Geographic Information System for the Pennsylvania Department of Transportation

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Given the potentially enormous impact of a geographic information system (GIS) and the myriad management and technical issues to be assessed in developing one, the Pennsylvania Department of Transportation (PennDOT) has undertaken research to develop a strategic plan for the development of a GIS for transportation. The planning process and the results of the research to date are described. In addition to PennDOT management and staff, the planning process included other commonwealth agencies that would likely be users or benefactors of PennDOT's GIS. The process involved (a) identifying and setting priorities for potential transportation GIS applications, (b) assessing existing computer systems and identifying data linkage options, and (c) developing a modular strategic plan that addressed priorities and incrementally enhanced PennDOT's GIS technology.

Sound decision making, and the systems and information needed to support it, has always been quintessential to the successful operation of any size and type of organization. In the public sector, the need for decision support systems has grown substantially as government agencies are being asked to "do more with less." As a result, the collective attention of the nation's public agencies has recently focused on such decision support systems as the geographic information system (GIS). The Pennsylvania GIS Interagency Work Group has defined the GIS as, "an automated system designed to allow users to more easily filter, manage, analyze, display, and share location-oriented data and associated explanatory information." A GIS combines nongraphic data (raw or calculated) and graphic data (computer maps) for the purpose of displaying and analyzing information, thus supporting the decision-making process.

There is general consensus that using a GIS can allow state agencies to improve their traditional missions of data collection and input, research and analysis, and information delivery more efficiently, while also providing an opportunity to expand their scope of operations in a cost-effective manner.

Transportation agencies must make maximum use of decision support systems because of diminishing resources, increasing demand, the need for public involvement, and the impact the transportation system can have on economic, environmental, and social conditions. The GIS is ideally suited for the transportation field because of the geographic nature of transportation features and because large amounts of data are already collected and stored.

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Within any department of transportation, probable GIS applications include roadway and bridge construction, planning and programming, safety analysis, pavement management, and maintenance planning. Recognizing the benefits offered by this new technological decision support system, PennDOT has taken a proactive and determined approach to establishing a GIS and helping the transportation industry take full advantage of it.

Because of the potential benefits that can be realized in virtually all state government agencies, PennDOT has taken a definite, cooperative interagency approach toward the development of a GIS. PennDOT is working closely with the Pennsylvania Department of Agriculture, the Department of Environmental Resources, the Governor's Office of Administration, the Governor's Policy Office, the State Data Center, and several other commonwealth agencies through the GIS Interagency Work Group.

Currently, the responsibility within PennDOT for the GIS is shared primarily between the Bureau of Transportation Systems Performance of the Office of Planning and the Bureau of Information Systems of the Office of Administration.

The Bureau of Transportation Systems Performance houses the cartographic services of the department, and therefore maintains all of the graphic data bases of computerized map files.

The Bureau of Information Systems, which is the custodian of the nongraphic data bases that the department will use in the GIS, is responsible for all electronic data processing planning and acquisitions.

PennDOT's GIS is in its planning and early development stages. The ongoing research includes (a) identifying priority applications, (b) assessing existing computer systems in relation to GIS development, and (c) developing a flexible, modular strategic plan.

INTERAGENCY COOPERATION

In the mid-1980s, many Pennsylvania commonwealth agencies began to exhibit an aggressive interest in the decision support capabilities of a GIS. PennDOT began to take the first recognizable steps in this direction through the extension of computer-assisted drafting and design (CADD) applications in the development of area-wide evacuation plans.

In 1987, an extraordinary multiagency effort to secure cooperation as well as to disburse information was initiated by

the state Department of Agriculture. A special presentation on GISs—about what they are and what they can do—was made before the state General Assembly.

As an outgrowth of this presentation and to ensure that the commonwealth moved toward increased computer integration, interagency coordination, technology acquisition, and data sharing, the GIS Interagency Work Group was formed. The work group's mission is to

1. Formulate a statewide GIS implementation methodology,
2. Foster cooperation among state agency GIS activities,
3. Eliminate duplication of effort in digitizing information among state agencies, and
4. Enhance data sharing between state agencies by identifying and adopting standards for use in digitizing information.

The work group, which is chaired by the Governor's Policy Office, consists of the following members:

- Department of Transportation,
- Department of Agriculture,
- Department of Commerce,
- Department of Community Affairs,
- Governor's Office of Administration,
- Department of Environmental Resources,
- State Data Center, and
- State Library.

The work group has been involved in disseminating educational information about the GIS to state agencies on request and scheduling educational seminars for state agency personnel interested in learning more about this technology in a hands-on environment.

HISTORICAL PERSPECTIVE

Computer-Assisted Mapping Program

The Pennsylvania approach to GIS development is to build a strong computer-assisted mapping program. This approach is solid because a GIS will be built around the core of an automated map, referred to as the "base" map.

Pennsylvania is well established as a leader in computer-assisted mapping. Its commitment to graphic systems in hardware, software, development costs, and consultant fees totals approximately $2 million. PennDOT's computer-assisted mapping program (CAMP), housed on the Intergraph computer system, began operations in 1984.

The two major efforts required to develop PennDOT's GIS are digitizing and segmenting. A highway must be digitized before it can be segmented.

Digitizing

Digitizing is the computerized drawing of roads and features. Because of time and resource considerations, and in the interest of producing useful DOT products as soon as possible, digitizing was separated into two phases: (a) state highways and major drainage features, and (b) local highways and minor drainage features.

The first phase of digitizing included

- Over 41,000 mi of state-maintained highways;
- Civil boundaries of state, district, county, township, borough, and city;
- Major waterways;
- Railroads;
- Airports; and
- Selected cultural features (e.g., parks and educational facilities).

The 7½-min topographic quadrangle sheet of the U.S. Geological Survey (USGS) is the source input document. The pieces of roads and topographical quadrangles are connected to form seamless counties, which are connected to form the state.

These map features have been manually digitized over a period of more than 2 years. The first phase, state highways, has been completed for the entire state. The second phase, local highways, will be completed in June 1991. (As of this writing, 58 of 67 counties have been completely digitized.)

Georeferencing is accomplished through the use of latitude and longitudinal coordinates in the polyconic projection. Positional accuracy is held to 30 ft of ground position. A more precise accuracy that would proportionally compound costs is not considered necessary.

Segmenting

In order to link spatial data to specific points, lines, or polygons on the digitized map, PennDOT has divided all state highways into segments. This segmenting establishes the linkages between existing data and computerized maps. For example, roadway management system (RMS) data such as network, federal aid system, local name, pavement type and condition, and state route are linked to highway segments.

The department began the state highway segmenting effort in December 1988; segmenting was completed in June 1990.

Data Transfer

Presently, the department is manually transporting a computer tape of extracted data from selected IBM mainframe computer data bases and loading it into the mapping data base file. Hardware and software requirements are being studied to enable direct networking with an IBM computer to provide real time data extracts.

CURRENT PENNDOT APPLICATIONS

Many opportunities exist for using a GIS to support transportation initiatives and enhance decision making capabilities. With the arrival of GIS technology, limitations based on data availability and information analysis time will begin to diminish and the creativity of the user will gradually govern the GIS applications.

These applications can be expected to follow the traditional areas of agency responsibility, namely pavement manage-

ment, traffic engineering, safety, planning and programming, bridge rehabilitation, etc.

In general, transportation applications of GISs chronologically follow three phases:

- Data retrieval,
- Data integration, and
- Data analysis.

As the system matures, an agency's use of a GIS will progress from data retrieval to data integration and finally to the more sophisticated application of data analysis.

Currently, the department is developing "smart maps" through data retrieval and integration of accident and project data bases to produce accident analysis maps and Twelve-Year Program project display maps. The accident analysis maps are being distributed to state police and local municipalities to enhance safety-related law enforcement efforts. The Twelve-Year Program maps will be used for regional public hearings to acquire public testimony for the biannual update of the Twelve-Year Program.

Although these current applications relate to highway systems, initial efforts are underway to integrate the rail, airport, and port data with the graphics as well. All transportation modes will become part of the GIS.

PENNDOT'S GIS STRATEGIC PLAN

The GIS concept introduces many opportunities for Pennsylvania. However, GISs are costly in resources and commitment. They require the cooperation of many organizations; they require technical expertise and planning; and they must have the support of decision makers. Therefore, a strategic plan is necessary.

With the cooperation of the GIS Interagency Work Group, the Department of Transportation is initiating the development of a GIS strategic plan for transportation. Informed decisions must be made as to how fast to proceed, how long will it take, how much it will cost, and how to get there from here.

Because of the unique opportunities afforded by a GIS, the strategic plan will be guided by an executive steering committee of top officials in the Department of Transportation as well as the Interagency Work Group and other departments. The steering committee contains a cross section of the potential users of a GIS. It has the necessary expertise and wide perspective to ensure that the strategic plan is technically sound and designed to meet user needs. The executive committee will be in direct communication with the department's top decision-making forums, specifically the Strategic Management Committee (SMC) and the Automated Technology Steering Committee (ATSC). The SMC is responsible for department-wide policy level decisions. The ATSC is responsible for decisions related to technology and electronic data processing. The tasks that the department has identified as necessary for the strategic plan are as follows:

- Task 1. Define the scope and focus of a GIS.
- Task 2. Review existing computer capacities.
- Task 3. Develop a modular strategic plan.
- Task 4. Present plan to top management.
- Task 5. Complete GIS Strategic Plan.

Tasks 1 and 2 are completed; Task 3 is underway.

Task 1 Findings

The specific objective of Task 1 was to "develop a categorized list of potential applications and recommended priorities."

After interviewing PennDOT managers and staff and other state agency representatives and reviewing the literature, the following categories of transportation applications were recommended as top priorities:

1. Safety Management. Provides decision support to ensure that safety aspects of transportation decisions are timely and appropriate and that safety enhancements are routinely included and fully integrated into the state's highway project development process.
2. Congestion Management. Provides decision support to monitor changes in congestion and develop strategies for dealing with congestion both by operational improvements and by demand reduction. These activities require system design, development, and implementation; data collection and analysis; and the development of short- and long-term plans.
3. Project Management. Provides decision support for the cost and schedule management of the department's priority projects.
4. Roadway Management. Provides decision support on the inventory of the existing roadway network and current condition data. It is used in making performance predictions that lead to needs and resource predictions.
5. Bridge Management. Provides decision support to establish formal procedures for selecting projects and strategies for bridge maintenance, repair, rehabilitation, and replacement. Considered in making selections are network needs as well as funding constraints.

In addition to these top priorities, the following transportation applications were identified as high priorities:

- Environmental impacts and design management,
- Routing management,
- Administrative management,
- Maintenance management,
- Photogrammetry management, and
- Geological management.

Task 2 Findings

The specific objective of Task 2 was to "assess and maximize the utility of existing computer systems for a GIS, identify linkage options among the various systems, and assess the immediate need to enhance existing computer components."

An agency must take full advantage of its existing resources when planning for a new technology. For a GIS, this necessity is especially true for data resources, as well as hardware and

software. For PennDOT, which has massive amounts of data and has digitized the state graphically, using existing data resources (both graphic and nongraphic) is perhaps the most important consideration in cost savings.

Task 2 findings follow:

- PennDOT possesses a modern, robust, well-thought-out hardware and software suite. The IBM 3090–based configuration and the Intergraph CAMP–CADD configurations provide the department an array of capabilities. Therefore, a strong computer foundation already exists. However, the current load placed on these systems is already high and increasing.
- The CAMP–CADD system has reached its maximum processing capacity. It is used by the department for developing special public relations graphics for various commonwealth agencies. Because of the high quality of these products, demand for them continues to increase. In its current production mode, the CAMP–CADD system has no excess capacity, but with enhancements it could play a significant role in any future GIS. Even if the department does not implement the GIS, the CAMP–CADD system will require additional hardware and software upgrades.
- Although both the IBM 3090 and the Intergraph CAMP–CADD systems are highly capable, the current data transfer method between them is inefficient.
- The CAMP–CADD and the commonwealth networks are adequate to meet current connectivity needs. However, the 9,600-baud transfer rate may not be adequate for GIS scenarios.
- Most of the data that would be required by the GIS currently exist within department systems. These data reside on a variety of platforms and formats. No additional data collection initiatives are foreseen exclusively for the GIS.
- Current demands placed on personnel with the needed knowledge and skills render difficult the development, support, and maintenance of a GIS without a decision by the department on the locus for GIS expertise.

In order to move toward GIS implementation, the department should

- Continue integration of nongraphic data. This process would be driven by user needs and administered by a centralized data administration. The integration would improve the quality of the data and provide decision makers with the ability to analyze relationships among data.
- Improve integration of graphic and nongraphic data. Linking the IBM and Intergraph systems would provide real time access for the increasing demand for quick-response displays and future GIS queries.
- Establish hardware and software environments to use the integrated data.
- Maximize and upgrade as necessary existing computer hardware and software on the basis of capacity and connectivity needs.
- Further assess the organizational impact of the GIS. Issues such as the structure of the organization, data sharing and security, maintenance, etc., should be addressed as part of the implementation.

Specific Task 2 recommendations were as follows:

Hardware and Software

- Structure the GIS to exploit the foundation of the existing IBM and Intergraph investments. Select GIS software that can manipulate the department's existing data resources.
- Optimize existing hardware resources by use of CPU capacity available in the Intergraph workstations that the department already possesses.
- Even if the department does not implement the GIS, the CAMP–CADD system will require additional hardware and software upgrades to accommodate increasing production demands.
- Determine what role personal computers (PCs) will play in the GIS so that existing PC investments can be used in the GIS. This survey could include stand-alone PCs, PC networks, and direct links to the IBM, Intergraph, and other GIS platforms.

Data Organization and Structure

- Make the necessary data in existing nonrelational data bases available in a relational format, which is a structure with a particular access method that is required by existing GIS software packages.
- Investigate use of software that allows the translation and updating of hierarchical data required in the GIS (e.g., the Roadway Management System and the Project Management System) to a relational image of the data set.
- Use relational data base formats for all future data base application development.

Organizational Issues

- Decide on an organizational structure and the locus of GIS expertise that best suit the department's GIS needs. Fundamental options are (a) centralized support for decentralized applications; (b) centralized support for centralized applications; or (c) decentralized support for decentralized applications.

Operations and Procedures

- Evolve beyond the use of tape transfer between the IBM and Intergraph systems by establishing a direct link between the two.

Linkages

- Establish a linkage between the IBM and Intergraph systems as a necessary step toward a fully functional GIS and as a help in providing better and more efficient solutions to the department's information management requirements.

- Take full advantage of relational interface system (RIS) technology.

Task 3 Findings

The strategic plan (Task 3) will incorporate the Task 1 priorities and the Task 2 recommendations when defining a modular, flexible approach to developing a GIS. Requirements for hardware, software, manpower, training, and consulting will be specified. The final strategic plan will be completed by June 1991.

An important and unique aspect of the strategic plan will be the development of the plan in modular form. Each module will be a unit of effort in the overall development of a transportation GIS and fully useable for a commonwealth GIS.

By dividing the myriad tasks necessary to achieve a multifunctional and multimodal GIS into small and affordable modules, much greater flexibility will be realized. Adjustments for changing management priorities can be made by changing the sequence of implementing the modules. In addition, progression options will be produced for each module, allowing options for how rapidly or slowly each module will proceed.

SUMMARY

Although PennDOT has already made significant investments in and taken strides in developing a GIS, the challenge is just beginning.

The efforts to develop a GIS continue at a steady pace while PennDOT investigates and plans for this new and exciting technology. As with many departments of transportation, the technology began with CAMP–CADD. As the potential for the GIS became evident, PennDOT played a major role in initiating a cooperative interagency work group to coordinate the state government's efforts. Simultaneously, PennDOT continued to advance toward a GIS by integrating some of the nongraphic data with computerized map files to produce some useful "smart maps." PennDOT is currently in the process of developing a strategic plan for the implementation of a GIS.

In Pennsylvania, as with many other states, the department of transportation has taken center stage in developing this highly useful and tremendously flexible technology—the GIS.

Publication of this paper sponsored by Committee on Transportation Data and Information Systems.