PROCEEDINGS

Data Integration for Asset Management

Forum and Peer Exchange

Chicago, Illinois
December 12–13, 2001

U.S. Department of Transportation

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Federal Highway Administration
Office of Asset Management

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CONTENTS

LIST OF ACRONYMS

AASHTO	American Association of State Highway and Transportation Officials
BID	Bridge Inventory Data (Florida DOT)
BPR	business process reengineering
BTRS	Base Transportation Referencing System (Ohio DOT)
COTS	commercial off-the-shelf
DBA	database administrator
DMV	department of motor vehicles
DOT	department of transportation
FHWA	Federal Highway Administration
FMS	Financial Management System (Mississippi DOT)
GASB	Governmental Accounting Standards Board
GIS	geographic information system
GIS-T	geographic information systems in transportation
GPS	global positioning system
GQL	graphical query language
HPMS	Highway Performance Monitoring System
ICAS	Inventory and Condition Assessment System (Virginia DOT)
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
IT	information technology
LRMS	Linear Reference Management System (Maine DOT)
LRS	linear referencing system
MOMS	Maintenance Online Management System (Florida DOT)
MP2	Maintenance Program (Florida DOT)
MPO	metropolitan planning organization
NBI	National Bridge Inventory
NCHRP	National Cooperative Highway Research Program
PAP	Pavement Analysis Program (Mississippi DOT)
PMS	pavement management system
PR	Physical Road (Michigan DOT)
RCI	Roadway Characteristics Inventory (Florida DOT)
SLD	Straight Line Diagram
SN	structural identification number
TAMS	Turnpike Asset Management System (Florida DOT)
TIDE	Transportation Information for Decision Enhancement (Maine DOT)
TIGER	Topologically Integrated Geographic Encoding and Referencing system
TINIS	Transportation Integrated Network Information System (Maine DOT)
TMIS	Transportation Management Information System (Mississippi DOT)
TRB	Transportation Research Board
TRIMS	Tennessee Roadway Information Management System (Tennessee DOT)
WAN	wide area network

NOTE FROM THE DIRECTOR

Office of Asset Management,
Infrastructure, Federal Highway Administration

The Federal Highway Administration (FHWA) Office of Asset Management, in partnership with the American Association of State Highway and Transportation Officials (AASHTO), is pleased to present this report on the Data Integration Forum and Peer Exchange held in Chicago, Illinois, in December 2001. The Forum was well attended, with 47 representatives from 26 states participating. Also attending were 44 individuals from local agencies, the Federal government, private industry, and international agencies. The Forum allowed transportation agencies to share their individual data integration experiences, ideas, and concerns. These proceedings document the Forum discussions, providing a reference for attendees and others interested in the subject.

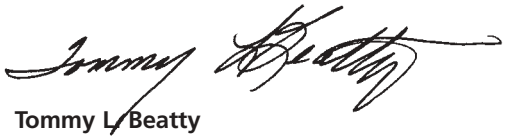
Asset Management is a strategic approach to managing transportation infrastructure. The goal of Asset Management is to get the best results and performance from the preservation, improvement, and operation of infrastructure assets with the available resources. The Asset Management approach to decision-making implies a comprehensive view of transportation assets where, for example, potential pavement projects are compared to bridge projects. To successfully evaluate such comparisons, data across asset types must be available, credible, and comparable. Data integration meets those needs by providing a common and consolidated set of information for infrastructure analyses, evaluation, and decision-making.

Given the importance of data integration to Asset Management, FHWA has made it a priority initiative. In August 2001, the FHWA Office of Asset Management published the *Data Integration Primer* and the *Glossary of Data Integration Terms.* These publications provide basic information and knowledge to transportation professionals interested in data integration, specifically in the context of implementing Asset Management.

As with all Office of Asset Management efforts, our guiding principle with respect to advancing data integration practices is the recognition that each transportation agency is different. No universal approach, strategy, or set of standards will fit all agencies. Our goal is to provide broadly applicable information and strategies that each organization may tailor to address its unique requirements.

The Forum presentations and open discussions called attention to many issues and challenges involved in data integration and data sharing, and gave participants valuable ideas for meeting the challenges. For example, we learned that obstacles arise from dissimilar and disparate data, legacy/stovepipe systems, and location referencing systems. Other important issues include managing people, choosing database management technology, and supporting integrated decision-making.

The Data Integration Forum marks the beginning of formal discussions among information management practitioners and others interested in making data more accessible and useful for Asset Management. From the Forum, FHWA, AASHTO, and the larger transportation community received valuable inputs to assist in developing a long-term research agenda.



Tommy L. Beatty
Acting Director,
Office of Asset Management

Note to the Reader. For help with technical terms used in the Forum and in this report, please refer to the *Data Integration Primer* and the *Glossary of Data Integration Terms,* which are available from the FHWA Office of Asset Management.

FORUM SUMMARY

"Less data is better than more."

Kirk Brown
Illinois DOT

"It's all about the people."

John Craig
Nebraska DOR

"Data is a corporate asset."

Lou Lambert
Michigan DOT

"If we continue to do business the way we did last year and the year before, we will not be needed."

Jim Steele
FHWA Michigan Division

On December 12–13, 2001, close to 100 transportation professionals from across the country, including representatives from 26 State departments of transportation (DOTs), gathered in Chicago, Illinois, to learn about integrating and sharing Asset Management data at the Data Integration Forum and Peer Exchange. The Forum was jointly sponsored by the Federal Highway Administration (FHWA) Office of Asset Management and the American Association of State Highway and Transportation Officials (AASHTO) Transportation Asset Management Task Force. It provided an overview of the state-of-the-practice in data integration for participants from State DOTs, local agencies, the Federal government, and private industry, as well as an opportunity to share experiences and ideas.

Highway and transportation agencies from seven States—Florida, Maine, Michigan, Mississippi, Ohio, Tennessee, and Virginia—presented their data integration efforts and experiences. A member of Transportation Research Board (TRB) Committee A1D09, Statewide Transportation Data and Information Systems, provided a summary of a recent peer exchange on data integration.

Welcome remarks were delivered by Kirk Brown, Secretary of Illinois DOT; John Craig, Chair of the AASHTO Task Force on Transportation Asset Management and Director of Nebraska Department of Roads; Lou Lambert, Deputy Planning Director of Michigan DOT; and Madeleine Bloom, then Director of the FHWA Office of Asset Management. Jim Steele, Administrator of the FHWA Michigan Division, delivered a luncheon speech on the importance of Asset Management data to senior managers. Prior to the State presentations and discussions, FHWA staff provided an overview of Transportation Asset Management concepts and the requirements and general strategies for data integration and data sharing.

This document contains (1) summaries of the presentations and group discussions, (2) major data integration issues and challenges identified at the Forum, and (3) an overview of current and future research and technical assistance activities. Copies of the Forum presentations can be downloaded from the FHWA Asset Management Web site (www.fhwa.dot.gov/infrastructure/asstmgmt/diindex.htm).

PRESENTATION HIGHLIGHTS

Florida Department of Transportation

TAMS: Implementing a Web-based Asset Management System

"The systems development process usually has its own course….We took the high road—full disclosure with everyone."

David Tassinari
Florida DOT—Turnpike

The Turnpike District of Florida DOT currently manages about 450 miles of highway. It is the largest toll road in Florida and the fourth largest in the country. The Turnpike currently relies on a dozen independent systems as sources of information for managing asset data. These systems are characterized by a diverse array of data repositories including spreadsheets, relational databases, State-mandated databases such as the Roadway Characteristics Inventory, and Federal databases such as the National Bridge Inventory (NBI). Each office uses one or more of the systems to acquire and process asset data for its own functions.

The Turnpike's financial planning process consists of 5-, 10- and 20-year financial plans, as well as annual budget estimates covering the Turnpike system and the various offices. Over the years the Turnpike has not had the ability to leverage its resources and make cost-effective Asset Management decisions. Replacement and repair decisions for all assets on the Turnpike are currently made using either rules of thumb or historical expenditures, and are focused on reactive rather than proactive strategies. On the financial reporting side of Asset Management, the existing systems cannot readily support the requirements of the Governmental Accounting Standards Board (GASB) Statement 34.

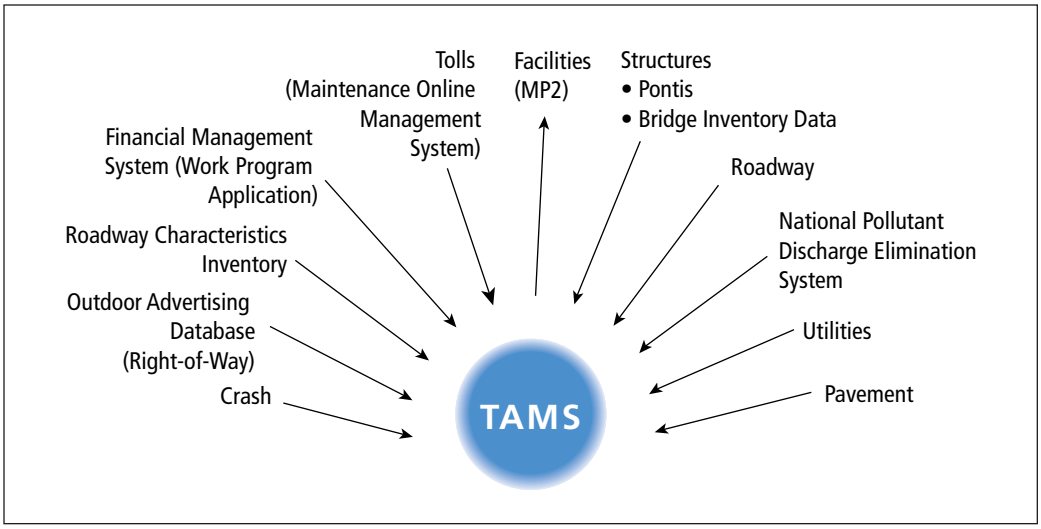
The Turnpike Asset Management System (TAMS) is being developed to record and track the performance of assets over time. This information will be used to generate budgets that allow the Turnpike to manage repair and replacement costs while providing an adequate level of service to customers. TAMS will allow the Turnpike to get a better handle on its budget, and it will provide a more reasonable process for determining renewal and replacement needs.

TAMS will bring data from all the databases into a graphically driven, Web-enabled, integrated framework. The system will be easy to use and accessible via the Turnpike's intranet. It will use maps to display asset location. The advantages of a Web-enabled system are that the user needs only a Web browser and there are no limitations on the number of users. It is also less costly to maintain, provides more data security, and takes advantage of industry standards. However, a Web-enabled system requires a very robust computer network such as the Turnpike's intranet.

TAMS will combine data warehousing and distributed data processing. The enterprise data warehouse will receive data from all disparate units (see side picture) except the facilities database, MP2. MP2 was designed and built in the 1990s and has not been updated. Therefore data will go from TAMS into MP2, while other databases will feed into TAMS.

As part of the TAMS development, the Turnpike conducted a concept study and prepared a detailed work plan. The concept study involved identifying existing data, integrating these data using the relational data model, and eliminating all redundant data. As part of the detailed work plan, the Turnpike conducted focus groups, identified existing systems and processes, identified hardware and software requirements,

analyzed data collection processes, and established a schedule. Before starting TAMS development, the Turnpike had integrated the data in its financial management system, combining three databases with redundant data for capital budgeting, cost reporting, and Federal billing. It had this and other data integration experiences from which to draw lessons, the most important being the need to foster relationships across users.



Turnpike Asset Management System Data Integration—Florida DOT

It is anticipated that TAMS will be fully operational in 2002. The assets that will be managed in TAMS include pavement, roadway, bridges, utilities, facilities, tolls, and others. The TAMS prototype allows the user to go through the system using a Web browser to pull down maps and to examine asset inventory characteristics by milepoint. The current version of TAMS is being used by the Florida DOT as a pilot inventory program for its new pavement management system (PMS), which is currently being evaluated using two commercial software packages. This system will be integrated with TAMS over the next five years.

A specific technical challenge that the Turnpike is facing in implementing TAMS concerns managing and integrating data that are acquired from emerging data collection technologies such as aerial photogrammetry, video-based systems, global positioning system (GPS) receivers, and voice recorder/recognition systems. Other technical and organizational challenges encountered include:

- Getting buy-in from staff, especially those who are reluctant to change,
- Breaking down territorial barriers,
- Ensuring that all databases are included,
- Developing good relationships with other offices, and
- Being able to respond to data users' needs (some users still prefer data on spreadsheets).

Words of advice and lessons learned based on experiences thus far are as follows:

- Follow your concepts.
- Plan your work and work your plan—develop a detailed process, work through that, stick with it, and inform your people.
- Employ the right people, including young engineers who have good backgrounds and attitudes but do not command very high salaries.
- Maintain a detailed schedule—realize that it will change but that you need to keep it going and stay focused on the goal.
- Report on what you do—white papers on TAMS helped achieve buy-in and turned around reluctance to participate. Document progress, steps, and decisions that have been made, and keep everyone informed.

The Turnpike is in a unique business position because it is a toll collection unit in a public agency. It has to make good business decisions and implement sound business practices within a government framework. TAMS allows the Turnpike to look at highway facilities as a corporate resource and get a handle on managing their assets.

"TAMS is not going to respond to all users' questions. . . . There will always be off-the-wall questions, and we cannot anticipate the questions that will be asked in coming years."

David Tassinari
Florida DOT—Turnpike

Questions and Answers

Q. You mentioned that meeting the needs of TAMS users is important, however, needs are dynamic. How will you handle a situation in the future when spreadsheets pop up once again? How do you make sure that TAMS will meet future user needs and not become similar to your integrated database of the past?

A. There is no guarantee—no system is going to be perfect. Our objective is to pull relevant data. People will still use their old systems, but we will be pulling relevant data from them. No system will meet everybody's needs. One problem users have is rekeying data from TAMS onto spreadsheets.

Q. What challenges did you have to overcome in rectifying what data elements needed to be cross-checked or harmonized to achieve data integration? For example, culverts—how do you come up with one standard definition for asset data?

A. When we encountered that situation for condition rating, we started to develop standards. Another example is tolling, which is being counted in different ways. We used lookup tables. We cannot force people to stop doing what they are doing.

Q. Is the TAMS Web interface one-way or two-way? Is it just a reporting tool or is it reporting and updating data?

A. Basically it is a reporting tool. Facility data will be maintained in the database, and other data will be processed through the client-server interface.

Q. If you have all those data in the database, why do you need a spreadsheet?

A. Sometimes you are asked questions that the system cannot answer unless you pull data down and do an analysis. For example, we have to do variance analysis on finance plan changes, but the required analysis tools are not built in. TAMS is not going to respond to all users' questions (e.g., what-if questions). There will always be a need to respond to off-the-wall questions, and we cannot anticipate the questions that will be asked in coming years. Also, sometimes the pertinent data are not there to allow all analyses and answer all questions.

Q. For your read-only users, do you provide workspace where they can store query objects and results?

A. Yes, they can come back later and pick up where they left off. There are browser point-and-shoot tools which allow that.

Q. Given where I come from, as a user, I get concerned when database and information technology (IT) people say they are going to remove tools I can use. I want users to creatively use the data. We cannot anticipate users' needs, but we need to make sure they have the ability to creatively develop and use their own tools because IT folks will not be able to do it for them.

A. If you generate the data directly from TAMS, you can develop and use your own tools. But TAMS is just one of the data sources. We are talking about pulling the data from TAMS and having central DOT accounting and programming/budgeting systems, not under TAMS, integrating these and other data. We need to cross over various systems and make the best efforts we can to meet users' needs, including bringing the data into spreadsheets.

Q. On the finance side, you raised your toll from three to six cents per mile. Are you tying this into your TAMS? What is the cost to reinvest in your highway system, to set long-term standards? You are giving premium road service. What is the thought process in terms of reinvesting strategies, and how are decisions made?

A. Metropolitan planning organizations (MPOs) decide which investments are needed. In the past our general consultant reviewed the highway system and recommended improvements using rules of thumb. Our central office (part of Florida DOT) establishes targets and dollar budgets for us based on our inventory, which does not necessarily reflect our needs. We want to get away from that. Our capital program is based on central office formulas (e.g., lane miles). As a Turnpike, we do not set our own course for routine maintenance. We need TAMS to do that. The performance measures help us leverage TAMS. The current toll charges cover operation, renewal, and replacement. We are looking into expanding our highway system by adding mileage.

Q. You are going to apply TAMS to develop long-term investment targets, but adding mileage adds significant maintenance costs. Have you put together an investment package on the additional 100 miles in terms of if and when you need to reinvest?

A. In a way we have. There is an aggressive plan over 20 years for $5 billion but not a systematic approach. TAMS will help in the process. We need to set aside money for improving service plazas. But how do we do that? Currently we set up a rule process. TAMS is going to pinpoint those kinds of projects and allow us to get a better handle on them.

Q. Do you also incorporate traffic and crash analysis? What other data are tied to the system?

A. We do have traffic and accident data to identify where deficiencies exist and where preservation dollars are necessary.

Q. Do you ever free up any of your toll roads from collecting revenues to recover the costs? Do you ever make a toll road toll-free?

A. For the Florida Turnpike, no. It is a viable statewide system, and we see it as one of the answers to Florida's transportation problems. If we take the bonds and bring 443 miles to districts, they will have to pick up the maintenance and preservation budget that is $22 billion short of needs. Tolls and toll roads are part of the transportation solution. Otherwise we would need to increase the gas tax.

"The Turnpike budget is based on central office inventory, which is not reflective of our needs.... We want to get away from that."

David Tassinari
Florida DOT —Turnpike

Maine Department of Transportation

TIDE: Data Warehousing Challenges and Lessons Learned

"Our legacy data system focuses on individual highway components rather than the entire highway system."

Nancy Armentrout
Maine DOT

"With TIDE, managers and staff have an easier, flexible, and powerful way to get data."

Nancy Armentrout
Maine DOT

Maine DOT has had good road information dating back to the 1970s. It is stored in a legacy system called TINIS (Transportation Integrated Network Information System). Everything in TINIS is locationally synchronized, all 23,000 miles of roads. The system maintains data on geometry, inventory, project history (completed projects), crashes, and railroad crossings. In the 1990s, as part of its initial geographic information system (GIS) efforts, Maine DOT prepared base maps using U.S. Geological Survey quad maps from the statewide GIS clearinghouse and added the link-node referencing system as a base. This process involved adding node numbers to intersections, adding legacy data, and building Arc/Info GIS route-systems to represent TINIS links. Users were then able to do dynamic segmentation and event overlays based on link-node referencing. With route-milepoint referencing capability, anything stored in TINIS can be mapped.

TINIS was a major achievement but has drawbacks. The dynamic segmentation is very slow to use. Additionally, a lot of TINIS data were not normalized, making it difficult to use dynamic segmentation for those attributes. The system has many screens but focuses on single highway elements like a bridge or a single link. It does not have the ability to look at the entire highway system unless a special program is written. With the exception of project history and crash records, TINIS maintains current year information only.

The Transportation Information for Decision Enhancement (TIDE) was conceived as a tool to combine data warehousing with a GIS capability. It integrates a number of systems to allow broader, systemwide analysis and reporting, wider use of data, faster data access, and easy, convenient user interface. The primary legacy database constraints that the agency wanted to overcome with TIDE were the reliance on a single programmer for developing reports, the highly coded and packed format of the databases, the inability to perform trend analysis, and the inability to look at the entire highway network. The benefits to the agency of implementing TIDE include easy access to information, the ability to analyze data (i.e., bridge and pavement) on a GIS platform, a better understanding of the transportation system, and improved decision-making.

The TIDE project consists of three phases (see side picture). Phase 1 involved developing the data warehouse with a GIS interface, producing maps, and incorporating ad hoc query capabilities. The emphasis in Phase 1 was on highway needs and adequacy, including going out and scoring highways based on performance measures. TIDE provides easy-to-use query and reporting using an off-the-shelf data warehouse query package (Hummingbird BI/Query), which Maine DOT also used for its finance data warehouse. Results of data queries can be mapped in TIDE, and historical data are also maintained and can be displayed. TIDE queries are similar to the bookshelf queries in Mississippi's TMIS (see description on page 14). They consist of standard button queries, template queries, and ad hoc queries.

The queries can be displayed on a map using ArcView GIS. This is very useful because most people think in terms of maps and most data are locationally oriented. These spatial queries enable one to look at data in any way, not just by link or node. The principal means of integrating roadway-related information in TIDE are the link-node and route-milepoint linear referencing systems (LRS). However, data are stored by link-node only because they are not greatly impacted by changes to the linear measurement. This allows queries on features by querying any route or the feature itself (e.g., a crash). A static segmentation model is used in TIDE to enable ad hoc data querying. Dynamic segmentation does not work in the BI/Query tool environment.

The focus of Phase 2 is to develop a linear referencing engine that will allow new databases to be correctly referenced by synchronizing their LRS with that of the legacy database. The linear referencing synchronizer is needed to integrate data correctly even if they do not have a common LRS. This work, started in 2000, brings in project, backlog, planning, tracking, asset management, and other databases. The synchronizer is called Linear Reference Management System (LRMS), and Maine DOT is currently looking at Exor's Network Manager system for this purpose. As part of Phase 2 the agency has also added functionality on the ArcView side of TIDE including a viewer for videolog images. Maine DOT also hopes to bring other external users into the TIDE family such as the Department of Public Safety, MPOs, and Councils of Governments.

Phase 3 of the TIDE project will involve migration of the legacy system TINIS to an Oracle Spatial database environment, adding data to the warehouse, and moving TIDE to a Web-based environment.

Questions and Answers

Q. In terms of static location snapshots, you said dynamic segmentation is too slow. How are you doing the preprocessing? What type of tool did you develop and how long does it take? Is it a batch program?

A. The system was written by a contractor a few years back. We run it every Friday. We start with a TIDE load, take data from TINIS, put them in Oracle tables, run segments on Oracle, and run them through ArcInfo. Segmentation used to take 19 hours, but a new server brought the total time down to 12 hours. Using dynamic segmentation with ArcInfo we create static segments, which takes about seven hours. Some of the processes run concurrently. GIS creates multiple segmentations that separate out the roads for performance (i.e. all public roads, State-aid and above, State highway and above, National Highway System (NHS), private roads). We send all GIS data out to the division offices on Sundays; this is an automatic copy of a table query from central office.

Q. How did you resolve the issue related to project coverage of segments?

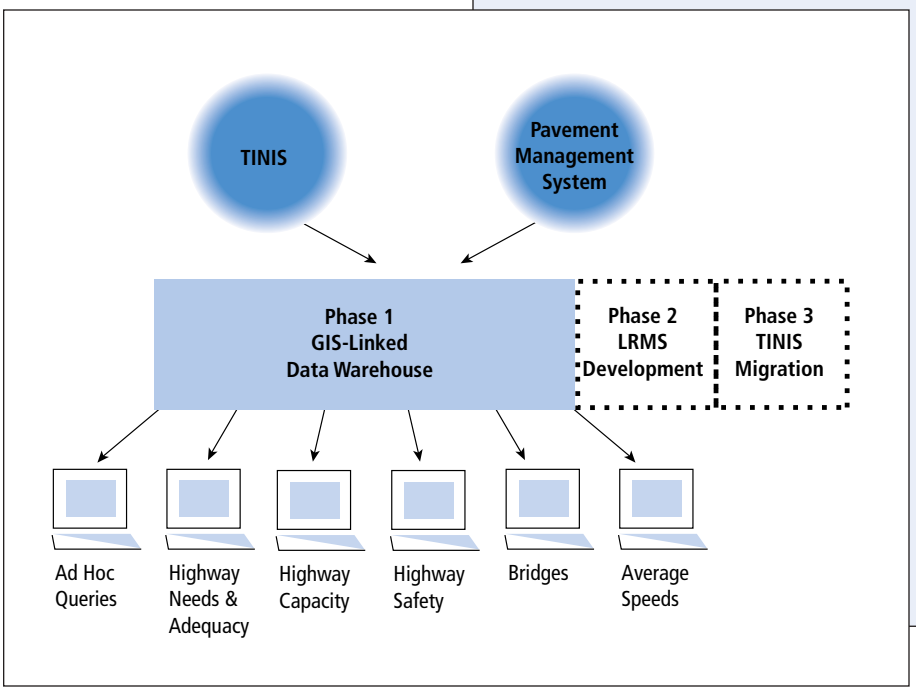
A. We still have not resolved that problem because we are still in Phase 2, developing the LRMS. To resolve that issue, we should not store project data against the link-node reference, which is a real cultural shift for Maine DOT because the agency feels that storing events by route-milepoint is something to avoid.

Q. You mentioned that the signaling/sign inventory does not integrate with TIDE inventory. Is that because of the difference in reference systems?

A. We have a situation similar to other agencies. We had a nice database—TINIS—at one time. Different units within DOT put data in TINIS. However it did not keep up with changing times and customer needs. Lots of data based on link-node were taken out of the system. Some still remain, but no one knows from what vintage the link-node network hails. Sign inventory, where it is automated at all, is in this situation.

Q. Is your legacy screen for browsing utilized for entry as well?

A. Yes, we are still using that right now. Entry is done with heads-down data entry. Phase 3 will take us away from that.



Transportation Information for Decision Enhancement Data Warehouse Project—Maine DOT

Maine Department of Transportation

Bridge Management Applications of TIDE

"By allowing us to graphically view the location and timing of candidate bridge, pavement, and safety projects, TIDE will help coordinate our capital improvement activities."

Colleen Gesualdo
Maine DOT

Maine DOT collects bridge data using the NBI standards. Bridge inspections include condition assessment and appraisal of deficiencies and maintenance needs. This information is typically accompanied by photographs. There is a wide audience for bridge inspection data throughout the State. The agency needed to find a more efficient way to share data among its seven regional offices as well as the central office, and to take advantage of data in its business processes. The agency was using a mainframe application to store some structural data, but the photographs and sketches that accompanied the inspection reports could not be accessed online.

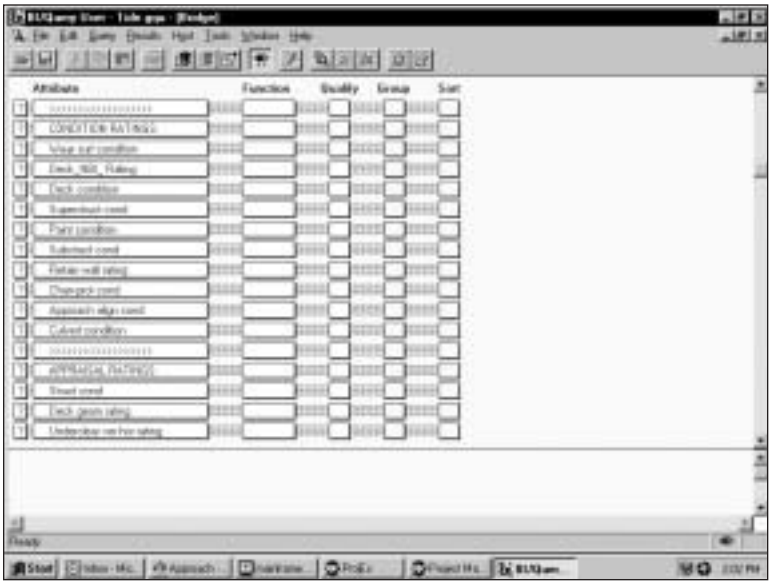
In the mid-1990s, the agency adopted ThumbsPlus, a commercial database software with graphic editing capability for indexing images. Bridges are indexed according to a 4-digit structural identification number (SN). Using this number to enter the database, the user can access inspection reports, sketches, surface inspections, underwater inspections, photographs, and other information for prioritizing candidates for maintenance and capital improvement programs.

The Maine DOT Bridge Management Section uses Microsoft Access to store data from expert field reviews, and expert opinion is used to evaluate alternatives and estimate the costs of bridge projects. These reviews are performed by a multidisciplinary team that evaluates various facets of a bridge project including engineering, environment, and right-of-way. Environmental experts help bridge engineers look at negative impacts of projects on plants and animals. Right-of-way professionals determine whether property along the project can significantly increase the cost of bridge work including approaches.

In 1997 the Maine DOT Bridge Management Section was invited to participate in TIDE joint application development sessions. The unit requested that TIDE include bridge condition, appraisal, inspection, dimensions, and other data about the structures. They also requested that users be able to build queries, create reports, generate maps, and show where deficient bridges are. All these capabilities have since been incorporated in the design and development of the TIDE data warehouse.

TIDE serves a multidisciplinary purpose in that one can look at crash data, bridge data, and link-node data all at once. The crash history data in TIDE are used to identify bridges with crashes on or near them. In the future, TIDE will allow Maine DOT to coordinate safety efforts and bridge efforts by region for capital programming purposes.

Maine DOT develops six-year plans for candidate bridge projects. The six-year candidates and the programmed projects become inputs to a system called ProjEx, which the agency uses for program planning and project scheduling. The system allows the user to track all candidate projects and generate biennial transportation improvement programs.



TIDE Bridge Data Query—Maine DOT

TIDE will help the agency coordinate its programs and projects. Plans are to move data from safety, pavement, and bridge management into TIDE for all candidate projects. The bridge managers will get together with pavement and safety managers to discuss hundreds of candidate projects. The system will allow them to view graphically all occurrences of all projects, determine which areas they will work in at the same time, and coordinate capital improvement activities.

Questions and Answers

Q. Can you give us your perspectives on the bridge management systems "BRIDGIT" and "Pontis"?

A. The BRIDGIT system was developed under a contract sponsored by the National Cooperative Highway Research Program. BRIDGIT offers a bottom-up approach rather than the top-down approach of Pontis. The model is used to predict bridge needs. However, BRIDGIT did not get support for software maintenance. Maine DOT uses BRIDGIT but is moving toward expert systems development, writing programs of our own to flag candidates for consideration in capital improvement programs. The scope of work and cost estimation will be based upon expert opinion.

Michigan Department of Transportation

Dealing with Multiple Location Reference Systems

"Each location reference system has advantages and disadvantages.... If you pick Bill's, Suzy loses. Owners don't want to cave in, that's part of the organizational environment."

Ron Vibbert
Michigan DOT

"It's been a long battle but the result is cool. How can anybody be excited about something so boring? But it's working!"

Ron Vibbert
Michigan DOT

Like other State agencies, Michigan DOT wrestled with the issue of location referencing. The agency started dealing with its multiple location reference systems while developing management systems responsive to the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991, and trying to build enterprise database applications. ISTEA required coordinated databases, and existing location referencing systems held the agency back for years. The challenge was in trying to get bridge and pavement people to agree, for example, on where a bridge starts and ends. It all boils down to how to define location.

Michigan DOT used to have a control section reference system consisting of a 5-digit number with lots of information embedded in it. Everyone had a different way of implementing this system, making it impossible to share data. A compromise was in order to develop a statewide location reference system and get away from existing reference systems.

Over the last 10 years, Michigan DOT decided to abandon all reference systems and selected the one used by the State Police. This choice allowed them to get past all the old, institutionalized data definitions. They migrated data from all legacy systems underlying the management systems (e.g., pavement, bridge) and rewrote the software, allowing them to drop all legacy systems including those operating on the mainframe. The result was a set of management systems (like an executive management system) with one database and one referencing system. Data are entered into and manipulated within the management systems.

The new location reference system consists of seven digits, is attribute-free, has no meaning to anyone, but nonetheless allows for maximum flexibility in attributes and data sharing. Migrating all the data to this new system was difficult, however, and system implementation took nine years. Considerable focus was required, especially since many people wanted to be creative with the location reference system.

Michigan DOT believes the new system is a success. All data have been moved into the system, and GIS and other tools are used to display and generate the data. With the new standards the agency is able to maintain reference across existing systems and has persuaded other agencies (e.g., Coast Guard, Department of Natural Resources, Census) to partner with them.

Michigan DOT offers specific recommendations for those thinking about developing a similar system:

- Pick a system that is attribute and application neutral and needs no creativity.
- Get special help in doing this, especially executive cover and support for a change of this magnitude.
- Do it quickly. Hire someone and get it done.
- Take advantage of opportunities, for example, leveraging GASB and Asset Management efforts as they reinforce the need to adopt a referencing system.
- Use GIS and GPS only for what they are worth—they are just tools, and they are not the solution.

Questions and Answers

Q. In your new location reference system, have you taken out all intelligence so it is a dumb number?

A. Absolutely.

Q. Can you explain what that number represents? How did you divvy up your network?

A. The name of this system is Physical Road (PR) System. We decided to identify roadway chunks that are as long as possible and make sense, and assigned the number to this roadway, with mileposts from beginning to end of each roadway. There is no other meaning than that. The number cannot be changed when set. It is neutral to location, just a dumb number assigned arbitrarily. This system has been used by the State Police for a long time, and it is really simple.

Q. Let's say you have a project that adds a segment to the beginning of a roadway: In other words, the zero point has shifted. How do you handle that?

A. We consider a "route" different from a "roadway"—a roadway can be part of many routes. If we have a PR number for a piece of roadway and add a new road, we give it a new PR number. If we did route-milepost, the zero would move. We keep track of the physical piece of road, not whether it belongs to a route; otherwise it would be a route-milepost system.

Q. So the piece of road is not being broken at intersections but rather at anything arbitrarily chosen to begin and end a roadway?

A. Yes, we try to make them stop at anything identifiable. An intersection would just be an event on the roadway.

Q. Does the milepost that you assign have to be continuous? Is it okay to have a gap?

A. No, we break the original segment into two segments.

Q. How then do you track history—for example, accident location—when you assign new PR numbers? Do you go back and adjust all the data on the old section?

A. We would never reuse a PR number, because it already refers to a roadway. We have a migration system that allows us to keep track of where a crash occurred, when it was first entered. We then roll it over to the new system so we do not lose that data when a new PR number is assigned to the roadway.

Q. Is your business rule to keep all your enterprise business data in current datum?

A. Actually we have two rules: (1) to keep the data in its original form, and (2) to roll it over to the new system, so we have a record of what was actually provided. However, this does not address geographic datum, which is kept in a different data layer. Our policy is to keep locations according to the physical road referencing system and then associate that system to the geographic datum, projection, or whatever the analyst wants to use.

Q. Is the PR number unique in the entire State? Does it cover State routes and county and local roads?

A. Yes, it is a unique number statewide, and the system covers all roads in the State including private roads. We will also be extending the system to railroads and other linear transportation features. There is currently a debate about including ports and shipping routes.

Q. When you assigned unique identification numbers to every road including locals, did you do a statewide centerline file? What if a county represents roads using southbound and northbound lanes, and yet the DOT collects 24,000 scale and represents single centerline? How do you deal with scale differences between organizations?

A. Our GIS shop was involved in this, and the centerline work was done by our central budget agency. We used many sources of information to develop the location reference system. We sent maps to county agencies and others to verify map accuracy. We used TIGER[1] files with 30-foot accuracy. The issue has been resolved between the budget and local agencies.

Q. What are you reporting for the Highway Performance Monitoring System (HPMS)? Is it the PR number or route number?

A. We have taken the PR number and put it under route number in HPMS.

Q. When you realign a road, do you differentiate PR and route numbers?

A. Yes.

Q. So the route number is not reported in HPMS. This sounds similar to location reference datum, where you are associating routes to unique stationary numbers throughout your network.

A. A route can have many PR numbers, and a PR number can have many routes. A problem arises if there is a Federal project with many inventory route numbers. We are allowed to report only one of the many roadways as we report projects, and thus we cannot give all the information we should. We are using the location reference system mercilessly and exploring opportunities to further market the system.

[1]TIGER stands for the Topologically Integrated Geographic Encoding and Referencing system, which was developed by the U.S. Census Bureau.

Mississippi Department of Transportation

TMIS: Managing Assets in an Enterprise Database Environment

"It takes a lot more effort and resources to start from scratch than to work off the legacy investments made in the past."

Don Grayson
Mississippi DOT

"TMIS was completed in 1998, but it is taking some time for the agency to adopt it."

Don Grayson
Mississippi DOT

Mississippi DOT started developing its Transportation Management Information System (TMIS) in 1994 in response to ISTEA. TMIS was designed as a GIS-based, client-server, data management system that will integrate and provide better access to departmental data. A substantial amount of legacy data has since been converted and integrated, including pavement, bridge, traffic, and accident data (see side picture). The Pontis Bridge Management System data now exist in the TMIS database. Prior to TMIS, infrastructure data resided on PCs, were outdated, and were not available online.

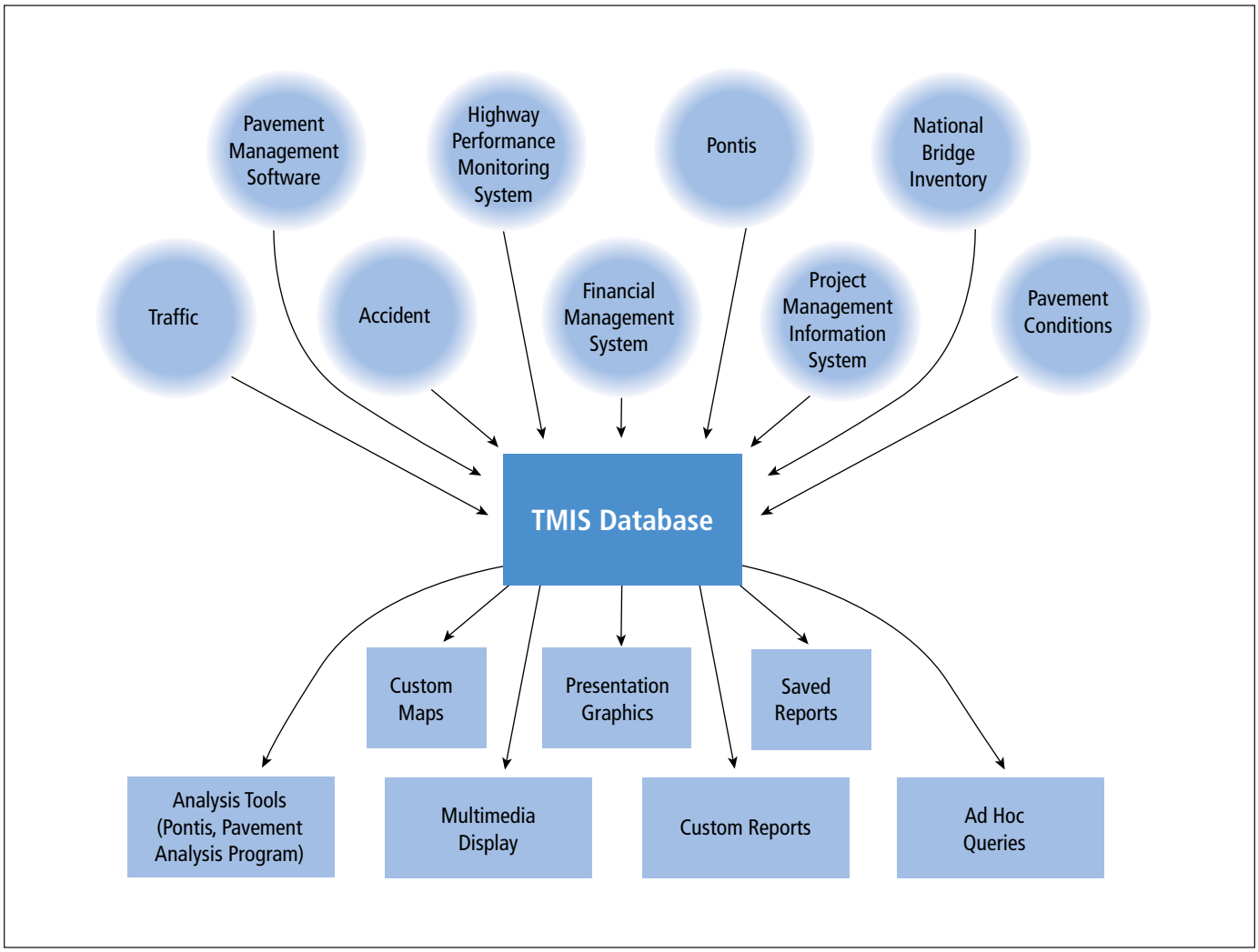
Location was the primary data integrator used, specifically the county route-log mile system. All data were converted to this LRS, some more easily than others. The GIS challenges include the basemap and route-log mile system, which is very static. The county-route-log-mile method is not very accurate, but road maps are not accurate either.

TMIS runs on Windows NT and 2000 operating systems on the client side. On the server side the data reside in a Sybase database (Sybase was the legacy database software of the agency). The system was developed using PowerBuilder application development software and Intergraph's MGE and GeoMedia GIS software. The Unix and GIS database servers are in the central office. The computer network line connects the district offices to the servers. In order to speed videolog data access and transmission, those data have been moved to the districts.

The user interface provides a desktop feel where one can click on icons to get around the system, extract data into spreadsheets, and save data. The TMIS database contains point and linear data for which the user can build and run a query at any time. Data can be accessed using standard, ad hoc, and bookshelf queries. The system also contains multimedia data including digital images and pavement videologs, all in the same Sybase database and accessible from map or direct LRS entry. One does not have to be a technical guru to run TMIS on a desktop computer. The hardest part is understanding the data.

TMIS is designed to support a variety of analysis tools that are used by the department including the Pontis Bridge Management System, the Pavement Analysis Program (PAP), and safety analysis tools. The Financial Management System (FMS) is used for maintenance and project management. The agency is now upgrading to the new version of Pontis and will be migrating data from TMIS to PAP. Safety analyses include sign inventory, hazardous location/intersection analysis, and accident diagramming.

Currently there is a difficulty associated with safety analyses because what the State Police calls a highway is not what the DOT calls a highway, and location reference information is not being collected by the State Police. Integrating TMIS with financial management applications is challenging, especially linking GIS information with project and maintenance information. The system can pull up and show maintenance activities and projects on a map, which Pontis and PAP can use, and tie FMS maintenance activities and charges to specific maintenance sections. The department has expressed a desire to develop a maintenance management system because the



Transportation Management Information System—Mississippi DOT

existing tools can only capture financial information about where maintenance work was done and cannot look at roadway furniture and predict what needs to be done.

Mississippi DOT faced many challenges in developing and implementing TMIS. Devising a consistent location reference system—to agree where the roads are and how long they are—took a year. The system was completed in 1998, but the agency is taking a long time to adopt it. People have their own legacy data and continue to use them. In retrospect, the system's developers feel they could have built the system differently and much faster by leaving out some partners. Clearly, however, involving data users from across the agency was well worth the effort.

"Many people still do not know how to use TMIS. Our challenge is to get the word out, again and again."

Don Grayson
Mississippi DOT

Questions and Answers

Q. We also use Sybase and GeoMedia in our agency, so we share some of the concerns and tribulations that you raised. You mentioned PowerBuilder—what is it?

A. PowerBuilder is a programming language owned by Sybase.

Q. Are you using Crystal Reports for queries?

A. No, we use MGE and Intergraph for queries.

Q. Can you save your query back to the desktop and e-mail it to somebody else?

A. Yes, you can put it in a bookshelf.

Q. What entities within the State are using your videologs? Are you finding this successful?

A. Different districts in our department use videologs. They use them to see the conditions of pavements and bridges in the counties.

Q. Do you have an outreach program for TMIS in the department?

A. We currently have pavement training for all areas. Many people still do not know about TMIS and what they can get from it—they would rather go to their file cabinets or go down the hall. Our challenge is to get the word out, again and again.

Q. Is each unit maintaining its own data? Is your sign inventory up-to-date?

A. Data owners collect their data, which are updated in the districts. Bridge and project data are updated every night. Sign inventory data are collected and maintained as signs change. There is an effort to update the statewide sign inventory. For the portions that have been collected, the sign inventory is up-to-date.

Q. How detailed is your maintenance record? Is it useful to other entities to extract information for bridge and pavement assessment?

A. At the moment, maintenance sections are not small enough to be used for detailed bridge and pavement assessments. The financial management system provides maintenance activities by pavement sections.

Q. Do you cross-populate to other functional units, such as annual average daily traffic? How do you do the synchronization?

A. Yes, we cross-populate data with other units. We synchronize the data every time they change.

Q. How do they get that data, manually or automatically? What is the synching mechanism?

A. There is a blender, and some of the data are synched up. It depends on where the data are kept. If data are kept and maintained in TMIS, they are synched up; if kept in other databases and maintained in TMIS, the owners of the databases are responsible for synching them up.

Q. It sounds like a data warehouse.

A. Yes, it is, except that pavement and sign data are stored and maintained inside TMIS. Bridge data are maintained in Pontis, and TMIS is a warehouse for that data. Finance data are maintained in FMS, and TMIS is a warehouse for that data. For pavements and signs, changes are made in TMIS, and we synch up those data. We are a blender.

Q. We are working on a statewide photolog system and heard some discussion about storing photologs. Are you storing them in district files? What is the response time?

A. We store them in the districts, copy them back into headquarters, and have them in both places. It takes less than a minute to pull up images.

Q. What about county offices?

A. They take less than 20 seconds, but the network is a bottleneck there. It is also a function of the technology used.

Q. Is TMIS being used to coordinate projects involving different assets, such as sign repair?

A. No, we can look at pavements and bridges separately but not both. We currently do not have integrated bridge and pavement analysis. There is no combined decision-support system.

Q. I get a sense that it is optional to participate in TMIS, that is, Bubba may not join you. Is your manager helping you market this and make this a mandatory integration? It sounds like a good thing to do.

A. It is mandatory that all data be stored in TMIS and kept up-to-date. Yes, Bubba has to put it in there, but he does not have to use the information. We currently have 40 users at any time, and 300 people have it on their desktops. There is a 50-50 split between data users and changers. We have 3,000 people at Mississippi DOT, and half of them have computers. All engineers could use it. We have to give it to those people and educate them.

Ohio Department of Transportation

BTRS: Data Integration Experience

"Our BTRS links roadway, bridge, culvert, traffic, crash, and other information in our data warehouse."

Leonard Evans
Ohio DOT

"We have experienced a 25 percent reduction in our workforce, but due to data integration, our project delivery/ productivity increased 75 percent….We have to get people involved."

Leonard Evans
Ohio DOT

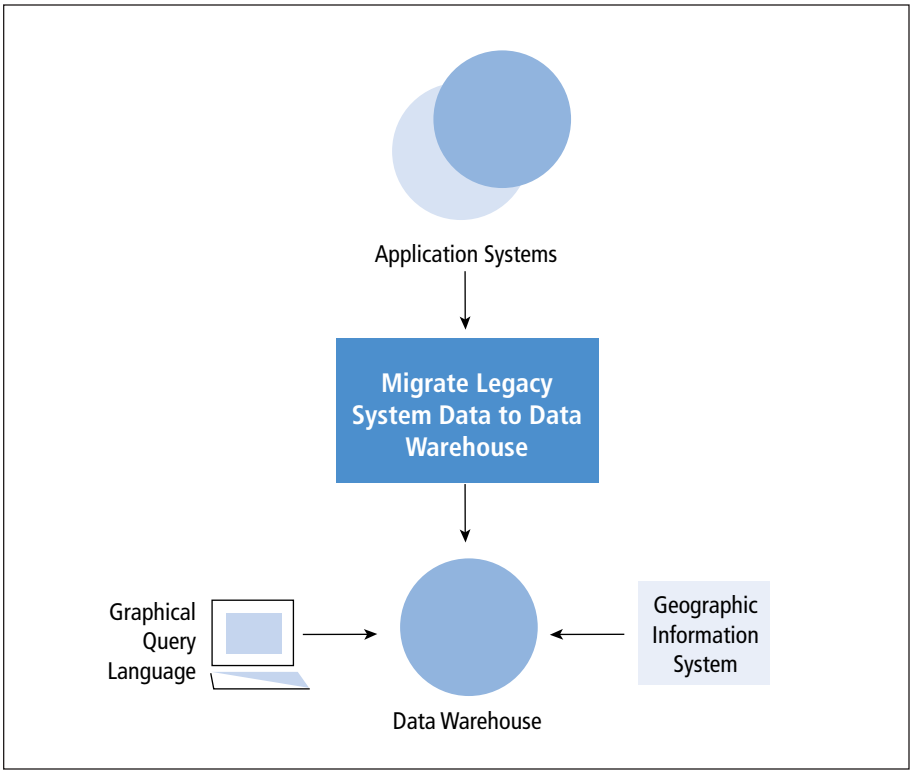
The Ohio DOT has been applying GIS tools to map a variety of transportation events. It all started with a project to map vehicle crashes. What the agency really wanted, however, was to use GIS to integrate all their data and overcome past problems they had with data conversion. The department chartered a cross-disciplinary team of people involved in managing and operating their legacy systems. This initiative greatly facilitated the business process reengineering of their data management activities.

Early in the process, the team surveyed their internal and external customers and identified various data users and their needs. For example, they have external customers who provide information to the legislature. The team worked well in surveying users directly to find out their concerns. As part of this effort they also identified and analyzed 12 legacy data systems to determine what their standards would be for the Base Transportation Referencing System (BTRS).

The BTRS standards substituted county and state true logs (actual log milepoints) to the existing straight line mile log points, and latitude/longitude (lat/long) coordinates to other standard road inventory attributes including county and route name and suffix. The true logs allowed the department to deal with duplicate and missing records, which normally resulted when a road was added to or removed from the straight line mileage. In the past these discrepancies were simply ignored. The lat/long coordinates were considered stable references because the GPS units used to collect them were deemed accurate.

Major challenges encountered in integrating data using the BTRS include correcting many station equations that caused significant problems, missing attributes on legacy data, and inconsistent definitions (e.g., the construction and project management system data). A brute force method was undertaken in which a record was forced on the database every thousandth of a mile and a lookup table was created that has log points with associated lat/long coordinates. This allowed all records to be associated with the BTRS and ensured that the legacy data problem is not perpetuated in the integrated database (that is, if a new project is entered on the Project Management System, it ensures that it is on the roadway in the BTRS). The BTRS project also involved changing records on legacy systems. Overall it took a major effort to upgrade the data systems to the BTRS standards.

To store the integrated data the department built a data warehouse (see side picture) that uses the Sybase data manager, the GQL query reporting tool for data access (similar to Maine DOT's), and the GeoMedia GIS software. Every evening the legacy data from active online systems is electronically transferred to the data warehouse. The warehouse uses BTRS standards to link all data records from any legacy database to other systems and pulls this data into a GIS environment. The linked data include roadway, bridge, culvert, traffic, crash, and other information—all of which are tied using the brute force method that brings all data into lat/long coordinates.



Base Transportation Referencing System Data Warehouse—Ohio DOT

Questions and Answers

Q. Are you familiar with the technical details of the data used for transportation modeling?

A. That information is in the traffic monitoring system.

Q. For business practice changes, what is the time lapse from start to when you decide where you need to be?

A. We worked with the BTRS and the database system work plan at the same time. For the PMS, a lot of time and effort were spent on the business process—about 18 months—defining what is what. We had a dysfunctional process being applied to a functional system. We also did not have funding. Before we developed the data warehouse for the PMS, we defined business rules that are tied to performance measures.

The integrated data warehouse is being used to build the districts' multiyear work plans, to segment asset data (pavements, bridges, signs, etc.) dynamically using GIS, to respond to ad hoc queries, and to create data records whenever data change. The development of the work plans involves many people working together, not just the information systems staff and accountants. Ad hoc reports allow users to view and select data attributes and communicate to people using the data warehouse what the data are about.

For pavement management the system is used to conduct tradeoff analysis and obtain information about what pavement activities are going on. Dynamic segmentation using GIS allows a variety of pavement analyses including condition assessment, performance prediction, and needs analysis and forecasting. The process identifies deficient pavement segments and provides linkage to the PMS to get more detailed information. The department's PMS data, which previously resided on spreadsheets, have all been converted to a relational database and link well with the data warehouse.

For congestion analysis, the system provides data to perform statewide highway capacity analysis (e.g., volume to capacity ratio) across the network.

The department is now focusing on using the system to track performance measures, levels, and standards for pavements and bridges. The data are used to allocate and manage future funding. This effort involves tying data from various users and validating their accuracy.

Tennessee Department of Transportation

TRIMS: Integrating Legacy Databases for Asset Management

"TRIMS was built to talk to other systems. It now contains data on pavements, bridges, maintenance inventory, traffic, roadside, guardrail, and signs."

Tom Eldridge
Tennessee DOT

The Tennessee Roadway Information Management System (TRIMS) database contains millions of data elements for all public roads in Tennessee. TRIMS is a software application that allows users to access data on their PCs and a data integrator that accesses and displays data from multiple systems in the same view. It is also Tennessee DOT's enterprise GIS.

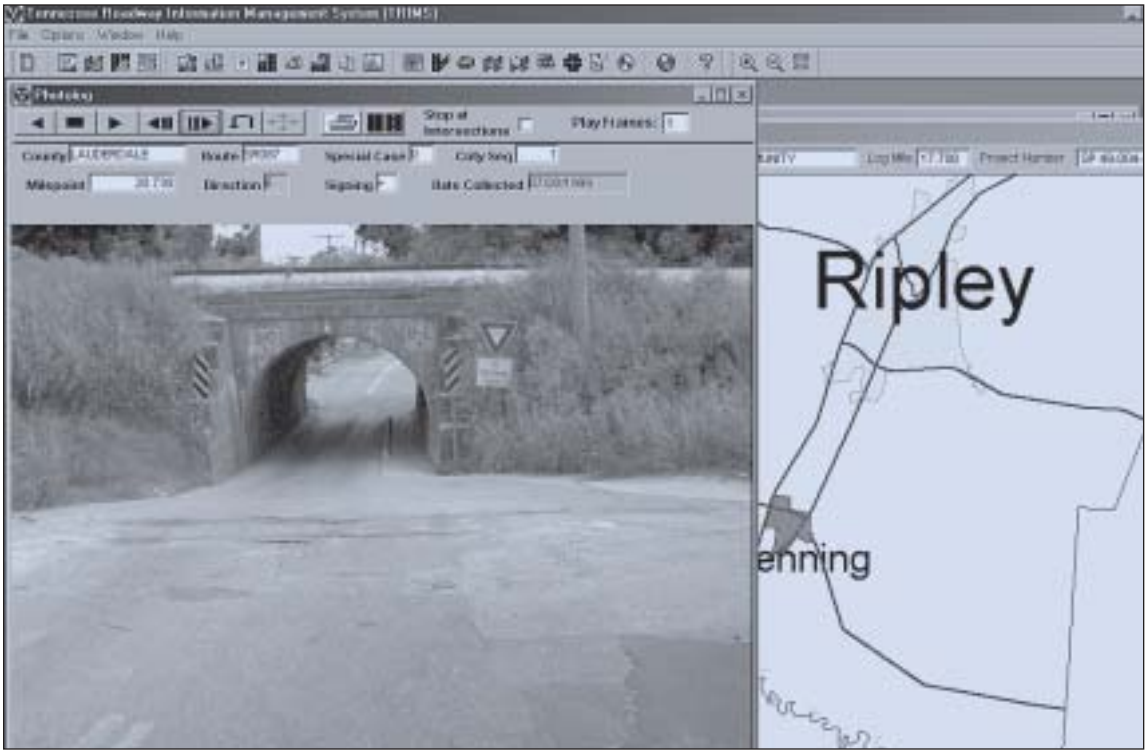
Tennessee was one of the first States to have a completely computerized highway database. TRIMS was first developed as a mainframe database in 1973. Originally, it only contained inventory on interstate and State routes. The old system of Straight Line Diagrams[2] was coded into the mainframe database.

TRIMS has gone through much growth and change since its beginning. It now operates in a client-server environment using Oracle database software and PowerBuilder user interface. Some functions of the system are also available on the Internet. TRIMS has powerful query, print, and viewing capabilities, is GIS-compatible through the GeoMedia software, and uses the county-route-log-milepoint location reference system. The information contained in TRIMS includes roadway feature, geometry, and inventory data; bridge and rail-highway grade crossing data; and crash and traffic data. Users can submit simple queries based on the location reference system, complex queries based on attributes, dynamic segmentation queries, and roadway composition queries. A relatively new feature of the system is thematic mapping that allows users to define and create maps for specific purposes and to produce desired reports and graphs.

The TRIMS database also includes high-resolution photographs that can be accessed using a toolbar or by selecting and clicking on the map (see side picture). These photos reside on Terrabyte servers in headquarters. They are very clear and bright when viewed in headquarters, but not that good across networks. The photologs are currently the most used part of TRIMS among users numbering about 800. Everyone likes it even though access in the districts can sometimes involve long waiting times.

TRIMS was built to talk to other database systems in the department. Currently it is linked to the agency's PMS, which uses a FoxPro database. While the system can produce pavement reports using condition information from the PMS (e.g., distresses, roughness), it does not analyze pavement data; the PMS does the analysis. Data from the HPMS are also being imported into TRIMS, and a new interface for pavement materials/testing data has been implemented. The database also includes NBI, maintenance inventory, roadside, guardrail, and sign data. In the future other systems used for project management/scheduling, construction management, and maintenance management will be linked as well.

[2] A Straight Line Diagram is a two-dimensional graphic representation of the physical roadway characteristics of a highway as if it had no turns or curves.



Tennessee Roadway Information Management System Photolog Image Linked to the Database

The regional offices use TRIMS to view information on a map for highway sections that are candidates for pavement resurfacing. When the list of candidate sections is entered into TRIMS, the user can see condition data, traffic volume, truck percentage, and other information. These data can be mapped and used for complex or thematic queries.

Future enhancements to TRIMS are underway to make it a more comprehensive database system and a more useful information/decision-support tool. These enhancements include linking new systems to TRIMS, tailoring commercial off-the-shelf (COTS) middleware software to serve as data integrator, and adopting software that can easily handle spatial data conversion. The photolog data will also be duplicated in the regional offices to improve access time and photo quality.

"Maintaining 800 users is a lot of work. We are looking at the intranet right now to move these users. There will still be a lot of power users who will need client-server, though."

Tom Eldridge
Tennessee DOT

Questions and Answers

Q. Have you interfaced for public viewing on the Internet information like the Statewide Transportation Improvement Program?

A. Another agency maintains the Internet link to that side. We have to duplicate things on their server, not link them into our database.

Q. What kind of highway materials data are you integrating into TRIMS? Is that on your LRS?

A. We only capture database elements for surface mix, aggregate sources, size and grade, and supplier data. We have just implemented that, so there is no history yet.

Q. On your photologs—are users capturing measured data from the photos or using them for reference?

A. We are using them for reference right now, most of the time just to see the condition of the assets.

Q. Connecticut's experience is that currently they have 157 desktop PC stations. They track photolog usage and estimate field trips saved, reduced vehicle usage, and gas consumption. The savings reported are in excess of $1 million per year. Do you track photolog usage? If so, do you attempt to quantify the benefits resulting from it?

A. We track how many queries and by whom, but not how long they use it or how many frames they look at. In the past we had 35 mm photos that we kept for 15 years, but no one used them.

Q. Did you say TRIMS can be accessed from the outside world?

A. Not yet. We have tried access through dial-up, but it is not usable that way.

Q. TRIMS seems to be very robust. How do you decide what gets added to it and when? Do you have a process that you follow?

A. We have an annual budget allocated to TRIMS. A team made up of IT, planning, and GIS people go over the list of enhancements that have been recommended. The list is prioritized, and we proceed from that.

Q. When you collect centerlines using GPS coordinates, is that dedicated or part of a comprehensive data collection effort? What types of accuracy do you get?

A. That is a dedicated effort done in-house. We bought three vans equipped with GPS receivers from a vendor. We are pleased with the accuracy: 1:24,000. That is too good to use in some places for cartographic purposes.

Q. What is your typical network connection, bandwidth, connection to regional office, and user base in the State? What is the dedicated server administration staffing to support the system?

A. We have a 100 BASE-T Ethernet in headquarters built between the floors, but we are getting ready to upgrade that. The wide area network (WAN) has much less bandwidth and is not standard anywhere. Most regions have T1s, but they share the network with other people when they get on the State servers. Bell South is currently working with the State to upgrade the WAN, looking for better ways to get it to the regions.

Database query is good in the regions, but for photolog/mapping they have to wait. Not very many do mapping, but many use the photologs. Currently one picture takes about four to five seconds to load, maybe a bit more in some places.

With regard to support staffing, we have one dedicated database administrator (DBA) in our IT section for TRIMS, but that person does other things too. We also have one contractor DBA and one dedicated contractor who does Oracle Spatial DBA for a pilot project, for an overall total of three DBAs. We have about four to five server support people who work on all 20 servers including Web servers. We also have help staff, with one person dedicated to TRIMS. Oracle is the most difficult server. We are using Name Servers, so there is no need to configure machines. Maintaining 800 users is a lot of work. We are looking at the intranet right now to move these users. There will still be a lot of power users who will need client-server, though.

Virginia Department of Transportation

ICAS: First Step Toward Asset Management

The Virginia Department of Transportation is undertaking a major effort to develop an Inventory and Condition Assessment System (ICAS) for all maintainable highway assets throughout the State. Started in 1995 with a conceptual design, ICAS resulted from a maintenance business process reengineering (BPR) analysis conducted by the department. The BPR was driven by a need to better describe and quantify Virginia DOT's highway infrastructure, make the best possible investments, evaluate the results of management strategies, and justify funding requirements in the State legislature.

ICAS is intended to have a comprehensive inventory of all assets that will be the basis for Virginia DOT's integrated highway maintenance management programs. A pilot project was initiated in 1998 involving data collection, system development, and training in three counties that represent various environments in the State. The manual data collection effort resulted in huge quantities of inventory data for all assets in those three counties including 5,000 centerline miles of roadway, 34,000 pipes and culverts, and 40,000 signs and signals. These data were collected using automated and manual inspection techniques, and they include geographic coordinates obtained from GPS receivers. The accuracy of the data was good, but the cost and level of effort incurred with manual surveys were high.

Virginia DOT needed to determine how to manage such enormous amounts of inventory data. The goal was to use this information to integrate the business processes in the agency starting with the maintenance programs and extending to the planning, design, construction, and operational aspects of Asset Management. The maintenance business processes that will be supported by ICAS include asset-based inventory and data recording, resource allocation (labor, equipment, materials), planning and scheduling, implementation, and performance monitoring and evaluation. ICAS will also allow the agency to perform life-cycle analysis of the assets. The long-term plan is to make the system consistent with Statewide intermodal, interagency, and interjurisdictional business processes.

Recognizing the amount and variety of asset data collected, Virginia DOT identified and focused on three concepts of data—location, connectivity, and time—that needed to be addressed in their data models in order to achieve integration. The concepts are based on the data model developed under a National Cooperative Highway Research Program (NCHRP) project.[3] "Location" is a primary data descriptor and integrator because most asset data are tied to location. "Connectivity" describes the relationships and relative properties among assets. "Time" enables analysis of asset history including deterioration and performance.

To implement the ICAS, Virginia DOT selected a commercial Asset Management software package (Highways by Exor) that is based on the NCHRP data model and supports multiple linear referencing systems. The software allowed the agency to

"A comprehensive inventory of highway assets will be our basis for making the best possible investments and for measuring our accomplishments."

Robin Bresley
Virginia DOT

[3] NCHRP Project 20-27, Development of System and Application Architectures for Geographic Information Systems in Transportation (GIS-T), developed a GIS-T design concept, a description of GIS-T applications, and other research topics to address data, institutional, and technological issues.

"Data collection is a minor effort compared to managing an integrated enterprise database. It is hard to understand what keeping data up in the system will be like until you actually get there."

Robin Bresley
Virginia DOT

bring legacy data in from existing systems that use different referencing methods. For example, data from the legacy highway records system, which uses link-node-offset referencing, were easily integrated into the ICAS database.

The adoption of commercial software for ICAS proved to be beneficial because it would have been a lot more difficult for Virginia DOT to design the system. The software was found to be manageable, upgradeable, and flexible, providing most of the required functionality for ICAS. Virginia DOT wanted data to be contained in tables, which the software does. The implementation of COTS software forced Virginia DOT to examine its organizational culture and challenge many of its current business processes including its decentralized decision-making activities. Adopting a commercial software also helped the department avoid the risks and control the costs associated with software development.

Some users of the commercial software package indicated that the organization might not get what was expected and therefore expectations may need to be managed. However, given that the business practice implicit in a commercial software provides a sound framework, Virginia DOT realized that the system they had imagined before adopting the software might not have been better after all.

Several important lessons were learned from the development of ICAS: choose a software based on the agency's data model and desired functionalities, define business requirements and rules in relationship to the data model, communicate the concepts of Asset Management and their direct relationships to the data, start with the smallest possible data set as system elements, and develop prototypes that satisfy the business requirements in the system. It is also important to show people what can be done with the system and the data.

Questions and Answers

Q. Does Virginia DOT have its own data server or are you buying space from Exor?

A. Virginia DOT has its own server.

Q. Where were you as far as foundation is concerned when Exor came in? Did you have legacy systems, stovepipes? Did you wipe them out or connect them with Highways by Exor?

A. We have not wiped out our stovepipes yet, but we have put in place the pieces that eventually will allow us to do that. For example, we have georeferenced our Highway Traffic Records Information System. We have been working with the construction group to use a common reference system but have not completed it yet. We will make maintenance data work first and then bring in other pieces of agency data to the system. All system decisions are made with a long-term view toward potential integration.

Q. You mentioned that if you were to do it again, you would develop a prototype in a smaller environment. What percentage of your time spent since 1995 would you attribute to business process analysis, and how far were you in that process when you selected Exor?

A. Our business process analysis was started in 1995 and completed in 1996. In 1998 we started collecting data, and after that we began to ask questions about how we would manage that data. We were done with the BPR when Exor was hired. In the near future the BPR recommendations will be reevaluated in light of real data and what it takes to collect and manage those data.

Q. Would you say that 20 to 25 percent of your effort in BPR was tied to the Exor product? My point is that we always underestimate the effort and resources needed for the business process analysis.

A. You are absolutely right. Ninety to ninety five percent of our effort right now is tied to the business process analysis for managing asset data, and 20 people are involved in it. We need to drop everything to make the system run. It is hard to understand what keeping data up in the system will be like until you actually get there. Actually deploying it is different from thinking about deploying it.

Q. Is Exor providing Virginia DOT's pavement management system software?

A. No, Virginia DOT has its own PMS software.

Q. Are you integrating this PMS software with ICAS?

A. We are working on integrating the inventory for pavement management, including roadway sections and pavement data. We also plan to integrate the analytical part of pavement management, but it is not yet available. We need to think about it in the near future. We will be working with the same location referencing system, so there is a connection. No heavy-duty pavement analysis is done in ICAS right now; that will remain in the PMS.

Q. Good job! As you wrap up your pilot in June, what are your next steps?

A. We have about 30 pages that describe our next steps. The big plan is getting a handle on the data needed to run the ICAS. It has huge cost implications for state-wide implementation. One idea is to have different data sets, a small data set for strategic budgeting for the entire agency and another very detailed and operational data set. We also need to do database surgery to have a cleaner data setup. But the biggest effort is getting a handle on the data. We need much more image-based data in the future than just walking/visual surveys. Exor is also bringing in the Web-based upgrade to their software.

Q. Do you keep track of lane-miles and centerline-miles? Do you know how many lane-miles you have?

A. Right now we are set up for centerline-miles. We have about 58,000 centerline-miles. Eventually we will be housing lane-mile data, but that is not in the current plan.

Q. You mentioned that you would start with a small prototype. Would that prototype mean one area with all asset types or one asset in a small or large area?

A. We would do one small area with all the asset types because it gives better snapshots of all data. Linear things are different than point things, and those kinds of behavior should be captured in a cross-section of data.

continued on next page

Q. One observation: Our State GIS can show control points, such as State lines and boundaries, that we cannot locate in the field. So we have a location reference system but we cannot locate our control points in the field.

A. Our staff works out operationally, sometimes on boundaries. The model that we are using does not have nodes at jurisdictional boundaries. We could do pseudo-nodes. We like the data model to be simple and thin and attached to the roadway network.

Q. What challenges did you have to overcome in rectifying what data elements needed to be cross-checked or harmonized to achieve data integration? For example, culverts—how did you come up with one standard definition for asset data?

A. We are lucky because we already have agency standard definitions for assets—that is not a wheel we are going to reinvent. Probably the biggest challenge is educating users coming online that those definitions do exist. Usually those definitions are high level, so we had to broadcast them to inform all users. We were fortunate to have programs that preceded us with that development.

Q. On long viaducts, are you going down span by span or do you treat an entire long viaduct as one entity? Are you treating them as links?

A. We have a table linked to our Bridge Management System, but it is a small subset of information. The viaducts just have regular numbers. The Bridge Management System keeps all the detailed bridge data.

Q. Do you also support traffic and crash analysis? What other data are tied to the system?

A. Accident analysis is part of our planning process. We are just building the highway inventory right now. We can pull accident data from the Department of Motor Vehicles (DMV) and put it into ICAS. Over time, instead of housing these data in the legacy system, we want to include DMV data in ICAS. We also want to integrate traffic load data once we are stable in collecting inventory.

Q. Earlier there was a question of data definition and integrating data elements from different databases. Different databases have common data elements. As we have very common elements in different databases with different syntaxes, how do you reconcile the metadata? Do States have a generic approach to metadata?

A. We are dealing with it on a case-by-case basis. We are not in a position to dictate ways of reporting data. It is an ongoing dialogue—we are not marching out with a particular recommendation. As our plan is to integrate by data tables referencing themselves to the network, metadata synchronization will be an issue for the enterprise, not us. We would hope that business units will synchronize their metadata.

"We are lucky because we already have agency standard data definitions for assets—that is not a wheel we are going to reinvent."

Robin Bresley
Virginia DOT

Summary of TRB Peer Exchange: Integrating Highway Information

In early 2001, several TRB committees associated with data and data information systems joined with the FHWA Office of Highway Policy Information to conduct a peer exchange surrounding the general topic of data integration and its application to various transportation contexts. Sponsored by FHWA, the Bureau of Transportation Statistics, and AASHTO, the meeting was attended by 22 participants from Federal, State, and local agencies. The goals of the meeting were to exchange ideas, share experiences, develop principles and success factors, and identify next steps to advance the state of the practice of data integration.

The participants discussed why data integration is necessary and developed a working definition. The group also identified a number of management issues associated with data integration including the need to create the appropriate organizational culture (which was seen as the biggest obstacle to overcome), set priorities on integration efforts, provide the necessary support, and ensure the quality of data. One idea that came out of the meeting was that, depending on an organization's circumstances, data integration can require different strategies. On one end there is mission-independent data, such as spreadsheets that do not need to be integrated, and on the other end are totally integrated data, such as those used for Asset Management, that require multiple coordinated and accessible data sources.

Five major guiding principles for data integration were identified: (1) assigning clear roles and responsibilities, (2) using transparent and adaptive technology, (3) defining a global framework but deploying incrementally, (4) balancing the enterprise and local perspectives, and (5) collaborating across institutional boundaries. The need to develop and measure success factors was also highlighted.

One next step for the group is to promote data integration within and between the States. The motivation to do so is coming from a multitude of agencies. How that data integration will be implemented will be difficult to determine.

The challenge for the transportation community, given that many players from many disciplines and agencies are getting involved in data integration, is to reach organizational coordination.

"We are excited that data integration is getting attention in Asset Management."

Ed Christopher
TRB Statewide Transportation Data Committee

ISSUES AND CHALLENGES FOR ASSET MANAGEMENT DATA INTEGRATION

"We are in the same situation as others, trying to get off flat files that we have been using for many years."

David Studstill
Georgia DOT

From the State presentations and ensuing discussions at the Forum it became apparent that several key issues and challenges characterize most data integration efforts. Those identified at the Forum, while obviously not constituting a comprehensive list, represent the primary data integration elements that need to be closely examined by transportation agencies.

Data Content, Format, and Sources

Data integration and sharing for Asset Management involve bringing in data from various sources. These data may be acquired using different types of equipment and can have diverse structures and formats.

The major issues that need to be addressed are which data need to be integrated, where the data will come from, and what their formats are. To answer these questions, an agency will have to identify the Asset Management business processes that the integrated data will support and examine the required data in terms of where and how they are collected and stored, and in what form.

Data need to be in electronic format to facilitate sharing. Electronic data exists in various forms (text, graphics, photos, videos) and can be stored in flat files or structured database files (relational, object-oriented). The files can be stand-alone or part of a database system (including legacy systems) that supports various business processes in the agency, such as pavement, bridge, equipment, finance, construction, and maintenance management systems.

Many agencies have asset data stored in traditional flat files that cannot be easily linked. The challenge is to create a comprehensive framework for data integration that includes all data items needed to perform the desired Asset Management business functions, addresses disparities in data sources and formats, and responds flexibly to changing data requirements (e.g., additional data items, revised data structure) when new business functions are introduced or when existing processes are modified.

Legacy Database and Decision Support Systems—The Stovepipes

Asset Management data in transportation agencies may be housed in legacy database systems that often provide decision-support capabilities for one or more business functions. The most common legacy database system used to support a wide variety of transportation applications including transportation planning and Asset Management is the highway network inventory database. This database is a comprehensive inventory of most elements of the highway infrastructure (roads, bridges, intersections, traffic control devices, etc.), but it often does not contain detailed information about the assets, such as their condition and history, and has limited or no analytical and data processing capabilities for Asset Management.

Business units within agencies have developed database/information management systems for specific applications including pavement, bridge, sign, equipment, finance, and others. These systems must be examined to learn what data they contain, how the data are stored, what business processes the systems support, who uses the systems, and who manages them. Many of these systems have their own databases but also use data/inputs from other systems to perform various analyses. Currently most of these systems within agencies are not linked, making it difficult to share data across systems.

The challenge for comprehensive Asset Management decision-making involving multiple assets is to link independent stovepipe systems. However, these systems often use different data management technologies and information system environments (i.e., database design, software, hardware), which makes it difficult for them to "talk" to each other.

Data Interoperability and Standards

Common, consistent definitions and formats of data across systems help ensure their interoperability in a linked or shared database environment. Because incompatible data formats and inconsistent definitions are prevalent among stovepipe legacy data systems in most highway agencies, standards for data definition, representation, storage, and communications are often established to ensure interoperability of the databases.

A standard data dictionary that contains descriptions and definitions of data is useful in promoting consistent data items for use within a single database system as well as across linked databases. The standards may be defined by the agency or may follow existing industry standards. If the data do not exist in the standard form as specified in the data dictionary, a conversion

"We are faced with a dilemma—how to integrate nine different systems."

Tim Biehl
Utah DOT

"Our systems use different definitions for the same piece of data."

Nadine Jobe
Washington State DOT

"People need to understand good strategies for managing organizational change and business culture."

Will Holmes
Kentucky Transportation Cabinet

routine is performed to temporarily or permanently transform the data. For example, in order to implement its standard BTRS, Ohio DOT converted some of the existing location data, which use linear referencing, to geographic coordinates so they can be used for various analyses.

The challenges for most agencies in developing and implementing data standards and in converting existing data to these standards include (1) coming up with suitable data formats, models, and protocols when existing databases are extremely diverse, (2) getting people within the agencies to agree to using and conforming to the standards, and (3) minimizing the level of effort and resources required to implement the standards.

People and Organizational Culture

Probably the most important and challenging aspect of data integration for transportation agencies is addressing the needs of people within and outside the organization. These people may or may not be direct users of the data, which makes the process even more complex.

The data integration strategy needs to recognize the fact that everyone working with data does things differently and therefore will be affected by the process in different ways and to varying extents. Data integration involves changes in the way individuals perform their tasks and carry out their responsibilities.

While the net result of integration will be highly beneficial to the agency as a whole, there will be some individuals or units who gain and others who lose, depending upon how the situation is viewed. It is almost impossible to develop a data integration strategy that satisfies the needs and meets the expectations of everyone with a stake in the Asset Management data. There will always be reservations or reluctance from some of the parties involved. The challenge is to help the people in the organization understand and appreciate the benefits of the process from the perspective of the entire agency and not their individual units.

Managing the expectations within and outside the agency is also of utmost importance and requires substantial effort. It is hard to change the business culture in most organizations where decisions are made by specific functions rather than on a more comprehensive level. One way to do this is to continuously educate and inform the individuals about the merits of integrated databases. There is also a need for support from top management who will rally behind the process, support the concepts, and encourage people in the agency to implement it.

Data Integration Architecture and Strategy

Data integration architecture is the framework that defines and describes the interrelationships between databases and systems as well as the technical specifications and protocols for interfaces, communications, and application products. The architecture is the "big picture" of the data integration strategy that shows how everything fits together and the mechanisms for integration.

The FHWA *Data Integration Primer*[4] identifies two basic approaches for data integration: (1) creating a data warehouse that contains all the integrated data, and (2) linking the existing databases or systems and providing a view of the linked data. The Primer cites specific advantages and disadvantages to each approach.

The choice of the data integration strategy depends upon many factors including how the integrated data will be used (by whom and for what purpose), the characteristics of the existing databases/systems (e.g., interoperability), the types and volume of data that need to be integrated, the information technology that is or will be available, the level of staffing and resources that the agency will engage in the process, and the structure of the organization (characteristics of business units such as their roles, data needs, people, and information systems).

The challenge for most agencies is finding the strategy that best fits their needs and working out the details of implementing the strategy. With the range of factors involved, this is clearly not an easy task.

"All the infrastructure is in place. What's not there is integration—the ability to integrate."

Ben Nelson
Kansas DOT

[4] *Data Integration Primer.* Federal Highway Administration Office of Asset Management. August 2001 (Publication No. FHWA-IF-01-016).

"This is the first time our regional directors have gotten together to discuss resource allocations and tradeoffs."

Lou Adams
New York State DOT

"We need to interface the highway inventory with pavement and maintenance data to allocate $700 million of maintenance funds to the districts."

Joe Graff
Texas DOT

Integrated Analysis and Decision-Making

One objective of data integration is to allow comprehensive analysis and evaluation of investment alternatives across asset types and business functions. This may involve one or more units within the agency responsible for managing assets and making decisions concerning the assets.

There are many dimensions to the analytical and decision-making processes for transportation assets. The processes can be at the operational level (e.g., how to repair a bridge component) or at the strategic level (e.g., how often to resurface a road). They can pertain to a specific project (e.g., a route or roadway section) or a network of roadways (e.g., all rural arterials). They can involve resource allocation and trade-off analysis across assets (pavements, bridges, guardrails, signs) or across jurisdictions (counties, districts, etc.). These dimensions increase the complexity of the processes, making them difficult to address fully in the data integration strategy.

Organizational issues are also involved when integrated analysis and decision-making cut across assets and business functions. These issues are especially difficult for agencies that are not used to operating in an integrated way. The challenge for most agencies, apart from developing and implementing a database strategy that supports integrated decision-making, is in keeping the databases useful and valuable to the users and customers.

Location Reference

Location data are necessary to manage transportation assets, and agencies use a variety of systems to describe location including linear reference systems, geographic coordinate systems, and other conventions. As location is the key identifier of Asset Management data, it is important that common or compatible location reference systems are used by databases so they can be linked or integrated.

A great deal of effort in data integration is spent identifying a standard location reference system and converting existing data to conform to this system. The challenge for transportation agencies is to come up with a system that adequately describes the data and supports all data collection, processing, and reporting requirements within and outside the agency. Getting consensus among data users and managers on which location reference system to use is very important.

Database Management Technology

A major element of a data integration strategy is the selection of software, hardware, and other tools to use for database management. A variety of database management software is available. On the hardware side, database servers with various configurations, operating environments, functionalities, and storage capacities are available.

Applications that draw information from the databases can be developed from scratch using computer programming software or application development tools. Alternatively an agency can adopt COTS software packages that are tailored for asset database management applications. There are advantages and disadvantages to either approach as pointed out in the State presentations.

GIS software and functionalities are often incorporated in the database applications either as the platform for integration based on location or as external software that provides mapping and other analytical and reporting capabilities to the database system.

Various units within agencies have often developed their own databases and database applications, including the legacy systems and GIS applications described earlier, using different software and hardware. This results in a data/system integration situation that is challenging and complex. People generally want to continue to use the software and tools they have used for many years, are familiar with, and meet their needs. The challenge for data integration, therefore, is to recognize the diverse data management approaches and either develop a framework that allows the data users to continue using their applications with the integrated data or provide in the integrated database environment the same functionalities those applications have.

Establishing agency standards for software, hardware, and programming tools may also help eliminate the diversity in database management practices in order to facilitate integration. However, coming up with standards that are acceptable to everybody and that meet the agency's current and future information technology and data management needs presents a significant challenge. For example, States are finding they need to develop World Wide Web applications for their databases or to make their database systems accessible via the Internet. This requires that software and hardware be Web-enabled and perform well in the Internet environment. Agencies simply cannot anticipate their future data management needs.

"We are trying to figure out how to put programs written in Fortran, COBOL, Assembler, and everything else together to make sense."

Randy Estes
Alabama DOT

"We used to have an integrated database until people built their own little systems."

Mary Ann Dierckman
Alaska DOT

FHWA'S DATA INTEGRATION PROGRAM

"Our agency is evolving in a kind of Darwinian style into Asset Management, providing structure to it and knowing where everybody is."

Chuck Smith
Illinois DOT

The Forum and Peer Exchange summarized here is one of many initiatives supported by the Data Integration Program in the FHWA Office of Asset Management. The program's purposes are to respond to the data integration needs of transportation agencies and to help facilitate information management and decision-making processes for transportation assets. The Office publishes information, and conducts and participates in discussions, research, information gathering, and outreach.

The primary objective of the Forum was to provide a venue for agencies to share their data integration experiences. Another objective was to gather input for the long-term research and technical assistance plan for the Asset Management Data Integration Program. This was accomplished through information gathering at the Forum and through the creation of the Asset Management Data Integration State Working Group. The group was organized following the Forum to guide the long-term data integration research and technical assistance program.

Current Initiatives and Plans

The Asset Management Data Integration Program currently includes the following initiatives and plans.

Case Studies and Best Practice Reports—Transportation agencies can learn much from what others are doing with respect to data integration, especially since many of them have similar business processes and organizational structures. Case studies of data integration experiences are a valuable source of information and knowledge to those who are undertaking or planning to undertake data integration initiatives. Case studies bring out important lessons on what works best and what to avoid under varying circumstances. They can also identify best practice strategies and tools.

Informative Materials—In addition to case studies and best practice reports, a variety of information and resource materials will be developed and published to inform on and assist with data integration, particularly in overcoming impediments. FHWA has already taken initial steps in this regard by publishing the *Data Integration Primer* and the *Glossary of Data Integration Terms*.

Innovative Tools—The Data Integration Program will investigate cutting-edge data management technologies. These technologies will include software utilities, hardware, and other tools with potential to simplify or enhance database integration.

Training, Education, and Outreach—Training and education will continue to be top priorities in the program. There is a need to develop and deliver forums, workshops, and courses that reach out to and educate Asset Management practitioners about the principles, strategies, and benefits of data integration. Training will include workshop sessions, peer exchanges, and formal training courses on specific topics and issues related to data integration. Additionally, existing academic programs in transportation and engineering will be examined to identify gaps in information and database management courses. Web sites and electronic discussion boards will be developed and maintained to reach out to and educate practitioners in the United States and around the world, as well as to serve as media for the exchange of ideas and experiences.

Partnerships with Industry and Other Organizations—Many transportation industry groups, research committees, and task forces are addressing data integration in Asset Management and other contexts. In addition to AASHTO's Task Force on Transportation Asset Management and other committees, TRB also has a Task Force on Asset Management. This Task Force recently established a data management subgroup to address a variety of Asset Management data issues including database integration.

Other committees and groups are focused on transportation/infrastructure data as they relate to urban and statewide planning and monitoring, highway information and management systems, technical applications, maintenance and operations, and spatial analysis. In addition, NCHRP, the National Research and Technology Partnership Forum of TRB, and other public and private organizations including the Midwest Regional University Transportation Centers are involved in data integration in an Asset Management context. Partnerships with these and other organizations are integral to furthering FHWA's Asset Management Data Integration Program.

"We don't want to make the same mistakes as others on data integration."

Bill O'Brien
Washington State DOT

"We'd like to get as many lessons learned from as many people as possible."

Scott Young
Colorado DOT

"Information management research is of the highest priority because Asset Management cannot be implemented without the required data and information."

Infrastructure Renewal Working Group
National Research and Technology Partnership Forum

Long-Term Research Plan

The Forum highlighted many technical and organizational challenges that transportation agencies face in their efforts to tie Asset Management databases and applications together or consolidate their data. A long-term research and technical assistance plan is being developed to identify specific topics and areas for future research, development, training, support, deployment, outreach, and other activities and products that will be valuable to agencies as they initiate or continue their data integration efforts. FHWA's existing Data Integration Program will be expanded to include activities in the long-term research and technical assistance plan.

A primary resource in the development of the long-term plan is the Asset Management Data Integration State Working Group, consisting of State DOT practitioners and representatives from FHWA and the Bureau of Transportation Statistics. The Working Group was organized to provide leadership and direction on addressing the challenges and issues associated with data integration. It will also provide continuous guidance and support on the data integration activities of the Office of Asset Management. Most Group members were drawn from the Forum participants. The Working Group includes liaisons from FHWA's headquarters offices and resource centers and representatives from 10 State DOTs: Alaska, Illinois, Kansas, Maine, Michigan, Mississippi, Montana, New York, Ohio, and South Carolina.

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www.fhwa.dot.gov/infrastructure/asstmgmt/diindex.htm

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