The Use of GIS for Surveyors and Engineers in Developing Nations for Building Infrastructure

Brent A. JONES USA

Key words: GIS (Geographic Information System), Design, Construction, Infrastructure, Developing Nation, CAD (Computer Aided Design)

SUMMARY

Using GIS to develop new infrastructure overcomes much inefficiency encountered in the past by surveyors and engineers. Traditionally, data was collected and input into GIS for concept development, planning and permitting. Survey and mapping data was collected and collated in a variety of different formats including tabular, CAD, and proprietary mapping systems. Engineers overlaid infrastructure design on these data, often in different files and disparate systems. Infrastructure was built, as-built data collected, and then data from all of these sources was converted into an operational facilities management system in GIS. Today, GIS has matured to encompass the entire process of infrastructure development, from concept and planning through survey, mapping, design, construction, as-built, and operations.

There are many advantages for using GIS for surveying, engineering, construction and maintenance. Fewer types of software are used, reducing training and licensing costs. With fewer types of software used, compatibility issues are minimized. Project personnel can more easily cross-train to other work functions. There is a reduced chance of error translating data from one system to another. And the operational GIS system stores the information collected from concept through construction, giving system operators much more data to operate and manage their system efficiently than has traditionally been used in facility management.

The Use of GIS for Surveyors and Engineers in Developing Nations for Building Infrastructure

Brent A. JONES USA

1. OVERVIEW

Developing nations face unique challenges with the design, construction and operations of new infrastructure. Nations with mature infrastructure have followed traditional technology models for planning, design, construction and operation of facilities. With GIS technology, the development of new infrastructure will follow new technology models eliminating data redundancy, miscommunication, and costly conversion when moving through the planning, design, construction, and operation infrastructure data continuum.

This infrastructure includes expansion to the electric network, the construction of new telecommunications facilities, both wired and wireless, and transportation networks of highways, airports and rail. Facilities development also includes expansion of gas transportation, storage, and delivery systems; water and wastewater systems; and emergency response systems including police, fire, medical, and rescue. Public health, food, and agriculture systems are also part of a nation's infrastructure.

2. PLANNING

The first stage with the development of new infrastructure is completing an inventory of existing pertinent geospatial data. This consists of gathering existing information that is known about the natural and manmade resources—information such as soil types, surficial and subsurface geology, land cover, land use, topography, ownership, existing infrastructure, etc. This data may have been developed from photogrammetry, orthophotography, field survey, satellite imagery, and other means. Much of this data would have been acquired ad hoc and at different times for a variety of original uses.

Generally, this data is in different formats and locations, and requires manipulation to overlay and visualize existing conditions. Often times this data is developed on different datums and coordinate systems and must be translated and manipulated to overlay it. When GIS is used as the central repository to bring this data together for additional analysis, many of these inefficiencies are avoided. GIS has been used this way successfully for quite some time.

Planning analysis will include the proximity to existing and previously planned infrastructure, particularly transportation networks (harbors, airports, rail stations, etc.), and energy and water resources. This analysis also includes census and demographic data best handled with GIS.

3. DATA ACQUISTION

Specific site data requirements for the design and construction of infrastructure are developed for quality engineering design and to minimize and accurately predict construction costs. Existing data accuracies are often not adequate for engineering design, primarily because this data was acquired for other reasons and does not meet the accuracy and currency requirements associated with engineering design.

Surveyors collect project-specific survey-grade data required for infrastructure design. Methods of data collection continue to evolve. Kinematic GPS, reflectorless total stations, and laser scanners have made precise data collection efficient and accurate. Surveyors are collecting more data as a result of these new technologies, ease of collection, and the automated data logging equipment associated with measurement equipment. This has resulted in a higher quality and quantity of data to be communicated to the design engineer on actual field conditions, but has placed a new burden on the communication mechanisms between the surveyor and engineer.

CAD (Computer Aided Design) software or a point coordinate file is usually used to deliver field survey data to the design engineer. With the large amounts of data collected with new technology and the need to overlay many other data sources, CAD files are no longer the most efficient way to convey data.

With existing survey technology, the substantial amounts of data collected for design and construction can be tied to the national grid/control network for archiving and reuse. The new control developed for a particular infrastructure expansion can be used to expand the existing control network if this data is properly collected and archived. Cost savings in control and survey data acquisition will be realized on future projects.

4. DESIGN

Prior to the engineering construction design of new infrastructure, demand analysis/need analysis is done for facility sizing. This includes the capacity analysis of energy delivery networks, transportation facility capacity, etc. This is generally an iterative process and most often leads to the need for additional data collection. During this process, communication between the surveyors and engineers is critical to insure all are working with the same current data. File-based data transfer systems can be problematic with this iterative process.

Following general engineering planning design, formal sketch/preliminary planning begins. Nomenclature here differs globally, but at this stage, engineering drawings are developed without construction detail. At this stage, various preliminary risk assessment analyses are completed using both survey-grade field information and planning-grade information. This analysis helps the engineer select the general design and construction type for the infrastructure. An example of this is analyzing the type of bridge to be constructed given parameters such as span, height, water depth, subsurface geology, capacity, etc. Following the type of bridge to be constructed (cable stayed, suspension, truss, etc.), preliminary design can begin.

During the design phase of new infrastructure, various modeling techniques are used to assist with engineering design. Many of these require large amounts of geospatial data. Modeling existing and proposed road networks, electric and gas piping, water distribution systems, telecommunications networks, and stormwater collection systems require a variety of geospatial data including topography, energy demand location, communication demand location, land cover type, and many others. Often, many engineers from different disciplines will be designing new infrastructure in the same location and at the same time. There are interdependencies on this infrastructure, such as telecommunications dependency on electricity. These interdependencies require consistent, correct, and current geospatial base information.

Again, using large amounts of data in file formats can be problematic because of data compatibility, currency, and new data being developed and not shared properly. Centralized data systems for the management of these data add efficiency, lead to less design rework, and facilitate the communication of actual and proposed conditions to the entire project team.

CAD stores geographic and facility data in a system of files. These files are overlaid for viewing and analysis to assist with design. Given the design tools that have been developed for use with CAD data, this can involve dozens of files, leaving opportunity for use of incorrect or out-of-date files. GIS offers a single source of data storage and retrieval to help eliminate these problems. Combining the use of CAD-developed design tools with the GIS repository for data yields an infrastructure design system that eliminates many areas of inefficiency and error.

The design process includes a pre-approval/visualization phase. In this phase, designs are rendered for visualization for regulatory and governmental approval. Advanced rendering technologies have assisted with the visualization of new infrastructure by non-technical reviewers and the general public to promote public awareness and create promotional materials. Following pre-approval, final approval of design is issued, and the final design and the development of construction drawings commences.

5. CONSTRUCTION

Construction of new infrastructure begins with the development of construction drawings based on the detailed engineering design. These drawings are used to communicate the intricate details of the engineer’s intent to the construction personnel. The engineer-contractor relationship in developed nations has often times been less than cooperative, leading to very detailed construction drawings to limit engineer liability and leave little room for contractor interpretation resulting in costly change orders. Many firms have avoided this by managing the design and construction practices together, commonly referred to as design-build.

Developing countries often work in the design-build model. This allows the engineers to work closely with construction personnel without the development of overly detailed construction drawings. Much of the construction detail is communicated with tabular specifications. Working in this environment can be enhanced by using a common data management system, accessed by both design engineer and construction personnel. CAD can be used effectively to communicate specific intricate details, but facility data and associated geographic data are best shared in a common database.

During the construction process, a variety of data collection functions occur including testing materials, documenting construction conditions at milestones, and recording final asbuilt conditions. This information is critical for future facility performance evaluation, expansion, and operational management. Properly managed, the collection of this data in an integrated GIS system can yield an operational facilities management system.

6. INFRASTRUCURE OPERATIONS

As asbuilt or final conditions data is collected, if certain facility attributes are collected concurrently, the asbuilt collection process will result in an operational facilities management system, AM/FM (Automated Mapping/Facilities Management) system, or GIS. Geographic information systems for facilities management are used for a multitude of operational functions including asset management, outage analysis, work management, automated vehicle location, gas leak detection, call before you dig, economic development, scheduled maintenance, regulatory compliance, map creation, new facility planning, and many more critical operational functions.

Infrastructure managers spend millions of dollars a year with double digit returns on investment developing facility management systems in GIS to perform specific functions. Traditionally, data is collected and converted from existing drawing and CAD files in an ad hoc manner to fulfill the specific data needs of the functions the GIS is designed to perform. Much data is left not converted into the GIS until a new specific need dictates new data requirements for inclusion in the GIS. Often, original sources of data are revisited for input of additional data. This results in costly inefficiencies.

Collecting infrastructure data at the point of the creation of the infrastructure eliminates these inefficiencies and has facility data ready and available for new AM/FM/GIS functions as their need arises without the need to convert paper maps and CAD files into the facilities management system. Many field data collection devices (kinematic GPS, laser range finders, reflectorless total stations, etc.) and software are readily available and interface with GIS to streamline this workflow, eliminating an additional data conversion procedure. Most of the surveying equipment vendors offer GIS data collection software with their instruments.

7. INFRASTRUCTURE DATA CONTINUUM

The collection of planning data begins the data continuum of developing new infrastructure. In areas where infrastructure is developed for the first time, or wholesale infrastructure us updated, this initial data development begins a foundation for survey, engineering design, construction, and operational data to be developed, shared, and disseminated, minimizing errors due to data incompatibility, age, accuracy, and completeness.

GIS provides the repository for this collected data, designs developed, and constructed facility information to be managed and shared. Using a central data system for the process of developing and constructing infrastructure gives the surveyors and engineers a common means to communicate geospatial data, maintain current data, and allow iterative design/data collection procedures without exchanging data files of differing format, version, and content. Continuing the use of a GIS through the construction and asbuilt phases of a project can deliver an operational facilities management system without the need for data conversion, additional data collection, and integration of other existing information.

Collecting data in the national grid/reference system will allow for future multiple uses of the survey and asbuilt construction data and will integrate with other facilities management systems. Beginning the process of the creation of new infrastructure in a GIS creates efficiencies throughout the engineering process and can deliver an operational management system that could cost millions of dollars otherwise.

CONTACTS

Brent A. Jones, PE, PLS
ESRI
380 New York Street
Redlands, CA 92373
USA
Tel. +1 909 793 2853
Fax + 1 909 307 3039
Email: bjones@esri.com
Web site: www.esri.com