Geospatial Information Technologies for Asset Management

DETAILS

0 pages | null | PAPERBACK
ISBN 978-0-309-43668-7 | DOI 10.17226/23230

AUTHORS

TRANSPORTATION RESEARCH

CIRCULAR

Number E-C108

October 2006

Geospatial Information Technologies for Asset Management

A Peer Exchange

TRANSPORTATION RESEARCH BOARD

OF THE NATIONAL ACADEMIES

TRANSPORTATION RESEARCH CIRCULAR E-C108

Geospatial Information Technologies for Asset Management

A Peer Exchange

October 30–31, 2005
Kansas City, Missouri

Transportation Research Board
Transportation Asset Management Committee
Spatial Data and Information Science Committee

Supported by
Federal Highway Administration

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Editor

October 2006

Transportation Research Board
500 Fifth Street, NW
Washington, DC 20001
www.TRB.org

TRANSPORTATION RESEARCH CIRCULAR E-C108
ISSN 0097-8515

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Introduction

Transportation asset management is a data-intensive process and data integration is a fundamental component to improve integrated decision making. The evolution of geographic information systems (GIS) and spatial technologies is providing powerful mechanisms for developing asset management decision-making products. However, many agencies are struggling with the development of these spatial products on an enterprise basis.

The Transportation Research Board (TRB) Transportation Asset Management Committee (ABC40) and Spatial Data and Information Science Committee (ABJ60) hosted a peer exchange to investigate state and local agency applications of spatial technologies for asset management activities and to identify ongoing issues and research directions. The peer exchange was supported by the Research and Innovative Technology Administration (RITA) of the United States Department of Transportation (USDOT). Six state and local transportation agencies were selected based on their leadership and progress in the application of spatial technologies towards asset management. Prior to the peer exchange, agency participants completed an extensive questionnaire on their uses of spatial technologies, their history of implementation, and perceived benefits and issues.

Results of the completed questionnaires, and subsequent peer exchange discussions, provided insights into the application of spatial technologies to meet asset management practitioner needs. In general, the agencies recognized the value of spatial technologies and had allocated significant resources towards the development of a broad set of spatially enabled asset management products. Benefits included more sophisticated analysis of data and the development of powerful decision-making products for internal and external access.

However, the agencies indicated that significant issues remain with the implementation of a true spatial data warehouse for developing comprehensive asset management products. These issues include data quality and accuracy, multiple spatial referencing methods, a lack of standards for interagency data sharing, and limited models for asset management decision analysis.

The peer exchange participants focused on three major issue areas in moving spatial technology applications to the next level: managing change, data integration, and communication. Upon a thorough discussion of these issues, the peer participants identified research to address three areas of interest: temporal issues, symbology, and data and visualization models. The roles of national organizations in sharing best practices and in promoting standards and open data architectures were also discussed.

Background

ORGANIZATION AND SPONSOR

The peer exchange was organized by the TRB's Transportation Asset Management Committee (ABC40) and Geographic Information Science and Applications Committee (ABJ60) and supported by RITA of the USDOT.

PARTICIPANTS

Invitations were extended to six state and local transportation agencies. These agencies were considered to be enthusiastic and proactive leaders in developing spatial technology applications for asset management. The agencies also were allocating significant resources to the effort and were focusing on a higher level of decision support with a broad view of assets. The participating agencies were

- Alaska Department of Transportation and Public Facilities;
- City of Edmonton, Alberta, Canada;
- Kansas Department of Transportation;
- New York State Department of Transportation;
- New York State Thruway Authority; and
- North Carolina Department of Transportation.

Table 1 lists peer exchange participants and responders to the questionnaire.

AGENCY QUESTIONNAIRES

Prior to the peer exchange, each transportation agency representative answered five questions to summarize their agency's activities in the application of spatial information technologies for asset management functions. The questions focused on existing applications, historical development, benefits, issues, and anticipated future efforts. The responders generally queried the diverse entities within their agency involved spatial technologies and asset management in formulating their responses.

The five questions were as follows:

1. How is your organization using spatial information technology (IT) to support and enhance asset management decision making and resource allocation?
    a. Give a brief history of how spatial technologies and asset management have evolved in your agency.
        - Briefly describe the status of asset management in your agency: formal system, management system components, fully–partially–not integrated, directly

TABLE 1 List of Peer Participants and Responders to the Questionnaire

Name and Title	Organization
Louis Adams, Head, Modeling and Forecasting Section	New York State Department of Transportation
Ocie Adams, Maintenance Management System Manager	Alaska Department of Transportation & Public Facilities
Cheryl Benjamin	New York State Office of Cyber Security and Critical Infrastructure Coordination
Jennifer Brandenburg, State Road Maintenance Engineer	North Carolina Department of Transportation
Carol Brandt, Program Manager, Geographic Information Services	Research and Innovative Technology Administration
Al Cepas, Pavement Management Engineer	City of Edmonton, Alberta, Canada
Theresa Cloake, Office of Infrastructure	City of Edmonton, Alberta, Canada
Joseph L. Darling, Director of Asset Management	New York State Department of Transportation
John Farley, Manager, Programming and Analysis, GIS Unit	North Carolina Department of Transportation
James Hall, Assistant Professor	University of Illinois–Springfield
Brian Logan, Cartography/GIS Manager,	Kansas Department of Transportation
Lee Maynus, Director, Office of Transportation Statistics	New York State Thruway Authority
Emily McGraw, Pavement Preservation Engineer	North Carolina Department of Transportation
Sue McNeil, Professor	University of Delaware
Richard Miller, Assistant Geotechnical Engineer	Kansas Department of Transportation
Robert Mooney	Federal Highway Administration
Thomas M. Palmerlee, Senior Program Officer	TRB
Kathleen Ramage, Road Network Services Manager	Alaska Department of Transportation and Public Facilities
Mark Sarmiento	FHWA
Dennis Slimmer, Assistant to the Director	Kansas Department of Transportation
Reginald R. Souleyrette	Iowa State University
Jack Stickel, Highway Database Management Supervisor	Alaska Department of Transportation and Public Facilities
Paul Szczepansk, General Supervisor, Infrastructure	City of Edmonton, Alberta, Canada
Frank Winters, GIS Administrator	New York State Department of Transportation

or indirectly tied to program development process, other functions.

- Briefly describe the status of GIS and spatial information technologies in your agency. Include existing capabilities and anticipated future capabilities. What is the level of integration of spatial technologies with asset management functions? Does your spatial referencing mechanism enable the integration of data and expansion of use in the future?
- Please include organizational areas that have primary responsibility over these functions.

b. Who are the primary users of spatial IT for asset management and how are they using it (staff-level only, director, governors, etc.)?

2. What are the benefits to using spatial IT to support asset management?

a. How has your transportation system improved or your program changed due to the use of spatial referencing of asset management data?

b. Has your spatial IT capabilities changed in response to the need for better asset management?

c. What areas do you plan to expand spatial information capabilities for asset management?

3. Please describe the status of your current situation in the use of spatial information technologies to access and integrate data to support asset management decision-making activities. Please indicate whether there are significant differences in capabilities for specific asset management components, e.g., pavement management and right-of-way management. In your answer, please address the following topics:

a. Current situation:

- Identification and integration of relevant legacy databases;
- Selection and maintenance of GIS software platform;
- Common referencing methodology or your methods to integrate differing referencing schemes;
- Integration of external information (specific major sources, integration method, e.g., fused database, interoperable database, within geodatabase or data warehouse);
- Data quality issues—accuracy, completeness, timeliness;
- Differing spatial resolutions of data;
- Metadata standards;
- Enterprise deployment (multiple offices and districts);
- History (accessibility of archived data files and version control of the spatial database);
- Established protocols (e.g., standard procedures–guidelines) for data collection; and
- Data collection issues such as data collection methods, frequency of updates of asset management information and location information (e.g., annual inventory process).

b. What are the remaining significant issues for spatially integrating data for asset management decision makers across your organization?

4. What spatial IT-enabled tools and products have you developed for user and management level decision support for asset management [e.g., information query and display,

network analysis, common decision support products, forecasting, Internet/intranet products, use of the Highway Economics Requirements System–State Version (HERS-ST) software]?

a. What products have proven most successful for asset management activities?
b. What future product developments do you believe would provide the greatest benefits?

5. What roles or actions can national organizations undertake to help state and local transportation organizations improve the use of spatial information technologies for asset management such as

a. In developing an interoperable spatial information infrastructure to facilitate the development of tools,
b. In capacity building,
c. In broader understanding of the capabilities of spatial information technologies throughout the transportation community, including policy makers,
d. In development of tools themselves,
e. In systematically documenting good practices in integrating data from various internal and external sources and management systems (i.e., bridges, pavement, traffic), data collection technologies, GIS implementation, and
f. Other roles or actions.

INTRODUCTORY REMARKS AND PEER EXCHANGE STRUCTURE

Sue McNeil, facilitator of the peer exchange and chair of TRB's Transportation Asset Management Committee, welcomed the participants. She indicated that the responses to the peer exchange questions demonstrated the significant benefits of using spatial information technologies for asset management. She emphasized that the purpose of the peer exchange would be to focus on the efforts necessary to move the use of spatial information technologies for asset management to the next level.

Carol Brandt of RITA emphasized the need in asset management activities to find intersections within and among modes and to integrate communications through all levels of government. The applications of spatial technologies are critical to support and enhance these activities.

The peer exchange then progressed with presentations by the agency representatives on their spatial technology applications directed towards asset management.

Alaska Department of Transportation and Public Facilities Perspective

OCIE ADAMS
KATHLEEN RAMAGE
JACK STICKEL
Alaska Department of Transportation and Public Facilities

INTRODUCTION

The Alaska Department of Transportation and Public Facilities' (ADOT&PF) mission is to provide for the movement of people and goods and the delivery of state services. The maintenance and operations (M&O) division's asset management system, the maintenance management system (MMS), helps project how maintenance activities affect the level of service (LOS) to the public. The program development division's Highway Database and GIS-Mapping Sections are developing a geodatabase that will integrate the storage and management of road centerline, attribute, and asset management feature data in a GIS environment.

ADOT&PF's differential Global Positioning Satellite system (DGPS) centerline data collection program and GIS deployment will provide the foundation for the MMS spatial information, which will be used to support and enhance asset management decision making and resource allocation. The geodatabase will provide location referencing and feature attribute information for key MMS assets. The geodatabase will link to external tables and databases to access location and attribute information for other assets.

The Highway Analysis System (HAS)–GIS interface will provide an interface between the legacy transportation database, the HAS, and the ESRI-based GIS. Data extracts and reports from the HAS–GIS interface will be provided for import into the MMS and use by maintenance staff.

The ArcIMS web-mapping application will be integrated with the existing highway data port data warehouse application. The new interface will allow users the option of mapping query results for the existing query capabilities as well as simple map query options. The enterprise geodatabase and a first generation ArcIMS web-mapping application will be available to internal ADOT&PF users this fall.

Question 1*a*. How is your organization using spatial information technology to support and enhance asset management decision making and resource allocation? Provide a brief history of how spatial technologies and asset management have evolved in your agency.

Asset Management

ADOT&PF's MMS helps project how asset life-cycle management actions and maintenance changes affect the LOS to the public. The quality assurance (QA) module planning function supports these life-cycle and LOS measurements and reflects the impact of budget changes. The system also tracks the maintenance and operations cost for labor, equipment, and materials to maintain the state's transportation infrastructure of highways, airports, floats, and docks.

ADOT&PF completed a feasibility study in 1991 to evaluate options for developing a comprehensive MMS. The study also looked at the opportunities to integrate legacy systems to leverage existing databases.

ADOT&PF developed the MMS based on the results of this feasibility study and a more detailed user needs analysis. The MMS consists of 13 software modules (both off-the-shelf and new module design), five record viewers with filter capability, and 36 reports.

The M&O division deployed the MMS in May 2005 (Table 2). Future work includes a GIS module that will integrate the department's asset management practices with assessment records and asset images.

Geographic Information System

ADOT&PF has a traditional GIS section that provides automated mapping capabilities. Many of the department's business applications, including asset management, lack a comprehensive and accurate digital representation of the state transportation network. The road network, attribute data, and transportation feature data, including many of the department's transportation assets, are stored in a legacy mainframe transportation database, the HAS.

The program development division's GIS mapping section manages the department's GIS activities. The GIS mapping and highway data sections initiated a multiyear, multiphase project, the HAS–GIS interface initiative, to provide an interface between the HAS database and the ESRI-based GIS. The objectives of this project are to develop targeted upgrade strategies that can be implemented in 3 to 5 years and will

- Establish HAS as the foundation for linear referenced-based GIS;
- Unify the processing, management, maintenance, and output of transportation spatial data and road centerline network data in an integrated system; and
- Improve data access, display, analysis, and output.

The HAS–GIS interface initiative has very specific goals. It is not intended to meet all the department GIS needs, e.g., right-of-way (ROW) survey grade requirements. The ROW section might still reference the work area to a route–milepoint within the HAS–GIS interface, then use ROW-detailed GIS to complete their work. The implementation plan calls for incremental work packages to build on the success of previous tasks and learn from each step of the process. Finally, the components of the interface (GIS, data warehouse, web applications) must fit with

TABLE 2 MMS Software Modules

Activity Plan	Maintenance Forces Project
Activity Standard	Needs Assessment
Adopt-a-Highway	Planning and Budgeting
Bridge Deficiency	Quality Assurance
Contract Management	Stockpile Management
Daily Work Report	Work Request Tracking
Internal Budget	

the anticipated funding and personnel levels for the next 3 to 5 years for the deployment phases and in the future for the full implementation.

ADOT&PF contracted with Cambridge Systematics, Inc. through the State of Alaska task order system to prepare a user needs analysis, user requirements, upgrade alternatives, and implementation strategies for developing a targeted GIS. The HAS–GIS Interface Implementation Plan (December 2003) recommends three phases to the deployment.

- Establish a geodatabase to integrate the storage and management of road centerline and attribute data in a GIS environment. This phase includes changes to business processes as well as software design and hardware acquisition.
- Deploy an enterprise geodatabase, providing linkage to external systems such as the MMS, and extending the architecture to a web-based service model.
- Migrate all applications from the legacy mainframe database to the geodatabase and the data warehouse environment.

Question 1*b*. Who are the primary users of spatial information technology to support asset management?

The ADOT&PF M&O division is the primary user of spatial IT for asset management. M&O personnel use various MMS modules for daily work activities and for managing the department's assets. The daily work report is the core of the MMS. The daily work report generates an electronic timesheet of pay record, personnel hours, and equipment usage for the accounting system. M&O staff prepares reports and analyses for ADOT&PF managers, the governor, FHWA, and the U.S. Coast Guard (USCG).

The department's transportation assets are also tied to other data collection programs that use asset management features for location referencing:

- Traffic data (volume, classification, weigh-in-motion);
- Highway Safety Improvement Program (HSIP)—vehicle crash locations;
- Pavement management system (PMS); and
- Bridge management system (BMS).

Question 2*a*. What are the benefits of using spatial information technology to support asset management? How has your transportation system improved or your program changed due to the use of spatial referencing of asset management data?

ADOT&PF hopes the QA module will demonstrate to the legislature the effects that proposed budget cuts or increases would have on asset life cycle and LOS. With more records created over time, the data history will support and help defend budget needs. The ability to maintain a steady budget to support infrastructure maintenance needs determines its life cycle.

Another QA benefit is the ability to provide real-time cost and level-of-effort data to answer legislature and customer questions. The ability to efficiently track customer service requests will improve relations and allows the public to participate in asset management. The legislature is interested in how the public perceives asset condition and LOS.

Question 2*b*. Have the spatial information technology capabilities changed in response to better asset management?

ADOT&PF conducted two pilot programs for collecting MMS feature inventory data. The first pilot program, by the GIS-mapping section staff, collected GPS coordinates for each feature (dwelling at the feature location for 30 s). Due to time and safety issues, this strategy was not a viable option. The second pilot program, by the NavStar Mapping contractors, collected the DGPS centerline coordinates and highway feature data for the program development division. During this pilot, NavStar Mapping collected digital measurement instrument (DMI) milepoint values for MMS features and their associated anchor reference point features (e.g., intersections). The MMS feature DMI milepoint will be adjusted based on the feature's distance to the anchor reference points and their milepoint values in the final centerline reference network. This adjustment assures data synchronization between the MMS data and the reference network.

This strategy is a viable option; the current asset feature data collection, including location referencing, is following this methodology. ADOT&PF has not fully implemented the procedures for the statewide asset management inventory and is investigating the possibility of using video log. Regardless of the data collection method used, in order to accurately integrate the feature location data into program development division's GIS, the feature location data must be synchronized with the centerline reference network.

Question 2*c*. What areas do you plan to expand spatial information capabilities for asset management?

The Alaska Marine Highway System (AMHS) tracks the high-speed ferries using a combination of GIS and GPS to report marine vessel positions to the USCG. These positions will be integrated into the 511 traveler information system later this year as demonstrated on the following website: http://511.alaska.gov/.

ADOT&PF is integrating a high-accuracy differential DGPS system with a snowblower and snowplow for winter maintenance in Thompson Pass, Alaska. Heads up displays, combined with a GIS, assists drivers with plowing operations during zero-visibility conditions.

Question 3*a*. Please describe your current situation in the use of spatial information technologies to access and integrate data to support asset management decision-making activities.

Identification and Integration of Relevant Databases

The GIS will be integrated with the existing data warehouse application, the Highway Data Port (HDP). The HDP provides limited menu-driven query capabilities for route log–attribute reports, route lists, public road mileage, vehicle crashes, and speed study reports. The HAS–GIS interface will provide an option to submit a GIS map query that generates tabular reports and an option to map the results from a HDP query for roads which have a reference network.

Selection and Maintenance of GIS Software Platform

ADOT&PF continues working with Cambridge Systematics, Inc. to deploy an enterprise geodatabase and other GIS applications. Specific tasks in this current work effort include:

- ArcSDE and Oracle geodatabase deployment;
- Data migration;
- Query and data maintenance tools development;
- Application and user tool development;
- ArcIMS Internet mapping applications; and
- ADOT&PF training.

Common Referencing Methodology or Your Methods to Integrate Differing Reference Schemes

Building a linear reference system (LRS) reference network is fundamental to the HAS–GIS interface deployment. ADOT&PF has a collection and data processing business model in place for road network and transportation features. The first priority is to collect data for all state owned roads, followed by National Highway System (NHS) roads, higher functionally classified roads, and local functionally classed roads. The road centerlines and transportation feature attributes will be stored in a spatial geodatabase.

Fundamental to asset management systems is the ability to easily and accurately report work activities and locate assets regardless of the application's linear referencing system. ADOT&F maintenance personnel typically reference work activity and asset location using proximity to established physical features such as historic mileposts, bridge deckings, and intersections. During the initial MMS design phase, M&O staff requested a milepost-based LRS. However, the proposed milepost based LRS would fall short of meeting the MMS requirements for data accuracy and integrating with a GIS because

- Both HAS and the new GIS locate transportation features using a route and milepoint LRS.
- The proposed milepost-based referencing system would not provide accurate reporting of work activities and asset location because
  - Where mileposts do exist, they do not accurately reflect the distance between mileposts, and
  - There are a lot of missing mileposts:
    - DOT&PF owns 1,100 roads covering 5,600 centerline miles;
    - 103 DOT&PF roads have mileposts, covering 4,100 centerline miles; and
    - There are 2,884 mileposts on the 4,100 mi of DOT&PF roads.
- Work activities and features assigned a location-based on the proposed milepost LRS would not necessarily match their location in the route and milepoint LRS.
- MMS data stored against the proposed milepost LRS would not accurately integrate with other data in the new GIS.

The GIS mapping, highway data, and MMS staffs spent a significant amount of time on how to handle the different user views of location referencing. The challenge is to provide M&O staff a way to report their work activity location in a manner they were used to (i.e., using proximity to established physical features such as mileposts) and to have that location information recorded against the route/milepoint linear referencing system. The solution includes

- Establishing route–milepoint as the MMS LRS, and
- Modifying the MMS work report interface (both the user and data interface) to allow users the option to select from reference features (and enter offset distances if appropriate) and have milepoint values assigned by the software.

As part of this solution, the highway database staff will provide a road network and reference feature data file for import into the MMS. The MMS asset management program is moving ahead with this solution. This approach will enable MMS data to accurately integrate with other transportation data. The enterprise data integration strategy for road network, feature, and maintenance data, where all data sets are based on the same LRS, will provide a foundation for MMS data spatial location referencing.

Integration of External Information

The MMS interfaces with eight legacy databases: the HAS, Alaska accounting system, payroll, human resources, maintenance station profiles, pavement management, bridge management, and state equipment fleet management. The focus on these eight legacy databases helps develop a comprehensive understanding of where and how investments for restoration or preservation of assets influence asset life cycle.

Relationships to external databases allow queries made from inside the geodatabase to read data from external databases. The geodatabase tables contain foreign keys which provide linkage to these external databases. The geodatabase tables store only the essential attributes extracted or duplicated from external databases. Access to data in the external databases may be restricted to a portion of their data. The major databases that are linked from the geodatabase are

- HAS,
- MMS,
- PMS, and
- HDP.

The HDP provides limited data warehouse query capabilities for internal ADOT&PF users. The HDP was created to establish a framework for accessing transportation data outside the HAS menu-driven environment, and meet the business needs of several frequently requested transportation datasets. The HDP will merge with the developing GIS application. The HDP query capabilities include

- Coordinated data system (CDS) route number—look up by common road name;
- Route log attribute Report—by CDS route number,
- Route lists—by geographic area and route attributes,
- Public road mileage report—by geographic area and route attributes,
- Accident data—by CDS route number,
- Accident data—by geographic area and route attributes, and
- Speed study reports—by CDS route number.

Data Quality Issues—Accuracy, Completeness, Timeliness

User confidence in the quality of the transportation feature and network data is critical to the HAS–GIS interface deployment. Data quality issues being addressed include data relevance, correctness, accuracy, precision, completeness, timeliness, usability, consistency, and conformity to expectations. ADOT&PF is currently developing business processes for

- Data collection procedures for features and road centerline network,
- Data QA,
- Criteria for referencing locations,
- Update cycles for spatial and attribute data,
- Prioritization on updating data fields and nongeometric business data,
- New sections and realignments, and
- Time stamping and archiving.

Differing Spatial Resolutions

Over the past 4 years, ADOT&PF has focused on collecting and establishing a reference network through a road inventory program. ADOT&PF purchased a data collection system from NavStar Mapping that incorporates DGPS, DMI, and auxiliary sensors that maintain linear positioning. ADOT&PF contracted for data collection from NavStar Mapping for both centerline and attribute data. ADOT&PF personnel plan to collect both data types in the future.

ADOT&PF has a multiyear highway inventory project to collect additional DGPS centerline coordinates, as well as highway point and linear features for all state-maintained roads, most NHS roads, and a few higher functionally classified roads. Accurate highway feature inventory, particularly department assets, continues to be the goal. All MMS data collection efforts must provide for data synchronization with the final edited centerline reference network. This will enable MMS data to accurately integrate with the new GIS.

Metadata Standards

ADOT&PF fully complies with the Federal Geographic Data Committee (FGDC) Content Standards for Digital Geospatial Metadata.

Enterprise Deployment

The enterprise geodatabase is being deployed this fall. ADOT&PF is concentrating on six existing core data business areas for the first generation geodatabase deployment:

- Traveler information (road weather, temperature data probe, 511);
- MMS;
- PMS;
- HSIP (accident reporting);
- Traffic data system [annual average daily traffic (AADT), vehicle miles traveled (VMT), and Highway Performance Monitoring System (HPMS)]; and
- BMS.

The geodatabase will store location and attribute information for key MMS features. The geodatabase design included careful consideration of which data elements would be stored in the geodatabase and which would be accessed from external applications. The efficiency of the GIS system was the utmost consideration. Table 3 contains these features and their attributes:

The geodatabase will carry the primary data fields to link to the MMS database for accessing location (route and milepoint) and attribute information for the following features shown in Table 4.

All geodatabase objects are organized into six layers that share some similarity of form or function:

- Reference network,
- Routes,
- Events,
- Jurisdictional boundaries,
- Digital orthophotos, and
- External databases.

TABLE 3 MMS Feature Data Stored with the GIS

Feature	Attribute
Bridges	Description, length
DOT maintenance facilities	Description
Culverts	Description, diameter, number of barrels, material type, headwall treatment, cross–approach
Guardrails	Length, type, end treatments
Rest areas	Description, road length, width, paved–unpaved
Paved shoulders	Length, width
Rumble strips	Length
Signs	Description, general sign category, *Manual on Uniform Traffic Control Devices* (MUTCD) code, number of signs on support structure, number of posts supporting sign structure
Turn outs	Description, road length, width, paved–unpaved

TABLE 4 MMS Features Accessed from the MMS by the GIS

Airports	Drainage structure routes
Anti-ice routes	Mowing street routes
Campgrounds	Rest area routes
Culvert routes	Sidewalk plow routes
Floats and docks	Snowplow routes
Grading routes	Sweeping routes
Inspection routes	Traffic signals

The reference network provides common underlying highway geometry for all ADOT&PF users. The reference network is based on these DGPS centerline data, providing a spatially accurate representation of the network with more precise measures for milepoint referencing. Centerlines are represented as links and nodes with traditional link–node topology. The topological structure, containing TransportLinks and TransportNodes, defines the connections and adjacencies among and between the elements of the network that allow transportation activities to take place.

Subtypes and domains are used to categorize and control the integrity of new data entered into the geodatabase. Subtypes are used to categorize a feature layer into a number of separate types without physically splitting the data into multiple feature classes. For example, the TransportNode feature class has a subtype field to distinguish system intersection anchor points for other anchor points.

Domains define a set of permissible attribute values for any field and ensure that only permitted attribute values can be entered into the geodatabase. Domains can be either coded values or ranges.

ADOT&PF identifies each road in the legacy transportation database, HAS, with a CDS route number. Each road number has a route name (CDS route number) and a route description (posted road name). The HAS database contains CDS numbers for all state-maintained roads, most non-state-maintained roads functionally classified higher than local road, and some non-state-maintained roads that are classified as a local road.

The CDS routes for the geodatabase are built from the centerline reference network. The geometry of any CDS route will be coincident with the underlying centerlines, but the CDS routes can have important attributes that may not be applicable to the underlying road segments. It is represented as a polyline M network with measures so that the events can be referenced using a linear measure on any particular route.

Transportation-related objects, such as maintenance assets, are not part of the network itself, but are related to the reference network or the route feature. There are two types of events: a line event with a route location that describes a portion of the route, or a point event with a discrete location along a route. The CDS route number field is a key field that is used to establish the relationship between event records and their routes.

A measure location is either one or two values describing the position on the route where the event occurs. A linear route location uses both a from- and a to-measure value to describe a portion of the route, while a point route location uses only a single measure to describe a discrete location along a route.

Each MMS “asset” has a unique id that provides the linkage between the MMS and the geodatabase. This unique identification is defined by an asset group type identification and an asset identification. For those assets that are stored within the geodatabase, the asset identification is assigned as part of the inventory data collection process. For those assets that are stored within the MMS, the asset id is assigned by the MMS system. Even the location information for these has to be contained within the MMS.

ADOT&PF selected the highest priority point and line events for the first generation geodatabase deployment. This priority was at least partially made on which fields could be used for multiple business needs. For example, some asset management features are used for the MMS as well as the accident, traffic, and highway design business areas. The number of point and line events may increase with future geodatabase deployments as more specific business needs are identified. Point and line events are summarized in Tables 5 and 6.

TABLE 5 Point Events

Point Events	
Accident	MMS external asset groups
Accident named intersection	Non-system intersection
Culvert	Signs
Cultural features	Traffic signals
DOT maintenance facility	Traffic station
Environmental point	

TABLE 6 Line Events

Line Events	
Accident named intersection–line	MMS external asset group–line
Accident named segment	NHS
Alaska forest highways	Number of lanes
Alaska highway system	Paved shoulders
Alaska state highway groups	PMS sections
Bridge	Rest areas
Federal aid	Road surface
Functional classification	Rumble strips
Guardrails	Speed limits
HPMS links	State Transportation Improvement Program (STIP) needs list
Maintenance category	Strategic highway system
Maintenance responsibility	Traffic direction
Median	Traffic links
MMS inventory	Turnouts

TABLE 7 Jurisdictional Boundaries

Jurisdictional Boundaries	
ADOT&PF regions	Maintenance station
Borough	Public safety detachment area
Census area	State
City	Town
Election district	Town point
Maintenance area	Urban–rural
Maintenance district	

The MMS inventory line event will provide a way to track those roads, or sections or roads, for which MMS feature data collection was performed.

The jurisdictional boundary feature classes to be included in the geodatabase are listed in Table 7.

Question 3. Part B. What are the remaining significant issues for spatially integrating data for asset management?

Geography

ADOT&PF has 33 maintenance stations dispersed throughout the state. Alaska's topography and the great distances to the maintenance stations, many of which are accessible by only by sea or air, pushes the cost and time to accomplish winter weather maintenance activities quickly. These factors will also be particularly challenging to bring GIS technologies to the field locations.

Road Centerline Reference Network

Additional, ongoing data collection is critical to a working GIS. Automating, to the greatest extent possible, the processing of centerline and feature data will streamline the addition of new data to the geodatabase. ADOT&PF has an on-going business process to address the road centerline reference network. A software package will be developed in the near future to help automate the centerline and feature data processing.

Synchronization of Databases

Keeping the road centerlines and feature data the same in both the geodatabase and the legacy mainframe databases is necessary to maintain both the GIS and the business application programs. At present, this is completely a manual process. The automation process will be examined in 2006.

GIS Layers of Different Scales and Versions

The orthorectified aerial photogrammetry and satellite imagery, which are used as background features to the base map, are gathered from several sources. There have been a few limited database layers developed for Alaska but there is no distribution, update, or validation involved. This is a very significant institutional issue. A statewide GIS committee does exist, but does not have a mandate or funding to improve the datasets.

Question 4*a*. What spatial information technology-enabled tools and products have you developed for user and management level decision support for asset management? What products have proven most successful for asset management activities?

The HAS–GIS interface deployment provides direction for significantly improving spatial capabilities for asset management. Key initiatives include

- Developing web-based access for simple queries and mapping, and full GIS software access for more detailed analysis;
- Developing mapping tools to assist users in performing linear referenced-based queries such as CDS route–mileposts, road name–mileposts, and latitude–longitude; and
- Improving the interoperability of the legacy mainframe database with external systems such as the MMS.

ADOT&PF will use Environmental Systems Research Institute, Inc.'s (ESRI's) ArcIMS for Internet mapping. The web applications will target the six core business areas. The application will have limited query capabilities to minimize the query and display time. The ArcIMS application will be integrated with the existing Highway Data Port data warehouse application. The new interface will allow users the option of mapping query results for the existing query capabilities as well as simple map query options.

ADOT&PF has purchased the ArcIMS extension MapOptix™ from GeoNorth LLC, the department's GIS partner in the geodatabase deployment. MapOptix is a companion product to ArcIMS for implementing and managing Internet applications, GIS portals, and web-based enterprise GIS systems without custom programming. MapOptix 5.0 provides enhanced capabilities for setting user preferences, developing query functions, and establishing display options.

Data extracts and reports from the HAS–GIS interface are to be provided for import into the MMS and use by maintenance staff. The data extracts include

- MMS road network data file (the route and milepoint linear referencing network) includes route number, road name, beginning and ending milepoint, M&O station, and route attributes (e.g., maintenance category, paved–unpaved, functional classification, NHS, borough, city, etc.).
- MMS asset data file includes asset description, route number, asset milepoint, asset type, asset identification, and M&O station for assets stored in the geodatabase:
  - Bridges,
  - Culverts,
  - DOT maintenance facilities,
  - Rest areas, and
  - Turnouts.
- MMS feature inventory data file:
  - Divided–undivided road centerline miles,
  - Paved–unpaved lane miles,
  - Paved shoulder miles,
  - Rumble strip miles,
  - Guardrail linear feet,
  - Bridge count,
  - Culvert count,
  - Turnout count,
  - Rest area count, and
  - Sign count.
- MMS reference feature data file includes feature description, route number, feature milepoint, and M&O station.

- Customized MMS route lists and general logs; reports are also available to M&O staff for use as reference material.

Question 4*b*. What future product developments do you believe would provide the greatest benefits?

- Road centerline reference network completion and update processes defined;
- Automated data processing tools;
- Automated synchronization of databases;
- Orthorectified aerial photogrammetry and satellite imagery; and
- Improved web-based GIS tools (ESRI and GeoNorth LLC).

Question 5. What roles or actions can national organizations undertake to help state and local transportation organizations improve the use of spatial information technologies for asset management?

Interoperable Spatial Information Infrastructure to Facilitate the Development of Tools

ADOT&PF recently entered into partnership with the Plate Boundary Observatory (PBO) to provide real property space, utilities, and Internet connection in exchange for the use of differential correction data. The department will also gain the opportunity to connect real time kinematics transmitters to the PBO Continuously Operated Reference Sites (CORS) to deliver correction data. These sites are located along the fault lines to monitor movement, with many of the CORS sites near the highways.

It is hoped that better collection methods and CORS or DGPS will reduce the post processing time and deliver accurate data to the user community. ADOT&PF continues to work to deploy DGPS and CORS with 5-s sample rates and the accuracy to improve data collection.

Capacity Building

State or national initiatives for composite, orthorectified aerial photogrammetry and satellite imagery, which are used as background features to the base map, would be extremely useful. This is a very significant institutional issue.

Broader Understanding of the Capabilities of Spatial Information Technologies

Increasing the availability of CORS sites will improve the timeliness of spatial data and reduce the processing time. Additionally, real-time kinematics provide the opportunity for other intelligent transportation system (ITS) applications for asset management.

Development of Tools

Web-based GIS tools—improvements in web-based GIS technology, such as by ESRI and GeoNorth—would increase performance. Server and network demands impact application performance.

Documenting Good Practices

Peer-to-peer opportunities—forums such as GIS for transportation (GIS-T) provide a great way to see what other agencies are doing and to share GIS development and deployment successes. Travel is sometimes restricted to take advantage of these opportunities. FHWA encouragement would be beneficial. Also continued support of the peer-to-peer program will enable states to get a close look at similar type deployments in other state DOTs.

City of Edmonton, Alberta, Canada, Perspective

PAUL SZCZEPANSKI
AL CEPAS
City of Edmonton Transportation & Streets

THERESA CLOAKE
City of Edmonton Office of Infrastructure

INTRODUCTION

The first vestiges of asset management in the City of Edmonton are found in the development of a PMS in the mid-1980s. The need to manage pavement assets formed the basis of an idea to organize a myriad of network descriptive and performance data into a format that facilitated relatively rapid analysis, optimization, and informed decision making. As the PMS matured into sophisticated software on an advanced operating platform, it became obvious that other assets could also benefit from the same type of approach.

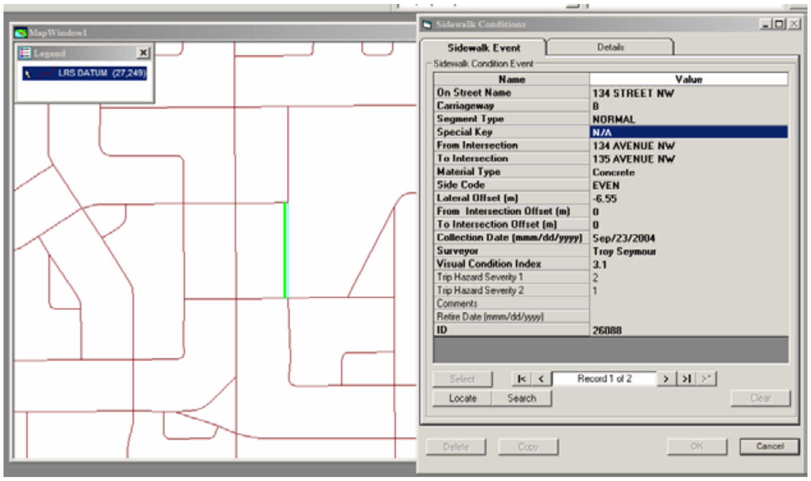
Our GIS was evolving at approximately the same time, driven by the need to increase the efficiency of storing and retrieving spatial data. It is only recently that the technology has become available to attach attribute information to spatial data, allowing asset information to be displayed in map form. This marriage of attribute data to a spatial environment is perhaps the most significant development of our time because it allows senior decision makers to quickly grasp the critical messages. It is finally possible to actually show the relationship of various budget scenarios to the performance of the network.

ASSET MANAGEMENT

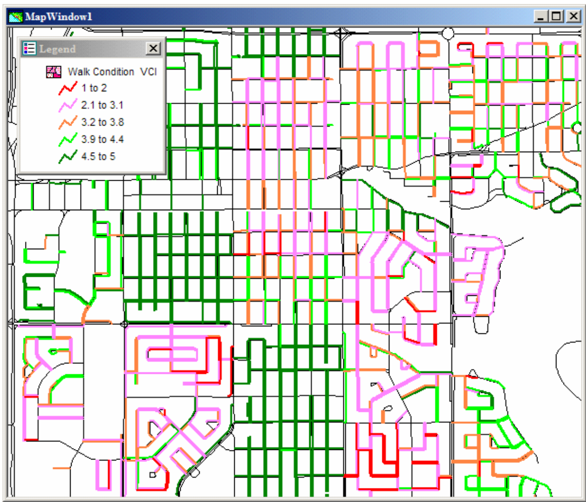
The City of Edmonton has formal management systems for pavement, bridges, vehicles, and buildings. The management systems for other infrastructure assets are in various stages of development and, though there is currently no overall corporate electronic asset management system, the data from each of the asset stewardship areas is synthesized by the Office of Infrastructure into a common format. Although the quality of data varies, senior management and council can get a sense of the relative value, condition, functionality, capacity, and risk exposure of all the corporation's assets. For example, condition information from each asset area is distilled into percentages of very good, good, fair, poor and very poor inventory. This standardized rating system applies across the corporation and provides a valuable tool to support improved decision making.

The critical components of any management system are a descriptive database (e.g., when it was built, geometric attributes, performance history, etc.), performance prediction to determine future needs, and an optimization routine to select the most cost-effective investments. All of these components exist within the PMS (Figures 1 and 2), but some are not yet available in other systems. Information from the PMS is fully integrated into program development.

(a)



(b)



(c)

FIGURE 1 Condition data: (*a*) recording, and (*b* and *c*) presentation.

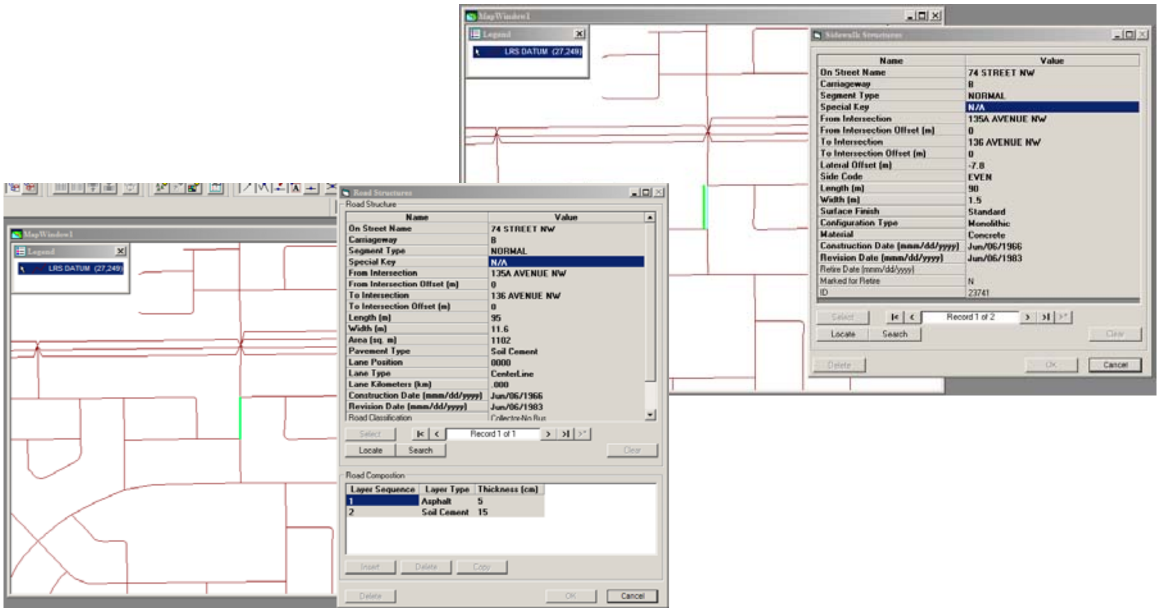


FIGURE 2 Geometric data in the PMS.

The system used by the City of Edmonton is referred to as the Spatial Land Inventory System (SLIM). It has been built and accessed through InterGRAPH's Geomedia products and Oracle spatial. It contains all curb alignments, property lines, and sidewalk locations. Various land use attributes are also contained within SLIM with the recent addition of transit attribute data. A LRS is used to position attribute data. Dynamic segmentation is available to integrate various data types. Road segments are cross-referenced to the PMS using pavement management section identification numbers.

PRIMARY USERS

The responsibility for data maintenance resides with the source business unit. Primary users are programming staff with the results compiled for senior management. One usage example is the generation of a draft 5-year road rehabilitation program map (Figure 3) using the results of the optimization from the Municipal Pavement Management System (Figure 4).

Changes to this initial draft can easily be made to accommodate coordination issues. In other scenarios, a series of maps showing projected network condition can be generated to reflect the effect of various budget levels.

In general, the benefit of using spatial IT is a more intuitive understanding of the needs associated with various assets. This capability is very recent to our organization, so it is too early to see any effects on the transportation system. Of course, the ability to automatically plot illustrative data has substantially reduced the manual effort. For example, prior to the integration with SLIM, candidate project segments would have to be individually selected and highlighted—a task that used to take up to a week. This task is now delayed only by the plotting speed of the

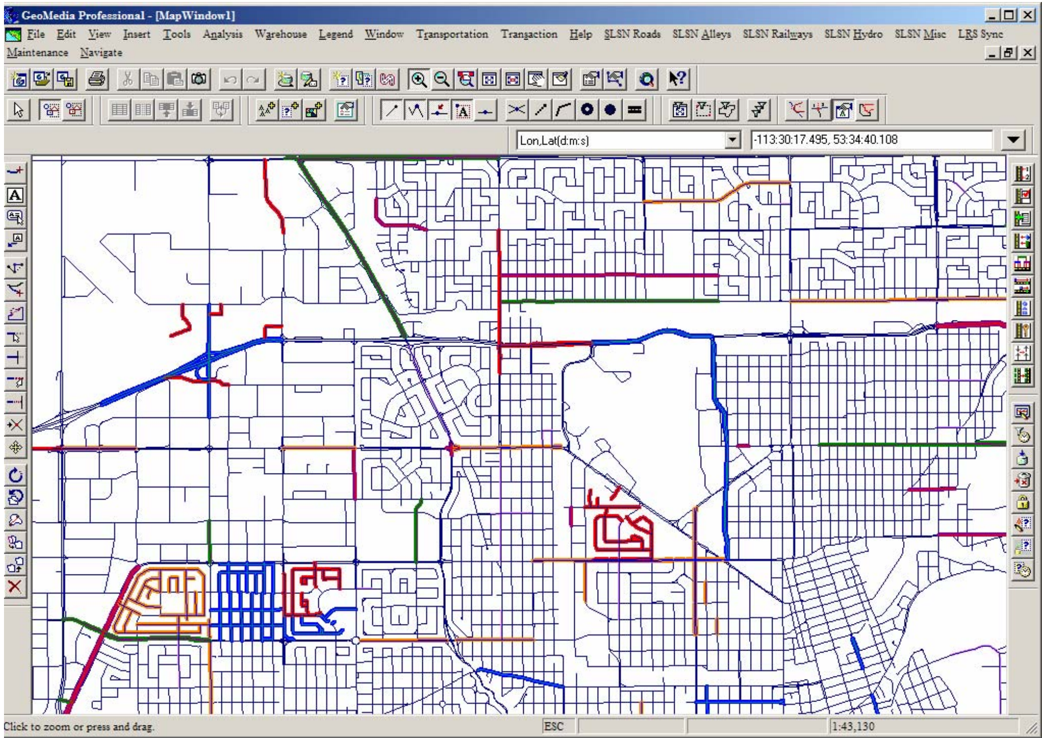


FIGURE 3 Transportation and streets: multiyear program map.

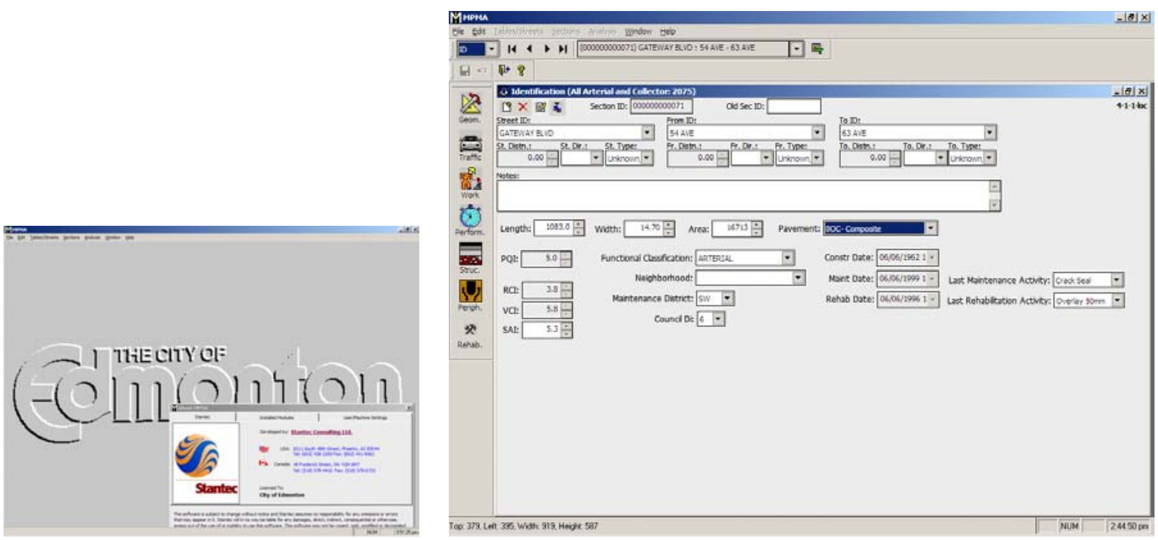


FIGURE 4 Municipal pavement management applications.

printer. Field data collection for sidewalk data is now done electronically and the data does not have to be re-keyed into the system. More extensive analysis is now possible as compared to the past. It used to be that some questions from senior management were extremely time-consuming but now responses can be given much more readily and with less effort.

The change in capabilities of the PMS has been mainly in response to a requirement to better illustrate the needs of the roadway inventory and to achieve more efficient data handling. The City of Edmonton is looking at expanding the spatial management capabilities to include other assets such as BMS integration, transit zones, traffic signs, auxiliary structures (e.g., guardrails), and traffic data (e.g., volumes, collisions).

CURRENT STATUS

The City of Edmonton Transportation and Streets Department can currently select a road segment on a map and bring up a screen that displays associated road construction and rehabilitation–maintenance history, length, width, area, sidewalk and curb lengths, type of walk, condition ratings for both walks and roads, and functional classifications. The lengths and areas of individual segments can also be totaled and an official inventory generated which removes the double-count at intersections.

The nonperformance data formerly resided in a COBOL-based database, which was decommissioned and converted into the SLIM environment (Oracle spatial database). Performance data is loaded from the Municipal Pavement Management Application (MPMA). We have also provided for new and altered roadway geometric data to flow back to MPMA from SLIM. This link is not fully functional at this time as we are awaiting the development of MPMA batch load software. Analysis and optimization is carried out within MPMA and the results are downloaded to SLIM for display. This degree of integration currently exists only for pavement, sidewalk, and curb assets.

A linear referencing tool is used to locate various features within the map. Surface distress data for roads and walks is collected biennially for arterial and collector roads and once every 4 years for local residential and industrial roads. Road roughness is collected on the same cycle, but only for arterials and collectors. Structural capacity information is collected on an irregular cycle on arterials and collectors. Calibration protocols exist for the automated collection equipment. Manual survey results are always checked against previous results and accepted if within a predetermined range. A resurvey is conducted if the results are out of range and there is no explanation from the segment's work history. Survey crews are also spot-checked in an attempt to head off incipient deviations from protocol. Missed links can be displayed.

Basic SLIM data is available to all civic staff at all facilities on the city's intranet (internal website) but data maintenance and complex thematic display capabilities are limited to those with InterGRAPH Geomedia access. Historical information is archived as it is retired by the introduction of updated information and is stamped with a revision date.

Remaining issues with spatial integration is inputting all of the assets into SLIM. There are still a lot of nonspatial records that need to be converted as well as records that do not exist in any form, e.g., traffic signs. This is expected to consume most of the corporate energy in the short to medium term.

The City of Edmonton has made a strategic decision to select InterGRAPH's Geomedia Product line and Oracle spatial for its entire GIS software platform. Staff has been dedicated to maintaining and enhancing the environment. Only one linear referencing scheme is currently utilized and, as additional assets are added, this may prove to be an issue. Integration is done with the MPMA system (FoxPro) to upload and download data between the two systems. The data quality issues of accuracy, completeness, and timelines are being discovered to be greater issues as the new spatial GIS system is utilized. Errors from the legacy text-based system are much more evident. Data quality issues can very easily cause analysis errors. “Close” is no longer “close enough.”

Since all of the spatial data is maintained within the SLIM repository, there are no differences in the spatial resolutions of data. Transportation and streets is currently proceeding with the development of more stringent metadata standards. Access is still limited but will be expanded to include many more staff members in the near future. The Oracle Workspace Manager and GeoMedia transaction manager handle version control with accessibility to archived data limited to selective staff, as it is not a simple exercise to retrieve and analyze temporal data. For data that is currently collected (manual and semi-automated), there are standards and guidelines in place but as we go into data collection through GPS, additional ones will have to be developed. Data collection for sidewalks is done using Intergraph’s IntelliWhere OnDemand product which downloads the spatial data and inventory data. We would like to move to real-time data collection.

DECISION SUPPORT FOR ASSET MANAGEMENT

Development efforts have focused mainly on the information flow issues between the field, SLIM, and MPMA. Screens have been developed to display attribute information for individual segments. In general, MPMA can be relied on to analyze pavement needs and the thematic mapping capabilities imbedded within Geomedia to display it. We also take advantage of the spatial analysis capabilities to further refine MPMA output to fine tune asset management decisions. MPMA has the capabilities for network analysis, information query, forecasting, and rehabilitation program development based on various budgets. Figures 5, 6, 7, 8, 9, and 10 illustrate examples of some of the output. The SLIM environment provides spatial query–display capabilities that further expand the tools for asset management.

MPMA along with SLIM and its various customized maintenance tools provide the majority of the tools for asset management activities. We believe that future product developments providing the most benefit would be more user-friendly software interfaces. Current software does not lend itself to casual use and, in order to function more efficiently, a more user-friendly software interface is required. System enhancements require IT expertise and can be very time consuming. As spatial information becomes more accessible, its impact on decision makers becomes more powerful as well.

In general, national organizations can best serve to set standards and best practices so that each jurisdiction does not have to reinvent the wheel on its own. Ultimately, a more standardized approach allows overall development and maintenance costs to be minimized and avoids the proliferation of customized “one-off” systems.

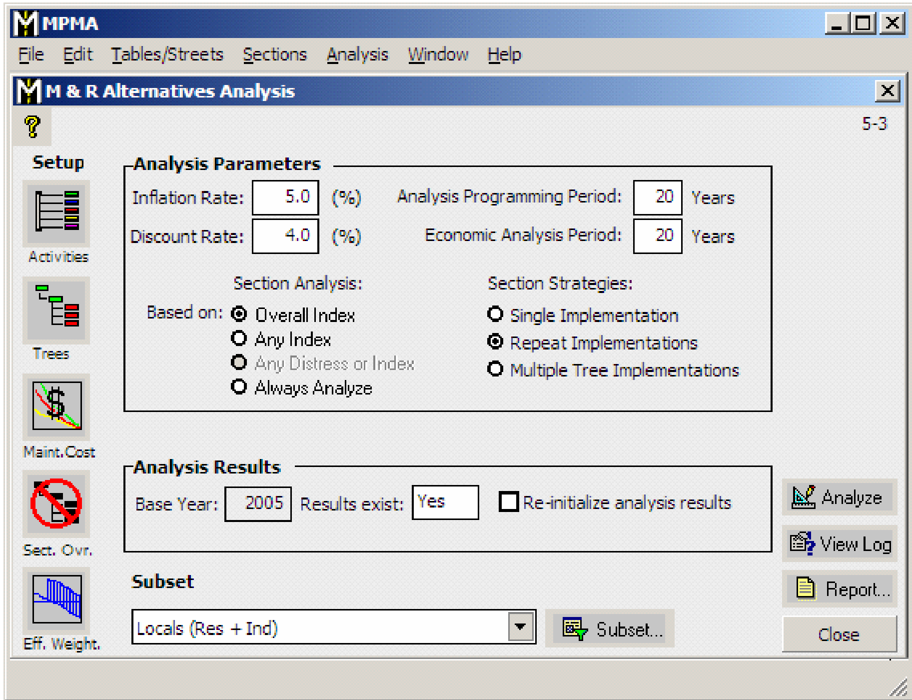


FIGURE 5 MPMA alternative analysis.

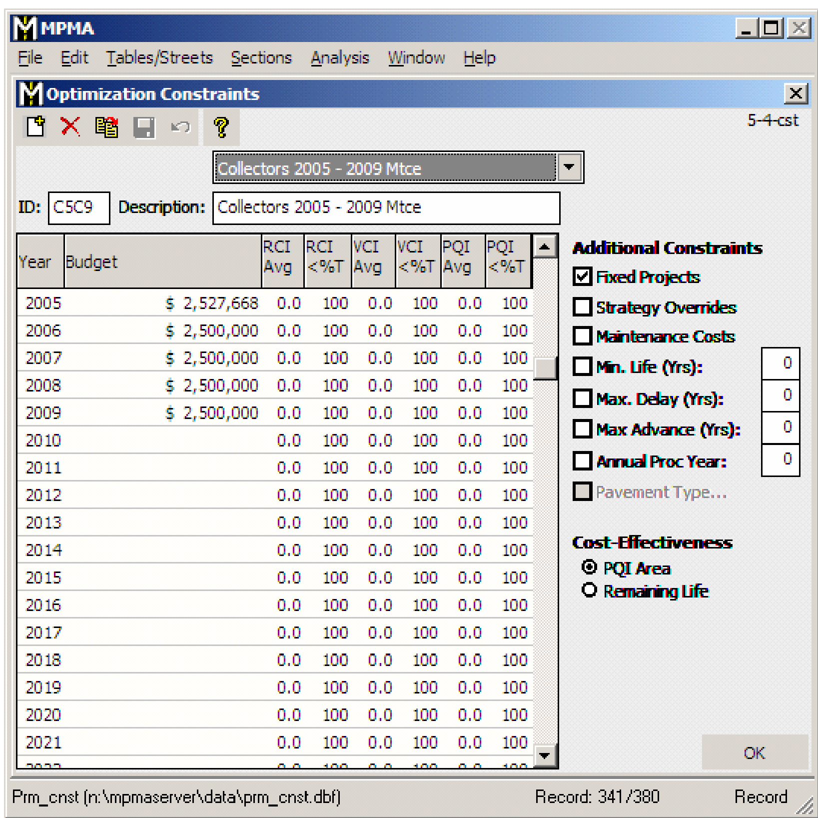
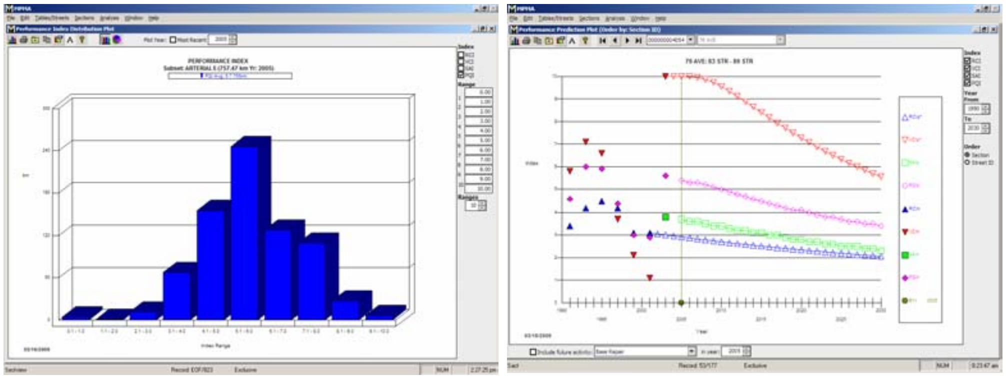
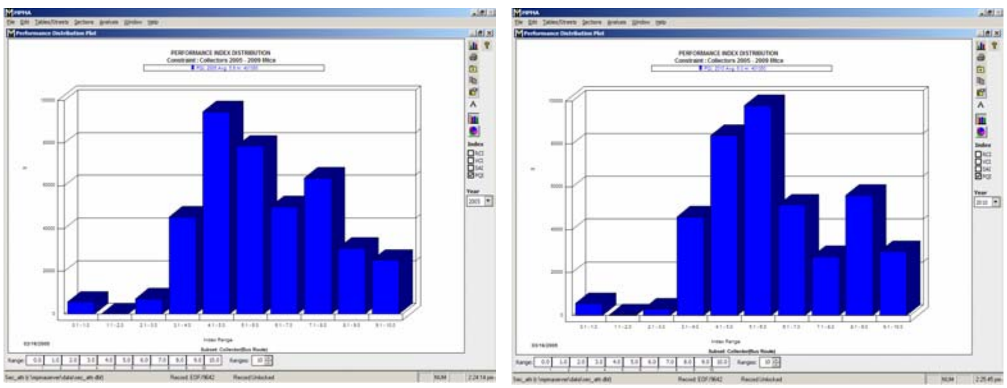


FIGURE 6 Optimization analysis.



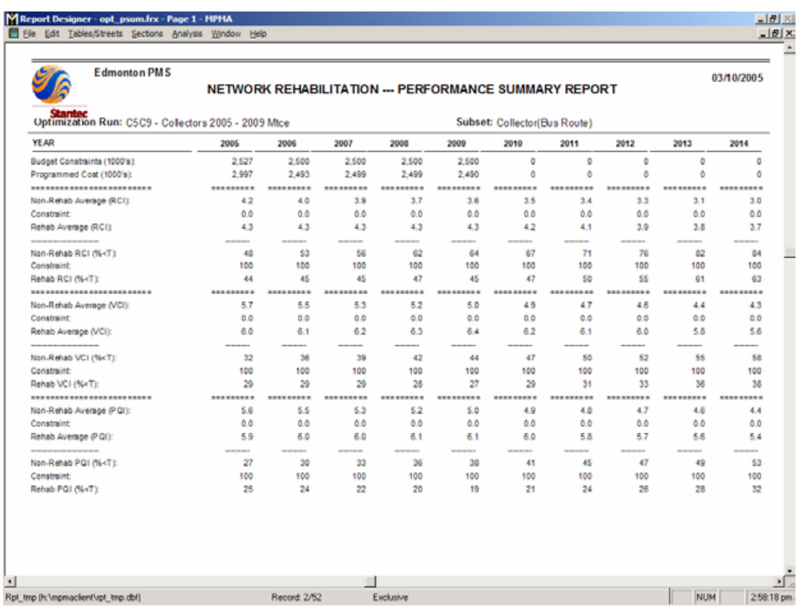
(a) (b)

FIGURE 7 Performance output: (*a*) arterial network; (*b*) collector MPMA section.



2005 2010

FIGURE 8 Change in collector network performance distribution: 2005 to 2010.



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Edmonton PMS

NETWORK REHABILITATION --- PERFORMANCE SUMMARY REPORT

03/10/2005

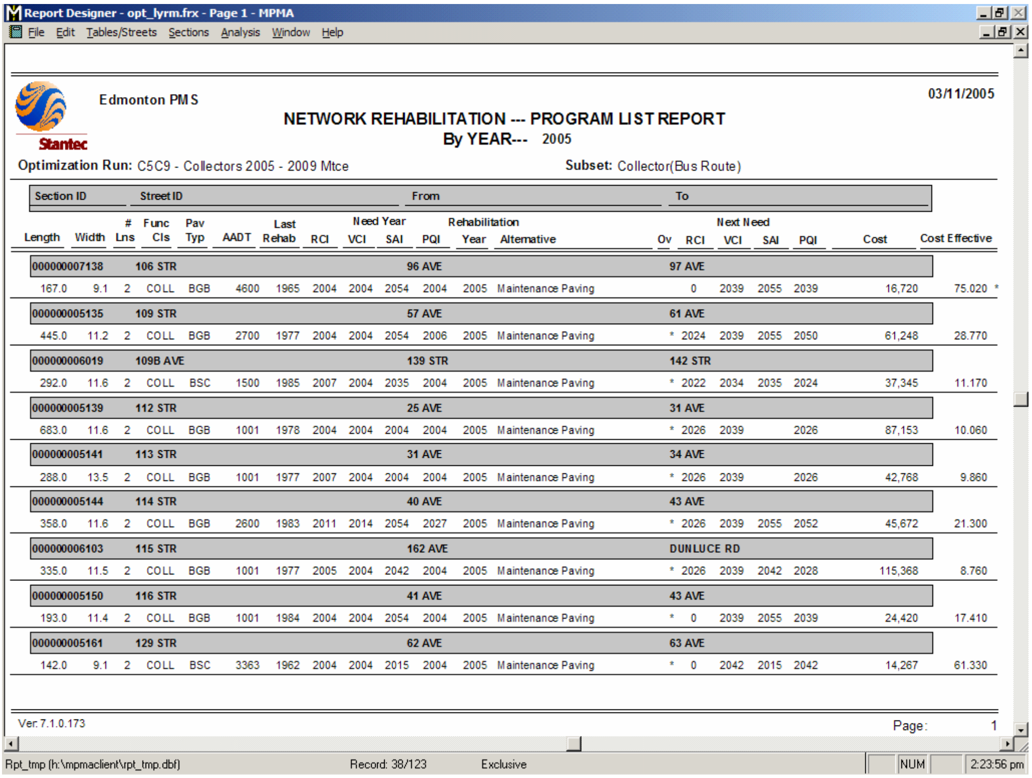
Stantec

Optimization Run: C5C9 - Collectors 2005 - 2009 Mtce

Subset: Collector(Bus Route)

YEAR	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Budget Constraints (1000's):	2,527	2,500	2,500	2,500	2,500	0	0	0	0	0
Programmed Cost (1000's):	2,997	2,493	2,499	2,499	2,490	0	0	0	0	0
Non-Rehab Average (RCI):	4.2	4.0	3.9	3.7	3.6	3.5	3.4	3.3	3.1	3.0
Constraint:	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rehab Average (RCI):	4.3	4.3	4.3	4.3	4.3	4.2	4.1	3.9	3.8	3.7
Non-Rehab RCI (%<T):	48	53	56	62	64	67	71	76	82	84
Constraint:	100	100	100	100	100	100	100	100	100	100
Rehab RCI (%<T):	44	45	45	47	45	47	50	55	61	63
Non-Rehab Average (VCI):	5.7	5.5	5.3	5.2	5.0	4.9	4.7	4.6	4.4	4.3
Constraint:	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rehab Average (VCI):	6.0	6.1	6.2	6.3	6.4	6.2	6.1	6.0	5.8	5.6
Non-Rehab VCI (%<T):	32	36	39	42	44	47	50	52	55	58
Constraint:	100	100	100	100	100	100	100	100	100	100
Rehab VCI (%<T):	29	29	29	28	27	29	31	33	36	38
Non-Rehab Average (PQI):	5.6	5.5	5.3	5.2	5.0	4.9	4.8	4.7	4.6	4.4
Constraint:	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rehab Average (PQI):	5.9	6.0	6.0	6.1	6.1	6.0	5.8	5.7	5.6	5.4
Non-Rehab PQI (%<T):	27	30	33	36	38	41	45	47	49	53
Constraint:	100	100	100	100	100	100	100	100	100	100
Rehab PQI (%<T):	25	24	22	20	19	21	24	26	28	32

FIGURE 9 Optimization output—network rehabilitation summary.



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Edmonton PMS

03/11/2005

NETWORK REHABILITATION --- PROGRAM LIST REPORT

By YEAR--- 2005

Stantec

Optimization Run: C5C9 - Collectors 2005 - 2009 Mtce

Subset: Collector(Bus Route)

Section ID	Street ID	From	To	Length	Width	# Lns	Func Cls	Pav Typ	AADT	Last Rehab	RCI	Need Year VCI	Need Year SAI	Need Year PQI	Rehabilitation Year	Rehabilitation Alternative	Ov	Next Need RCI	Next Need VCI	Next Need SAI	Next Need PQI	Cost	Cost Effective
000000007138	106 STR	96 AVE	97 AVE	167.0	9.1	2	COLL	BGB	4600	1965	2004	2004	2054	2004	2005	Maintenance Paving		0	2039	2055	2039	16,720	75.020 *
000000005135	109 STR	57 AVE	61 AVE	445.0	11.2	2	COLL	BGB	2700	1977	2004	2004	2054	2006	2005	Maintenance Paving	*	2024	2039	2055	2050	61,248	28.770
000000006019	109B AVE	139 STR	142 STR	292.0	11.6	2	COLL	BSC	1500	1985	2007	2004	2035	2004	2005	Maintenance Paving	*	2022	2034	2035	2024	37,345	11.170
000000005139	112 STR	25 AVE	31 AVE	683.0	11.6	2	COLL	BGB	1001	1978	2004	2004	2004	2004	2005	Maintenance Paving	*	2026	2039		2026	87,153	10.060
000000005141	113 STR	31 AVE	34 AVE	288.0	13.5	2	COLL	BGB	1001	1977	2007	2004	2004	2004	2005	Maintenance Paving	*	2026	2039		2026	42,768	9.860
000000005144	114 STR	40 AVE	43 AVE	358.0	11.6	2	COLL	BGB	2600	1983	2011	2014	2054	2027	2005	Maintenance Paving	*	2026	2039	2055	2052	45,672	21.300
000000006103	115 STR	162 AVE	DUNLUCE RD	335.0	11.5	2	COLL	BGB	1001	1977	2005	2004	2042	2004	2005	Maintenance Paving	*	2026	2039	2042	2028	115,368	8.760
000000005150	116 STR	41 AVE	43 AVE	193.0	11.4	2	COLL	BGB	1001	1984	2004	2004	2054	2004	2005	Maintenance Paving	*	0	2039	2055	2039	24,420	17.410
000000005161	129 STR	62 AVE	63 AVE	142.0	9.1	2	COLL	BSC	3363	1962	2004	2004	2015	2004	2005	Maintenance Paving	*	0	2042	2015	2042	14,267	61.330

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FIGURE 10 Optimization output—recommended section listings.

CONCLUSION

In summary, the use of spatial data systems to display the results of specific asset management decisions is a very powerful tool for decision-makers. The complexities that are often lost in traditional distilled presentations can now be understood by any manager through a visual display of asset conditions for a variety of strategies. The main challenge now is to design more user friendliness into spatial software systems so that even casual users can benefit from the tremendous knowledge that is stored in these data warehouses.

Kansas Department of Transportation Perspective

BRIAN LOGAN
RICK MILLER
DENNIS SLIMMER
Kansas Department of Transportation

INTRODUCTION

The Kansas Department of Transportation (KDOT) is responsible for numerous assets including roads, bridges, land, buildings, vehicles and equipment, financial resources, materials and stock, and data and information. KDOT does not use an overarching asset management system to track and maintain these assets, but rather establishes funding programs for each asset and tasks a person or group to sub allocate the funds according to their own processes. Because the responsibility of managing these assets is distributed, the approach to asset management and the use of spatial IT varies by asset.

QUESTIONS

Question 1. How is your organization using spatial information technology to support and enhance asset management decision making and resource allocation?

Asset management and the development and use of spatial technology tools have evolved somewhat independently at KDOT, but efforts to marry them up continue. Formal management systems for highways and bridges were built independently many years ago. Both systems are directly tied to programming projects through prioritization and optimization systems. The PMS was developed in the early 1980s and contained a LRS key similar to the current agency standard. Bridges were historically identified and spatially represented by unique IDs and maps. In time, these were linked to the agency LRS and to geodetic coordinates. PMS is housed in the Bureau of Materials and Research; the BMS is housed in the Bureau of Design. The other KDOT assets have varied degrees of management systems and use of spatial technologies.

Both road and bridge data, at least at some level, are stored in another agency system called Control Section Analysis System (CANSYS) managed by transportation planning. This system is predominantly organized by "control sections," but contains all relevant info for the LRS key. For several years this system has been migrating to a relational database and dynamic segmentation based on the LRS key.

The cartography–GIS unit in the Bureau of Transportation Planning has driven spatial technologies. This unit has worked hard to develop and maintain the appropriate tools to allow spatial representation of agency data. For instance, they are developing a system called KGATE that allows users to query data and display dynamic maps through a browser. They see this type of application as their duty in promoting geospatial enablement throughout the agency.

Each of the groups involved in asset management have at least one advocate for geospatial enablement and integration. Within the last year, the secretary of transportation has been a vocal advocate of geospatial enablement and is strongly promoting it as another tool to help manage KDOT assets.

Question 2. What are the benefits to using spatial information technology to support asset management?

Like any systematic approach to problem solving, it is difficult to attribute the benefit to an individual component like spatial IT. However, since PMS started tracking pavement condition in the early 1980s the condition has reached and maintained stated goals. Perhaps more telling is that the system was used to obtain state resources for improving the roadway condition in 1989. Based on the success of that program, the state legislature again supported funding for transportation in a 1999 program. Unfortunately, our use of spatial technology had an unintended consequence in the second program. For both programs, representative maps were presented to the legislature showing the diversity of locations our asset management systems would select given the current information in our various data systems. In the first program, the legislature acknowledged and approved our process. In the second program, they approved the specific projects not the process. (This only directly affected our reconstruction and system expansion program, but it had a significant ripple effect on the other programs). Therefore, while the spatial IT helped get the programs through the legislature, we need to find better ways to demonstrate the process through the technology to maintain appropriate programmatic flexibility.

Spatial IT continues to develop and it is slowly being mainstreamed into KDOT processes. The benefits of spatial technology, or as KDOT calls it geospatial enablement, include not just mapping and display capabilities, but data quality improvements and data integration. A widespread effort is underway to help data owners and managers understand the needs for and benefits of spatial attributes. At this point, spatial information technologies are geared up to help with asset management, especially as asset management becomes more integrated across the historical management systems.

Question 3. Please describe the status of your current situation in the use of spatial information technologies to access and integrate data to support asset management decision-making activities.

Although KDOT has responsibilities and assets beyond highways and bridges, only the management systems and spatial tools for highways and bridges will be described as examples. Even with that qualifier, three major data systems are involved: CANSYS, BMS, and PMS. CANSYS is integrated with both BMS and PMS and is used to feed a prioritization system to select the most needy bridges and highways for replacement or reconstruction. BMS and PMS then use prioritization and optimization techniques on the remaining bridges and highways to maintain these assets.

The state of Kansas has an official GIS platform, but KDOT was grandfathered in under an alternative platform. While this dichotomy causes some consternation, it has forced KDOT to pursue very flexible processes and procedures for spatial technology. Similarly, KDOT has many referencing schemes. The geospatial enablement effort includes an education effort to show data owners and managers how they can use the scheme that best suits their needs and still integrate their data with spatial tools or data referenced by other means. A research effort is ongoing to develop a "geospatial referencing engine" to accommodate the varied assortment of referencing schemes for integration purposes.

Allowing flexibility for data collection, protocols, and differing spatial resolutions is also important to KDOT asset managers. Thus, the processes are allowed to be whatever is most appropriate to manage the individual assets, not rigid processes dictated by all-encompassing standards. However, the flexibility increases the importance of business rules to ensure that the integration points are coordinated and data is available across systems at the appropriate times. Many of these rules need to be clearly defined and documented to ensure continued function and integration of systems. In addition to documenting the business rules, the flexibility of data systems will underscore the need for good metadata. Data system owners are currently responsible for their own metadata, but few are rigorously developing and maintaining metadata. Again, the geospatial enablement education effort is pushing the importance of metadata and trying to assist data owners in documenting their holdings. One of the benefits of good metadata and geospatial enablement is to allow data users a means to do their own discovery. In other words, these tools will allow a user to find the relevant data and determine if it is appropriate for their need.

Another benefit of the metadata will be to help determine the temporal nature of the data. Historical data is maintained for many of the KDOT assets, but the spatial links that accompany the data may not be maintained. For instance, a route may be renamed but the historic data for that route will keep the old name. Ideally, mechanisms to account for temporal data will be developed and deployed.

Temporal issues aside, the most significant remaining issues to spatially integrating data for asset management decision makers across KDOT relate to education, acceptance, and documentation. The education piece is underway on many fronts. The goal of the geospatial enablement education is to show (and assist) managers of existing data stores how to geospatially enable their data and to show (and assist) developers of new systems how to incorporate geospatial concepts. The acceptance piece includes both a hammer and a carrot. The hammer is in the form of executive orders and funding approvals incorporating an acknowledgement of geospatial concepts being considered for IT projects. The carrot is in the form of geospatial savvy individuals helping in development processes in other areas of the agency to show the benefits of enabling the data and systems.

Question 4. What spatial information technology-enabled tools and products have you developed for user- and management-level decision support for asset management?

Historically the asset management systems were used to generate static decision maps to explain or communicate decisions. Some of these maps were simply used internally for data validation while others were used as part of legislative testimony. The maps were generally well received, but led to requests for additional maps. Some decision maps are produced annually, like those showing pavement condition, and are posted on the Internet. Since the number of eyes viewing the data via these maps has increased due to posting on the Internet, the supporting data has received much greater scrutiny resulting in identification and correction of bad data. Comments about the maps also frequently lead to more in-depth discussions of the management systems and the processes for programming projects.

Some of the decision maps are now being replaced with dynamic mapping capabilities for the asset management decision makers. While none of the spatial IT tools employed by

KDOT were developed specifically for asset management, many of the tools are used to support asset management processes. One example is KGATE which is a browser-based application to query and display data from disparate sources on a map. It is also built to generate and display reports, so it is a good start on providing users with a central point of discovery. Continued development of KGATE should provide even more benefit by spatially integrating data for the user. Of course, this depends on data owners making their data accessible and geospatially enabled.

Question 5. What roles or actions can national organizations undertake to help state and local transportation organizations improve the use of spatial information technologies for asset management?

While KDOT is interested in assistance from national organizations in improving the use of spatial information technologies for asset management, we are fairly comfortable with our overall plan and direction in both areas. Assistance with how to educate asset management users and policy makers both for how they can help make these tools work and for how they can use these tools to improve their process or their ability to explain their systems would be beneficial. Documentation of good practices may be one way of communicating this assistance.

SUMMARY

KDOT has developed several asset management systems and tools and continues to refine and improve these tools. Efforts to mainstream geospatial enablement should improve data access, data integration, and data quality. Other benefits will include better understanding of the processes the data support, better documentation of the data and processes, and better capability to explain the data and processes to decision makers and the public. The integration of asset management and spatial tools is underway at KDOT which will help KDOT and those who rely on our assets.

New York State Department of Transportation Perspective

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INTRODUCTION

The New York State Office of Cyber Security and Critical Infrastructure Coordination (NYSOCSCIC) was established in 2002 and now has overall responsibility for coordinating, promoting, and facilitating the development, effective use, and sharing of geographic information within New York State (see http://www.nysgis.state.ny.us/ and http://www.cscic.state.ny.us/). They are the state government's GIS policy-setting agency and operate cartography, orthoimagery, digital data improvement, and data-sharing programs, including the state's GIS clearinghouse.

The New York State Department of Transportation (NYSDOT) was established in 1967 to deal with the state's complex transportation system and the ever-increasing need to coordinate the development of transportation with each mode serving its best purpose (see http://www.dot.state.ny.us). Until 2001, NYSDOT was the host agency for the state's cartographic program, including digital mapping, at which time this function was transferred to NYSOCSCIC. The department is host for New York's interagency traveler information gateway (see http://www.travelinfony.com/tig/). The department operates more than 15,000 mi of highway with 7,600 bridges that carry 59 billion VMT annually.

The New York State Thruway Authority (NYSTA) provides a user-fee supported highway and canal system that delivers high levels of safety and service (see http://www.thruway.state.ny.us). The Thruway is a 641-mi tollway with some nonfee segments. The canal system has four canals, 524 inland waterway miles, 57 locks, 79 fixed dams, and 11 movable dams.

NYSDOT establishes policy for the statewide transportation network. Today, the New York State transportation network includes

- A state and local highway system that annually handles over 100 billion vehicle miles. This total system encompasses over 110,000 highway miles and 17,000 bridges.
- An extensive 5,000-mi rail network over which 42 million tons of equipment, raw materials, manufactured goods, and produce are shipped each year.
- 456 public and private aviation facilities through which more than 31 million people travel each year.
- Over 130 public transit operators, serving over 5.2 million passengers each day.
- Twelve major public and private ports which handle more than 110 million tons of freight annually.

QUESTIONS

Question 1*a*. How is your organization using spatial information technology to support and enhance asset management decision making and resource allocation? Provide a brief history of how spatial technologies and asset management have evolved in your agency.

Spatial technologies at NYSDOT in the 1970s included manual scribing of lithographic films for production of printed 1:250,000, 1:24,000, and 1:9,600 scale maps and use of photogrammetric methods for small scale mapping used for facilities design. A milepoint system (hundredth of a mile precision) was established for physical and administrative inventory, pavement condition reporting, and traffic monitoring on touring routes. Bridges were located by latitude and longitude. The first statewide digital mapping of use for asset management was created during the 1970s by digitizing the 1:24,000 quadrangle maps. As part of an accident surveillance system, the digital maps included unique link and node identifiers for each public highway and intersection. A field posted reference marker system was deployed on state highways as a part of the accident system project and is used to track highway maintenance activities. Construction projects use stationing to locate assets. Digital records of bridge condition since the late 1970s and pavement condition since the mid 1980s are accessible to the workforce. Inventory and condition reporting for smaller assets such as traffic signals, signs, and pavement markings have been centralized from time-to-time, but are generally kept by regional offices or districts. A culvert inventory was recently migrated from dBase in regional offices to Oracle at the main office.

ESRI ArcView and ArcGIS have been widely deployed to the NYSDOT workforce since the early 1990s. Today, mapping technologists in NYSOCSCIC provide digital GIS-base map data layers showing the cartographic representations of features that are used by technical professionals throughout state government. NYSDOT program areas own data that can be joined to these GIS data layers to produce thematic maps. GIS coordinators in program areas are the first line of support for their colleagues and providers of metadata for data their program area shares with the workforce.

NYSOCSCIC is completing deployment of a high accuracy (±8-ft rural, +–4-ft urban) digital street map compiled from orthoimagery in support of a new accident location information system (ALIS) (see http://www.nysgis.state.ny.us/gisdata/inventories/details.cfm? DSID=932). The new statewide GIS street database contains all New York state streets, including up-to-date street names, route numbers, alias–alternate street names, and address ranges. Network Navigation details (travel direction, grade separations, restricted turns, etc.) in the new product will support attachment of attributes sufficient for automated permitting of oversize and overweight loads as well as other path-finding operations. The new street database is expected to be used by all levels of governments in NYS in their day-to-day activities. Any asset data with a spatial reference or street address can be linked or mapped to the new street database. NYSOCSCIC is working with many state agencies to map their existing tabular data to the new street database. NYSOCSCIC is also using the new streets database to improve the spatial location of existing assets. Keeping the new GIS streets data current will be critical to its long-term usability. NYSOCSCIC is in the process of building a strong, long-term GIS data maintenance program and is partnering with other state agencies, local governments, and other data users that are adopting the street database as the base layer in their GIS applications.

The administrative framework for asset management in New York State is the update process for the statewide and metropolitan transportation improvement programs. The 11 NYSDOT regional offices and New York State's 13 metropolitan planning organizations (MPOs) each has considerable latitude in making tradeoff decisions among candidate investments that meet the project selection criteria in the NYSDOT 21st Century Mobility Goals for Pavement, Bridges, Safety, and Mobility. A Program Support System and ArcView Executive Capital Program Viewer are used to record and report the accomplishments of candidate investments. Pavement and bridge condition forecasting models provide outputs that can be joined to GIS base map data layers. The following two citations provide more details: T. W. Clash, J. B. Delaney. New York State's Approach to Asset Management: A Case Study. In *Transportation Research Record: Journal of the Transportation Research Board, No. 1729*, TRB, National Research Council, Washington, D.C., 2000, pp. 37–38; and J. J. Shufon, Adams, L. H. Conceptual Framework for Defining and Developing an Integrated Asset Management System. In *Transportation Research Record: Journal of the Transportation Research Board, No. 1848*, TRB, National Research Council, Washington, D.C., 2003, pp. 37–44.

Trade and trade agreements, traffic growth, especially trucks, and IT that supports a more efficient flow of goods are the drivers for an ongoing transformation at NYSDOT. Implementation of asset management principles is one of nine strategies for producing new results and measuring transport system performance. Results in five areas will be used to gauge the department's accountability to its customers: mobility and reliability, safety, economic competitiveness, security, and environmental stewardship. Formation of an Office of Performance and Asset Management within the NYSDOT operating division and appointment of asset managers in NYSDOT's regional offices is underway as of the summer of 2005. For the past decade, inventory and inspection, data analysis and forecasting, and program development were each resourced as separate functions and managed by different executives.

Question 1*b*. Who are the primary users of spatial information technology for asset management and how are they using it?

Technical professionals in regional and main office program areas are the primary users, including: asset inventory, condition and performance assessment, maintenance and capital program development within a single asset class, horizontal program development across multiple asset classes, program implementation and delivery, and performance monitoring. The Executive Capital Program Viewer is designed to meet the needs of Regional Directors and main office executives, both in the office and while making presentations to customers, stakeholders and authorizers (e.g., the governor, budget office, legislature, and congress).

The new statewide GIS streets database and other associated GIS data layers are expected to be used by all levels of New York State government in their day-to-day activities to provide improved government services including law enforcement, homeland security, emergency response, economic development, tax disbursement, vehicle routing and much more. The new data layers have been incorporated into the state's critical infrastructure application, a disaster preparedness–emergency response secure GIS application that provides authenticated emergency response personnel access to information vital to their response efforts.

Question 2. What are the benefits of using spatial information technology to support asset management?

The resolution of multiple referencing methods, that each has temporal change, to represent diverse data at a common place on the earth would not be possible, absent GIS data models and business rules. Use of multiple linear referencing methods and dynamic segmentation of linear features are foundational to time-series analysis of our asset condition, extent, use, and performance records as well as our program planning and work history data series.

Question 2*a*. How has your transportation system improved or your program changed due to the use of spatial referencing of asset management data?

The spatial and temporal proximity of needs from various programs (e.g., pavement, bridges, safety, and mobility) and candidate investments has allowed for combining of various work on various proximate routes into a single construction contract. In the past, a paving contractor, a guide rail contractor, a striping contractor, and a mowing contractor might have each decided to work in the same place on the same day. Also, visualization of adverse customer service impacts of simultaneous work on parallel routes has resulted in scheduling work to allow for adequate customer service.

The ability to link or map existing tabular data to the new GIS streets database has resulted in the creation of many new GIS data sets that can now be overlaid and analyzed against each other and other asset data, allowing for improved data analysis. The new streets database has also been used to improve the spatial location of assets in existing GIS data sets.

Question 2*b*. Have your spatial information technology capabilities changed in response to the need for better asset management?

Our governor's determination to be a leader in e-government has been a far more important driver than advances in our practice of asset management. The conversion of the state's crash records system to be digital—from the generation of the police report using GPS coordinates, driver license bar code scans, and vehicle registration bar code scans—has been focal. Attaching the crash location to the asset entity associated with the crash requires both the high-accuracy digital mapping and the differential correcting of the GPS coordinates of the crash.

Question 2*c*. What areas do you plan to expand spatial information capabilities for asset management?

The 1:24,000 scale digital streets layer that has been in use since the 1990s does not contain connection details topology. The high-accuracy statewide GIS streets database that is currently being deployed has that capability. Thus, the cartographic representation of freeway ramps at interchanges in the new base map and will be available for mapping condition and performance of those assets.

Question 3*a*. Please describe the status of your current situation in the use of spatial information technologies to access and integrate data to support asset management decision-making activities.

Identification and Integration of Relevant Legacy Databases

NYSDOT has a prototype transportation asset management tradeoff model working in Microsoft Access, as described in *Transportation Research Record: Journal of the Transportation Research Board, No. 1848*, on pages 37–44. The data tables in Access use an integer key to identify each of approximately 7,000 linearly referenced asset management entities. The data table is then event theme joined to GIS layer cartographic representation of the entities to enable the conflation process. The asset management entity key is then assigned by conflation to data records imported from legacy databases. Legacy data sources include: highway sufficiency ratings (physical inventory, pavement condition, and AADT), bridge data management system (inventory and inspection), safety information management system (locations for which statistically significant clusters of crashes have been recorded), congestion needs assessment model (extent, duration, and intensity of recurring and incident traffic congestion), and program support system (scope, schedule, cost, and accomplishments of investment proposals). Decisions on whether to further refine and deploy the tradeoff model are awaiting completion of highway data management system and highway data store IT projects that will provide an Oracle data warehouse for use as a data input source for the asset management tradeoff model. If the tradeoff model concept is to be deployed, preparation of an IT project proposal would be the first step in scoping the effort to move from prototype to production status.

Selection and Maintenance of GIS Software Platform

ESRI ArcView and ArcGIS are available upon request for deployment to any employee at NYSDOT. Deployment is via LANDesk. ArcGIS licensing is concurrent log-in based. Vendor product version upgrades are run in a test environment prior to deployment in production. Server based GIS products, ArcSDE and ArcIMS, are maintained in the main office and provide the corporate GIS data repository and the web hosting environment. ArcPad software is included in our next GIS site license and it will be used on handheld field devices. Licensing for all GIS software is centrally administered.

NYS OCSCIC's new statewide GIS streets database is being deployed in three different formats (ESRI geodatabase, ESRI shape file, and MapInfo TAB) so that the majority of GIS users in New York State can import the new data directly into their GIS software packages.

Common Referencing Methodology or Your Methods to Integrate Differing Referencing Schemes

Multiple linear referencing schemes are in widespread use. Spatial conflation is the integrating mechanism. Standard linear reference transformation and overlay tools are used. Legacy data systems store attributes for both the primary route and overlapping routes carried by a pavement section. Selecting only the attribute data associated with the primary route prior to conflation results in greatly improved data integrity.

The issue of allocating bridge attributes for the purpose of economic analysis (e.g., benefit–cost or minimum life-cycle cost) in the context of network-level transportation asset management has many possible paradigms. For the NYSDOT tradeoff model prototype, bridges that carry or cross the Interstate system were allocated to the asset management entity associated with the Interstate highway, not the highway carried by the structure, because the rational nexus for creation of the bridge was the construction of the Interstate system (including funding and ROW). At the junction of two Interstate routes, bridges were allocated to the Interstate with the lowest route shield number.

With respect to cartographic models for displaying bridges in GIS at various scales, the proper representation of a bridge would be a point or point symbol (e.g., 1:125,000 scale), a line feature (e.g., a long bridge at 1:24,000 scale), or a polygon (e.g., any bridge at 1:200 scale). In a spatial data model with robust topology, the bridge (and perhaps each span of a multispan bridge) would have association with the feature carried and each feature (multiple features allowed) crossed, and associated attributes. The spatial topology in the robust spatial data model is not necessarily directly related to allocating economic consequences of investment alternatives to asset management entities at the network level of analysis.

It is important to note that NYSDOT's GIS bridges file that includes a point for every bridge (over 19,000) carrying or crossing a public road has had every point spatially moved to correspond to the new statewide GIS streets database.

Integration of External Information

For the prototype asset management tradeoff model, open database connectivity (ODBC) methods have been used to query and download data from IBM DB2 mainframe and Oracle server database entities. To date, our program and financial data in IBM DB2 and our transportation asset data in Oracle are not fused or interoperable. Some tables are replicated in both products to overcome the lack of direct connections among entities stored in those two products.

The new GIS statewide streets database and the other data layers created as part of the project are stored in Oracle using the SDE data scheme.

Data Quality Issues: Accuracy, Completeness, Timeliness

Pavement work history records are complex to access and analyze and may not be complete for paving work accomplished by state forces.

Bridge condition and performance records at NYSDOT are increasingly focusing on management of spans of a bridge, rather than the entire bridge. The cartographic representations of bridges in GIS are not yet created to display this level of data detail.

Conversion of New York's crash reporting from paper forms to digital data entry is underway, with a several-year backlog of injury and property damage crash records on paper queued for data entry to digital form.

As mentioned earlier, keeping the new GIS streets data current will be critical to its long term usability. NYSOCSCIC is in the process of building a strong, long-term GIS data maintenance program and is partnering with other state agencies, local governments, and other data users that are adopting the street database as the base layer in their GIS applications. Data maintenance pilot projects are underway with several different counties and local governments in New York State to test various ways that will allow easy and efficient reporting of data updates and also easy and efficient extraction of the new information for incorporation into the new GIS data sets.

Differing Spatial Resolutions of Data

Thus far, NYSDOT pavement and bridge attributes are kept at a precision of hundredths of miles, which is consistent with use of distance measuring instruments on field inventory vehicles. Databases under development at this time allow for more precision in the future. New York has reference stations in place statewide to facilitate differential correction of location data gathered using GPS receivers. The accuracy of the GPS-collected locations is greater than the high-accuracy statewide streets layer.

Metadata Standards

NYSDOT program areas that own attribute data and share it for use in GIS are asked to provide a metadata document for each shared data series. NYSOCSCIC has similar requirements for data that is shared through the New York State GIS clearinghouse (http://www.nysgis.state.ny.us).

Enterprise Deployment

NYSDOT is implementing its most recent transportation asset inventory and inspection systems using centralized multitier architecture. The client for these applications is a web browser. For some applications, access from outside the enterprise firewall is enabled. Temporary field office locations, such as construction field offices, have commercial broadband Internet service with virtual private network protocol connection to enterprise data stores and applications. For aspects of asset condition and performance forecasting that have not yet been migrated to web technology, LANDesk is used to deploy standalone Microsoft Windows desktop and laptop applications, with replicated data, to employees.

History

The milepoint LRS at NYSDOT is updated annually. For the casual user, the most commonly used entity is the most recently certified version. For advanced users, a milepoint history data layer has linear measure date activated and deactivated fields that are used to join archived records of original entry to the cartographic representation with locational integrity. Archived records of original entry are available annually for the past several decades from network file servers. At this time, NYSDOT has not adopted a business rule that requires historic asset attributes necessary for trend analysis to have their locational attributes transformed to the current version of the milepoint LRS. Best practices used in commercially available asset management products do make asset condition and performance history available for analysis in the current linear measure version.

The new statewide GIS streets database will be updated continually and NYSDOT, the New York State Department of Motor Vehicles (NYSDMV) and NYSOCSCIC will have immediate access to the updated streets data. Once a month the streets data will be processed and repackaged for monthly distribution to all New York State GIS Data Sharing Cooperative members through the New York State GIS Clearinghouse. Other related GIS data sets will be updated at least annually with some data sets available quarterly.

Established Protocols for Data Collection

NYSDOT's manuals for bridge inventory and inspection are at the following URLs: http://www.dot.state.ny.us/structures/manuals/man_inventory.html and http://www.dot.state.ny.us/structures/manuals/man_inspection.html. NYSDOT's Pavement Condition Rating Manual and Highway Sufficiency Ratings Documentation are paper-only documents. An Asset Management Data Collection Guide (prepared by the Virginia Transportation Research Council) that is being balloted at AASHTO during the summer of 2005 is likely to be considered by NYSDOT for adoption as departmental guideline.

Procedures and processes used to build the original statewide GIS data sets are detailed in the "Product & Process Description Document" available at: http://www.nysgis.state.ny.us/gisdata/inventories/details.cfm?DSID=932

Data Collection Issues

The update cycle proposed for the NYSDOT asset management tradeoff model is annual. Some data series, such as bridge inspection, are updated on a 2-year cycle.

Question 3*b*. What are the remaining significant issues for spatially integrating data for asset management decision makers across your organization?

A Transportation Data Model (UNETRANS) has been developed by a group of ESRI Transportation Industry users, consultants, ESRI business partners, and academics, including NYSDOT staff (see http://support.esri.com/index.cfm?fa=downloads.dataModels.filteredGateway&dmid=14). The goal is to define an "essential data model" for ArcGIS user organizations within the transportation industry, and in particular for roadway management organizations (e.g., DOTs), as well as for railroads, transit, airport, and waterway authorities. Central areas for the group include road and rail network topology, LRS, dynamic event representation, and asset location and management. NYSOCSCIC's new GIS base map does use portions of the UNETRANS model. To date, NYSDOT is not implementing the UNETRANS data model nor is the department procuring Oracle's Enterprise Asset Management application suite (see http://www.oracle.com/applications/maintenance/eam.html).

The NYSDOT bridge data management system and highway data management system (including traffic monitoring and generation of HPMS datasets) each have a one of a kind data schema. A significant decision is whether NYSDOT should continuing to invest more effort in deploying and supporting one of a kind data models versus using data models that are currently emerging as de-facto industry standards.

As a result of 1970 legislation, a statewide set of tax maps were generally drafted on Mylar map sheets 30 in. high by 42 in. wide. The original maps remain where the maintenance is to be done; generally in a mapping office at the county level of government. The maps are not available statewide as a GIS layer, either in scanned raster image format or as vector feature format. Consequently, owners of transportation rights of way do not have a GIS layer that accurately delineates the right of way boundary and the property lines of the abutting parcels.

The lack of such a layer will be a shortcoming as transportation facility owners' move into mapping the locations of appurtenances with GPS receivers.

The base tax maps were originally prepared using aerial photographs specifically created under controlled conditions. The aerial photographs clearly show all geographical features such as streets, roads, lakes, streams, railroad and utility lines, as well as property occupancy lines when they are well defined on the ground. Points of reference on the ground will have been prominently marked so as to provide check points on the photography. This photography is used as the foundation for preparing base manuscripts and includes features shown thereon that will assist the plotting of parcels. The base manuscripts are the basic maps from which the final tax map is prepared. All deeds or other instruments of conveyance are examined to determine the ownership of each parcel to be plotted on the maps.

The parcels are delineated on the tax map using the data obtained through deed research and plotting. Every parcel on a tax map is assigned a parcel number and a coordinate locator number. An index map is prepared showing the area covered by the tax map in a city, town, or village. When the tax map is completed, the map sheets may be bound together in sets or otherwise filed by the city, town, and village. Paper prints are provided to the assessors. The assessor's copies of the tax map are a public record and must be displayed and made available for inspection by the public.

The New York State Real Property System (RPS) physical inventory and valuation data stores and application programs assist the assessing community in producing an equitable assessment roll. The system allows the assessor to keep their assessment and inventory information current. Using RPS, reports that are required by New York State rules and regulations and by state law can be produced. The system also assists the assessor in the performance of their assessing functions and the valuation of properties in their jurisdiction. The tax map parcel number and the latitude and longitude of a point approximating the parcel centroid are among the digital fields available for use in a GIS and asset management context.

Question 4. What spatial information technology-enabled tools and products have you developed for user and management-level decision support for asset management?

The NYSDOT Pavement Needs Assessment Model (analogous to FHWA HERS model, except widening decisions are out of scope in the NYSDOT model) generates an event theme output for use in GIS. The NYSDOT Bridge Needs Assessment Model (analogous to FHWA BIAS) generates an attribute table that is Roadway Data Management System (RDMS) key joined to a GIS layer of bridge points in GIS. The NYSDOT Congestion Needs Assessment Model generates an event theme output table that has multiple subsets of attributes (set filter on rows to use one subset) for use in GIS.

The NYSDOT highway sufficiency ratings annual pavement rating process is used to discover new and realigned routes and generate work orders for changes to the GIS milepoint linear referencing measures calibration, which is then used to event theme join the sufficiency rating attributes for use in GIS. The NYSDOT Bridge Data Management System bridge attributes are RDMS key joined for use in GIS. The NYSDOT safety information system generates crash attributes. Crash rates data are event theme output for use with the GIS reference marker linear referencing cartographic representation. The NYSDOT program support system exports highway and bridge element attributes of investment candidates and implemented capital and maintenance projects for use in GIS. The NYSDOT Executive Capital Program Viewer is an

ArcView extension that enables NYSDOT executives to query and display the department's capital program at their office or while mobile (data is replicated to the laptop computer). The prototype asset management tradeoff model uses GIS preprocessing to import data for use with internally generated RDMS asset management entity keys and also produces event theme output for use with the NYSDOT milepoint linear referencing GIS layer.

Question 4*a*. What products have proven most successful for asset management activities?

NYSDOT relies heavily upon the GIS interoperability for all of the cited asset inventory, condition, and performance assessment, maintenance, and capital program development within a single asset class, horizontal program development across multiple asset classes, program implementation and delivery, and performance monitoring systems. The widespread deployment of ArcView to the workforce (site licensing), with associated training and program area GIS coordinator "go to" access for end users has been a very cost-effective strategy to enable asset management productivity. The public–private partnership of NYSDOT with ESRI and others to advance the theoretical basis for application of linear referencing systems to transportation asset management has also leveraged in-house NYSDOT staff capabilities.

Question 4*b*. What future product developments do you believe would provide the greatest benefits?

NYSDOT staff has proposed a tradeoff model that uses economic analysis principles and produces results that can be event theme joined to NYSDOT's milepoint linear referenced GIS layer.

The fall 2005 publication of *NCHRP Report 545: Analytical Tools for Asset Management* by NCHRP Project 20-57 is foundational to further development of spatially enabled technical tools for asset management. The asset manager–project tool is designed to keep spatial referencing data on each data record to facilitate interface with GIS for data input and output. The software from this NCHRP project is being pilot tested in 11 states and further developed by the AASHTOware program as their first set of asset management technical tools.

Question 5. What roles or actions can national organizations undertake to help state and local transportation organizations improve the use of spatial information technologies for asset management?

Interoperable Spatial Information Infrastructure to Facilitate the Development of Tools

The 2001 public review of the National Spatial Data Infrastructure (NSDI) Framework Transportation Identification Standard is long overdue for finalization. This is especially critical given the discontinuation of development for the NSDI Transportation Data Content Standard at the proposal stage. Similarly, the results of the mid-2004 comment period on transportation and addressing geospatial data theme proposals have yet to be announced. On an even broader scale, adoption of a common North American standard, especially for those agencies in the Halifax to Mexico City North American Free Trade Agreement (NAFTA) corridor, would be beneficial.

Capacity Building

The USDOT RITA should continue and upgrade the products of the former Bureau of Transportation Statistics GIS office. FHWA should continue the public release of HPMS and NBI data and assure that capabilities to join the data to RITA GIS layers are supported. Development of an NHI course to cover the topic of this TRB circular may be prudent.

Broader Understanding of the Capabilities of Spatial Information Technologies

Elected policy makers, such as state legislatures, already understand spatial information technologies in the context of the election redistricting process that follows each decennial census. The pervasiveness of GIS powered pre-trip planning internet sites should by this time have familiarized the transportation community with spatial and temporal information. Use of the technology by transportation executives while they are mobile (e.g., meeting with customer and stakeholder groups) is probably much less sophisticated than use by their private-sector logistics counterparts (e.g., freight railroad executives meeting with potential customers). Perhaps some AASHTO executive level webcasts on how to sell proposed transportation investment programs using GIS would be fruitful.

Development of Tools

The NCHRP program should be used by the states to develop tools. Deployment of developed tools and their support and enhancement is a proper role for the AASHTOware program. Pooled fund SPR studies are another mechanism for states to achieve economies of scale in tool development. Public–private consortiums such as GIS-T also have a role. Purchase of commercially available off the shelf products such as Hansen Information Technologies and Agile Assets suites should not be overlooked. The gap analysis in *NCHRP Report 545: Tools for Asset Management* is not yet so old as to be useless.

Documenting Good Practices

Under current operating practices, the FHWA Office of Asset Management is handling systematic documentation of best practices and technology sharing through their case studies series. Their office includes staff specializing in data integration, as do the FHWA regional resource centers. One limitation of the studies done to date is that they are paper only documents. Publication of the documents in a digital format that complies with Americans with Disabilities Act (ADA) requirements for the Internet is long overdue.

Other Roles or Actions

Practitioners can continue the discussion online at http://assetmanagement.transportation.org in the topic area "j. Integration of Data and Management Systems."

The 2004 TRB paper on Geospatial Information Infrastructure for Transportation Organizations (see http://trb.org/publications/conf/CP31spatialinfo.pdf) lists several recommendations on how federal transportation agencies can facilitate improved decision making in the states by promoting spatial data and technologies. NYSDOT staff concurs with the findings in that report. Specifically USDOT can form information clearinghouses and facilitate partnerships among state agencies. USDOT can take an active role in representing the transportation sector in standard setting organizations. USDOT's programs can help to raise the awareness of the importance of spatial technologies at all levels within transportation agencies, but most importantly at the executive level. Training and education programs should be enhanced to build the human capital needed to support the spatial infrastructure.

It is not necessary for the federal transportation agencies to develop tools, but rather empower and enable other entities to more effectively work together. We can look to the National Geodetic Survey (NGS) as a good example. NGS no longer performs large surveys or builds COORS stations. Rather they have created a framework for the work done by the states and others to coalesce. They are no longer implementers, but rather conveners and guiders.

SUMMARY

New York State has recognized spatial IT as a critical e-government function and provides centralized policy, technology transfer, and data-sharing functions via the web. The state's public sector providers of transportation facilities and services, include urban public transportation authorities and the NYSTA. These agencies together use GIS for operational, tactical, and strategic management of fixed and rolling stock assets. Reporting of the condition and performance of New York's transportation system to customers relies heavily on spatial IT.

New York State Thruway Authority Perspective

Lee Maynus
New York State Thruway Authority

QUESTIONS

Question 1. How is your organization using spatial information technology to support and enhance asset management decision making and resource allocation?

History

Established as a public benefit corporation during 1952, the NYSTA initially performed all of its mapping functions by manually scribing all printed maps and drawings. A common milepost (accurate to 0.1 mi) system was established. This system is currently used in evolved form (0.01 mi accurate). The general position of nearly all highway elements, appurtenances, and structures are referenced in this way. This mapping was augmented with stereographic photogrammetric methods during the early 1990s.

Modern GIS methods and software began to be used during 1993, with the initial mapping of the Canal Corporation parcels and waterways, using MapInfo software. Between 1993 and 1998, Thruway specific geospatial mapping was undertaken on an ad hoc basis, principally from interested personnel working on specific projects and in isolation.

During 1997–1998, a GIS task force explored whether or not it would be to the Authority's interests to adopt GIS as a standard corporate tool and, if so, how would it benefit the Authority. The task force concluded, during April 1998, that it was to the Authority's interests to adopt GIS with the identification of specific cost savings and the enabling of certain types of previously infeasible analytical activities.

During 1999, the Authority adopted the ESRI ArcGIS platform and established a GIS coordination unit within its headquarters' IT Department. The general charge of the unit is to maintain Authority-specific mapping standards, insure compliance with NYSOCSCIC standards and serve as a resource to the Authority division and departmental GIS coordinators. Additionally, the GIS unit also maintains and distributes the ArcGIS software, including the base ArcGIS 9.1 package, and the 3D, Spatial Analyst, ArcIMS, and ArcSDE extensions.

NYSTA and Canal Corporation have joined the New York State GIS Data Sharing Cooperative. A GIS data server has been established, and a GIS route system, modeling the Thruway's mileposts, has been developed. Standards for mapping data to this route system have also been laid out.

NYSTA's LRS is another essential component of the Thruway's GIS. This LRS, the milepost system, is the basis upon which most existing Thruway databases have been built, and most information has been collected. Using the Thruway route system modeled in GIS, Thruway GIS users can map existing databases (both personal and enterprisewide) for their particular applications. Combining this visual component and spatial analytical capabilities of GIS, users can now bring their data "to life" and enhance the quality of data analysis and decision making.

In terms of capability, individual users often prepare maps in relation to specific projects. Generally, they link or fuse their own data to base map layers that are maintained by the GIS unit. When data is linked or joined to a base map layer, the base map layer is remotely held and maintained by the GIS unit, allowing for automatic updates. Sometimes it is more advantageous for the user to maintain a copy of the base map layer locally, such as when he or she chooses to fuse the project data to the base map layer. In such instances, the user is required to maintain the currency of the base map themselves and be mindful of copyrights that may present.

A significant number of applications have been prepared for the intranet, allowing anyone to access the GIS with a standard web browser. Such applications include: Current Thruway Incidents, a photolog viewer, highway/bridge/facilities, rock slopes, fiber optic network, survey monumentation, aerial photos, Roadway Weather Information Systems (RWIS), planned lane closures, occupancy permits, highway capacity LOS, detour routes, scheduled construction work, ITS elements, the planned capital program, and the current year's construction program.

The principal asset management database within NYSTA is the Infrastructure Inventory and Inspection System (IIIS) which is housed in an Oracle relational database. A separate ArcGIS application has been developed in-house to access many of the data elements that are contained with IIIS within an ArcGIS environment. Specific asset features accessible in this manner are structures (inventory, inspection, access needs, and flags), highways (inventory, survey, guiderail, asphalt cracking, concrete surface data, and rock slope inventory), and culverts (inventory and inspection data).

Question 1*b*. Who are the primary users of spatial information technology for asset management and how are they using it?

Technical staff at all levels use the spatial information. Many of the products are available via the internal intranet for any desktop user to access them. Uses vary. GIS is used for physical or operational needs assessment and identifying the location of a planned or underway construction project for coordination purposes. Other uses relate to identifying the geographic balance of the capital program and its focus, as it relates to the condition assessment, etc.

Other uses entail relating the Authority's maintenance sections to the state DOT and local highway departments (e.g., maintenance coordination) and for public information purposes.

Question 2. What are the benefits to using spatial information technology to support asset management?

Benefits generally result from the visualization aspects offered by the GIS system. Typically, the underlying datasets consist of large tables that are not readily understood as they relate to the larger transportation system. Tables are often merged or metrics derived from the tables and then visually displayed. This visual display can often reveal relationships or conditions that would have previously gone unnoticed.

Question 2*a*. How has your transportation system improved or your program changed due to the use of spatial referencing of asset management data?

The program areas generally operate the same before GIS-related products became available. What has happened is more complex questions are being asked in response to the availability of GIS-related systems. An influencing factor concerning the use of such systems is that more asset descriptors (e.g., condition data, reference points, feature identifies, etc.) are being placed into databases that can be drawn upon. For example, in the past it was more difficult to coordinate lane closures with adjacent projects resulting in mistakes and disputes among the contractors and NYSTA. Another benefit is the bundling of individual projects into a single, larger, construction contract in areas where there are geographic overlaps. This has resulted in bid savings (economies of scale) and a reduced need to coordinate the activities of several contractors.

Question 2*b*. Has your spatial information technology changed in response to the need for better asset management?

Spatial IT has led to better asset management. The technology has actually changed little, as significant investments have been expended towards establishing the current spatial information systems. What is being observed, though, is more asset-related information products are being placed on the internal intranet for the benefit of non-GIS users. The use of web-related products is partly in response to better asset management needs and strikes a balance with respect to the specialized training that comes with GIS and the resultant use of information.

Question 2*c*. What areas do you plan to expand spatial information capabilities for asset management?

During 2006, the NYSTA intends to concentrate upon putting live weather information on the intranet ArcGIS application. Additionally, it plans to maintain planned improvements to its digital orthoimagery activities and participate in the maintenance of NYSOCSCIC's new statewide GIS streets database.

Question 3*a*. Please describe the status of your current situation in the use of spatial information technologies to access and integrate data to support asset management decision-making activities.

Identification and Integration of Relevant Legacy Databases

Due to the fact that the Authority standardized upon a milepost system many years ago, many legacy databases are easily mapped. However, these legacy databases create additional work for IT professionals, who must maintain them. During 2006, a project is planned to convert core databases into an Oracle environment.

Key legacy databases include the Authority's BMS, the PMS, the Accident Reporting System and Capital Program Management System (CPMS). While these represent isolated silos, staff works around this problem by storing copies of relevant data fields onto their local PC and performing geospatial analysis from there.

The most difficult database to use is the CPMS, because project locations are described in bounds ("from–to" format). This does not lend itself for mapping onto the GIS base map and it is usually left to the data handling skills of the analyst to work around this issue.

The larger issue with the isolated systems is not the fact they are "legacy" in the sense that they use outdated technology, but they are isolated information silos that can be hard to access. These silos often have excellent and very up to date information as they are usually maintained by an advocate who is motivated towards keeping them up to date. Unfortunately, these data may reside upon someone's desktop PC, making it difficult to link to that data in a dynamic manner.

Selection and Maintenance of GIS Software Platform

ESRI ArcView and ArcGIS, with related ESRI extensions, are the Authority standard. This package was standardized in 1999 through the employment of a selection committee. Maintenance is performed via a maintenance agreement that is under state contract. Actual maintenance (upgrades, etc.) is performed remotely via Microsoft's System Management Server.

Common Referencing Methodology or Methods to Integrate Differing Referencing Schemes

The Authority maintains all of its spatial data using the NAD83 (meters) datum. In terms of specific referencing, it assigns facility, travel direction, and milepost (.01-mi data field resolution) to all highway and bridge structures. Each ramp has a specific identifier and linear referencing system of its own. The mainline and ramp basemap is mapped at a 1:8000 resolution.

Buildings, maintenance areas, rest areas and similar point or polygon-based systems have a unique identifier that is associated with a specific centroid latitude and longitude. One recently discovered issue involved how structures are referenced. Structures are identified by milepost, but no travel direction identifier is recorded or whether or not the structure serves both travel directions.

A compounding issue lay with identifying the structure as being an overhead or mainline bridge. When the BMS system was established, the emphasis was on capital program management. It was relatively unimportant concerning the travel direction served by the structure and whether or not the structure is an overhead or not (capital responsibility was the same regardless).

Integration of External Information

The Authority is a member of the New York State GIS Data Sharing Cooperative. As a member agency, it has rights to use other member agencies' geospatial data. Most significant of these data is NYSOCSCIC's orthoimagery (aerial photographs) and wetland layers that are produced by the New York State Department of Environmental Conservation. Other significant data sources include those produced by the New York State DOT and the Bureau of the Census.

Generally, these data are fused by the end user or simply linked if the basemap data warehouse is being used. Linking is the preferred method as it is easier maintain the copyright the data provider still retains.

Data Quality Issues: Accuracy, Completeness, Timeliness

Data accuracy has always been an issue. Generally, this relates to both completeness (partially or wholly unpopulated fields) and timeliness. In general, experienced users know to beware of any data field prior to incorporating heavy reliance upon said field. Due diligence is often expressed through frank discussions with the data owner, spot checking and discussions with others whom have used the data.

Pavement treatment history is very good and readily accessible. Unfortunately, structural treatments are not as well documented (other than a treatment occurred, as evidenced by a change in condition rating). Accident data can be readily mapped. However, there is a 4- to 6-week delay between receipt of the paper accident report and the transcription into the database.

Differing Spatial Resolutions of Data

This issue is akin to data quality. Typically, the Authority's data can be mapped to ±1 m, but engineering survey data is collected on the centimeter level of accuracy. The poorest resolution often is found with U.S. government data sources.

Depending on the use, this problem may not manifest itself at all. System wide analysis (say, 1 in. = 1 mi) is fairly insensitive to such issues. This issue becomes more apparent at the area level resolutions (say, 1 in. = 50 ft) and, perhaps, intolerable at the site level (say, 1 in. = 5 ft).

Metadata Standards

Program areas that provide data for other areas are required to document their products via data dictionaries and similar metadata documents. Depending upon the user's diligence, ad hoc work that resides upon a single user's desktop may or may not be well documented. Any material that is shared through the New York State GIS clearinghouse follows the requirements set forth by the NYSOCSCIC.

Enterprise Deployment

The Authority uses a "floating seat" method concerning the deployment of ArcMap, with four simultaneously active seats available. With respect to ArcView, it has a group license of 31 seats. All of the Authority's divisions have access to these products and central base map data warehouse via the Authority's fiber optic network. Remote users can access the spatial data via a secure virtual private network. However, this access method may not be practical if broadband connectivity is not available.

The intranet has been very successful with respect to bringing spatial technologies to the casual end user. While limited with respect to flexibility, every desktop within the Authority has access to these products via a web browser.

History

NYSTA functions as an internally open organization, such that most users can request access to relevant databases with little or no justification. Exceptions are present, though, with respect to contract-related and financial databases.

Highway and structural data archives are readily available from 1988 onward. Detailed traffic counts are available from 1990 onward.

Established Protocols for Data Collection

Each program area has its own standardized data collection procedures and methodologies that predate the advent of geospatial technologies. In relation to this, the geospatial attributes have been added as a separate, linkable, file, or an existing file extended by adding more columns.

Data Collection Issues

Highways are inspected on an annual basis and structures are inspected on a biennial schedule. Facilities, such as buildings, are also inspected on an annual basis, but are the most difficult to manage in a geospatial environment because there are not standardized data files/data fields, other than very basic attributes (square footage, etc.). Traffic data is collected daily and is GIS "ready."

Question 3*b*. What are the remaining significant issues for spatially integrating data for asset management decision makers across your organization?

The single largest issue involves the training and cultural preferences of asset managers. Many decision makers are unfamiliar with the actual use of ArcGIS and tend to rely upon others for the preparation of display material, using ArcGIS. Additionally, these managers are very comfortable with their current methods, which are not reliant upon ArcGIS. To wit, they do not readily grasp the value, beyond display purposes.

Technical issues lay with the lack of consistent internal standards concerning assets. While many databases/tables have had some level of spatial integration, some do not. Collecting spatial information is often expensive with consultant forces (some quotes have been has high as $50 per reading). As a result, these tasks are often dropped from various inventory/inspection activities.

Question 4. What spatial information technology-enabled tools and products have you developed for user and management-level decision support for asset management?

The authority has deployed Current Thruway Incidents, a photolog viewer, highway–bridge–facilities, rock slopes, fiber optic network, survey monumentation, aerial photos, roadway weather information system (RWIS), planned lane closures, occupancy permits, highway capacity LOS, detour routes, scheduled construction work, ITS elements, the planned capital program, and the current year's construction program.

Currently under development is the report card performance measurement system. This application is intended to provide a bottom line high level assessment of the highway–structure's condition and its ability to reliably serve traffic.

The principal asset management database within NYSTA is the IIIS, which is housed in Oracle relational database. A separate ArcGIS application has been developed in-house to access many of the data elements that are contained with IIIS within an ArcGIS environment. Specific asset features accessible in this manner are structures (inventory, inspection, access needs, and flags), highways (inventory, survey, guide rail, asphalt cracking, concrete surface data, and rock slope inventory), and culverts (inventory and inspection data).

Question 4*a*. What products have proven most successful for asset management activities?

The IIIS application is very useful to many managers for querying certain features, etc. The planned lane closure and planned capital program has been very successful with respect to avoiding conflicts with ongoing activities.

Question 4*b*. What future product developments do you believe would provide the greatest benefits?

An overhauled facilities database that will more readily permit geospatial representation of the Authority's nontransportation assets. Improved querying and data fusion tools would also greatly assist the poor or non-computer-savvy manager obtain datasets for localized analysis.

Question 5. What roles or actions can national organizations undertake to help state and local transportation organizations improve the use of spatial information technologies for asset management?

In general, the establishment of a geospatial ideal or identified "best practices" would greatly assist with providing a greater understanding to managers the benefit of spatial asset management. Particular emphasis should be given towards existing tasks–practices that are greatly assisted (instead of simply done differently) and those that are generally infeasible–difficult to perform without geospatial technologies.

The development of an open "best practices" data architecture and open source code to a suite of tools–applications would greatly spur the uniform development of geospatial tools. A similar example of this approach lay with the open development of the 1985 Highway Capacity Software. The application was placed in the public domain and many private sector individuals used this as a means to jumpstart applications that greatly extended the methodologies contained within the software.

The National Spatial Data Infrastructure's Geospatial One-Stop webpage (http://www.geo-one-stop.gov/) represents an attempt to provide a clearinghouse structure for practitioners to reference. What is missing is sample datasets, data dictionaries, relational database structures and topologies that provide real world examples to interested parties. Since an idealized/best practice geospatial data system can be developed in a number of ways, several samples can be provided as choices for the practitioner.

North Carolina Department of Transportation Perspective

JENNIFER BRANDENBURG
JOHN FARLEY
EMILY MCGRAW
North Carolina Department of Transportation

QUESTIONS

Question 1a. How is your organization using spatial information technology to support and enhance asset management decision making and resource allocation? Provide a brief history of how spatial technologies and asset management have evolved in your agencr Agency.

Asset Management

In North Carolina DOT (NCDOT) asset management is defined as the M&O of existing roadways. Recently, there has been some emphasis placed on the decision-making process of funding levels between new construction and maintenance. The department has developed a strategic long-range transportation plan (LRTP) which addresses this split in detail, but currently no changes have been made to the funding process. In this agency, asset management falls under the chief engineer's office on the operations side of the organization and supports the 14 highway divisions in their day to day maintenance of a 78,000-mi roadway system; the second largest in the country.

The director of asset management oversees bridge maintenance, road maintenance, pavement management, oversize-overweight permits, roadside environmental, secondary roads, equipment, and intelligent transportation. Within asset management, there are several stand-alone management systems in existence. The MMS, developed by Agile Assets, was implemented approximately 2 years ago. The BMS, which was developed by North Carolina State University, and the PMS, which was developed in-house, are both very old systems and slated for replacement. Our equipment management system is a part of the financial management system (FMIS). An intelligent transportation traffic systems management system is currently under development within our IT organization. All of these systems are stand-alone at this point with no link to GIS or each other.

The department is currently in the process of procuring Agile Asset's Pavement Management product, which will have a direct interface with the existing MMS. Full integration of this system will only occur with the completion of the LRS. The expectation of our GIS unit is that our LRS will be completed by the time PMS is ready to be implemented. Currently, with no functional LRS, all data integration is done by hand on paper maps.

Geographic Information System

NCDOT established a GIS unit approximately 11 years ago. The unit resides within the engineering transportation systems branch, which itself falls under the IT division of the NCDOT.

The NCDOT GIS unit consists of three sections: mapping, road inventory, and technology. The duties of the mapping section and the road inventory section basically remain the same as they have been since inception although, in some cases, they are utilizing newer technology to fulfill those duties. The master maps are now in digital files rather than on mylar, and the road inventory section's road data management process is currently being converted from a mainframe flat file to an Oracle database. However, the core data update processes have not evolved to more efficiently build–update the mapping and data files concurrently. In addition, the technology section needs the data provided by the mapping and road inventory sections in order to develop applications relevant to transportation projects.

Each section performs many of the same tasks as before the merger. The NCDOT GIS unit is currently undergoing some major changes to capitalize on the strengths of all three sections and promote greater communication and interoperability.

The current capabilities of the NCDOT GIS unit have recently been greatly enhanced with the implementation of an enterprise licenses agreement (ELA) with ESRI. In addition to the ELA, the GIS unit is also making some key hires of junior and senior staff to take full advantage of ESRI GIS technology. This technology includes the development of custom GIS including those deployed through the web. In addition, the GIS unit has a full suite of tools and applications for providing advanced data modeling, data development, and spatial analysis.

In the near future, the GIS unit anticipates having the capability to implement and maintain an enterprise spatial database to support linear referencing as well as advanced network analysis. In addition, we will be developing more advanced n-tier spatial applications.

As it stands today, the GIS unit provides the underlying inventory of features for asset management, whether they have a spatial component or they are modeled strictly in a tabular format. The level of integration today is mostly in the form of ad hoc processes. The spatial referencing methods and processes being implemented today will enable even more even more integration and expansion of data in the future. This includes more reliable and timely information being available to our customers.

Because GIS and asset management reside in different parts of our organization priorities sometimes vary and communications are difficult

Question 1*b*. Who are the primary users of spatial information technology for asset management and how are they using it?

The current primary users of spatial information from NCDOT can be broken into two broad categories (internal and external) along with their uses for spatial technology:

Internal

- Transportation planning branch
  - Planning and decision support
    - Staff level
- Photogrammetry unit
  - Planning and analysis
    - Director and staff level
- Division offices
  - Inventory and decision support

        - Staff level
- Pavement management unit*
    - Inventory and decision support
        - Staff level
- State road maintenance unit
    - Inventory and decision support
        - Staff level
- NCDOT administration
    - Decision support
        - Staff level

*Operations users are few and their knowledge of the system varies primarily due to a lack of support and training. There is no formalized method of training and updating existing users. As with all programs of this magnitude, there are "super-users" scattered throughout the organization. However, with no real vision of what this technology can do for the field they struggle with making the technology useful to them. Operations users develop their skills and knowledge to their own level of comfort because of a lack of guidance from management on what is expected.

External

- North Carolina Center for Geographic Information and Analysis (CGIA)
    - Reference and inclusions into NCOneMap
- Other state agencies
    - Reference and analysis
- Educational institutions
    - Reference and analysis
- FHWA
    - Inventory and analysis
- Private data providers
    - Reference and resell

In addition to those groups mentioned above spatial information is also provided to other agencies both within and without DOT, albeit to a lesser degree.

The vision for the NCDOT GIS unit is to provide transportation information through an enterprise spatial database to both internal and external customers as needed. This would greatly increase the primary user base, both in terms of new users and more integration with existing users, as the data would be more readily available. In addition, the information would be timelier in terms of recent changes to the system.

Question 2. What are the benefits to using spatial information technology to support asset management?

With limited spatial referencing technology in place, our experience is limited to creating individual maps that show information from different databases, e.g., a map that shows pavement-related data and a separate map that shows traffic related data on the same roadway. This problem seriously limits the usability of our existing GIS technology at this time.

A proposed plan for expanding spatial information capabilities for asset management includes improvement of database technology as well as the deployment of information through different custom applications. The improvement of database technology would include the implementation of ESRI's ArcSDE with an Oracle RDBMS backend. This technology would form the cornerstone of the enterprise spatial database. In conjunction with ArcSDE new applications would be developed to not only deploy information from different asset management systems to secondary and tertiary users, but to also allow for better integration with said systems by linking them directly to the enterprise spatial database.

Question 3*a*. Please describe the status of your current situation in the use of spatial information technologies to access and integrate data to support asset management decision-making activities.

Identification and Integration of Relevant Legacy Databases

NCDOT established a mainframe system called the "universe" to maintain some pertinent information on the state maintained roads within North Carolina. The universe file is in the midst of undergoing an upgrade both in terms of its underlying technology as well as its role within DOT. The migration of the Universe to Oracle from the mainframe system on which it now resides will enable many key changes to the information it provides as well as access to the data itself. The current mainframe system was developed for tracking and reporting information to the FHWA. Over time, many groups both within and without DOT have also used this information for their own purposes. However, due to the cumbersome universe file structure and the difficulty in the average user gaining access to data, it is rarely used to support asset management decisions. Unfortunately, the mainframe universe system has not evolved to keep pace with these new uses. NCDOT is now working on changing this paradigm to extend the uses for the universe to better address our customers' needs.

Selection and Maintenance of GIS Software Platform

The NCDOT GIS unit primarily utilizes ESRI products, with access to most of ESRI's GIS suite of applications. This includes ArcGIS, ArcSDE, ArcIMS, and ArcServer. In addition, the GIS unit utilizes Oracle as its RDMS.

Common Referencing Methodology or Methods to Integrate Differing Referencing Schemes

The primary method utilized by the NCDOT GIS unit for integrating differing referencing schemes follows standard spatial practices. This includes discrete real world coordinates in North Carolina State Plane to information referenced to a linear feature, such as those segments that constitute the North Carolina State Maintained Road System.

The linear referencing system being developed by the NCDOT GIS unit is described as follows:

Conceptual Design NCDOT LRS

The core of the NCDOT LRS is the Linear Datum, which is comprised of Framework Transportation Reference Points (FTRP), Framework Transportation Segments (FTSeg), related entities, and their relationships. This in turn provides the fundamental referencing space for the transformation among various linear referencing methods, network models, and cartographic representations. This is illustrated in Figure 11.

The Linear Datum is created by projection of the state-maintained roads (the physical transportation network) on to the planar surface of the Earth defined by NAD83 State Plane, North Carolina. End points, county boundary points, state boundary points, and the intersections of roadways are used as the FTRP, which define the beginning and end points of the FTSegs. Unique identification numbers are assigned to each FTRP (P#) and FTSeg (F#) as illustrated by the diagram in Figure 12.

The Linear Datum is represented by LRS Spatial Database, which is managed through the GIS Line Work Edit Tool. Each segment of the state maintained road network is assigned a Generation 1 (G1) FTSeg when newly digitized. GIS operations, such as dynamic segmentation and network analysis, are supported and can be applied to the NCDOT LRS and related business data.

While a few referencing methods are supported, such as route-milepost referencing and distance/offset referencing methods against FTSegs, the primary linear referencing method of NCDOT LRS is the distance–offset referencing method against the G1 FTSegs, which uniquely represents the whole physical highway transportation system.

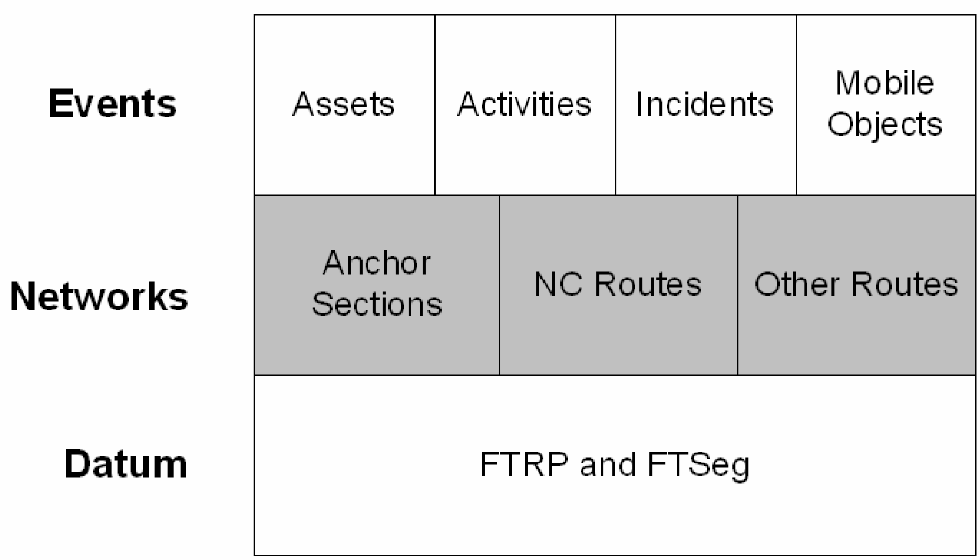

FIGURE 11 NCDOT LRS.

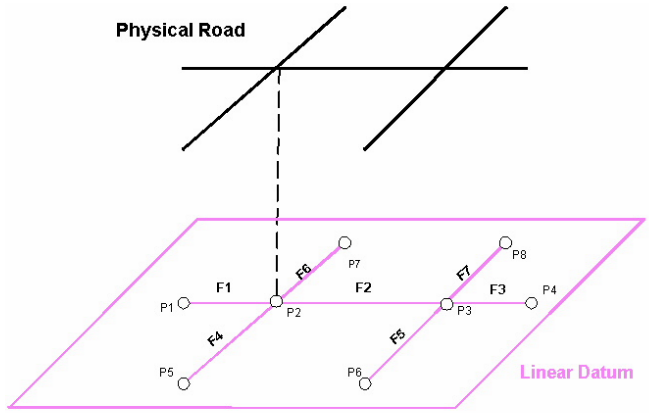

FIGURE 12 North Carolina DOT Linear Datum.

When a new segment of state maintained road is added to the system, a G1 FTSeg is added. Once added to the Linear Datum, a G1 FTSeg will always remain in the LRS as originally defined. As illustrated in Figure 13, addition of a new system road BE, which intersects the existing road ABCD, does not split G1 FTSeg AC. In other words, G1 FTSeg AC is still in the system. At the same time, a new G1 FTSeg BE and two new FTSegs (AB and BC) are added to the Linear Datum. Point B is a FTRP as defined by the intersection of roadways.

It is highly recommended that point or linear events are stored against the G1 FTSegs due to the unique stable properties, which helps to reduce the need and overhead of data processing. In addition, G1 FTSeg's allow for historical tracking of events. It is important to note that storage of the events against G1 FTSegs does not prevent system application interfaces being designed so that the event location measurements are taken against other supported referencing methods.

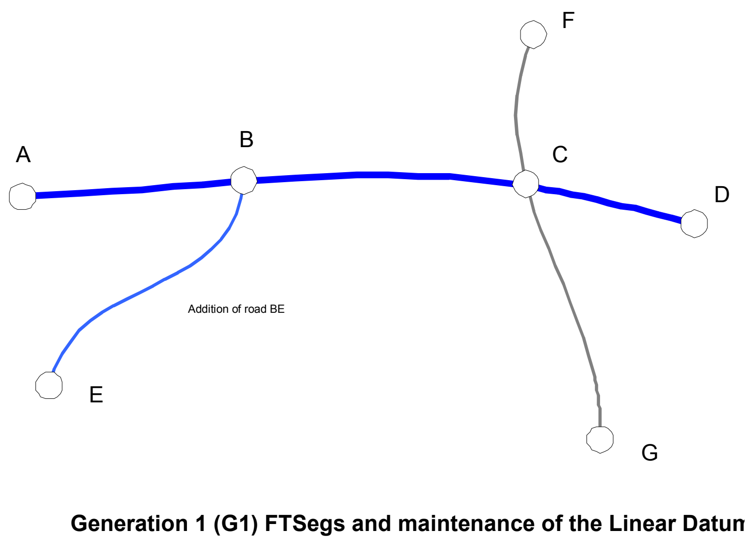

FIGURE 13 NCDOT FTSegs.

Integration of External Information

The NCDOT GIS unit utilizes data and information from many different sources to develop a series of spatial data sets used throughout NCDOT. Perhaps the most important involves combining our mainframe universe flat file with spatially enabled road segments. Next to the universe, the GIS unit acquires many different types to data from local agencies. These include locally maintained roads, aerial photography, and tax parcel information.

Other sources include internal DOT and state agencies such as the NCDOT Rail Division and the North Carolina Department of Commerce. The most prolific source of information, particularly from a reference standpoint, is the North Carolina Center for Geographic Information and Analysis (NCCGIA).

Upon complete development of the LRS, field usability of a GIS system will be dependent on the need to input coordinate data from agency management systems and then illustrate that data in a GIS format. There will be a constant need to update the road files with updated history on the work performed, alignment changes, road additions–deletions, pavement condition data, etc.

Data Quality Issues: Accuracy, Completeness, Timeliness

The GIS unit does face some challenges in terms of the accuracy, completeness, and timeliness of our core (state-maintained roads) data sets. First, the overall accuracy of the data is difficult to ascertain as different processes with different data sources were used in developing the core data. The GIS unit investigated and adopted a methodology for determining the overall accuracy of the core data, but has yet to put the adopted methodology into practice as other higher priorities have taken precedence.

Second, the core data set is rather complete in terms of statewide coverage. Completeness does become an issue at times as missing data is found. However, most often this is due to the timeliness or the current process for inputting changes to the system. In addition, NCDOT GIS unit is tasked with maintaining only the state-maintained road system. This also causes problems such as missing information for a feature for which the NCDOT is not responsible. It is important to note that one of the goals of the NCDOT GIS unit is to develop methodologies for acquiring, integrating, and maintaining all roads within North Carolina.

Finally, one of the greatest challenges to the GIS unit in terms of its core data set is timeliness. Information about NCDOT's road infrastructure goes through many phases and many different groups. By the current process, this information is difficult to maintain in a timely fashion. This problem is exacerbated by the mainframe universe system since it was not designed to accommodate a yearly reporting structure as opposed to maintaining data in a quarterly or monthly cycle.

Differing Spatial Resolutions of Data

Currently, the GIS unit does receive data with a variety of resolutions and accuracies. In the past this presented something of a problem, as metadata on the information received was scarce. Today, more metadata is forthcoming with newly acquired information so utilizing information of different resolutions becomes less problematic

Metadata Standards

The NCCGIA has adopted as its metadata standard the Content Standards for Digital Geospatial Metadata from the FGDC. By extension, this has also become the metadata standard for most North Carolina State agencies.

Enterprise Deployment

With the improved software licensing, the tools are available and training does exist between ITRE and our GIS Unit. One missing piece is a master plan for an enterprise-wide deployment to identify who is responsible for developing this vision and how the different needs of the different users will be met. This is currently under development.

History

Currently, the GIS Unit does not have a formal process or methodology for maintaining archived or historical information. Informally, some historical information may exist in select data sets, but these are usually on an ad hoc basis.

Established Protocols for Data Collection

Because of the lack of ability to use the data collected in the field and no direction from the central units, the field users have not collected a large amount of data that could be integrated. These protocols will be developed taking into consideration the end users needs.

Data Collection Issues

The NCDOT GIS unit does not have a problem with data collection issues, but rather the challenge comes with the processing of that data and the establishment of methodologies for maintaining said data.

Because of the lack of ability to use the data collected, there are no protocols in place for the updating the data.

Question 3*b*. What are the remaining significant issues for spatially integrating data for asset management decision makers across your organization?

Perhaps the biggest issue with spatially integrating data for asset management decision makers across our organization is the development and implementation of an enterprise spatial database that supports the NCDOT linear referencing standard.

Question 4*a*. What spatial information technology-enabled tools and products have you developed for user and management-level decision support for asset management? What products have proven most successful for asset management activities?

The NCDOT GIS unit has implemented a prototype application to assist the Division of Bituminous Operations (DBO) for Division 6. This prototype provides a means to connect and spatially view chip seal data. The initial phases of the project also included GIS assistance in developing digital planning zones based county boundaries.

The prototype itself merged certain road characteristic databases with the chip seal information. A custom tool was then developed to help select specific attributes from the merged spatial layer. However, this prototype was cumbersome and difficult to replicate on a statewide basis and this function will be absorbed into MMS and PMS.

Question 4*b*. What future product developments do you believe would provide the greatest benefits?

The future developments that would provide the greatest benefit are the implementation of the enterprise spatial database and the GIS application development environment. In addition, completion of the linear referencing attribution and reporting system (LARS) and the GIS/PMS integration module will allow the PMS to dynamically link to the current state road network. Finally, in terms of the data itself, the LRS effort currently underway in the GIS unit would greatly enhance the timelines and correctness of the underlying data.

Question 5. What roles or actions can national organizations undertake to help state and local transportation organizations improve the use of spatial information technologies for asset management?

GIS Needs

Perhaps the most help that national organizations can take in terms of assisting state and local transportation organizations is in the area of data modeling. A lot of attention has been paid to data models as they relate to an exchange standard, but it seems that less effort has been spent on a useful data model for an individual organization itself.

As technology advances occur at such a fast pace, it is even more important to develop and maintain transportation models that take full advantage of these advances.

Another area, which could be of great benefit, is increased opportunity and focus on establishing, sharing, and maintaining contacts and case studies from state and local transportation organizations.

Asset Management Needs

Case studies on how other states use GIS data for asset management and condition-based budgeting.

Strategies for integrating existing databases and management systems with GIS data with examples of what worked and what did not.

Peer exchanges where asset management and GIS practitioners have an opportunity to discuss issues and develop plans for improvement.

Summary of Agency Responses

JAMES P. HALL
University of Illinois at Springfield

James P. Hall presented a summary of the agency responses to the questionnaire. The previous agency sections provided specific examples of how individual agencies are using spatial information technologies to support and enhance asset management decision making and resource allocation. The following summarizes agency perceptions of the benefits, issues, and future directions.

QUESTIONS

What are the benefits to using spatial information technologies to support asset management?

Agencies identified a wide variety of benefits both internal and external to their organizations.

- Visualization for DOT personnel, managers, legislature.
- Enabling more complex analysis of data for decisions—e.g., program development—bundling of projects, intermodal.
- More sophisticated analysis—travel flow—modal direction, ramps.
- Enterprise integration of data sources for asset and modal evaluation.
- Intranet/Internet delivery of information.
- E-government capabilities—public access.
- Integration of external data.

Please describe the status of your current situation in the use of spatial information technologies to access and integrate data to support asset management decision-making activities.

Despite some successes, agencies are still struggling with data integration issues. Data quality issues of accuracy, timeliness and completeness are of increasing concern.

- Many agencies were using Arc/Info products in conjunction with an Oracle database.
- Wide variety of legacy systems and platforms.
- Data integration problems.
- Multiple linear referencing methods.
- Data quality, timeliness, accuracy problems—common and potentially critical issue.
- Problems in integrating more precise information, especially with future data collection.
- Need for more details in the data, e.g., specific bridge spans.

- Access to historical data was not typically spatially enabled within agencies.

What are the remaining significant issues for spatially integrating data for asset management decision makers across your organization?

Agencies generally acknowledged that asset management activities are enterprisewide and there are significant implementation issues in implementing an enterprise spatial data warehouse to serve asset management functions.

- Technical and organization difficulties in implementing an enterprise resource.
- Field data collection, validating, and updating—expensive, especially with large geographic coverage.
- Updating–validating road centerline.
- Integrating databases internal and external—different identifiers, timeframes, precisions.
- Limited established transportation models for analysis.
- Right of way and parcel map inaccuracies.
- Training and cultural issues of users, managers.
- Lack of consistent internal standards.

What spatial information technology-enabled tools and products have you developed for user and management-level decision support for asset management? What products have proven most successful for asset management activities?

- Web-based queries—internal for managers and districts.
- Static decision maps—public use, data verification.
- Dynamic decision-making products—what if analysis, primarily still under development.

What future product developments do you believe would provide the greatest benefits?

- Road centerline—verification, accuracy.
- Automated data collection processing.
- Data integration–conflation tools.
- More sophisticated web-enabled analysis tools.
- Economic analysis tradeoff models.
- More integration with nontransportation assets.
- Improved query products for use by non-computer-savvy managers, including use–accessibility while on the road.
- Enterprise implementation.

What roles or actions can national organizations undertake to help state and local transportation organizations improve the use of spatial information technologies for asset management?

- Share best practices—case studies, documentation, exchanges, website discussion.
- Promote open data architecture.
- Finalize NSDI efforts, North American Standard (NAFTA), Transportation Data Content Standard.
- Upgrade national data sources—better standards.
- Develop transportation models.
- Educate asset managers of capabilities.
- Gap analysis.

SUMMARY

In general, the responding agencies recognized the value of spatial technologies and had provided significant resources towards the development of spatially-enabled asset management products. The benefits included more sophisticated analysis of data and the development of powerful decision making products for internal and external access.

However, the agencies indicated there were still significant issues with the implementation of a true spatial data warehouse for developing comprehensive asset management products. These issues include data quality and accuracy, multiple spatial referencing methods, a lack of standards for interagency data sharing and limited models for asset management decision analysis.

Agency responders also recognized the roles of national organizations in sharing best practices and in promoting standards and open data architectures.

Major Issues and Research Directions for the Future

JAMES P. HALL
University of Illinois at Springfield

MAJOR ISSUES

Results of the completed questionnaires, and subsequent peer exchange discussions, provided insights into the application of spatial technologies to meet asset management practitioner needs. The peer exchange participants focused on three major key issue areas in moving spatial technology applications to the next level. These three key issues were managing change, integration, and communication as summarized in the following.

Managing Change

Both institutional and technology change are becoming a way of life for public-sector agencies. Managing change means looking for and implementing new ideas and technologies, and continuous training (from the technician to the chief executive officer).

Question 4 Part B identified some successful products with significant benefits. What is stopping agencies from adopting these immediately?

Integration

Data integration means different things to different people. The ability to use seamlessly consistent and appropriate data across applications is the ultimate objective. What does it take to move this concept forward? What tools and techniques are relevant to different organizations? What parts of this process do you have to customize to your particular application or organization? How do you develop good working relationships with other organizations?

Communication

Spatial information technologies provide rich opportunities for communication of information about the asset management process and an agency's assets. Are decision makers aware of these opportunities? Are the technical experts showcasing the tools? How do the technical experts know what the decision makers need? Is it trial and error?

BREAKOUT GROUPS

The breakout groups, as a community of practitioners and researchers, then focused on determining the actions necessary to see results in the next 2 years. The groups were also charged with identifying the pay-off for the asset management community including:

- Which experiences need to be shared with a broader audience and how?
- In which areas do agencies need help?

- Can we identify the benefits of focusing resources in these areas?

The following summarizes the key points of discussion and relevant questions resulting from breakout group discussions.

Integration of Spatial Data for Asset Management Systems

Organizational Issues

- Do we really need to integrate everything? How do agencies prioritize?
- There may be forces other than resources (time and funding) impeding the integration of data, e.g., turf, security
- How to integrate asset data to be able to show the financial implications of decisions over time?
- Why does integration take so long? Haven't we been talking about this for years?
- What are the legal implications of data integration (e.g., section 409)?
- Integration does not solve everything and can only produce a product as good as the inputs.
- Identify potential products to promote integration.
- Need a synthesis of state experiences in integrating data for asset management focusing on:
  - Where within the organization does the data reside, who does the integrating?
  - What works/does not work?
  - Identification of innovative methods, e.g., New York State's Critical Infrastructure Response Information System (CIRIS) Google-type search tool?

Technical Issues

- Standards are needed for data and system interfaces (not systems) but must be balanced with flexibility. Standards may also limit functionality of legacy systems, and costs may include loss of investment in previous systems (learning curve).
- How are temporal issues addressed? Static copies of base maps and archived history–attribute files? Can dynamic recreation of previous versions be used to speed the process, reduce data requirements and enhance access?
- How can financial systems be integrated with asset management spatial data?
- What are the implications of metadata standards on integration? Conversely, what is the value of (or risk of using) integrated data that have no metadata?
- What are the security implications of data integration?
- How do we get to comprehensive data integration (beyond bridges and pavements)—e.g., safety and economic development costs–values? Can these disparate forms of information be integrated?

Resource Issues

- Assuming integration can reduce redundancy of data and systems or increase productivity, who pays for preparing spatial data to be integrated? If costs exceed resources or benefits accrue to another group, how to provide incentive or shift resources?

- How much does integration cost and how long is it going to take?
- Magnitude of data integration efforts appear to be as large or larger than data collection costs, at least in the short run.

Managing Change

- Like "herding cats," there is really no solution.
- Process needs to be separated from the personalities.
- Need to sell the ideas – it is really about marketing.
- Education–training is important (particularly using demos for the policy decision makers).
- Focus needs to be on practical solutions not just neat ideas.
- The implementation of high-benefit, high-visibility products can help with managing change.
- Sharing of lessons learned.
- Make sure link between asset management and spatial data is in the asset management training course.
- Develop case studies of experiences.

Communication

- Need to build a field with common language.
- Education as well as communication.
- Identify what we have.
- Present to upper management, make sure they are informed.
- Communication is a two way street – listen to user needs
- Needs assessment.
- Information needs.
- Focus on products that promote communication.
- Market existing tools.
- Need a synthesis on what asset management means.
- Need for input from asset management subcommittee.
- Linking performance measures and remaining life with asset management.
- Showcase small pieces.

RESEARCH DIRECTIONS

Based on presentations from the three breakout groups, the peer exchange participants identified research to address three areas of interest:

- Temporal issues,
- Symbology, and

- Data and visualization models.

Temporal Issues for Asset Management

Asset management activities include the analysis of assets over time, in particular for performance assessment and forecasting purposes. As such, access to a spatially enabled historical information resource is needed. Asset management-related data attributes have a time period for which they are valid (more than just time stamping) and base maps are frequently used as snapshots to depict data from a given time. There is also a need to communicate resource requirements within the framework of what agencies plan to do and what they have accomplished.

Temporal issues also have a future component. Agencies need the capability to show the implications of decisions on the future conditions of assets. In short, agencies need to know where they are now; they need to know how they got there; and most importantly from an asset management perspective, they need to know how they will get to where they want to be in the future.

There was also discussion on the appropriate level of temporal data for asset management. Through examples, the participants noted that the intended uses of the data changed the degree of precision needed for temporal attributes. For instance, the timing of pothole repairs for an operations group might need to be recorded to the day or hour of the work for scheduling purposes. On the other hand, a budgeting group might only need temporal data recorded by month, quarter or year.

Some of the benefits of having temporal capabilities included legal implications. An example is fixing tripping locations on a sidewalk where the incident under litigation occurred 7 years prior. Transportation agencies need to be able to turn back the clock and know the condition of assets (and the corresponding liabilities) at that time.

Finally, the peer exchange participants discussed the need to investigate if anyone has already solved or partially solved the temporal issues with asset management-related data. One suggestion was to look at other areas such as utilities to see if they have developed transferable solutions to these types of problems.

Symbology

With advances in spatial technologies, and applications accessible via the Intranet/Internet, spatial views of information are growing in use across many transportation, government and public functions. The breadth of applications include program development, pavement management, and safety management.

It was suggested that there is a need for standardization of spatial symbologies to represent features to assist in understanding across a broad base of users, practitioners and managers. The symbology would incorporate a higher level view and more detailed query or feature classes. Participants noted that standard symbols should also have portability among multiple agencies such as states and local government agencies. Examples include the spatial display of multi-lane facilities, traffic categories, traveler information, congestion, and roadway crash characteristics in commonly accepted symbology formats.

A research synthesis could provide potential sources to guide this symbology development including cartographic legends, international standards, FHWA mapping guidelines, and utilities. It was suggested that the symbology should also accommodate persons with disabilities and meet appropriate standards. Other potential symbology sources noted include the ITS community, design standards, leading transportation agencies, natural resource agencies and possibly AASHTO standards.

Since many transportation agencies are currently developing these types of accessible spatial applications, standardized symbologies will enable agencies to address these issues early in the development process.

Data Models

Data modeling and visualization are important capabilities of spatial technologies. However, many agencies are searching for effective ways to analyze, model and display information to assist in complex asset management decision making.

The spatial access to information can be overwhelming with conflicting views of how to use the data. It is important for agency personnel develop methods to view the data for decisions on trade offs, gap analysis and network condition.

Basic questions that agencies can ask are: what is asset management in my agency, and what are we trying to model. This will help address the types of modeling to support specific functions. For example, forecasting mechanisms for condition assessment and program development can be powerful tools. However, many agencies are struggling to model the complexities of available data. It was noted that there is a need to take spatial data to the next level and produce outputs that answer complex questions and assist in programmatic choices.

Current efforts for modeling are at a smaller level of integration and agencies are using an incremental approach to develop products. However, with the increasing trend towards the enterprise integration of asset management related spatial data, many participants reported a need to develop corresponding analytical and modeling tools and techniques.

Some also noted a need to investigate what other agencies are using and to portray differences between state and local agencies.

Information Dissemination

The peer exchange, as a final effort, discussed how to disseminate the information on agency practices in these areas. While recognizing the need to increase the dialogue among practitioners, including across multiple levels of management, many participants were concerned about travel constraints. Several expressed satisfaction with NHI courses and FHWA's peer-to-peer programs but felt that more mechanisms are needed.

APPENDIX

List of Acronyms

AADT	Annual average daily traffic
ADOT&PF	Alaska Department of Transportation and Public Facilities
ALIS	Accident Location Information System (New York State)
AMHS	Alaska Marine Highway System
BMS	Bridge management system
CANSYS	Control Section Analysis System (KDOT)
CDS	Coordinated data system
CIRIS	Critical Infrastructure Response Information System (New York State)
CORS	Continuously Operated Reference Sites
CPMS	Capital Program Management System (NYSTA)
DBO	Division of Bituminous Operations (NCDOT)
DGPS	Differential Global Positioning Satellite system
DMI	digital measurement instrument
DOT	department of transportation
ELA	Enterprise Licenses Agreement
ESRI	Environmental Systems Research Institute, Inc.
FGDC	Federal Geographic Data Committee
FHWA	Federal Highway Administration
FMIS	Financial Management System (NCDOT)
FTRP	Framework Transportation Reference Points (NCDOT)
FTSeg	Framework Transportation Segments (NCDOT)
G1	Generation 1 FTSeg (NCDOT)
GIS	Geographic Information System
GIS-T	GIS for Transportation
GPS	Global Positioning Satellite
HAS	Highway Analysis System
HDP	Highway Data Port
HERS-ST	Highway Economics Requirements System–State Version
HPMS	Highway Performance Monitoring System
HSIP	Highway Safety Improvement Program (ADOT&PF)
IIIS	Infrastructure Inventory and Inspection System (NYSTA)
IT	Information Technology
KDOT	Kansas Department of Transportation
LARS	Linear Referencing Attribution and Reporting system (NCDOT)
LRS	Linear referencing system
M&O	Maintenance and Operations (ADOT&PF)
MMS	Maintenance management system
MPMA	Municipal Pavement Management Application (City of Edmonton)
NAFTA	North American Free Trade Agreement
NCCGIA	North Carolina Center for Geographic Information and Analysis
NCDOT	North Carolina Department of Transportation

NGS	National Geodetic Survey
NHS	National Highway System
NSDI	National Spatial Data Infrastructure
NYSDMV	New York State Department of Motor Vehicles
NYSDOT	New York State Department of Transportation
NYSOCSCIC	New York State Office of Cyber Security and Critical Infrastructure Coordination
NYSTA	New York State Thruway Authority
ODBC	open database connectivity
PBO	Plate Boundary Observatory
PMS	Pavement management system
RDMS	Roadway Data Management System (NYSDOT)
RPS	Real Property System (New York State)
RWIS	Roadway Weather Information Systems
SLIM	Spatial Land Inventory System (City of Edmonton)
RITA	Research and Innovative Technology Administration of the USDOT
ROW	right-of-way
UNETRANS	Unified Network-Transportation
USDOT	U.S. Department of Transportation
VMT	vehicle miles of travel

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