. All responses must be in by the specified time and the specified location in order to be considered. Set your time to be a few hours before the close of business. Inevitably a bidder will get stuck in traffic or a courier will be delayed. This will give you a little cushion and allow you time to check in responses while still allowing you to go home at a reasonable time.

4 EVALUATION OF PROPOSALS

Evaluating proposals should be done by the RFP committee with all the members using the same criteria as listed in the RFP. This process should be documented in case a protest arises. If you have been specific defining your GIS needs and defining how bidders needed to respond, the evaluation process should be straight forward.

Sample Questions - Has the bidder:

- Proven they can meet all of the functionality needed?
- Provided pricing that can be compared with other responses?
- Described the types of services and support in an understandable way?
- Provided references and related experience for you to check on?

Criteria for Evaluation

It is important that this process be documented in case a protest is submitted or to explain why a proposal was not accepted. Each of the criteria needs to be measurable or quantifiable.

Functional capabilities

In the Needs Assessment phase GIS functionality was identified and documented. This documentation of functionality should be defined in the RFP and used for this evaluation. Develop a checklist of the various functions and have each committee member fill out the checklist for each proposal.

Vendor Support

Without proper support any system is doomed to failure. Part of the evaluation is to understand the type of support being offered. What kind of response time is being offered and what are the standards. Will the vendor provide answers to a problem within 24 hours of a call? Will they provide on-site vs. factory service for hardware problem? Make sure you are comfortable with the level of service being offered.

Cost / Maintenance Fee

There are a lot of ways to state the price of a proposal. It is recommended that you be specific as possible in the RFP and bidder's meeting about how the price should be structured. The more pricing can be itemized in the proposal the easier it will be to compare the responses to each other. A suggestion is to develop a pricing form for each bidder to fill out and include with their proposal. As a minimum have separate pricing for software, hardware, services and support. More detail for each of these sections would be nice, just don't get too carried away.

Interviews / Benchmark Test (see Benchmark Test Guide)

After the RFP committee has evaluated the written proposals, a "short list" of bidders should be agreed upon. Any proposals that are not in compliance with the RFP or do not rank high in the evaluation should be eliminated from consideration the remaining bidders comprise the short list. Some marginally qualified bidders may need to be eliminated as well to keep the short list of bidders a manageable size. These short list bidders will be invited to a interview and/or a benchmark.

During this process you will be evaluating the bidder on:

- Ability to interact with your organization
- Technical ability
- Ability to communicate effectively

Selecting a Proposal

Once the Interview / Benchmark is completed. The RFP committee members should compile all of their evaluations independently then meet as a group. This meeting should review all of the proposals and begin to focus on which proposal to select. At this meeting questions may arise that need to be answered in more detail. Take the time to get these answers from the bidder before a selection is made (generally a phone call will work but sometimes a follow up interview is needed if practical).

Once all of the committee's questions are answered, it should move quickly to making a selection and notifying the bidders. At this point a contract needs to be put in place that defines the scope of work outlined in the RFP. This contract needs to be executed before any further phase of GIS implementation is started.

5 GIS DELIVERY AND INSTALLATION PLAN

Once you have selected a vendor(s) for your system you will need to coordinate the delivery and set up of all of the components. there are many resources to call on to do this. The most obvious being the vendor. They should have demonstrated that they have some level of expertise with GIS and can help you get up and running quickly. It is a good investment to buy their services to install and set up the system for you. These service can be contracted for on a time-and-material basis or under a scope-of-service contract.

The most effective means of describing how to prepare the RFP is to do so by example. The remainder of this guideline consists of selected parts from an actual RFP, - presented here to illustrate the scope, content, and level of detail needed. A properly prepared RFP increases the chances that the vendor responses will be most appropriate to the needs of the local government.

6 SAMPLE HARDWARE SPECIFICATIONS

Specifications for a system configuration to support Geographical Information System (GIS) development and operational applications follow. The system configuration consists of various devices that will be networked together to support data capture, storage, processing and display in both digital and hard copy forms, including:

- mapping/analysis workstations (2)
- color laser printer (1)
- black and white laser printer (1)
- cartridge tape drive (1)
- color raster plotter (1)

The proposal shall include technical and functional capabilities of the devices offered to meet these specifications. Provision of the following information should be included for each device:

- manufacturer
- model number
- capabilities/configuration of each device in comparison to the device specifications
- documentation provided with the device (i.e., manuals)
- warranty included in the purchase price
- the nature and duration of user support services included in the purchase price such as maintenance agreements, user support and service, and the average time period between requests for user support and on-sit technical service if available.

GIS Workstations

The Mapping/Analysis workstations will support a wide range of GIS activities, including database development, database quality control, user application development, database maintenance and all GIS applications supported by fully functional GIS software such as cartographic production, geographic database queries, and advanced geographic analysis using both spatial and attribute information. One of the GIS workstations must support high capacity data storage, and multi-user GIS processing, and should perform all GIS operations and applications within acceptable user response times.

General Specifications for Workstations:

- Mass storage may be configured within the workstations' cabinetry and/or as external drives
- The workstations should be configured with a single high resolution (1280 x 1024 or greater) color monitor with at least 19" minimum diagonal screen dimension
- All devices shall include a keyboard and a pointing device such as a mouse
- Each GIS workstation should be network-ready, and should be capable of connecting to a local area Ethernet network and supporting a minimum transmission speed of 10 megabits per second (mbps).
- Multi-user, multi-tasking operating system supporting logical security measures such as user name/password validation, and user access privileges.
- The devices should support virtual memory operations, either through a dedicated hardware controllers(s) or through software (operating system) functions.
- Descriptions of options for upgrading speed and performance through the addition or replacement of boards or other components in the existing cabinetry of the workstations should be provided.

Specific Details of Workstations:

Both workstations should support the following hardware specifications:

- The workstation should include a minimum of a 32-bit processor supporting both 64-bit address and data buses. The CPUs should operate at a minimum of 75 MHz clock speed and/or have enough processing speed and capacity to support other intelligent GIS client devices. These will consist of X-Stations or PCs. The workstations may have multiple CPUs on board.
- The devices should include at least 128 MB (megabytes) of main memory and shall support 32 MB memory modules and be expandable to at least 256 MB.
- The devices should be configured with mass storage disk drive(s) for direct access of data and software functions. They will have a minimum of 3 GB of mass storage each
- The workstations will be configured with a quad speed CD-ROM drives that will facilitate the installation of upgrades to the operating system, installation and upgrade of application software, and user access and review of systems and application documentation.
- The devices should also be equipped with one 1.44 or 2.88 MB floppy drive each
- The server must support multi-user/multi-tasking operations and must concurrently support both server and host workstation functions.

- Vendors shall describe options for upgrading the speed and performance of the server and mass storage capacity through the addition or replacement of boards or other components in the existing cabinetry. Also, Vendors shall describe options for increased performance and mass storage that involve connection of devices external to the existing cabinetry.

Small-Format Color Printer

One (1) color printer will be used for the production of color hard copy graphic plots and nongraphic report generation.

The color laser printer should meet the specifications or equivalent described below:

- Minimum of 300 dots per inch (dpi) resolution
- Minimum 100 sheet paper tray
- Minimum of 4 MB memory onboard with capacity for memory upgrades
- Support for letter, legal size, and 11"x17" paper sizes
- Built-in postscript compatibility
- Serial and parallel interface

Sample hard copy outputs from the proposed device(s) shall be included with the proposal.

Cartridge Tape Drive

The system should include one (1) 4mm DAT tape subsystem for the Planning and Zoning Department. The tape should have a capacity of not less than 5 GB. The tape subsystem will provide a mechanism for performing system and data back-ups.

Large-Format Color Raster Plotter

A color raster plotter shall be included for the production of high quality, large format cartographic products. This device must provide a high-volume color plotting capacity. The plotter shall support 36" x 42" plots and produce color plots at a minimum resolution of 300 dots per. The plotter shall be compatible with the proposed LAN hardware and communications protocols and must be accessible by all workstations on the LAN. A sample hard copy output from the proposed plotter(s) shall be included in the proposal.

Additionally, the plotter shall meet the specifications described below:

- Capable of supporting true color plotting
- Minimum of 8 MB memory onboard with capacity for memory upgrades
- Support for all paper sizes, A through E size
- Built-in postscript compatibility
- Serial and parallel interface

Provide four (4) replacement paper rolls with the printer. The paper should be a high quality glossy bond.

7 NETWORK AND COMMUNICATIONS SPECIFICATIONS

There is a requirement to connect new hardware in two departments. Existing software consists of Intergraph's I-Dispatcher, emergency response dispatch system. Requirements for each level of communications are outlined in the section below. Vendors shall state the level of compliance and provide a description and cost quotation for all hardware and software components needed to meet the requirements at each level of data communications. Vendors should include in the cost proposal the cost of any specialized hardware devices that will be required to implement the proposed communication network.

Network Processing Requirements

Network processing requirements are as follows:

- Storage of data which is accessible by users on the network by specifying particular files, collections of features or attributes, and geographic areas
- Access security to allow assignment of different levels of access rights to portions of the GIS database by user name or physical device
- Ability to support query workstations on the network, directly connected to the server, or connected through remote communication lines so that network users can have access to these devices and vice versa
- Ability to allow database queries directly from workstations on the network without the need to download data to workstations
- Ability to allow network-wide access to plotters and printers, all with print/plot queries for generating hard copies

Network Management and Monitoring Capabilities

The proposed physical network should also be able to perform the following network management functions:

- Access to data on remote nodes by reference to the node, disk, directory, and file
- Access to programs on remote nodes by similar reference
- Assignment of logical names or aliases for programs or data locations on remote nodes
- Control of peripheral devices from any node on the network
- Passing of mail messages across nodes
- Program-to-program communications across nodes
- Monitoring of traffic and errors on the network

The proposal shall include all cabling and devices required to implement all data communication connections, utilizing existing facilities.

Network Speed and Capacity

The proposed system must operate at a minimum raw data speed of 10 megabits per second. The Proposer shall provide information about the upper limit in numbers of mapping/analysis/query workstations that can be supported without major degradation in response time or error rates on the proposed network.

Transactions and Data Exchange with Existing Systems

Initially, the GIS network will not support on-line links with the existing IBM mainframe. Access to data residing on the mainframe will be accomplished by downloading data onto 9-track tapes and then re-writing this data onto current industry standard media such as 4mm data tapes or CDs.

§ SOFTWARE SPECIFICATIONS

Software Component Overview

The GIS software components shall fully support and exploit the capabilities of the proposed hardware platform and shall provide full functionality for entry, editing, maintenance, analysis, display, and hard copy output of both graphics and tabular data on a continuous and interactive basis.

For purposes of this procurement, software component capabilities have been grouped into the functional categories of:

- Database structure
- User interface
- Data entry
- Data editing/maintenance
- Data query and analysis
- Data display/output
- Application development
- Operating system requirements

Data Editing And Maintenance

The proposer shall describe the tools and capabilities of the proposed system to modify and manipulate spatial and attribute data in the GIS for the following categories:

- Interactive Graphic Editing
- Attribute Editing
- File Copying
- Deletion of Features
- Edit Controls
- Rubber Sheeting
- Coordinate Registration and Transformations
- Quality Control/Error Detection
- Merging, Extraction, Edge Matching of Data
- Data Transactions, including the capabilities of the proposed system to translate data into and out of the following formats:
 - GFIS to Proposed System Format (specify how attribute data is addressed)
 - AutoCad DXF (specify how attribute data is addressed)
 - AutoCad CWG (specify how attribute data is addressed)
 - Intergraph IGDS (specify how attribute data is addressed)
 - USGS DLG and DEM
 - TIGER Line Files
 - ArcInfo Export Files
 - Exchange data with KVS Computer Assisted Mass Appraisal (CAMA) System

Data Query And Analysis

The proposed software shall support the following data query and analysis capabilities:

- Graphic Data Query
- Area/Perimeter/Distance Calculation
- Attribute Data Query
- Spatial Aggregation
- Buffer Analysis
- Address Matching
- Polygon Overlay Analysis
- Linear Network Analysis
- Area Districting and Zoning

Data Display/Output

The data display and output tool capabilities that the proposed software shall support including the following:

- Graphic Display
- Tabular Display
- Raster Image Display/Production
- Vector Map Overlay
- Hard Copy Map Production
- Hard Copy Report Production
- Map Plot/Display Relationship with Scale
- Graph/Chart Production
- Interactive Map Composition

Application Development

The Proposer shall propose one or more software components that, in a well integrated manner, provide the following capabilities and features:

- Menu Design and Custom Application Development
- Programming Features
- Supporting High-Level (4 GL) Programming
- Subroutine Libraries

Basic Operating System Requirements

The operating system component of the software shall be the primary operating system of the proposed hardware platform and shall provide all of the traditional features of current operating systems as described below:

- Multi-user Support
- Multi-tasking, Multi-threading Support
- Security Management
- File Management
- Memory Management
- Database Backups
- Error Monitoring/Disaster Recover
- System Diagnostics
- Anti-viral Protection
- Electronic Mail (E-Mail)

Network Management Functions

The proposed system shall provide capabilities for monitoring and managing all data and devices on the GIS network as one unified system and support the following capabilities:

- Multi-user Database Access and Maintenance
- Monitoring of network Activity
- Network Problem Diagnostics
- Print and Plot Management

9 GIS DATABASE STRUCTURE

Database Model

A GIS database model defines the nature and usage of spatial (geographic) data with a database. The proposed software shall support a spatial data model that is capable of creating, managing, and manipulating data sets, defined on the basis of spatial coordinates and associated attribute data sets.

Feature Types: The data model shall support multiple feature types including point, node, line, polygon, and text features

Data Storage: Features shall be stored as double precision x and y coordinates

Data Types: The data model shall support multiple graphic and nongraphic data types

Database Organization: Vendors shall describe strategies for organizing data into logical groups on the basis of data themes, and shall describe the capabilities of the data model for supporting simple and complex feature types.

Topological Data Structures

The geographic data model shall support the creation and maintenance of topological data. Topology shall be created through execution of a software function to structure graphic data sets. Vendors shall describe the ability of the proposed data model to support logical polygons, networks, and user-defined topological structures.

Design

Software capabilities that support large-scale engineering and design activities should be outlined as well as specific engineering functions and appropriate modules.

Raster Image Data

The Proposer shall describe support for storage of raster map images (e.g., scanned bluelines, orthophotos) and for raster scanned documents.

Continuous Geographic Database

The geographic data model shall support the creation and storage of a continuous geographic database

Relational Database Management System

The Proposer shall recommend a relational database management system (RDBMS) that will be able to maintain a minimum of 30,000 records of parcel ownership information in a single table and shall provide functionality for updating database content, queries, and production of reports. The recommended RDBMS must be either a part of the GIS software or have a direct access capability.

10 SUMMARY

The RFP sections presented above give a good example of the scope of topics and level of detail needed. This particular RFP did not present a conceptual data model for consideration by the vendors, but rather specified general characteristics for the GIS data model required. An actual conceptual data model, rather than its general characteristics, could be more useful to vendors, and thus more productive for the user's organization.

GIS DEVELOPMENT GUIDE: GIS SYSTEM INTEGRATION

1 INTRODUCTION

At this point in the GIS development process the GIS hardware and software have been acquired and data conversion is complete (or a substantial portion has been finished). Different components of the hardware and software may have been purchased separately. It is now necessary to put all the pieces together, test them to make sure they work as expected, and to initiate all procedures necessary to use the GIS.

2 GIS SYSTEM COMPONENTS

GIS Software

Vendors will usually install and test their software. Acceptance criteria (often the performance measures used during the pilot study or benchmark test) will be needed and the vendors must meet these criteria before you relieve them of their obligation to you. Check the functionality of the program(s) to ensure that you received what you expected. The vendor should fix any problems that arise, either in software functionality or performance prior to you indicating acceptance of the software.

Check that not only the main GIS software works, but that it works in relation to the other software programs that are part of your "total system," which also includes all legacy databases, software, and hardware. In addition to acceptable performance for each individual piece of software, make sure all software works together. Once the total system is your responsibility and problems arise it can be very difficult to determine the part of the system causing the trouble. Although not nearly as common as in the past, the first response of a vendor can still be "blame the other guy!" Make the *vendors* **responsible** for providing you with one integrated system. Remember - they are the experts. Do not allow anything to be left up to you to check or test. If you are uncomfortable about something or do not understand how something works, talk to the vendor representative and get an explanation. Additionally, technical support is an extremely valuable necessity. All contracts should include on-site technical support and then on-going phone support after the installation is complete.

GIS Hardware

Implementing your hardware system is about the same as your software and must occur simultaneously. Contract with the vendor to install and test the hardware components. As with the software, choose acceptance criteria for the hardware and operating system. Check functionality and performance of the hardware and have the vendor resolve any problems. Make sure the hardware is able to support the software, database, and network as required. Technical support, both on-site and telephone, should have been included in the contract with the hardware vendor.

2 GIS Development Guide

Database

Integrating and testing hardware and software components are fairly well-defined processes and vendors have good experience with these tasks. However, dealing with larger and more complex databases has not been nearly as common in the GIS area. Therefore, adequate procedures and vendor experience may be lacking. There are two processes which remain basically user responsibility:

- building a master database or library (database integration)
- integrating the database with the GIS hardware and software

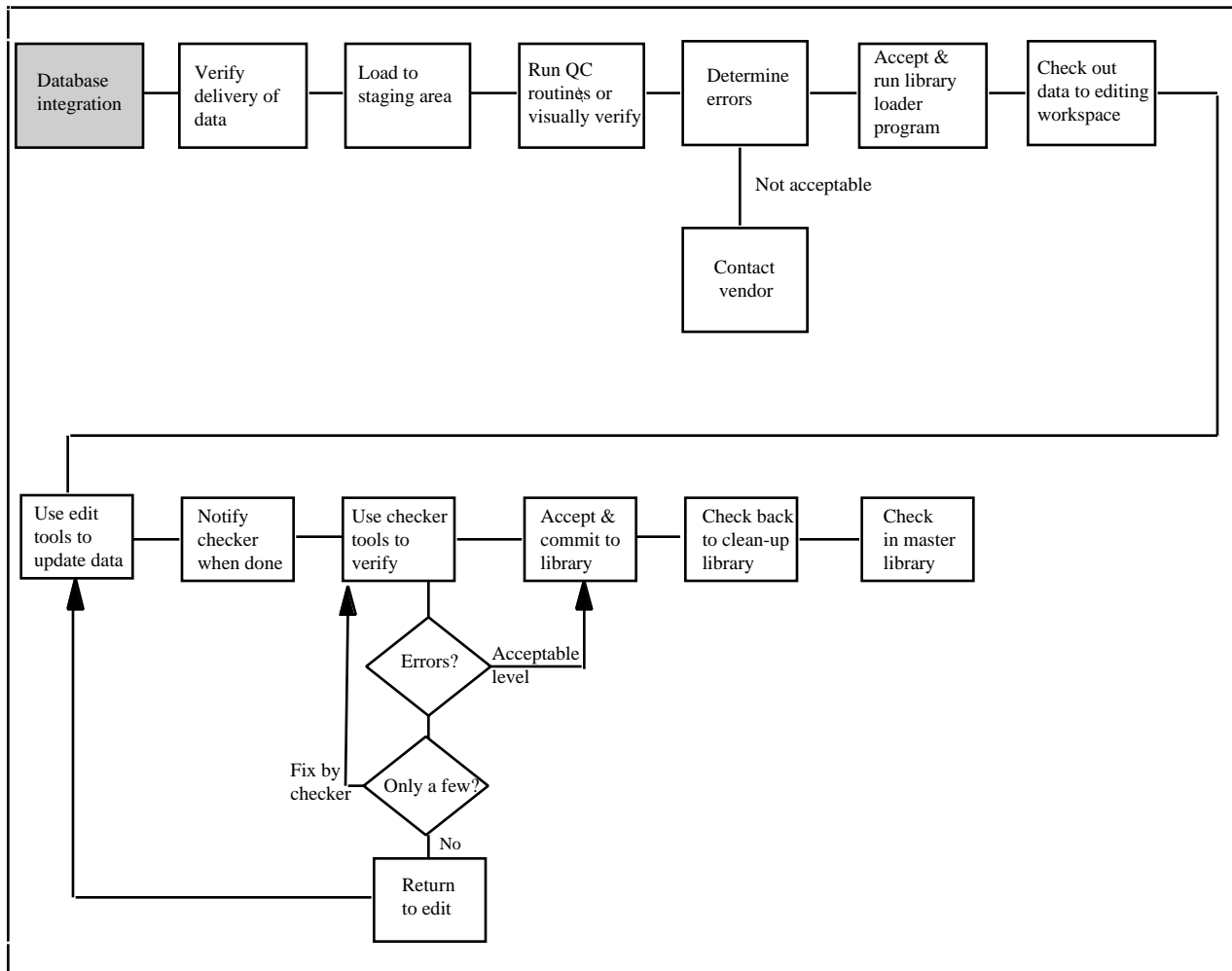


Figure 1 - Database Integration

Figure 1 illustrated the steps of building the master database from the converted data files (the product of the digitizing or scanning process). The overall process deals with quality control checking, other editing procedures, correction procedures, checking corrections for accuracy and finally placing the data file into the master database (or library). It is assumed that organizing data entities into logical groups (i.e., layers) has been defined during the previously completed logical/physical database design activity. Processing to enter data into the master database may involve restructuring the content of the digital/scanned files from data conversion into the final database structure, usually combining entities that may have been digitized separately.

Other database building processes that must be accomplished within the activities shown in figure 1 are:

- linking GIS layers to attribute tables
- edgematching between areas used in digitizing and repartitioning the spatial extent into the final organization
- initialization of all database related procedures needed for both establishing the database and its continued maintenance

Procedural components needed to complete the database include those on the following list. Many of these procedures will have been defined, at least initially, during database design and/or the pilot study and benchmark activities. The procedures are:

- naming convention for all files (covering versions, status, etc.)
- definition of error conditions
- definition of accuracy requirements
- quality control routines
- manual editing procedures
- checking procedures (verification of corrections)
- error recording (flags associated with data or other error/accuracy information recorded in the database)

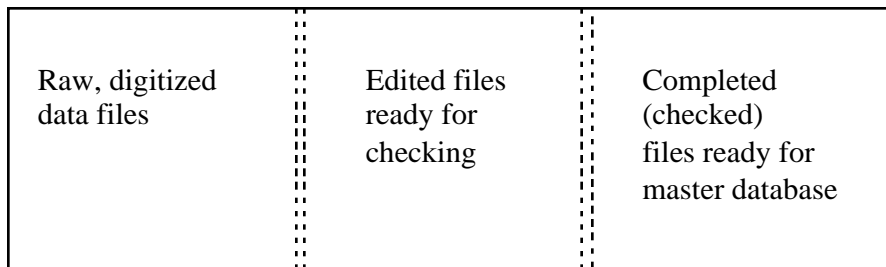


Figure 2 - Library Structure to Support Editing

4 GIS Development Guide

The second major process is the integration of the database and all other system components (figure 3).

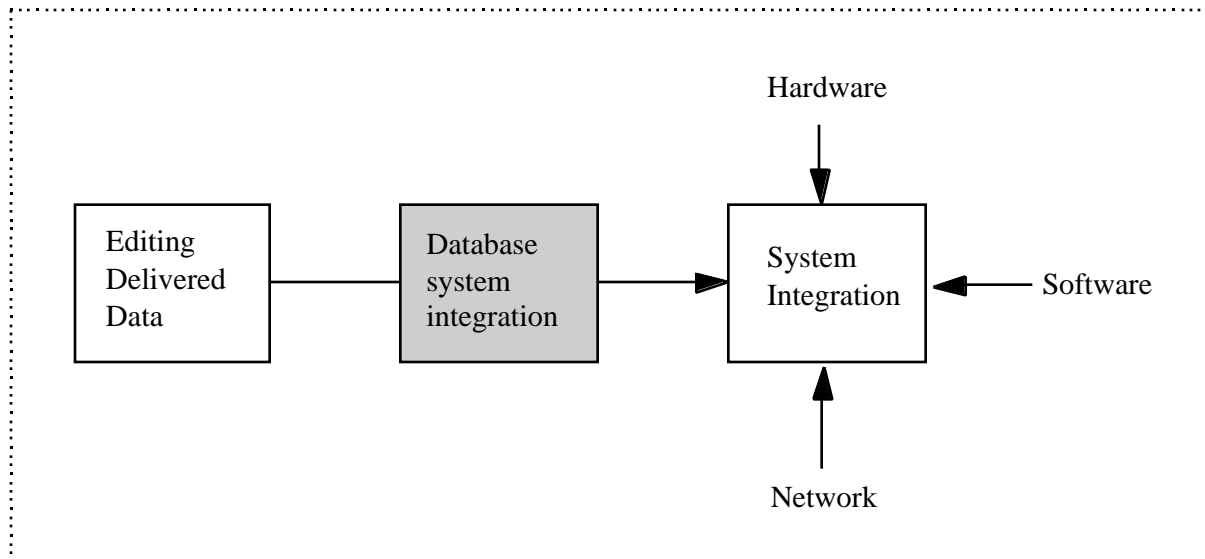


Figure 3 - System Integration

3 SYSTEM TESTING

Once the installations are complete, you need to test your integrated system. Test how the software programs work together, how the network is running, are the computers running slowly when complex functions are requested or all workstations are running simultaneously, and if data retrieval is quick enough, to name a few. This process should continue at least a week, if not more. It is important to experiment with the system on multiple days, with different processes running, and with different numbers of people accessing the data. Ask your staff to document any problems and report these to the vendor. See that resolutions are provided back to you in a timely manner. Utilize technical support lines and keep in mind that the vendors are responsible for following through on what they told you would work.

4 USER TRAINING

Most hardware and software vendors offer classes to teach new users about their products. You can usually include vendor instruction as part of your contract with them. User groups often offer information sessions on software products where you can learn valuable information. Proper instruction is important, however, and is a step that should not be disregarded.

GIS DEVELOPMENT GUIDE: GIS APPLICATION DEVELOPMENT

1 INTRODUCTION

Through time, as users become more experienced with GIS, they require more complex applications. The initial Needs Assessment will contain some applications of a complex nature, however the majority of initial applications will be straight-forward, using the basic functionality that is part of every commercial GIS (e.g., query, display). The more complex applications usually are not supported by the basic functions of a GIS but must be programmed using the GIS macro language or other programming language. This guideline identifies several categories of applications that must be prepared by users and how overall requirements change over time.

2 WHY APPLICATIONS ARE NEEDED

Sales brochures, live demos and journal articles touting the impressive and extensive array of GIS capabilities creates the impression that application development is a non-issue. The vendors, it would seem, have already developed fully functional, out-of-the-box, meet-your-business-needs, GIS software. GIS can and should do anything and everything.

So why are we talking about application development?

Applications are the icing on the GIS layer cake; the highest level of customizable software. The underlying "cake" provides the functionality common to all user disciplines. Commercial GIS packages tend to focus on the common or basic applications - the "cake." When it comes to specialized uses, application development fills the needs for functionality. Though there is a great deal of commonality in the basic spatial query and display functions, there is still a need for other advanced applications. We need additional applications because needs are different between organizations.

Commercial GIS development is driven by market pressure. The software vendors only respond to what makes economic sense for their market share. What's important to your organization may not be important to others. Because of this, there are no truly "off-the-shelf" applications that will match all of your needs. You either have to adapt your uses to *their* data model and functionality or you develop applications to fit *your* use environment.

3 CATEGORIES OF APPLICATIONS

Application development is not rewriting the GIS software, but instead custom applications to meet specific needs. The applications may be as simple as a set of preferences that are stored for each user group or individual and are run as a macro at startup time. Or they may be a very complex query that selects a group of layers, identifies features of interest based on attribute ranges, creates variable width buffers, performs a series of overlays and produces a hard copy map. In either case, an application is required to convert the user's ideas into a usable, stable product.

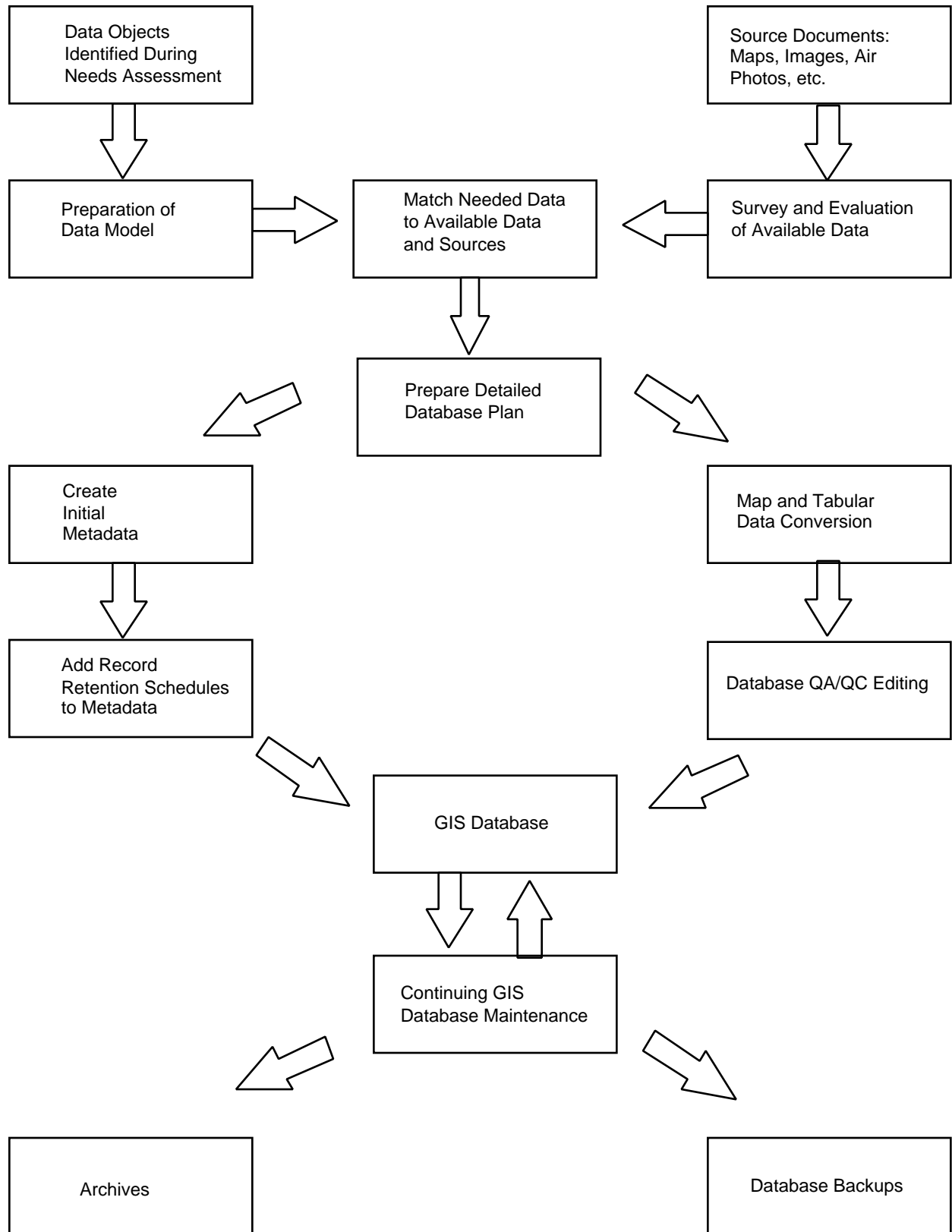


Figure 1 - Life Cycle of a GIS Database

4 DATABASE APPLICATIONS

Applications are not restricted to user-defined needs. One of the short-comings of the needs assessment methodology presented earlier, is the focus on only end-user query, analysis, and display requirements. Collective needs, particularly those related to system-wide functions, are not identified by individual users. The most important of these are the data administration functions for maintaining the quality and integrity of the database, such as quality control, verification, editing, back-up routines, and security.

Database applications fall into the following categories:

- database set-up (described as part of GIS System Integration)
- database management
- database maintenance
- data archiving and retention

Figure 1 again shows the database life-cycle. Each step identified in figure 1 needs to be fully defined, as appropriate to the specifics of the GIS program. The main point here is not how these steps are completed but rather to identify all of the necessary steps and to emphasize the importance of planning and executing each one.

The MSAccess™ metadata software tool accompanying these guides sets forth a structure for creating documentation needed for the management and maintenance of the GIS database. Table definitions for the metadata tool are in the appendix to the GIS use and Maintenance Guideline.

Formal Specifications for Advanced Applications

The documentation of applications is the Needs Assessment guideline describes methods suitable for preparing full and formal specifications for all applications. However, most applications in a new GIS will be of the simpler, more basic type (display, query, map overlay). These applications will likely be satisfied by the normal functionality that is included in most commercial GIS.

More complex applications, either database or spatial analysis, will require development using the GIS macro programming language. For these applications the process of preparing formal specifications, similar to what any large programming project uses, should be followed. The techniques recommended in the Needs Assessment guideline are data modeling by application (E-R technique) and data flow diagramming. These techniques are suitable to provide an overview of a complex application. Additional techniques should be used, as appropriate, including:

- structural analysis and programming
- rapid prototyping

As the application development needs increase, there will be a need for additional staff with the appropriate programming skills and experience using the macro programming language of the GIS.

GIS DEVELOPMENT GUIDE: GIS USE AND MAINTENANCE

1 INTRODUCTION

The last step in GIS implementation is to put the system to use. With system integration and testing complete and at least some applications available for use, the system can be released to users. Two broad categories of activity must be in place at this time:

- user support and service
- system maintenance (database, hardware, software)

While we are describing the activities here, it should be noted that most of what is recommended in this final guideline *should have been defined during the detailed database design step*. So, if you are reading these documents for the first time and have yet to begin an in-depth system planning activity, you should add everything that follows to the Database Planning and Design and Pilot Study/Benchmark steps.

One final comment - usually substantial time passes between the initiation of the needs assessment and the time a GIS is ready to use. A lot will change during this time period. The GIS design activity is in itself a change agent - users will understand more about a GIS and its associated technology after the needs assessment is concluded and will consequently expect more. The applications originally identified, plus all subsequent derived information, will change; the available GIS hardware and software will change; and the underlying computer technology will change. So basically, while you the GIS designer is trying to come to a set of definitive decisions to implement the GIS, everything is constantly changing. The best you will be able to do is to monitor all areas of possible change, at best a difficult task, and to decide on the GIS with the knowledge that the maintenance phase will have to accommodate substantial change. Any and all procedures we have discussed as "maintenance" in these guidelines will need to be put in place immediately after the corresponding document is created or decision is made.

2 USER SUPPORT AND SERVICE

User support falls into the following categories:

- basic orientation in GIS is preparation for the needs assessment
- continued briefings during the planning, design, and implementation phases
- user training courses as needed in computing, general purpose software, databases, GIS, and spatial analysis
- user involvement and evaluation during pilot study and benchmark tests
- user training in specific application use

- technical support service while GIS is in use
- user feedback procedure to identify system enhancements - GIS functions/applications and database
- data error/problem reporting and resolution procedures
- user feedback on data accuracy and system performance
- user involvement in decisions on all system upgrades - data, software, and hardware

It is difficult to identify which of the above is most important. This will vary by situation and over time. However, the first main point in user dissatisfaction comes with the time period between the needs assessment, where expectations are raised, and the first operational use of the system. This user dissatisfaction can be such that there is a temptation to develop quick-and-easy applications for early use, to take short-cuts in database development, or to extend a pilot study into actual use. Such a situation cannot always be avoided, however any premature use of this type will likely lead to more user dissatisfaction in the long term.

GIS System and Database Maintenance

The structure of this task is shown in figure 1. Three driving components of maintenance and change are: system enhancements, database expansion, and routine system maintenance (updates). Figure 1 indicates the type of change that may occur in each component and identifies the benefits and costs associated with the on-going GIS maintenance activity. As users can be negatively affected by charges, major enhancements or expansions need to be subjected to user review, even if the change is only internal to the GIS and on the surface would not affect users.

3 DATA MAINTENANCE PROCEDURES

Managing Existing Data

Backup / Restore

A reliable backup system is necessary for any database. Should anything happen to your hardware (i.e. the file server disk drive crashes), you will be able to restore your backup data to another machine and be operational again in minutes without losing the database. Determine a schedule for regular backups of the system. This can be done daily, weekly, or monthly depending on the size of the database and amount of changes being made to it. If your staff only makes edits once a week, a weekly backup should be enough. However, if changes are constantly being made, a daily backup is important. If you have a large dataset that would be time consuming to backup every day, consider backing up only part of the database daily and then do a full backup once per week.

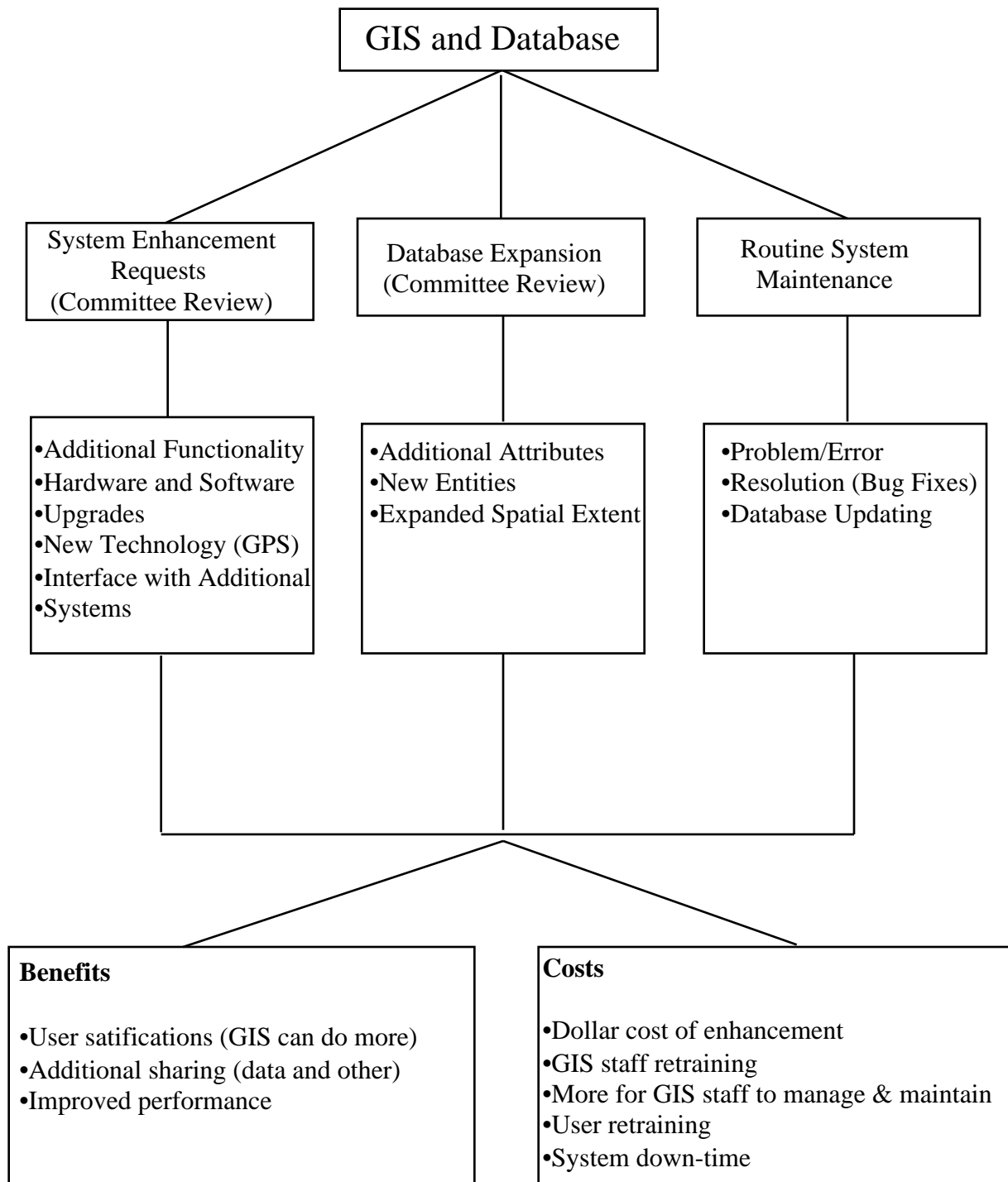


Figure 1 - Overview of GIS Maintenance

Granting Access To Data

Often times GIS applications call for users to display and/or analyze the data only, without editing it. By granting read only access to the data to these types of users, you eliminate any chances for data to be deleted or otherwise altered. If you have other users who edit data, such as supervisors or trained technicians, grant them read and write permissions to the data. Data access can usually be handled by the GIS application, by the database software, and/or by network (if you are running one) software security operations.

Another important function in data maintenance to consider is transaction maintenance. This type of application registers items in the database such as when a record was updated, by whom, and from what source the changes came from. A history log is kept on each record and old records being updated can be sent to an archive file. This step may seem unnecessary in the beginning, but as the database enlarges an application such as this will be of great value. If there are problems or questions with data, you will know exactly who to turn to to question its accuracy and quality.

Records Management And Retention

Four important questions should be looked at with regards to management and retention: what to keep, how long to keep it, how to keep it, and how often to keep it. The New York State Archives and Records Administration is currently developing additional guidelines to regulate and define records management and retention policies for GIS in local government. Until these guidelines are completed, please see the "Local Government Records Technical Information Series No. 39" pamphlet for more assistance. A record in a GIS is difficult to define. It can include: data in the database, maps, aerial photographs, data dictionaries, and metadata. To help determine how long to keep your data, obtain a retention schedule from SARA. These are used for hardcopy data retention but can be modified and used for your purposes. Electronic media is generally used for data storage. Again, SARA is developing regulations on this, so it would be best to contact them for guidance.

Reviewing Current Data For Potential Errors and Changes

Develop a system for QC of the data. Most likely the dataset will be too large to be able to check everything. Determine what will be checked and what degree of accuracy you require. Several things you should look for are described below.

Incompleteness

Begin by checking to make sure all the layers of data that should be in the database are there. Also, make sure no layers are repeated. Define a process for checking some of the individual features of each layer. Determine if there is any missing data and make sure data is not repeated in more than one layer.

Errors

There are two types of errors you should be concerned with: positional and attribute. Positional errors are defined as absolute or relative. “Relative accuracy is a measure of the maximum deviation between the interval between two objects on a map and the corresponding interval between the actual objects in the field. For example, a measurement on a map from a water valve to the street centerline must be within a certain relative accuracy requirement to be accepted. Relative accuracy does not relate to a reference grid and the correct geographic position of the object is not relevant. Absolute accuracy is a measure of the maximum deviation between the location where a feature is shown on the map and its true location on the surface of the earth (Montgomery and Schuch, 132-133).” Attribute errors are problems with the feature itself, not where it is located.

Topological Errors

Many GIS software packages are equipped to find topological errors in your dataset. Use available tools, or develop your own, to detect the following types of errors: closure (unclosed polygons), connectivity (unconnected arcs that should be connected), and coincident features. Coincident features (shared arcs) are difficult to locate; they may appear to have one arc between two features, but it turns out to be two arcs, one on top of the other. This should be corrected because it can result in sliver polygons (small gaps between two polygons).

Detecting Change and Identifying Sources for Updates

As a local government several internal sources for data updates would include: building permits issued, real estate transactions, subdivisions proposed and/or approved by the town council, and zoning changes. This is all important information you might want to include in your GIS. External sources of data updates might include: aerial photo surveys, subdivision contractor drawings, the Department of Transportation, the U.S. Postal Service, the Office of Real Property Services, and state and federal agencies (i.e. environmental groups, soil surveys, and the Coast Guard).

Collection of New Information

Once you have determined that there are new pieces of information you want to capture in your GIS, you must decide how you will collect it. Data conversion can be expensive; however, you know what the accuracy and quality of the data will be and you will get the information when you want it. Many of the sources listed in the above section will have digital data they would be willing to sell. Consider signing a contract to receive any updates they make. A third option for data collection is finding a way to work it into the staff’s daily routine. This makes data collection take longer, but it does not disrupt workflow and it costs less. Determine what field crew or staff would be able to capture the data without it being a burden on their job and decide which people know the most about the data you are attempting to capture.

Applying the Edits and Tracking Changes

Editing the database can become a tedious task. However, it is important to the data integrity that the edits are done accurately and consistently. All changes should be tracked in a way, as described above, that will allow you to determine when the records were updated, by whom, and what level of confidence the data was rated. When necessary, a history log can be displayed for each record and all changes to the data will be noted. Archiving data is a good way to keep out-of-date information from cluttering the system, while allowing easy recall should there be something wrong with the updates or new data.

Verifying the Corrections

Develop a QC process or use the procedure you've already implemented to check the corrections made. You will not want to verify every change made, but you could select a random number of records and confirm that corrections were made correctly.

Updating the Master Database

Once edits are made and you've verified that they were updated correctly in the database the master database can be updated. If edits are being made on a daily basis, the master database may be updated on a daily basis as well, but be sure not to skip the correction verifying step.

Distributing the Updates to Users

This will depend on the technology being used. Some users will have access to a modem and can dial-up and download any edits you make. Other users will have to receive the data on a tape or disk. Determine a schedule and plan for distributing edits to your users that best suits your company.

Montgomery, Glenn E. and Harold C. Schuch, GIS Data Conversion Handbook, GIS World, Inc. and UGC Consulting, Fort Collins, 1993.

Appendix A

OrganizationInfo

Name of organization/agency:

Town of Amherst

Department:

Assessor

Room/Suite #:

Number and Street Name:

5525 Main Street

City:

Amherst

State:

NY

Zip Code:

14221-

Phone Number:

(716)555-8888

Fax Number:

(716)555-7444

Contact Person:

John Henry

Phone Number/Extension:

(716)555-8888 x777

Email Address:

jhenry@assr.amh.gov

Organization Internet Address:

general@assr.amh.gov

Comments:

CONTINUE Inputing
For This
Organization

Input NEXT
Organization

EXIT Database

ReferenceInfo

Organization:	<input type="text" value="Town of Amherst"/>
Filename:	<input type="text" value="ParcelMap"/>
File Format:	<input type="text" value="ARC/INFO"/>
Availability:	<input type="text" value="yes"/>
Cost:	<input type="text" value="\$15.00"/>
File Internet Address:	<input type="text" value="ftp.assr.amh.gov/pub"/>
Metadata Created By:	<input type="text" value="Lee Stockholm"/>
Date Metadata Created:	<input type="text" value="07-May-95"/>
Metadata Updated By:	<input type="text" value="Laura Hiffel"/>
Date Metadata Updated:	<input type="text" value="15-Feb-96"/>
Metadata Standard Name:	<input type="text" value="New York State Local Government Standard"/>
Comments:	<input type="text"/>

CONTINUE
Inputing For This
File

Input NEXT File

SAVE and Input
Next
Organization

DataObjectInfo

Data Object Name:

Type:

Data Object Description:

Spatial Object Type:

Comments:

**CONTINUE with
Spatial Info**

**CONTINUE with
Attribute Info**

**CONTINUE with
Lineage Info**

**CONTINUE with
Update Info**

**Input NEXT Data
Object**

**EXIT Data
Object Info**

SpatialObjectInfo

Data Object Name:	<input type="text" value="Parcel"/>
Spatial Object Type:	<input type="text" value="Polygon"/>
Place Name:	<input type="text" value="Amherst"/>
Projection Name/Description:	<input type="text" value="UTM"/>
HCS Name:	<input type="text" value="State plane Coordinate System"/>
HCS Datum:	<input type="text" value="NAD83"/>
HCS X-offset:	<input type="text" value="1000000"/>
HCS Y-offset:	<input type="text" value="800000"/>
HCS Xmin:	<input type="text" value="25"/>
HCS Xmax:	<input type="text" value="83"/>
HCS Ymin:	<input type="text" value="42"/>
HCS Ymax:	<input type="text" value="98"/>
HCS Units:	<input type="text" value="Feet"/>
HCS Accuracy Description:	<input type="text" value="National Map Accuracy Standard"/>
VCS Name:	<input type="text"/>
VCS Datum:	<input type="text"/>
VCS Zmin:	<input type="text" value="0"/>
VCS Zmax:	<input type="text" value="0"/>
VCS Units:	<input type="text"/>
VCS Accuracy Description:	<input type="text"/>
Comments:	<input type="text"/>

**CONTINUE with
Source
Document**

**GO BACK to
Data Object
Form**

SourceDocumentInfo

Data Object Name:	<input type="text" value="Parcel"/>
Spatial Object Type:	<input type="text" value="Polygon"/>
Source DocumentName:	<input type="text" value="Parcel Map"/>
Type:	<input type="text" value="Map"/>
Scale:	<input 1"="200" 50="" =="" feet="" feet"="" to="" type="text" value="Variable: 1"/>
Date Document Created:	<input type="text" value="17-Nov-89"/>
Date Last Updated:	<input type="text" value="05-Oct-94"/>
Date Digitized/Scanned:	<input type="text" value="24-Apr-95"/>
Digitizing/Scanning Method Description:	<input type="text" value="Manual digitized with Wilde B8"/>
Accuracy Description:	<input type="text" value="90% of all tested points within 2 feet"/>
Comments:	<input type="text"/>

**GO BACK to
Data Object
Form**

AttributeInfo

Data Object Name:	<input type="text" value="Parcel"/>
Data Attribute Name:	<input type="text" value="SBL Number"/>
Attribute Description:	<input type="text" value="Section, Block, and Lot Number"/>
Attribute Filename:	<input type="text" value="Parcel,PAT"/>
Codeset Name/Description:	<input type="text" value="N/A"/>
Measurement Units:	<input type="text" value="N/A"/>
Accuracy Description:	<input type="text" value="N/A"/>
Comments:	<input type="text"/>

**CONTINUE with
Data Dictionary**

**GO BACK to
Data Object
Form**

DataDictionaryInfo

Data Object Name:	<input type="text" value="Parcel"/>
Data Attribute Name:	<input type="text" value="SBL Number"/>
Data Type:	<input type="text" value="Character"/>
Field Length:	<input type="text" value="15"/>
Required:	<input type="text" value="Yes"/>
Comments:	<input type="text"/>

**GO BACK to
Data Object
Form**

Lineage

Data Object Name:

Data Object1:

Data Object2:

Description of Spatial Operation and Parameters:

Accuracy Description:

Comments:

**GO BACK to
Data Object
Form**

UpdateInfo

Data Object Name:

Update Frequency:

Date:

Updated By:

Comments:

**CONTINUE with
Archive Info**

**GO BACK to
Data Object
Form**

ArchiveInfo

Data Object Name:

Parcel

Retention Class:

A

Retention Period:

Permanent

Date Archived:

31-Dec-95

Archived By:

Lee Stockholm

Date to be Destroyed:

**GO BACK to
Data Object
Form**