CONFERENCE PROCEEDINGS 31

Geospatial Information Infrastructure for Transportation Organizations

Toward a Foundation for Improved Decision Making

Committee on Multimodal Transportation Requirements for Spatial Information Infrastructure

TRANSPORTATION RESEARCH BOARD
OF THE NATIONAL ACADEMIES

TRANSPORTATION
RESEARCH BOARD
WASHINGTON, D.C.
2004
www.TRB.org

Transportation Research Board Conference Proceedings 31
ISSN 1073-1652
ISBN 0-309-09468-2

Subscriber Category
IA planning and administration

Transportation Research Board publications are available by ordering individual publications directly from the TRB Business Office, through the Internet at www.TRB.org or national-academies.org/trb, or by annual subscription through organizational or individual affiliation with TRB. Affiliates and library subscribers are eligible for substantial discounts. For further information, contact the Transportation Research Board Business Office, 500 Fifth Street, NW, Washington, DC 20001 (telephone 202-334-3213; fax 202-334-2519; or e-mail TRBsales@nas.edu).

Printed in the United States of America.

The conference was sponsored by the Bureau of Transportation Statistics of the U.S. Department of Transportation.

Committee on Multimodal Transportation Requirements for Spatial Information Infrastructure
Ysela Llort, Florida Department of Transportation, Chair
David S. Ekern, Idaho Department of Transportation
Kathleen L. Hancock, University of Massachusetts, Amherst
Robert C. Johns, University of Minnesota
Brian C. Logan, Kansas Department of Transportation
Xavier R. Lopez, Oracle Corporation
Harvey J. Miller, University of Utah
Randall J. Murphy, Consultant
Michael J. Shiffer, Chicago Transit Authority
James M. Sims, Southern California Association of Governments (retired)
Wayne Watanabe, King Metro Transit
Francis M. Winters, Jr., New York State Department of Transportation

Transportation Research Board Staff
Mark Norman, Director, Technical Activities
Thomas M. Palmerlee, Transportation Data Specialist
Frederick N. Scharf, Program Assistant

TRB Publications Office
Norman Solomon, Senior Editor
Jennifer Correro, Proofreader
Jennifer J. Weeks, Senior Editorial Assistant
Juanita Green, Production Manager

Cover image: Orthophotograph of Chicago, Illinois, Loop with overlays of several Chicago Transit Authority bus and rail routes. (Courtesy of Chicago Transit Authority.)

THE NATIONAL ACADEMIES

Advisers to the Nation on Science, Engineering, and Medicine

The **National Academy of Sciences** is a private, nonprofit, self-perpetuating society of distinguished scholars engaged in scientific and engineering research, dedicated to the furtherance of science and technology and to their use for the general welfare. On the authority of the charter granted to it by the Congress in 1863, the Academy has a mandate that requires it to advise the federal government on scientific and technical matters. Dr. Bruce M. Alberts is president of the National Academy of Sciences.

The **National Academy of Engineering** was established in 1964, under the charter of the National Academy of Sciences, as a parallel organization of outstanding engineers. It is autonomous in its administration and in the selection of its members, sharing with the National Academy of Sciences the responsibility for advising the federal government. The National Academy of Engineering also sponsors engineering programs aimed at meeting national needs, encourages education and research, and recognizes the superior achievements of engineers. Dr. William A. Wulf is president of the National Academy of Engineering.

The **Institute of Medicine** was established in 1970 by the National Academy of Sciences to secure the services of eminent members of appropriate professions in the examination of policy matters pertaining to the health of the public. The Institute acts under the responsibility given to the National Academy of Sciences by its congressional charter to be an adviser to the federal government and, on its own initiative, to identify issues of medical care, research, and education. Dr. Harvey V. Fineberg is president of the Institute of Medicine.

The **National Research Council** was organized by the National Academy of Sciences in 1916 to associate the broad community of science and technology with the Academy's purposes of furthering knowledge and advising the federal government. Functioning in accordance with general policies determined by the Academy, the Council has become the principal operating agency of both the National Academy of Sciences and the National Academy of Engineering in providing services to the government, the public, and the scientific and engineering communities. The Council is administered jointly by both the Academies and the Institute of Medicine. Dr. Bruce M. Alberts and Dr. William A. Wulf are chair and vice chair, respectively, of the National Research Council.

The **Transportation Research Board** is a division of the National Research Council, which serves the National Academy of Sciences and the National Academy of Engineering. The Board's mission is to promote innovation and progress in transportation through research. In an objective and interdisciplinary setting, the Board facilitates the sharing of information on transportation practice and policy by researchers and practitioners; stimulates research and offers research management services that promote technical excellence; provides expert advice on transportation policy and programs; and disseminates research results broadly and encourages their implementation. The Board's varied activities annually engage more than 5,000 engineers, scientists, and other transportation researchers and practitioners from the public and private sectors and academia, all of whom contribute their expertise in the public interest. The program is supported by state transportation departments, federal agencies including the component administrations of the U.S. Department of Transportation, and other organizations and individuals interested in the development of transportation. **www.TRB.org**

www.national-academies.org

Contents

Preface

As a basis for advancing sound decision making, the Bureau of Transportation Statistics (BTS) of the U.S. Department of Transportation (USDOT) is committed to developing high-quality transportation data and information. With the understanding that geospatial data provide an important infrastructure for managing and integrating information necessary for informed decision making, BTS asked the Transportation Research Board to conduct a project to provide recommendations for improving geospatial information infrastructure among and across all modes of transportation.

The objectives of this project were to (*a*) characterize the current practice in geospatial information technologies in transportation organizations; (*b*) identify problems and opportunities in coordination, communication, and cooperation on geospatial information among transportation modes; (*c*) suggest mechanisms for the development, management, and coordination of geospatial information technologies throughout USDOT; and (*d*) recommend approaches for enhancing geospatial information within transportation organizations. The intent is to provide recommendations to transportation agencies, primarily at the federal level but also at the state and local levels, to enhance decision making through rethinking institutional roles and responsibilities; building capacity and commitment; and augmenting the creation, sharing, and use of geospatial information.

To prepare this report, the committee drew on information presented at three workshops held in three cities during 2002 and on committee research and deliberations during and after the workshops. The workshops were cosponsored by the American Association of State Highway and Transportation Officials (AASHTO). The first workshop, held in Chicago in May 2002, examined the role of geospatial data in the project delivery process. The second workshop, held in Seattle in June 2002, focused on safety, security, and mobility. In each of these workshops, committee members provided background material on the state of the art, and speakers presented subject matter on the use of geospatial technology related to their mode, organization, and discipline. The third workshop, held in Washington, D.C., in October 2002, reviewed current activities of the modal administrations within USDOT in using the Global Positioning System, geographic information systems, and remote sensing to make decisions. Representatives of each modal administration were invited to present their perspectives. All three workshops included ample time for discussion of the issues through breakout sessions designed to provide feedback to the committee.

The committee met in December 2002 to review the workshop results and draft a summary report to address the mission and objectives of the project. This document is the result of that meeting.

The report commences with an executive summary, which briefly summarizes the importance of geospatial information in decision making and the recommendations resulting from this project. This is followed by a presentation of selected current practices, trends in decision-making tools, and a detailed discussion of the committee's findings and recommendations. The report concludes with a call to action to all decision makers to take responsibility for ensuring that decisions are made with the best information possible.

This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the Report Review Committee of the National Research Council (NRC). The purpose of this independent review is to provide candid and critical comments that will assist the authors and NRC in making the published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process.

The committee thanks the following individuals for their review of this report: James Altenstadter, Pima County Association of Governments, Tucson, Arizona; Michael F. Goodchild, University of California, Santa Barbara; Michael McNerney, DMJM Aviation, Fort Worth, Texas; Brian Rowback, New York State Department of Transportation, Buffalo; William G. Schuman, Iowa Department of Transportation, Ames; and Joseph M. Sussman, Massachusetts Institute of Technology, Cambridge. Although these reviewers provided many constructive comments and suggestions, they were not asked to endorse the committee's conclusions or recommendations, nor did they see the final draft of the report before its release.

The review of this report was overseen by C. Michael Walton, University of Texas, Austin. Appointed by NRC, he was responsible for making certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authoring committee and the institution.

The committee thanks the many individuals who contributed to this study, especially committee member Kathleen L. Hancock, who took the lead in consolidating much of the committee's work. The support of AASHTO in organizing the three workshops was instrumental in ensuring strong representation from state departments of transportation.

Executive Summary

Making well-informed, responsible decisions is critical to shaping the nation's transportation infrastructure. Geospatial data are a foundation for relevant and critical information for planning, engineering, asset management, and operations associated with every transportation mode at all levels of government and administration. One definition of geospatial data is found in the executive order on coordinating geographic information and access: "'Geospatial data' means information that identifies the geographic location and characteristics of natural or constructed features and boundaries on the earth. This information may be derived from, among other things, remote sensing, mapping, and surveying technologies. Statistical data may be included in this definition at the discretion of the collecting agency."[1] Extracting these data, transforming them, and making them available to decision makers has dramatically increased in importance as all modes and levels of government face increasing responsibility for improving efficiency while maintaining mobility, improving safety, and anticipating and addressing security threats.

The supporting information used in this project was primarily obtained from three workshops held in three cities during 2002. The first workshop, held in Chicago in May 2002, examined the role of geospatial data in the project delivery process. The second workshop, held in Seattle in June 2002, focused on safety, security, and mobility. The third workshop, held in Washington, D.C., in October 2002, reviewed current activities of the modal administrations within the U.S. Department of Transportation (USDOT) in using geographic information systems (GIS), the Global Positioning System, and remote sensing to make decisions. Representatives of each modal administration were invited to present their perspectives. All three workshops included ample time for discussion of the issues through breakout sessions designed to provide feedback to the committee.

The committee offers a series of findings that have been divided into three areas:

- Institutional roles and responsibilities,
- Capacity and commitment building, and
- Geospatial information.

Recommendations based on these findings address strategies to enhance the interoperability of geospatial information among and across modal and multimodal transportation organizations and are addressed to USDOT. While all transportation organizations need to embrace geospatial technologies to improve decision making, the committee believes that USDOT needs to take a leadership role for the transportation system as a whole. Likewise, each modal administration should develop capabilities to use these technologies and provide leadership within its mode. Because the committee believes that many of the greatest payoffs can come

[1] Executive Order 12906, published in the April 13, 1994, edition of the *Federal Register*, Vol. 59, No. 71, pp. 17671–17674. Amended by Executive Order 13286, published in the March 5, 2003, edition of the *Federal Register*, Vol. 68, No. 43, pp. 10619–10633. See also www.fgdc.gov/publications/documents/geninfo/execord.html, Coordinating Geographic Data Acquisition and Access: The National Spatial Data Infrastructure.

from improving the efficiency of the multimodal transportation system as a whole, coordination of geospatial technology initiatives within USDOT is essential. That is a role that the Bureau of Transportation Statistics has begun to play. The committee believes that this leadership role within the department and within the transportation community needs to be strengthened with adequate resources, formal departmental recognition, and management support.

Although the recommendations resulting from this project are specifically addressed to USDOT, they can apply to all levels of decision making and should be considered by every agency and decision maker as they relate specifically to each environment. The findings are summarized below; the recommendations are discussed in detail in Chapter 4.

Institutional Roles and Responsibilities

The roles and responsibilities of decision makers must evolve if we are to leverage geospatial information and tools to best advantage. This entails building and maintaining different relationships and enabling new and creative ways to do business. To accomplish this,

- The role of government should shift from implementer to facilitator/enabler and role model, allowing agencies to become more flexible and responsive;
- Different relationships should be established, both horizontally across functions and vertically across levels of government and the private sector, to ensure that resources are used most effectively;
- The transportation sector should play an active role in national and international activities associated with the establishment of standards and other data exchange and outreach initiatives; and
- Current project-based data acquisition should be transformed into a systematic activity for building and sustaining a geospatial information infrastructure.

Capacity and Commitment Building

The ability of organizations to apply geospatial information technologies to improve transportation is dependent on the awareness and appreciation of an organization's leaders, the level of knowledge of staff, the development of human capital, and the advancement of the geospatial infrastructure for use by an organization. To ensure that these abilities are leveraged,

- Assistance should be provided to agencies to incorporate technologies into their day-to-day operations and, as necessary, expand and modify their business processes to capitalize on these technologies;
- Current and future transportation professionals at all levels should be well grounded in geospatial information concepts and should continually update their knowledge and skills in geospatial information technology;
- Techniques, tools, and innovative approaches for using geospatial information and technologies should be disseminated to transportation professionals quickly and effectively; and
- The state of the art of geospatial information technology should be advanced by developing fundamental knowledge that influences long-term technological innovations in the use of geospatial information for transportation.

Geospatial Information

Geospatial information and technology are a critical part of the transportation infrastructure. With the emergence of GIS from static map production to near-real-time decision support, the availability and accessibility of hardware and software tools that manage voluminous databases, and the availability of more and more data, increased interoperability and the necessary infrastructure to support that interoperability are critical to positioning agencies to take advantage of these capabilities. To advance the use of these tools,

- Different levels and types of transportation organizations need to combine geospatial information to improve decision making and resource allocation; and
- A mechanism needs to be provided for transportation stakeholders to access information and policies for all levels, modes, and application areas of transportation.

Information, and the data and technologies that support and generate it, is not without cost. However, it should be viewed as infrastructure that is just as necessary as bridges, ports, runways, rails, and roads. Its cost is minimal compared with the potential for what one speaker described as "billion-dollar bonehead decisions" that could occur without adequate information. To ensure that we make the best decisions possible, we need to support the information infrastructure, or we will find ourselves without the means to make the necessary decisions.

Chapter 1
Foundation for Action

Making well-informed, responsible decisions is critical to shaping the nation's transportation infrastructure. Geospatial data are a foundation for relevant and critical information for planning, engineering, asset management, and operations associated with every transportation mode at all levels of government and administration. Extracting these data, transforming them, and making them available to decision makers have dramatically increased in importance as all modes and levels of government face increasing responsibility for improving efficiency while maintaining mobility, improving safety, and anticipating and addressing security threats.

Geospatial data are everywhere and pervade virtually all aspects of daily life. However, they do not stand alone as something that can be seen, touched, or felt. Instead, they work in concert with a family of technologies that result in society being served and enhanced in new and different ways. This family of tools ranges from decision-support systems that are used for top-level decision making to systems for collecting and processing data.

This report is a call to action and includes a recommended program to enable transportation leaders, administrators, planners, and operators to leverage the full benefits of geospatial information, its family of tools and technologies, and the professionals who use them for making informed decisions.

Geospatial data can enhance transportation user mobility, safety, and security. When professionals combine the data with current tools and technologies, the promise demonstrated over the last 10 years for improved efficiency in planning, policy development, asset management, and operations can be realized. Now is the time to move from experimentation and limited application to widespread and integrated use. The theme and vision presented in this report focus on steps to expedite deployment and institutionalize geospatial data as a fundamental part of the business model for the 21st-century transportation agency.

On the basis of the presentations and its deliberations, the committee concluded that to respond to a world in which data and technology are evolving more rapidly than the institutions that use them, a new model for development and use of geospatial information by the transportation system is needed. In this changing world, the perception of the federal role needs to shift from decision maker and implementer to leader and facilitator. The actions necessary to make widespread use of geospatial data in a systematic way could be achieved through a focused alliance and collaboration among public, private, and academic communities. A key is in recognizing that the role of federal agencies is to enable state and local agencies and the private sector to carry out their missions. A practical role, rather than to mandate data requirements, would be to solicit data from data owners and providers and to encourage data sharing among agencies, users, and decision makers. As customer expectations and management requirements for more timely data increase, especially in areas like security, organizations will need to develop arrangements for sharing real-time information.

Sharing data for the sake of sharing is not an effective strategy. Alliances and collaboration should be based on careful analysis of potential benefits and

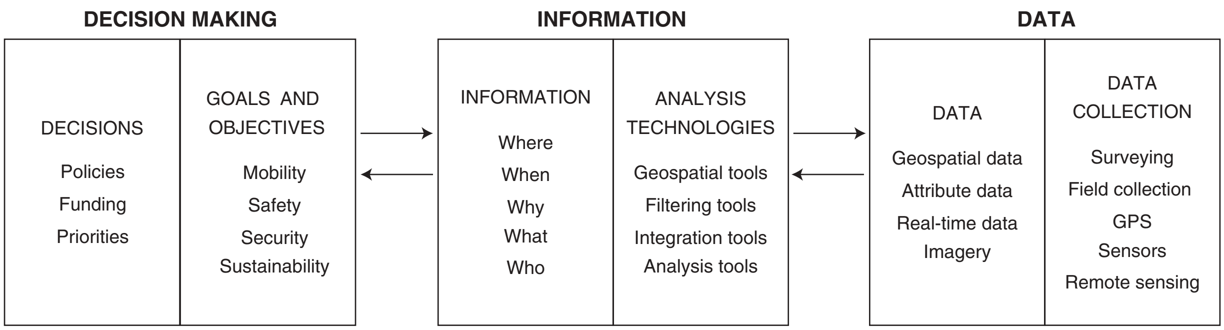

FIGURE 1-1 Data to decisions (GPS = Global Positioning System).

responsibilities of potential partners. Resources are limited. Maintaining effective relationships requires resource commitments that must be justified to taxpayers and investors. Providing workable standards, protocols, and documentation is not without cost, so the benefits to all stakeholders must be clear. Organizations and customer expectations are transitioning from systems that provide data for "snapshots" at certain times to more dynamic requirements like 511 systems. Business processes that focus on the ultimate service or products provided, not on improving the efficiency of current practices, must evolve.

Understanding how geospatial technologies can be implemented within and across agencies and recognizing the costs and benefits of doing so will advance this transition. Geospatial data underpin decision making and are a part of the transportation infrastructure requiring sustained, continuous funding. When managers, decision makers, and policy setters consider issues in combination with the resources they have, they must be able to recognize the benefits of geospatial data and technologies. The burden of providing this knowledge in an easily comprehensible manner falls largely on the providers of the data and technology. Funding becomes available if a compelling case is made to the people who control the funds. Geospatial data and technology providers must effectively inform funding providers of both the value of these technologies and, more important, the cost of making decisions without them. Success stories, lessons learned, research results, and cost–benefit analyses, to name a few examples, must be developed, published, and promoted for this to happen.

Enhanced coordination among related efforts must also be encouraged. Such coordination can be stimulated from above, from below, and from the sides, but it seldom comes from within. This may be because an individual, a department, or an agency is motivated to meet its own objectives with its own limited resources. Coordination or sharing of data and technologies typically draws from these resources. Without a mandate from above, peer pressure, or the support of practitioners, little coordination or sharing appears to occur. Awareness and understanding can promote coordination as more people recognize the positive results that can accrue.

Providers of transportation, the delivery system for economic viability, are under increasing pressure from multiple fronts—the need to maintain mobility, improve safety, and anticipate and address security threats, and to do so more efficiently and with increasingly limited resources. The diversity and complexity of these demands require a comprehensive understanding of the issues facing decision makers. This understanding, in turn, requires multiple sources of data that are accurate, timely, and usable; the tools and technology to integrate these data into the information necessary to support responsible decision making; and the necessary business processes to make the best use of these data and technologies. Figure 1-1 illustrates how, from one direction, good decisions rely on a solid foundation of data collection, while from the other direction, data that are collected must be robust enough to provide the foundation for sound decision making.

The past decade has shown that it is impractical for federal and state transportation agencies to collect, maintain, and develop comprehensive geospatial data sets to support broad decision-making activities. A more viable approach appears to be to encourage agencies—public or private—that are closest to the source to collect and maintain data necessary for their missions and to facilitate sharing of these data while developing the expertise to integrate them into broader decision-support environments. Sustained leadership and funding for collecting, maintaining, processing, and sharing data are important to this approach. In an environment where leadership is changing more frequently, educating leaders is an increasing challenge requiring both analysis of the utility of more comprehensive data and regular communication with leadership on those benefits.

Chapters 2 and 3 provide a series of representative current practices related to geospatial information and their present use in decision making within select transportation agencies. A view of what can be expected from geospatial tools and technologies in the future and how these might affect transportation decision making is presented. Chapter 4 sets forth findings and recommendations with regard to institutional roles and responsibilities, capacity and commitment building, and geospatial information infrastructure. Chapter 5 renews and emphasizes the call to action supported by this report.

Chapter 2
Current Decision Making Using Geospatial Information

Transportation decisions range from simple, straightforward decisions to complex multimodal, multijurisdictional, multilevel decisions. Prioritizing road repairs requires knowing where repairs are needed and what measures to use for prioritization. The necessary information is probably collected and maintained by the office that makes these decisions. Identifying possible transportation corridors between Canada and Mexico requires information from multiple modes, jurisdictions, levels of government, and other stakeholders. The comprehensive data that are required by decision makers to make effective decisions must come from multiple sources with varying degrees of interpretation, integration, and analysis from each of those sources. These data must then be integrated to provide the necessary information for making informed decisions. An effective data integrator is geographic location, which is the core of geospatial information.

Currently, the level at which different sources of information are combined and integrated is primarily a function of the day-to-day operating activities of decision makers. Figure 2-1 provides a schematic of one way to consider the different areas in the transportation decision-making structure. In most current structures, interaction among levels is limited to day-to-day requirements usually focusing on particular modes, jurisdictions, and functional areas. Because resources for all participants are constrained, transportation agencies are beginning to identify strategic partners to provide and integrate data for a broader systems approach to decision making. To support optimization of the multimodal capacity of the transportation network, information should flow smoothly along paths identified as critical on each of the three axes. These interactions should be expanded and enhanced to provide the necessary information for effective and informed decision making.

The following sections provide examples of how transportation professionals currently use geospatial information. The examples were selected to demonstrate both the limitations and the potential for geospatially based decision making as it is currently applied in a wide variety of types and levels of organizations.

National Perspective for Aviation

Over the past decade, the challenge of increasing capacity while maintaining safety has been one of the most important facing the aviation industry. The challenge was intensified by a healthy economy in the late 1990s, growing urban densities, and a society increasingly reliant on air transportation. To meet it, the federal government increased funding for airport improvement projects, spurring much of the current construction at airports nationwide. Not surprisingly, however, these initiatives have brought their own challenges, including heightened public concern about aircraft noise and emissions, a need for improved coordination of the vast activities at airports, and a need for better planning with surface transportation modes.

The Federal Aviation Administration (FAA), airports, and industry responded by working together to improve

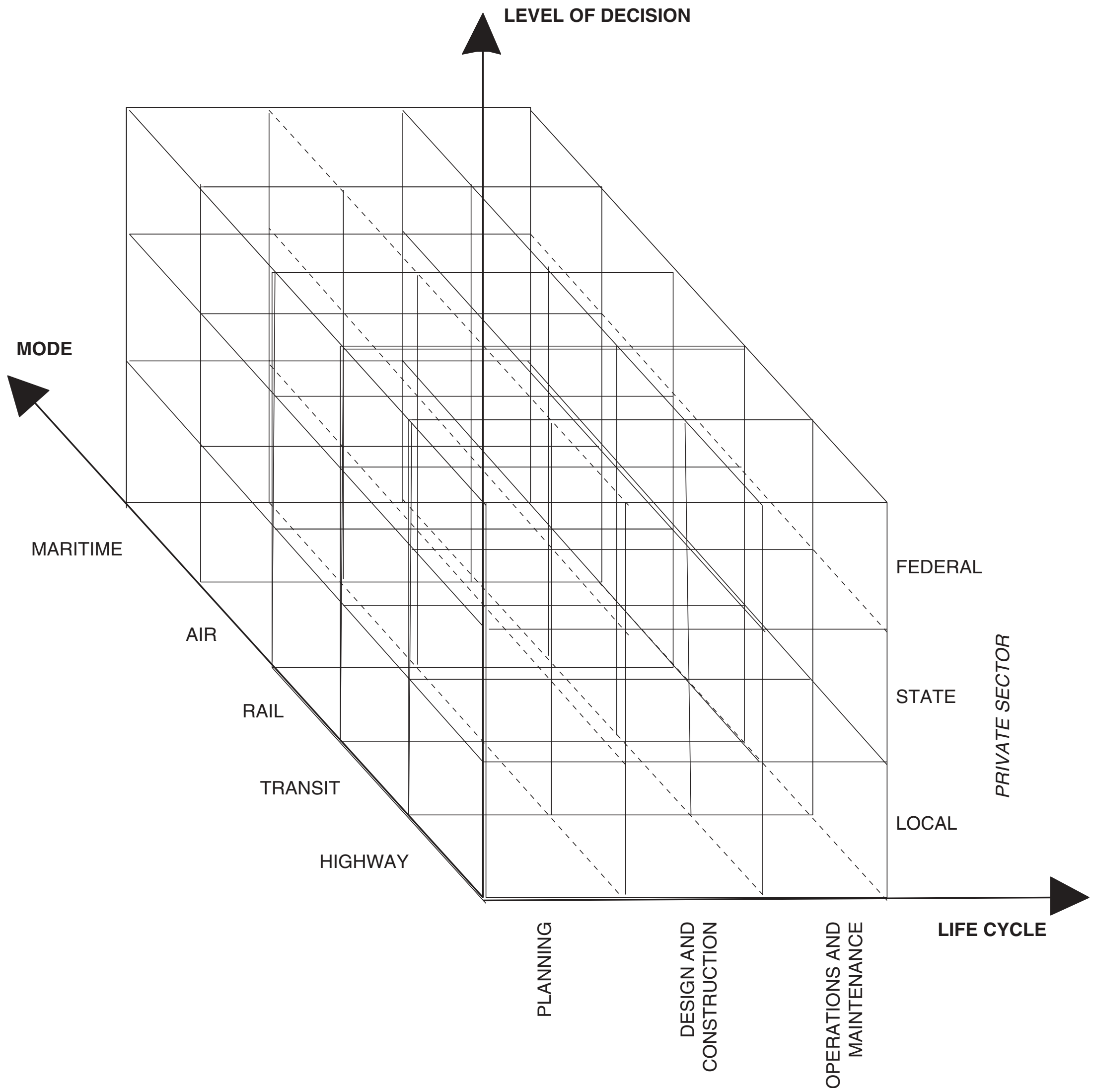

FIGURE 2-1 Transportation decision-making schematic.

the operating capacity of existing infrastructure while maintaining a high level of safety. Examples of initiatives include the use of the Global Positioning System (GPS) to help navigate aircraft and increased information about aircraft movements on the ground to reduce runway incursions. These initiatives are vital to FAA because, in addition to its safety, certification, and regulatory roles, FAA has operational responsibility for 30,000 commercial flights that move more than 2 million passengers each day through U.S. airspace.

The events of September 11, 2001, heightened the focus on improving security at airports and presented many new challenges. Existing facilities need to be reconfigured to accommodate new equipment and security restrictions, which is a technical and logistical challenge. Developing and implementing new processes and procedures, not to mention recruiting and training staff, are organizational challenges that have consumed the attention and budgets of decision makers.

The economic downturn has also brought new challenges to the aviation industry. With major air carriers in bankruptcy and airports struggling with constrained budgets, the industry faces significant financial challenges. The result has been staff reductions and project delays at many airports.

The challenge of increasing airport security—in addition to increasing capacity, addressing environmental concerns, and maintaining safety in an environment of reduced financial resources—requires the aviation industry to make better decisions with fewer resources.

Current Practice

Information technologies, specifically geospatial data technologies, are helping aviation decision makers to do this by increasing their understanding and decision-making capabilities. Providing pilots with electronic airport maps in the cockpit, giving airport managers a comprehensive view of the facilities they manage, highlighting underground utilities to construction crews, and describing FAA height restrictions to local zoning boards are examples of how geospatial data and technologies have helped.

Geospatial data and technologies are improving decision making at two levels. First, geospatial data and analytic tools at the desks of airport and FAA decision makers have allowed them to do more. An example is the FAA Obstruction Evaluation/Airport Airspace Analysis program, which helps FAA staff members evaluate potential airspace obstructions, such as a high-definition television tower in the vicinity of an airport, on the basis of electronic information submitted by developers in conjunction with a variety of FAA data sets. With the system, data collection work and response times are reduced, and existing staff can better keep up with increasing numbers of inquiries.

Second, geospatial data and technologies have helped bridge the gap between departments and organizations that have data relevant to each other. A good example is the technical and organizational connection between the city of Chicago and O'Hare International Airport's Geographic Information System (GIS) departments. Data concerning roads, transit, municipal jurisdictions, parcels, and so forth, which are needed for planning and development purposes, are seamlessly available to staff members at O'Hare. Conversely, the airport's investment in a differential GPS (DGPS) base station to support aircraft navigation may become helpful to city snowplow and work crews, who rely on knowledge of the location of their vehicles and equipment.

Challenges

The most significant barrier to the deployment of geospatial data and technologies to help the aviation industry make better decisions with fewer resources is lack of awareness and understanding. Too few FAA and airport managers realize the value that geospatial data and technologies can bring to their organizations. This is not surprising, because the implementation of geospatial data and technologies within the aviation sector is still in its infancy. The current lack of forums to share successes, written case studies, cost–benefit analyses, and aviation participation on key geospatial committees contributes to this problem.

Limited funding to develop and deploy geospatial data and technology is also a barrier. Substantial funds are spent on development and maintenance of aviation infrastructure, but little is spent on development or maintenance of the data that are an essential component of this infrastructure. The result is a reduced ability to maximize the level of service provided by that infrastructure over its life cycle. To make matters worse, data collection efforts are often duplicative due to lack of coordination, and the resulting data sets are often poorly maintained due to a lack of understanding of how and why maintenance should be done. Simply put, a disproportionately small amount of funding is available for geospatial data, and the funds that are available are not spent effectively.

Lack of federal coordination, leadership, and support has also constrained the adoption of geospatial data and technology in the aviation sector. For example, many airports have moved forward with their own geospatial data standards. In each case, funds have been consumed, and a unique solution to a universal problem has been developed. Until recently, little or no attempt has been made to coordinate these efforts. Fortunately, the GIS Working Group of FAA's National Airspace System Information Architecture Committee, the Standards Working Group of the American Association of Airport Executives' GIS Subcommittee, the Bureau of Transportation Statistics' Air Model Advisory Team, and FAA's Airport GIS Project have begun to address this problem. FAA is also embracing the e-government philosophy and is actively supporting better data management and sharing. Coordination among these groups is just beginning, however, and ongoing assistance is needed from above.

Summary

The use of geospatial data and technologies within the aviation sector is in its infancy, especially in comparison with other modes such as road transportation. However, aviation has reached a critical juncture as enough "grassroots" initiatives at FAA and airports have demonstrated the potential of the technology and FAA management, key associations, and an increasing number of airports have taken notice. Meeting the challenge to coordinate and communicate horizontally among agencies and vertically among FAA, airports, and municipalities will help the sector "do more with less."

Geospatial data about airports are a national asset critical for operational, safety, and security purposes. The meticulous nature of the aviation industry has created a plethora of data sources. Lack of data on individual activities is not the problem. The problem lies in the collection, coordination, and dissemination of the data and the ability to integrate disparate data sets to form a resource that can be used by FAA, the Department of Homeland Security, airports, and other stakeholders. This presents an opportunity for airports and FAA to improve the way they work with geospatial data.

A similar opportunity exists with regard to geospatial technology. Because aircraft and airport operations are carried out in a similar way throughout the country, and the world for that matter, tools and enabling procedures with wide appeal can be developed. Standards, implementation guidelines, data creation procedures, common interface designs, and so forth are all areas where coordination of development will lead to economies of scale that will enable many aviation organizations to more fully tap the potential of geospatial data and technology.

State Perspective for Highways

Several challenging issues face the managers of the nation's highway networks. The economic health of a region is directly linked to mobility. The performance of the highway network is more critical now than it was even 5 years ago. Highway managers are faced with challenges to provide 24/7 services and information availability for road and lane closures, the need for increased coordination, limited resources, reduced enterprise focus, and the need to address multiple concerns with capital improvement projects. Gone are the days of solving congestion problems simply by building more lanes.

Incidents must be cleared quickly, and many organizations participate in mobility concerns. The next few paragraphs describe examples of how geospatial analysis and GIS are providing a decision-support environment that is working well to help meet the needs of highway agencies. The examples are taken from current work flows in planning and design. Finally, the section "Challenges" illustrates a few areas of untapped potential.

Current Practice

Two areas that have relatively mature geospatial technologies are planning and design.

Planning

Decision making using geospatial technologies and data plays a big role in allowing highway organizations to meet changing demands. In the past, one group would process traffic crash data and propose priority safety improvements. Another group would examine pavement or bridge data, still another would focus on mobility and congestion data, and so forth. Each group would advance capital improvement plans. Now these competing opportunities can be overlaid and analyzed in GIS. That is being done in many organizations. The result is better, more efficient highway improvement plans that address multiple opportunities and optimize investments. Another key improvement has been the ability to more carefully target road and lane closures to perform multiple activities while traffic is diverted. The overlay of geospatial and temporal highway improvement plans makes this possible. This functionality can be delivered not just to technicians but also throughout the organization, including top decision makers. Geospatial analysis and GIS help to integrate the parts of the investment process, not just data.

Design: The Data-Hungry Highway and Bridge Design Process

In the past, a disconnect existed between geospatial analysis and highway design. This was due largely to the high precision requirements of the design process. The relationship between mapping scale and cost is not linear. The cost of collection and storage of data often increases geometrically as the accuracy of the data increases. Mapping the entire road network at a scale suitable for highway and bridge design has not been practical. Now, designers are finding the GIS environment useful, not for a geographic base on which to start a design, but rather for its power in data retrieval and information integration. Designers still need to build plans on the basis of photogrammetric or surveyed base maps. The supporting information needed for proper design work is then drawn from GIS. The combination of statewide (relatively) high-resolution orthophotographs and georeferenced photolog images has provided new ways of observing the highway system. Some of the data needed for design that required trips to the field in the past can now be observed from the desktop. All of the metrics used to advance a highway project to the design stage are important to ensure that the results of the design address the concerns that made the project important in the first place. These include environmentally sensitive areas, accident rates, traffic volumes, bridge and highway inspection results, population trends, and more. In the past, gathering, compiling, and analyzing this information were resource intensive. Today, this information is easily consolidated in a GIS environment, once an organization has made the significant investment to develop the technology and data infrastructure to generate compatible data.

Challenges

Data Life Cycle

The data life cycle of the highway network needs to reflect more closely the life cycle of the highway itself. For example, when a new highway is planned, location data are defined. Then when the project is designed, detailed computer-aided design (CAD) data are created. Once the project is completed and maintenance activities are ongoing, better mechanisms are needed for using the best geospatial representation without overwhelming users or computer systems. Existing CAD data are so detailed and voluminous that trying to use them in a standard GIS environment has been a bit like taking a drink from a fire hose.

Partnerships and Expanded Enterprise

Transportation agencies operate much less independently than they did in the past. To meet performance and reliability goals, transportation agencies must partner with local governments, police agencies, private companies, and others. Better mechanisms are needed to efficiently share all data, including real-time data, outside the agency computer networks. Web-based GIS environments hold promise as transportation agencies expand what is considered the enterprise.

Summary

As demands increase and resources do not, transportation agencies can no longer afford to produce single-purpose data sets. Agencies must build critical mass in data maintenance among multiple participants. This increases the start-up time of data development projects, because the needs of the various participants must be considered. Partnering that includes the private sector is necessary for the long-term sustainability of the data needed to support decision making.

Data Provider Perspective for Maritime Transportation

The mission of the National Oceanic and Atmospheric Administration (NOAA) is to describe and predict changes in Earth's environment and conserve and wisely manage the nation's coastal and marine resources. This task consists of seven strategic goals; the primary one relating to transportation is to promote safe navigation. About 3,500 ships annually are involved in accidents on the nation's waterways, and the stress on the nation's ports continues to increase substantially. During the last 50 years ships have doubled in size, and oceangoing commerce has tripled. By weight, more than 76 percent of U.S. international merchandise trade, or more than $500 billion annually, is waterborne.[1] Much of this cargo consists of hazardous materials. As the capacity of cargo ships continues to rise from earlier ships that held about 1,700 twenty-foot equivalent units (TEU) to vessels of today that hold more than 7,500 TEU, stress on U.S. waterways, ports, and landside rail and highway facilities continues to rise. The capacity of passenger vessels has grown as well. The increases lead to more urgent requirements for accurate and intelligent data.

Current Practice

The primary product of the National Ocean Service (NOS) is the nautical chart. Bowditch defines a nautical chart as a conventional representation of a navigable portion of the surface of the Earth on a plane surface. It shows the depth of water, aids to navigation, dangers, and the outline of adjacent land and land features that are useful to the navigator and is intended primarily for marine navigation. Basically, the nautical chart is a repository of several data types collected by using a variety of different techniques of differing levels of quality. Charting material consists principally of dredged channel data supplied by the U.S. Army Corp of Engineers, aids to navigation from the U.S. Coast Guard, topographic and hydrographic surveys made by NOS, and miscellaneous surveys and textual information provided by other government and private organizations. All material must be critically examined, with particular attention directed to the actual date of the survey, geographic datum, depth unit, plane of reference, purpose, and quality of the survey.

Electronic chart display and information systems can use georeferenced databases (electronic navigational chartes) of attributed objects capable of performing programmed behaviors, with DGPS to provide a navigational tool that can plot a vessel's course and provide information to mariners as they navigate through a given area. These smart data are used to alert mariners to potential problems.

Challenges

In February 2001, fog closed the Houston Ship Channel to inbound traffic, leading to a backlog of almost 80 ships at one point. Fog delayed the unloading of crude

[1] Bureau of Transportation Statistics, *Pocket Guide to Transportation*, 2004, p. 37.

oil tankers in the Gulf Coast region, leading to a drop in U.S. just-in-time crude oil inventories of 12 million barrels and a significant increase in gas prices. Such events highlight the need for sightless navigation systems based on accurate current information. Geospatial data products must continue to evolve to meet these requirements.

Charting the more than 95,000 miles of U.S. coastline and 3.5 million square miles of open water is a substantial task. Challenges include accurate horizontal and vertical datum transformations as well as data format conversions. The nautical chart consists of information that was collected over years with a variety of resolutions. Many of the data date back to the 1940s. With DGPS, today's mariner is often capable of determining position with a greater degree of accuracy than was the case when the data were collected. Improving positional accuracy is a major challenge. Because paper and raster nautical charts consist of data from a variety of sources, the need for data transfer and accuracy standards is critical in a government that is being asked to do more and more with fewer resources.

Summary

Currently, no commercial off-the-shelf product completely addresses the needs of both vector and raster chart production. By allowing appropriate access to and completely defining all aspects of planned and existing systems, strategic goals, and development efforts, the development process can be expedited. Management at all levels must understand and agree with the need to implement new geospatial data tools and technologies. This understanding positively affects budget requests and staffing needs for implementation of solutions.

As NOAA's nautical decision making and charting production transition to the use of geospatial analysis and GIS technologies, six critical items need to be addressed to ensure success. Strategic partnerships with data providers should be further developed to increase efficient data transfer, acceptance, and application. Computational middleware for extracting information needed for NOAA geospatial data products will demand organized development and documentation. Data serving, storage, and archival will require significant information technology development, planning, organization, and investment. Emerging technologies and market advances must be continually evaluated, documented, and openly published for review. Internal and external development of systems, programs, and personnel should be encouraged through increased education, exposure, and access. Finally, success stories must be validated, benchmarked, and presented to decision makers.

Federal Perspective for Railways

Geospatial information and technology are essential to the public side of the railroad industry in four major areas: mobility, safety and security, policy analysis, and capacity. These key issues not only affect the rail mode but are critical to the interface with the highway, maritime, and aviation modes. The United States railroad system includes freight and passenger transportation and is both competitive and cooperative with other modes. The Federal Railroad Administration (FRA) measures freight mobility by tracking shipments from origin to destination on the basis of the waybill sample and its geographically coded railroad system for the United States to simulate movements throughout the country.

A critical issue with respect to safety and security is the movement of hazardous materials. By simulating these movements, rail inspectors can be directed to the high-volume rail lines to optimize their inspection activities. Geospatial data technology also provides the capability to relate rail traffic to the demographic characteristics of adjacent communities to assess the potential impact of derailments and other incidents. FRA works with the Department of Defense and the Military Traffic Management Command to designate certain rail lines as essential to defense, a procedure similar to that used for the Strategic Defense Highway Network. The physical condition of these lines, which also connect military installations, is paramount in the event of a national emergency.

Current Practice

General Issues

FRA requires geospatial data for policy analysis at the national, regional, and local levels. An example is analyzing railroad grade crossings. Many states have inventoried their grade crossings by using GPS, which provides a linkage to the national rail system and its database. The decision to add protective hardware, close the crossing, or physically separate the rail line and the highway can have major impacts on the railroad company, the highway system, and the surrounding community.

Another policy issue for which geospatial analysis is used extensively is the evaluation of potential rail mergers. These mergers are international in scope yet local in impact. FRA's database includes both Mexico and Canada for analysis of cross-border impacts. Use of geospatial information technology to illustrate the impacts for policy makers is invaluable.

Rail capacity has become a major issue because the funds available to railroads to invest in capacity improvements are limited. This presents a competitive disadvantage with respect to other modes with more stable or plentiful funding sources. Rail line capacities and demands can be evaluated more readily and presented to funding agencies by using geospatial information technology.

Note on Private Rail Companies

Private rail companies such as CSX and Norfolk Southern make extensive use of geospatial data and electronic technologies in day-to-day operations. One focus is in the area of facilities management to control maintenance of track, structures, bridges, yards, and other infrastructure features. Geospatial technology, in particular GPS, is used to track individual rail cars for inventory control. Freight shipments are tagged electronically and tracked from origin to destination. However, this information is not readily available to transportation analysts for use in intermodal applications. It is used internally to help reduce costs and improve competitive advantage vis-à-vis other modes of transport. This report, which examines the use of geospatial data and technologies in multimodal applications, did not address private rail systems. FRA has a major regulatory role with private railroads, which results in an environment that is not conducive to the sharing of geospatial information. Representatives of the American Association of Railroads and their new GIS groups were invited to participate in the October workshop but did not do so.

Challenges

One of the significant weaknesses limiting the use of geospatial technology is the lack of application programs. The industry needs programs that are easily accessible, have real-time capability, and are customized to specific problems. Often the data are available, but the ability to organize and visualize them for problem solving is extremely limited.

Summary

The use of geospatial data technology to improve mode integration is particularly important with respect to the movement of freight on railways throughout the United States and North America. The physical infrastructure is ubiquitous. However, without the ability to pass information electronically between modes and nodes in the system, efficiencies are lost. The pressures of "just-in-time" delivery where multiple modes are involved have focused attention on the need for an information infrastructure that can provide fast, reliable tracking of freight shipments across all transport modes. Having core geospatial standards that cut across modes and expedite the interchange of information and addressing the problems that result from a mix of private- and public-sector responsibilities are important to the rail mode.

Local Perspective for Transit

Demand for transit services is always greater than the resources available. Transit agencies must continually look for the most efficient and effective deployment of service. They must also be aware of federal, state, and local requirements to distribute service equitably—in a manner serving all economic, racial, and cultural groups.

Current Practice

Geospatial data provide a foundation for most of the activities performed by transit organizations. Geospatial technologies are used to collect, analyze, and display planning data such as census information, rider surveys, travel patterns, ridership counts, on-time performance, jurisdictional boundaries, sensitive environmental zones, and so forth for service planning, which determines the general location of bus routes and facilities. The data are typically combined with transit service routes and facilities. Developing vehicle schedules and paths requires geospatial data to locate vehicle layovers, turnarounds, transfer points, and in-field restroom locations.

Facilities staff use geospatial data together with property data, including zoning and permitting information, to manage bus stops, park-and-ride lots, transit centers, trolley/rail power infrastructure, bases and garages, and other service-related facilities. Operations staff are responsible for the operation of vehicles on the street or other rights-of-way. Geospatial technology applications provide real-time tracking of bus, paratransit, and rail vehicles. Tracking of transit vehicles is critical for operating efficiencies (e.g., maintaining headways, rerouting vehicles, performance tracking, signal priority). Geospatial technologies and data are especially important in managing snow situations requiring emergency route and schedule changes.

Transit agencies must provide more and better means to communicate with the public. The growth of the Internet has raised expectations for customer information and service availability. Geospatial technology is at the core of many customer service applications. Besides simple, static map products, such as timetable route maps, many transit agencies are using complex GIS-based ride-matching and itinerary-planning applications. Smart fare card systems are capable of calculating location/distance–based fares. Automatic stop annunciation and destination signage are also beginning to appear in transit vehicles. Some agencies are able to transmit real-time vehicle location information directly to the public via the web and wireless devices. Multimedia systems provide an effective means to communicate with both internal staff and the public concerning service changes and capital facilities programs.

As a public service, transit systems have always been keenly aware of traditional security issues such as vandalism or assaults. Since September 11, 2001, transit agencies have become more alert to the possibility that transportation systems could be terrorist targets. Vehicle operators can trigger silent alarms to call security personnel to vehicles whose locations are monitored in real time. Security staff members gather and analyze location-based incident data to determine trends and optimum deployment of personnel. Similarly, safety staff members analyze crash data to improve training and plan infrastructure changes. Planning for future security scenarios will require much greater levels of data coordination with other agencies.

All publicly funded agencies have an obligation to report on their services to the public, local government officials, and state and federal agencies. Ridership counting and reporting are essential for transit agencies. Onboard automatic passenger counting systems require a geospatial reference to assign passenger activity to locations. Transit agencies use geospatial technology to comply with National Transit Database reporting requirements, including passenger miles and vehicle miles. Geospatial data technology is a key tool in analyzing and reporting on the distribution of services to ensure that all racial, cultural, and economic groups are equitably served.

Challenges

Geospatial data technologies have become key tools for supporting transit business, but even greater use of these technologies will be required if transit is to meet the challenges of the future. The primary challenge is in enhancing the ability to share information and work collaboratively to improve decision making. Three examples of areas that would benefit from such enhancement are safety and security, mobility and capacity, and environmental decision making. The increased threat of terrorism requires a much closer working relationship between all transportation and homeland security agencies. Implicit in this working relationship is the sharing of data. Such sharing must be rapid and exact—data that are delayed, misinterpreted, or missing could have catastrophic consequences.

With increasing congestion and decreasing resources for road infrastructure, a critical need exists for transportation providers, public and private, to work collaboratively. The sharing of geospatial data is an important step in any coordinated mobility efforts, whether moving goods or people. Mobility concerns are not subject to public agency boundaries, and the sharing of data, both intermodally and interjurisdictionally, must be improved.

Compliance with environmental requirements could be made more efficient with greater data sharing, and the cost and time required to produce environmental impact statements might be reduced.

Summary

Transit agencies must manage assets, provide service to customers, and plan for future requirements with limited resources under multiple levels of regulation and reporting requirements. Geospatial information provides the framework to perform the necessary activities within the necessary time frames.

Local Perspective from a Metropolitan Planning Organization

Metropolitan planning organizations (MPOs) often represent and make decisions involving multiple modes that affect their jurisdiction. In many cases, they provide some of the best insight into multimodal interactions and data needs. The issues for MPOs illustrate, on a smaller geographic scale, the challenges facing the transportation industry as a whole. Decisions associated with activities of MPOs and local planning agencies such as cities, counties, and special districts start and end with geospatial data. From the analysis (where is it? how big is it? what is it like?) to the adopted plan (where will it be? how big will it be? what will it be like?), nearly all decisions and associated data used in the planning process are organized by geographic location. This applies to both qualitative and quantitative information about the human, natural, and built environments.

Current Practice

Local planning agencies, by necessity, have been creative in compiling, integrating, and using geospatial data. Appendix A provides a summary of data typically used as part of the multimodal planning process. The source, associated applications and users, and related problems and issues for commonly used data sets are provided. Unfortunately, budgetary and institutional constraints limit the widespread use of geospatial data to the most readily available and least expensive data sources. Many of the richest and most robust data sets that would be useful for planning are unaffordable, inaccessible, or out of date, or they provide only partial coverage of the geographic planning area.

Challenges

Most MPOs and large planning agencies use the basics: geographic base files, census files, and transportation model input data. Most are users of basic GIS tools available from leading private vendors. Widespread use of other data sets is limited by several factors, including the following:

- Budget limitations and policies: Data acquisition projects must compete with many other needs that show a more immediate and tangible payoff. Data purchases often do not clearly fall into either operating or capital budget categories.
- Lack of institutional coordination: For various reasons—lack of metadata and data catalogs, failure to archive, agency rivalries, legacy (and often "home-grown") file layouts and software—local governments find it difficult to share data among themselves and with other levels of government.
- Costs of data maintenance and update: In addition to the initial acquisition cost, many large data sets require frequent and sometimes labor-intensive updates to maintain their usefulness. Many agencies cannot, or do not, allocate sufficient resources for this purpose.

Summary

The most difficult issues facing local planning agencies relating to the efficient use of geospatial data are not technical in the sense of software or hardware. They concern how government agencies operate on a day-to-day basis and how the agencies relate to each other in data acquisition, management, and dissemination. Now that technical tools, data storage capacity, and computer power are sufficiently developed and deployed in the private sector, expectations have risen significantly among planning agencies and their constituencies. Institutions and procedures have not kept pace.

Chapter 3
Trends in Decision-Making Tools
Geospatial Technologies

There is consensus among most professionals that the geospatial technology exists to support most of today's decision-making activities. Developing the ability and commitment to adapt to this technology quickly, in terms of both upgrading equipment and techniques and educating and training staff, is a challenge facing transportation agencies. To complicate matters, geospatial technology continues to expand and improve rapidly to meet new demands, placing an even greater burden on relatively slow-moving public agencies to take advantage of the new capabilities.

To provide decision makers with insight into the potential available to them, the following sections present relevant trends in geographic information systems (GIS) and geographic information science (GISci) that will affect decision-making abilities and tools. "GIS" refers to the technologies for capturing, storing, processing, and communicating geospatial information. "GISci" refers to the theories, models, and methods that underlie GIS (Goodchild 1992). The development of location-based services (LBS), an important trend in the provision of geoinformation to casual users, is also discussed. These trends will change the scientific and technological context for multimodal geospatial information infrastructure in transportation.

Industry Trends

In the past few years the geospatial information industry has undergone significant changes. It has evolved rapidly from proprietary and highly specific GIS-based applications to broader inclusion in an organization's information technology enterprise environment (see Box 3-1). Although the market for highly specialized GIS will continue, a faster rate of growth for geospatially enabled applications and services (call centers, command and control, business intelligence, emergency response) is emerging. This transition is most pronounced in transportation, public safety, telecommunications, and utilities. Public-sector agencies are beginning to realize the value of integrating location capability into their systems and, in doing so, reaping significant benefits in having access to and using the billions of dollars worth of geospatial data created over the last two decades.

GIS Trends

GIS are evolving to reflect changes in several areas. The expanded ability to collect and manage information, multimedia capabilities, the development of location-aware technologies (LATs), and mobile computing are a few examples of these changes. The following paragraphs provide some ideas of what these may mean to transportation professionals.

Data Poor to Data Rich

New methods for collecting georeferenced data include automated, real-time data capture and environmental

BOX 3-1
Enterprise Business System Environment

The evolution toward location-enabled enterprise business systems is being driven, in part, by the native geospatial capability in mainstream database technology. The leading database vendors, Oracle and IBM, now provide native spatial data types, spatial indices, and spatial operators. With these advances, organizations are realizing that managing geospatial data is just like managing any other data type. Advantages include the following:

- Geospatial data can be managed in an open database management system format and accessed by using Standard Query Language (SQL).
- Any third-party GIS tool can query and perform spatial operations on geospatial data—just as it would attribute data.
- Geospatial data can be queried and displayed from business applications such as customer call centers, command and control centers, and tracking applications by industry standard reporting tools using SQL.
- Centralizing geospatial data management reduces the overhead of running multiple data servers, reduces training requirements to run different applications, and minimizes application integration costs.

monitoring devices such as automated weather stations and intelligent transportation systems (ITS). Such methods, in combination with reductions in data storage costs, have led to massive enterprise databases and data warehouses. Geospatial data infrastructures, such as the U.S. National Spatial Data Infrastructure, are facilitating the sharing and interoperation of geospatial data. This is resulting in rapid growth in digital geospatial data as well as new methods for exploiting the rich information buried in these data sets. Techniques such as data mining and exploratory visualization have great potential to reveal hidden space–time patterns and relationships missed by traditional transportation models and analysis methods. Conversely, as data become more available, concerns and expectations about their use and quality rise. Resources for data maintenance, which are already limited, are stretched further. As the availability and use of real-time systems grow, these strains will grow.

Remote sensing (RS) is also experiencing a major renaissance. Improvements in RS technologies are creating substantial increases in various types of resolution: spatial (1 meter and below), temporal (high revisit rates, geosynchronous, aerial platforms), and spectral (hyperspectral sensors that can collect 200 or more bands of spectral data). This is leading to new opportunities for socioeconomic and transport applications, including RS of vehicles and detailed urban morphology. The U.S. Department of Transportation has created the National Consortium on Remote Sensing in Transportation to explore emerging transportation applications (www.ncrst.org).

Multimedia GIS

GIS are moving beyond traditional data models. The distinction between raster and vector will no longer be meaningful from the user's perspective: GIS will include automated intelligent conversion between these formats as necessary. The collection and storage of georeferenced multimedia, including text, sound, and imagery, are also possible. Georeferenced multimedia can help elected officials, key stakeholders, and the general public understand complex transportation issues, such as proposed changes in transportation infrastructure and services. This can foster a supportive environment for collaborative decision making (Shiffer 2001; Shiffer et al. 2003). For example, by using a virtual geographic environment, a neighborhood group could "tour" a planned transit station and suggest changes while the station is still in the design phase. Similarly, transportation officials and stakeholders could "fly through" a proposed highway corridor to assess aesthetic and other impacts.

Location-Aware Technologies

LATs are devices that can report their position in geographic space. These technologies may also have wireless communication capabilities, either to the Internet or to a voice communication system such as a cellular telephone network. Methods for reporting location include Global Positioning System receivers and radiolocation methods that piggyback on wireless communications. Vehicle-based inertial navigation systems that compute distance and direction from a known location are also possible.

LATs will transform GIS and transportation. Some trends associated with these technologies include ITS that require vehicle tracking and LBS coupled with wireless Internet to provide information about entities based on their location in space and time. These technologies and services will provide unprecedented capabilities for collecting real-time data on transportation systems that will allow designers, managers, and planners to assess system performance and policies for improving performance. They will also provide real-time transportation system information to users.

Network and Mobile Computing

Network computing will lead to the development of "information appliances" or special-purpose computers. With such systems, most computing and data processing will occur remotely at a server or servers. Internet GIS technology will allow the deployment of web-accessible geographic data servers and geographic data warehouses. It will also allow computation to be distributed and geospatial analytic tools to be shared. Mobile (wireless) technology will allow "ubiquitous computing" through handheld and wearable devices or possibly through devices embedded in infrastructure. This could permit GIS anywhere, anytime (within limits, of course: anyone with access to a wired or wireless telephone will have access to GIS). One possibility is the development of field-based GIS, with which a researcher could adaptively collect, edit, and analyze data in the field. Mobile GIS can allow "augmented reality." For example, the analyst will be able to wear lightweight goggles and see a GIS data view imposed on a real view of some scene. With such devices, GIS could migrate from specialized technicians to every professional within a transportation organization, including those in the field.

GIS as a Tool Kit

Traditional GIS, as a unique software package, is likely to disappear within the decade. Most enterprises store their data in large database management systems. GIS can more easily migrate to data than can data to GIS. Also, because geospatial database management is different from geospatial analysis and cartography, it is more effective to have separate software systems to support these different functionalities. Uncoupling geospatial data management from GIS allows the support of a much wider range of geospatial applications, including LBS.

Instead of emerging as stand-alone software, GIS will emerge as a multilayer, modular architecture that separates geospatial database management from geospatial analysis and cartography. The development of object-orientation, componentware, and open-source software means that software in general, and GIS specifically, will no longer have a wide range of vendor-supplied tools that try to do everything with limited success. Rather, GIS will be a flexible tool kit of basic geospatial operations that the user can combine to perform specific tasks.

This means that GIS will probably cease to be independent software and will instead be transformed into a tool kit linked to enterprise database systems. For transportation organizations, this means that the separation between GIS data and other data will cease to exist, and thus the artificial separation between geospatial analysis and other types of analyses will also disappear. In addition, transportation organizations will be able to build or adapt models and methods for localized needs rather than use methods that are designed for everywhere and hence nowhere. The power and scope of geospatial analysis and cartographic visualization in transportation planning, design, and management may increase. Managers and decision makers will have access to GIS data and products in making high-level, strategic decisions.

GISci Trends

At the same time that the tools are progressing, the science behind geospatial analysis is rapidly developing. Adding time and possibly other dimensions to the traditional three dimensions of space, expanding the ability to mine multiple data sets for previously unidentified patterns, and performing analyses from the perspective of an object in space as opposed to the space with objects moving through it will profoundly affect how transportation professionals do business over the next generation. These trends and their possible effects on transportation decision making are described below.

Multidimensional GIS

"Multidimensional GIS" refers to geospatial representations and analytical tools that can accommodate two- or three-dimensional space and time in an integrated manner (see Box 3-2). The multidimensional linearly referenced system, recently developed under the sponsorship of the National Cooperative Highway Research

Box 3-2

Multidimensional GIS

Multidimensional GIS goes beyond the traditional static map to include representation and analysis of 4D information (Raper 2000). Some of these ideas have also been developed for socioeconomic applications (Frank et al. 2001). Recent breakthroughs in spatiotemporal data modeling include the event-based spatiotemporal data model, which maintains spatiotemporal data as a sequence of temporal events associated with an object in space (Peuquet and Duan 1995), and the three-domain model (Yuan 2001), which treats time as a temporal object instead of an attribute, giving the spatial, temporal, and semantic domains equal emphasis.

Program, uses the three-domain model to develop a transportation data model that can reference facilities and events in 3D space and time as they relate to a transportation network.

The development of multidimensional GIS will remove a substantial mismatch between the static 2D world of GIS and the dynamic 3D world of transportation. More data related to a transportation system will be easily accommodated and analyzed within a common framework.

Geographic Data Mining

Traditional geospatial analytical methods were developed in an era when data collection was expensive and computational power was weak. The volume of georeferenced data now available can overwhelm techniques designed to tease information from small, homogeneous databases (Miller and Han 2001). "Geographic data mining" refers to the search for patterns in massive geodatabases. Current tools include spatial clustering, classification, exploratory spatial analysis, and geographic visualization.

Geographic data mining will become more important in transportation as information, specifically spatiotemporal data on network flows and space–time trajectories, becomes available through ITS and LBS, respectively. Traditional transportation modeling and analytical techniques cannot handle the massive and noisy spatiotemporal data available through these technologies. Also, transportation and land use systems can have complex spatial and temporal linkages that traditional methods cannot capture, such as the effect of a traffic crash at one place and time on traffic congestion at other places and times in the network, or the effect of a new highway on land use in the first year and air quality in 5 years. Geographic data mining techniques can help uncover these hidden relationships.

Beyond Place-Based Theories and Methods

Traditional place-based methods of analysis, such as travel demand modeling, urban theory, and general GIS, are increasingly limited in their ability to effectively analyze complex interrelated systems. Mobility and information technology have allowed activities to be increasingly disconnected from place. For example, work can occur in an office, a home, a coffee shop, or a park. A "people-based GIS" (see Box 3-3) extends place-based GIS to encompass dynamic and mobile objects that perform activities within a dynamic geometry that represents space (Miller 2004). Technologies that support a people-based GIS include position-aware technologies for data collection and geographic knowledge discovery for massive, noisy space–time databases.

> Box 3-3
> **People-Based GIS**
>
> Numerous theories and technologies exist to support a people-based GIS:
>
> - *Time geography* focuses on spatiotemporal constraints on behavior.
> - *Activity theory* examines how humans arrange activities in space and time and how transportation, telecommunication, and urban systems emerge from individual activities.
> - *Multidimensional GIS* (see Box 3-2) includes representation and analysis of 4D information.

Location-Based Services

LBS consist of a broad range of services that incorporate location information with contextual data to provide a value-added experience to users of the web or wireless devices (see Box 3-4). In contrast to the passive fixed Internet, users in the mobile environment are demanding personalized, localized, and timely access to content and real-time services. Targeted data, combined with location determination technology, are essential to add personalized value to an end user's mobile experience. With such technology, wireless carriers and portals could significantly increase the value of services to subscribers while opening up new revenue opportunities.

Through new applications, mobile offerings can be personalized to users' lifestyles and preferences and can be synchronized with other portable devices. The variety of applications and services is large, from pure content and advertising to emergency 911, navigational services, fleet and asset management, logistics, and location-sensitive billing. The high level of interest in location services, coupled with corresponding technology developments, has spurred the development of a rapidly growing location services industry and has created a multifaceted assortment of participants, service concepts, and business models.

Important similarities and differences between LBS technology and GIS exist. Much of the underlying mapping, spatial indexing, spatial operating, geocoding, and routing technology that is used to deliver LBS originates from the GIS industry. What makes LBS technology different is that it is deployed on a foundation of information and wireless technology. The value chain of a GIS is generally limited to the providers of a desktop or client server solution, whereas the value chain of LBS

Box 3-4
Types of LBS

Safety services: End-user assistance services, such as Enhanced 911 (E911), are low-usage services designed to provide assistance to the end user in case of an emergency. These types of services can be expected to gain a high market acceptance because of the general concern of the public for personal security. With a push from the Federal Communications Commission's E911 mandate and new location solutions, wireless carriers will be able to route an emergency call on the basis of the caller's location and the Public Safety Answering Point jurisdictional boundary and determine the nearest emergency center, thus dramatically reducing response time.

Information services: These types of services include traffic information, navigation assistance, Yellow Pages, travel/tourism, and so forth. Users will come to expect voice-enabled driving directions and walking directions, as well as information services, whereby requested information is delivered by Wireless Application Protocol, a Short Message Service message, interactive voice response, Multimedia Markup Language, or a call center operator.

Enterprise services: These services include vehicle tracking, logistics systems, fleet management, workforce management, and "people finding." Today, many of these services are offered by legacy mobile data systems. However, with the growing availability of broadband wireless capability, these services may be merged into digital wireless networks. Deployment of mobile location services is taking hold first in the enterprise applications.

Consumer portal services: As consumer technology platforms and wireless carrier infrastructures are upgraded to support ubiquitous, accurate location information, consumers will begin to access navigational services, such as driving directions. Location-aware devices will deliver "local" news, weather, and traffic information determined by the location of the device through an icon-based user interface.

Telematics services: "Telematics" most often refers to vehicle navigation systems, such as OnStar, that allow drivers and passengers to use Global Positioning System technology to obtain directions, track their location, and obtain assistance when a vehicle is involved in a crash. In-car systems, however, are car- or machine-centric, as opposed to handheld mobile devices, which are user-centric. Unlike static CD-ROM–based in-car navigation systems, online mobile systems allow users access to up-to-date, time-sensitive information and databases, such as those concerning traffic congestion.

Triggered location services: As carriers form partnerships with location-based application providers and businesses, they will be able to initiate trigger services that provide information to consumers or corporate clients when they enter predetermined areas. Some examples of trigger services include location-sensitive advertising, billing, and logistics.

includes many participants ranging from hardware and software vendors, content and online service providers, wireless network and infrastructure providers, wireless handset vendors, and branded portal sites.

Significant performance and scalability requirements further differentiate GIS solutions from LBS solutions (Box 3-5). Delivery of wireless location services might be considered similar to the delivery of other utility services. Online content services generally require large data servers, large enterprise hardware offerings, and significant midtier cached application servers that allow the service to scale and perform. LBS also require the delivery of personalized content to tens of thousands of users on an hourly and daily basis, in contrast to GIS.

Customers also want the provision of LBS to be automatic, with carriers and wireless portals integrating a variety of Internet and enterprise information services on the basis of customer preferences, enabling a user to focus on informed decision making. Using this functionality, a real-time traffic application may automatically access multiple information sources at other companies, across the Internet on dozens of websites, and on other servers within the organization to provide integrated traffic information. Similarly, a customer checking on the availability of a hotel in a given city might access geocoding services that identify the locations of the hotels nearest the customer, who might then cull data from real-time travel services to obtain room availability, book a room, and obtain driving directions from the customer's current location to the hotel.

As the general public becomes accustomed to this type of environment, providers of transportation services and information will be expected to provide comparable functionality, which will both require and

BOX 3-5
LBS Requirements

High performance: Delivers answers to subsecond queries required for Internet and wireless.

Scalable: Supports thousands of concurrent users and terabytes of data.

Reliable: Delivers up to 99.9999 percent uptime.

Current: Supports real-time and static information delivery.

Mobile: Available from any device, wireless or wire line, and from any location.

Open: Supports common standards and protocols—HTTP, Wireless Application Protocol, Wireless Markup Language, Extensible Markup Language, Multimedia Markup Language.

Secure: Leverages underlying database locking and security services.

Interoperable: Integrates with e-business applications such as customer relationship management, billing, personalization, and wireless positioning gateways.

generate geospatial information that is not currently available. The technologies presented in this section will play an important role in the future of transportation as they evolve, both in the development of decision-making tools and in data collection. How transportation organizations harness this technology has yet to be established or even considered. However, they must begin positioning themselves to take advantage of the technology as it becomes a part of everyday activities.

REFERENCES

Frank, A. U., J. F. Raper, and J.-P. Cheylan (eds.). 2001. *Life and Motion of Socio-Economic Units*. Taylor and Francis, London.

Goodchild, M. F. 1992. Geographical Information Science. *International Journal of Geographical Information Systems*, Vol. 6, No. 1, pp. 31–45.

Miller, H. J. 2004. What About People in Geographic Information Science? In *Re-Presenting Geographic Information Systems* (P. Fisher and D. Unwin, eds.), John Wiley (in press).

Miller, H. J., and J. Han. 2001. Geographic Data Mining and Knowledge Discovery: An Overview. In *Geographic Data Mining and Knowledge Discovery* (H. J. Miller and J. Han, eds.), Taylor and Francis, London, pp. 3–32.

Peuquet, D. J., and N. Duan. 1995. An Event-Based Spatiotemporal Data Model (ESTDM) for Temporal Analysis of Geographical Data. *International Journal of Geographical Information Systems*, Vol. 9, No. 1, pp. 7–24.

Raper, J. F. 2000. *Multidimensional Geographic Information Science*. Taylor and Francis, London.

Shiffer, M. 2001. Spatial Multimedia for Planning Support. In *Planning Support Systems: Integrating Geographic Information Systems, Models and Visualization Tools* (R. K. Brail and R. E. Klosterman, eds.), ESRI Press, Redlands, Calif.

Shiffer, M., A. Chakraborty, B. Donahue, G. Garfield, R. Srinivasan, and S. McNeil. 2003. Spatial Multimedia Representation of Chicago Transit Authority Rail Infrastructure. In *Transportation Research Record: Journal of the Transportation Research Board, No. 1838*, TRB, National Research Council, Washington, D.C., pp. 1–10.

Yuan, M. 2001. Representing Complex Geographic Phenomena in GIS. *Cartography and Geographic Information Science*, Vol. 28, No. 2, pp. 83–96.

Chapter 4
A Vision for Strengthening Decision Making

On the basis of its meetings and deliberations, the committee believes that the only viable approach to achieving the goal of a comprehensive, timely, and usable geospatial information infrastructure is for stakeholders to work in concert. The stakeholders consist of modal administrations, offices within modal administrations, state and local agencies, vendors, associations, academic institutions, private industry, and anyone with a vested interest in the effective and efficient operation of the transportation system.

The data providers, who control the collection and maintenance of their individual data sets and who continue to perform their day-to-day decision making, are the foundation for achieving this goal. On this foundation, links to other offices, modes, and levels of decision making must be maintained and strengthened, institutionalizing the process to establish a sustainable geospatial information infrastructure. The links apply both to the data and technology and to the ability of these agencies to expand their business processes. The necessary links must be established to ensure that the information infrastructure is comprehensive and usable by all stakeholders. Concurrently, gaps in the information infrastructure that are not in the domain of any individual office must be identified and a plan developed to establish ownership of those data. Those data owners must understand the value of their data to others. Incentives can often be provided to enable those owners to collect and maintain the data.

For this to occur, a clear coordinating mechanism within the transportation community must be established to ensure that (*a*) the individual data providers are identified and have a way, and the incentive, to share their data; (*b*) the links and relationships between stakeholders are established or strengthened and institutionalized; (*c*) a plan is established and maintained to fill information gaps; and (*d*) decision makers understand the importance of having and using the geospatial information infrastructure. The coordinating entity should come from the federal level, specifically the U.S. Department of Transportation (USDOT), and it should operate as enabler, not as implementer or mandator. Individual states could extend this model by establishing a coordinating entity to provide the same services to local agencies and act for them at the federal level.

Because such a development would require a change in paradigm for transportation stakeholders at all levels, the new roles and responsibilities of these stakeholders must be established and understood. The first section of recommendations, "Institutional Roles and Responsibilities," addresses this issue.

An understanding emerged from this project that two distinct issues were limiting successful implementation of a comprehensive geospatial information infrastructure. The first is the lack of or limited awareness on the part of decision makers, particularly at the level of resource allocation, about the availability and use of the geospatial information infrastructure and the potential cost of making decisions without geospatial information. The second is the inability of organizations (*a*) to keep pace with the rapid expansion of this technology, (*b*) to ensure that staff receive the necessary training to effectively use the technology, and (*c*) to expand their business processes to fully enable the technology. The second section of recommendations, "Capacity and Commitment Building," addresses these issues.

As relationships and understanding improve and broaden, the physical process of establishing and maintaining the geospatial information infrastructure itself must be addressed. Guidelines and incentives must be provided to stakeholders for actively participating in building, maintaining, and using the infrastructure, and examples and approaches for addressing specific aspects, such as metadata, financing, and legal issues associated with partnering, must be supplied. Identifying missing data and supporting the development of those data, improved tools, and new or unique approaches to decision making are also important. The third section of recommendations, "Geospatial Information," focuses on these aspects of the geospatial information infrastructure.

The fundamental purpose of the following recommendations is to enhance the ability of decision makers to improve the basis for their decisions while optimizing resources necessary to maintain the information used for these decisions.

The recommendations are divided into three categories, and each category is further subdivided into areas:

- Institutional roles and responsibilities
  - –Roles
  - –Partnership builders
  - –Representing transportation in the wider geospatial community
- Capacity and commitment building
  - –Outreach
  - –Training
  - –Education
  - –Applied research
  - –Knowledge building
- Geospatial information
  - –Technical guidelines
  - –Clearinghouse

Each area includes one or more recommendations for consideration by all levels of transportation organizations, but in particular for the federal government and more specifically USDOT and its Bureau of Transportation Statistics (BTS).

To enable stakeholders to participate in and strengthen the geospatial information infrastructure, the first series of recommendations focuses on defining and communicating the roles and responsibilities of participants involved in this process. Identifying a coordinator for interactions and the remaining recommendations is of critical importance, particularly for establishing the recommended partnerships and ensuring that transportation is represented in related initiatives.

The second series of recommendations addresses the need to educate and inform leaders and decision makers of the value of investment in the geospatial information infrastructure, as well as the need to advance human capital at all levels in the understanding and use of geospatial technologies.

The final series of recommendations is specific to geospatial information itself and emphasizes the establishment of guidelines for sharing data and a clearinghouse for information and best practices in the use, dissemination, and sharing of geospatial data.

Institutional Roles and Responsibilities

Discussion

Improvements in transportation decision making require a change in the overall view of the collection and use of geospatial data. Focusing on technical tools and standards alone is not enough. Instead, the roles and responsibilities of all participants must be fundamentally redefined. Different relationships and new and creative ways of collecting and disseminating data are necessary.

When transportation modes were independent and separable, they could be viewed as static infrastructure. Today, users have found ways to achieve more integration of modes to accomplish their needs. The explosion in travel demand has placed more stress on the transportation system as a whole. The economy has now become geospatially integrated at national and international levels. The effort that has gone into increasing capacity on individual systems has spotlighted the lack of coordination across system connections.

The committee heard many instances of transportation organizations successfully using geospatial information to improve activities within their organizations and within modes. However, few examples of the sharing of detailed spatial knowledge between modes to improve system performance were evident. Even within modes, diffusion of successful practices was limited.

Findings and Recommendations

Roles

Finding In transportation, the role of the federal government appears to be evolving from implementer and decision maker to facilitator/enabler and role model. A paradigm shift is occurring from mandating compliance to facilitating collaboration and alliances. This shift can allow agencies to become more flexible and responsive and seek out relationships with the highest value to their organizations.

Recommendation 1a While the roles are less well defined in this new environment, the committee believes that USDOT is best positioned to embrace the role of facilitator/enabler in developing improved geospatial information infrastructure, empowering agencies to build relationships both across USDOT and throughout the federal government. All transportation organizations need to be active. In an era of devolution of responsibilities, this is not a recommendation for increased federal authority but a call for the federal government to be a convener of interested parties and a consolidator of information. Having a single agency focus within USDOT could encourage relationships between and across modes and provide a clear voice for areas important to transportation, such as intermodal connections, that are not located in an existing administration or agency. Because the committee believes that many of the greatest benefits can come from improving the efficiency of the multimodal transportation system, coordination of geospatial technology initiatives within the department is essential. BTS has begun to play that role. The committee believes that this facilitation role within the department and within the transportation community needs to be strengthened with adequate resources and management support from the Office of the Secretary and the modal administrators. While the committee believes that much will be gained by all the modal administrations strengthening their capacity and use of geospatial technologies, BTS has responsibilities and interests in all the modes. Because of these interests, USDOT has designated BTS as the leader in geospatial activities among the modes. The committee believes that strengthening that role can lead to improved coordination among the modes and understanding of areas for capacity improvements. No other federal agency has such a multimodal perspective. In the short run, no nonfederal transportation organization, such as the American Association of State Highway and Transportation Officials or the Association of Metropolitan Planning Organizations, has the interest or expertise to serve this facilitation role.

Partnership Builders

Finding The transportation sector is diverse and complex, with local activities based on policies established at the local, state, and federal levels and in conjunction with the private sector. Many different relationships are necessary, both across and between levels, to ensure that resources are used efficiently. Geospatial information and the underlying data can improve the communication channel required to achieve understanding across government levels, modes, transportation organizations, and physical locations. Transportation organizations include associations; societies; and public, private, and academic entities.

Recommendation 1b USDOT should enable and facilitate the creation of geospatial information technology partnerships across government levels, modes, transportation organizations, and users to ensure that communications are open and available to partners for implementation of the other recommendations presented here.

Representing Transportation in the Wider Geospatial Community

Finding Because transportation geospatial data and attributes have unique requirements, the transportation sector should be represented and play an active role in national and international activities associated with establishing standards and other data exchange and outreach initiatives. While BTS has been involved in federal coordination activities, USDOT, in serving the interests of industry and state and local governments, is not adequately represented in nonfederal national and international standards-setting organizations.

Recommendation 1c USDOT should take an active role within standards-setting organizations to ensure that the interests of the transportation sector at the federal, state, and local levels are adequately represented. Active representation is especially important in governmentwide initiatives such as the Federal Geographic Data Committee and Geospatial One-Stop.

Finding The development of geospatial information infrastructure has been approached differently by various agencies on the basis of their specific needs, interpretation of federal guidance, and political influence. Data acquisition and maintenance need to be thought of not as a project-based function but as a systematic component of the transportation infrastructure.

Recommendation 1d USDOT should establish a rationale and a procedure for including support of a sustainable information infrastructure in overall transportation funding. Such support would be a small proportion of the total funding for transportation improvements and would not necessarily require new funds. Establishing the need and eligibility for use of existing funding is critical.

Capacity and Commitment Building

Discussion

The capacity of organizations to apply geospatial information technologies to improve transportation is dependent on several factors:

- The awareness and appreciation by an organization's leaders of the value of their investment in geospatial information technologies;
- The level of knowledge that current employees have about applying specific geospatial information techniques and tools;
- The development of human capital—the understanding and skills of new employees and of teachers of future employees;
- The ability of organizations to evolve their business practices to capitalize on these technologies; and
- The development and advancement of the geospatial information infrastructure—technologies, data streams, and analysis techniques—available for and used by an organization.

Power of the Technology

Geospatial information technologies are complex tools that have developed rapidly over the past two decades. The ability to use computer technology to store location data, associate these data with information, and display and analyze this information for varying purposes has advanced dramatically. Early uses such as the development of computer maps have expanded to the development of sophisticated geographic information systems (GIS) for transportation and urban planning, environmental streamlining, system operations, and policy analyses.

Given the geospatial nature of transportation, these technologies have great potential for improving the efficiency of planning, design, construction, and operations of transportation systems. They are increasingly used by multiple levels and disciplines throughout transportation organizations. However, their development has often advanced faster than staff capabilities. The value of these technologies is often not well understood by decision makers, who are reluctant to invest in the geospatial infrastructure needed to benefit their organizations. To take advantage of the capabilities of geospatial information technologies, transportation professionals and leaders must remain current on their applications and their value.

While current geospatial technologies need to be better utilized by transportation organizations, great potential exists in developing new technologies and applications that improve transportation. Computing power, sensing systems, and display and analysis software are advancing rapidly. Investments that lead to innovations in transportation applications of these technologies, in research to develop new tools, and in the education of the future transportation workforce are needed.

The recommendations outlined below are primarily addressed to USDOT. However, many of the actions suggested are for the benefit of academic institutions and state, regional, local, and private-sector transportation organizations, as well as for federal agencies, and thus require involvement and partnerships among these key stakeholders. The focal point for carrying out these recommendations could be BTS in close collaboration with the modal administrations.

Findings and Recommendations

Outreach

Finding Many transportation agencies have yet to take full advantage of new developments in geospatial information technologies.

Although top executives and professionals of these agencies are often aware of the relevance of these technologies, there is a lack of clarity concerning what the technologies and data streams mean to business practices. A need exists to assist agencies in incorporating these technologies into their day-to-day operations.

Recommendation 2a USDOT should consider providing outreach to decision makers and users of geospatial information by taking the following actions:

- Facilitating the development of a clearinghouse of best practices to inform transportation administrators and professionals about examples of improvements in transportation business practices through geospatial information technology. The clearinghouse should be an integral part of any national initiative, including Geospatial One-Stop and the National Transportation Library.
- Promoting best practices and proven innovative processes using geospatial technologies for policy analyses and presentations to top executives and other decision makers.

Training

Finding The state of the practice in geospatial information technologies is rapidly evolving as new technologies and data become available for transportation organizations.

A need exists on the part of transportation professionals at all levels to continually update their knowledge and skills in geospatial information technology.

Recommendation 2b Consideration should be given by USDOT and other key organizations involved in transportation to facilitating the rapid development of training programs in geospatial information technologies and their deployment to specific transportation audiences. The programs could include short courses, workshops, and other means of continuing education and outreach. The training should be linked to the evolving business needs of transportation organizations.

Education

Finding A need exists to ensure that current and future transportation professionals are well grounded in geospatial information technology concepts.

Recommendation 2c USDOT should facilitate interaction with the educational community to (*a*) enable transportation professionals to provide input to the development of curricula in the teaching of geospatial information technologies and (*b*) develop reciprocal learning programs that transcend traditional internships to encourage the exchange of knowledge between students and professionals.

Interactions could include workshops or visiting committees that allow professionals to make recommendations to academia concerning needs related to geospatial information technologies. These approaches will ensure that the education is relevant to the needs of transportation organizations and incorporates broad understanding of geospatial information technologies.

Applied Research

Finding A need exists to continue to develop techniques, tools, and innovative approaches to take advantage of the geospatial information infrastructure for transportation and to ensure that the information is disseminated to the transportation profession. Short-term applied research that develops new tools and adapts existing tools to support various functions, such as transportation planning, environmental streamlining, engineering, construction, and operations, would be included.

Recommendation 2d USDOT should consider initiating an applied research and development program that centers on geospatial information technologies for transportation. A proactive technology transfer program that shares research results and innovations among the public and private sectors and academia would be part of this effort.

Knowledge Building

Finding A need exists to advance the state of the art of geospatial information technology by developing fundamental knowledge that will influence long-term technological innovations in the use of geospatial information for transportation.

The development of geospatial information technology knowledge is in its early stages. This recommendation would complement the short-term applied perspective recommended above with a longer view of developing knowledge that helps solve tomorrow's transportation problems. It would also enhance the expertise and increase the number of faculty in academic institutions who are involved in teaching and conducting research on geospatial information technologies for transportation. An example of knowledge building is to develop data models and software tools that can accommodate temporally varying and moving entities to integrate analyses of multimodal transportation systems from the perspective of the system user (people or goods) or service-delivery concept with the traditional static facility approach.

The results of the education and applied research initiatives recommended above should be used in defining these longer-term research needs.

Recommendation 2e USDOT should foster knowledge building by

- Sponsoring research-based education programs at universities that focus on knowledge discovery and long-term technological innovation;
- Using resources offered by university consortia, university transportation centers, special institutes, and other venues to identify basic research opportunities and to accelerate long-term research; and
- Improving mechanisms to disseminate the results of university research.

Geospatial Information

Discussion

Geospatial information and technology are a critical part of the transportation infrastructure and are central to the support of the core goals of improving efficiency, mobility, safety, and security. Safety and security issues directly affect mobility. Improving the efficiency of security operations will directly improve mobility. Conversely, security measures implemented without concern for mobility are likely to impede mobility. To operate effectively, transportation policy and programs must be integrated with information technology and the associated data.

Two trends have highlighted a need to access geospatial information from existing operating systems or agencies: (*a*) the emergence of GIS from static map production to dynamic "anytime, anywhere" GIS and (*b*) the availability and accessibility of hardware and software tools capable of managing, storing, and mining voluminous databases. Whereas GIS formerly relied on limited libraries of stored, prepackaged data sets, and in many cases still do, the ability exists to produce on-demand geospatial representations of virtually any data from one or multiple sources.

Several actions are necessary to ensure successful access to this information.

- *Define data*. Transportation agency data are usually tightly focused on delivery of specific products or services. The precise definition of data elements, especially input data, is often not essential to delivery of the final product and thus is not always available. To ensure availability of data, creators and maintainers of the data need to consistently provide metadata or related documentation with every data product.
- *Develop and maintain data catalogs, data dictionaries, and metadata*. In most cases, agencies themselves do not know the extent of the data they have. Rarely have they taken the time to produce the data catalogs, dictionaries, and metadata that allow effective sharing of information beyond the original purpose. The resources necessary to providing appropriate documentation should be built into all data activities and projects.
- *Access legacy systems*. Operational information systems, especially in the public sector, generally have a long life span. A shortage of funds for capital spending and cumbersome procurement processes result in maintaining systems without upgrading them as new technology becomes operational. Vendors no longer support vital system components, including hardware, software, and data structures. Therefore, operating agencies, even those performing similar functions, use a myriad of different legacy systems. Extra effort must be made to establish bridges from legacy to current systems.
- *Archive data*. In many cases, data are collected, used for a single purpose, and then discarded. Since data archives are frequently not important to the mission of the owning agency, these data are not archived. Procedures and activities should be defined to archive available data.
- *Embrace change*. Agencies develop systems and procedures focused on their mission. Procedures are developed over time, and changes can be disruptive. Agencies are then generally resistant to requests that involve additional cost, staff time, or changes in these procedures. New technologies and procedures can be used to minimize disruption and maximize flexibility in collecting, storing, and sharing data and should be incorporated into standard operating procedures.
- *Address legal/liability issues and privacy concerns*. Archival, storage, and sharing of data by agencies potentially expose agencies to increased legal liability. Similarly, the ability to monitor transportation systems at the level of an individual object or person, coupled with the accessibility of archived data, can create potential violations of personal or commercial privacy, since detailed historical records and biographies can be reconstructed from such data. As databases become more accessible over the Internet, as public and private agencies enter into data-sharing agreements, and as data mining and “spider” technologies improve and receive wider application, these concerns continue to grow. Such technologies allow government or private entities to know a person’s identity, location, activities, and spending habits. A closely related concern is homeland security. The ubiquitous availability of geospatial data makes it possible for almost anyone to easily identify the geographic location of sensitive or critical infrastructure, as well as structural details and operating characteristics. These concerns place dual burdens on public agencies. First is the decision as to what data to protect and what data to make available to the public. The second is how to secure sensitive information from unauthorized release and use. Since agencies generally collect data for a specific use, security entails a combination of electronic measures, facility safeguards, and data-handling procedures. Public agencies should begin to address these concerns through identification of policies and procedures that protect data providers and users while maximizing availability of information.
- *Bridge institutional fiefdoms*. Information is power, and there is strong institutional resistance to dissemination of the very entity that provides the source of institutional power. Data generators also are often concerned that others may use undocumented data inappropriately. Extra effort is necessary to design systems and paths of communication for multiple users. Careful charting of benefits to all participants (including their parent organizations), data-sharing responsibilities, and incentives is an important tool in addressing this significant challenge.
- *Access private-sector data*. While the private sector has access to most public-sector databases, the public sector does not have access to most private-sector data, particularly for goods movement. Even when proprietary issues are not a concern, incentives and a legal framework for sharing information are lacking or ambiguous. Public agencies should work with the private sector to clarify and strengthen benefits of partnerships and establish safeguards to protect stakeholder interests.

Positioning agencies to take these actions requires institutional evolution, education, and bridge building between agencies that have the data and the planning, policy, and design organizations that need the data. For cooperation to occur, benefits must be clear to all participating parties.

The following findings and recommendations are organized to address issues related to ensuring access to geospatial information and comprehensive coverage of multimodal geospatial information. The emphasis of these recommendations is on interoperability and providing the necessary infrastructure to enable this interoperability, not on rigid consistency or mandates.

Findings and Recommendations

Technical Guidelines

Finding The diverse requirements for geospatial information to address the complexity of the transportation sector do not lend themselves to a single approach to collection, analysis, display, or dissemination of that information. However, a need exists for different levels and types of transportation organizations to combine geospatial information to improve decision making and resource allocation.

Recommendation 3a USDOT should be a leader in facilitating the development of guidelines for providing and disseminating data through information clearinghouses. At the federal level, such leadership could include facilitating consistency in data collection and dissemination for systems of national interest. At other levels, it could include providing best practices for and awareness of effective use of data standards and guidelines to facilitate information exchange.

Recommendation 3b USDOT should consider initiatives to build partnerships among the public and private sectors and academia to facilitate interoperability among software systems and mode-specific applications. Emphasis should be placed on

- GIS tools that are based on open architectures and standards and platform-independent languages;
- Open interfaces that allow querying across different databases and application components; and
- Geospatial decision-support and web-based geoinformation services that facilitate communication among analysts, decision makers, and other stakeholders.

USDOT should give strong consideration to creating a regular forum to bring together key public- and private-sector data providers and users to identify ways to reduce barriers to ubiquitous data sharing.

Clearinghouse

Finding Confusion exists in the user community about the myriad of geospatial databases and the associated standards, requirements, and policies, or lack thereof, applying to collection, use, and dissemination of this information. Issues include privacy, proprietary and legal restrictions, quality and accuracy, and reporting requirements. A need exists for a mechanism for transportation stakeholders to access transportation information and policies for all levels, modes, and application areas of transportation. At the national level, this is particularly true for compiling and managing information for intermodal connections and for ensuring that the transportation "seamless" multimodal user perspective is represented in policy decisions.

Recommendation 3c USDOT should consider implementing or expanding and maintaining a clearinghouse for transportation geospatial information and related best practices, either independently or as part of one of the national initiatives. As practical, a knowledgeable evaluation of existing practices should be included with examples. As the transportation community adopts more operational systems providing real-time data, a special challenge is developing approaches to handling this type of geospatial data. Among the functions a clearinghouse could facilitate are the following:

- Coordinate, through partnerships with professional trade organizations, vendors, state and local governments, and others, the identification of major data sets currently collected or archived for use by all other stakeholders.
- Use metadata, instead of standards, for establishing linkages to or additions of data to the clearinghouse.
- Provide incentives for the completion of metadata as part of data programs.
- Develop protocols to allow the public to have selective access to private-sector data subject to reasonable protection of proprietary and competitive interests.
- Provide examples of best practices for policies associated with privacy, proprietary and legal restrictions, quality and accuracy, and reporting requirements. Examples could include contracts, annotated legal decisions, documented best practices, guidelines, and standards.
- Provide examples of and guidance for the successful financing of geospatial data, such as the creative models used by the U.S. Geological Survey, the U.S. Postal Service, and the Census Bureau.
- Publish details of implementation and maintenance of the USDOT clearinghouse as a showcase for others at the state or regional/metropolitan level.

Recommendation 3d USDOT should identify critical gaps in the multimodal geospatial infrastructure and work to identify resources, through partnerships and clarification of funding eligibility, to develop the necessary information to fill those gaps.

Recommendation 3e USDOT should actively participate in initiatives to review issues related to legal liability and privacy concerns specific to transportation uses of geospatial information with the objective of proposing changes in law or procedures that may be necessary to provide reasonable protections to agencies and organizations that archive and provide data.

Recommendation 3f USDOT should facilitate collaborative projects among its modal administrations, state and local transportation organizations, private companies, transportation associations, and academic institutions by identifying funding, peer review, and in-kind contributions of data, software, and hardware. Projects and their results should be promoted to the transportation community via any or all of the following: the clearinghouse, publications, and an annual conference.

Chapter 5
Call to Action

The potential for having comprehensive, timely, and usable geospatial information necessary to support informed decision making in transportation is good. However, that potential has been realized only in a limited number of cases and not on a broad, systemwide scale. This report represents a call to action to transportation agencies, primarily at the federal level, to make this happen.

Past and Current Reports

The call for enhanced geospatial information is not new. During the last decade, nearly one document each year has recognized or evaluated the need for geospatial data as part of a comprehensive information decision-support environment (see Box 5-1). Findings from these reports consistently maintain the theme that the comprehensive data necessary for effective decisions at a national level or to be provided to state or local decision makers do not exist, except for very specific applications, and that integration across data sets has not been practical. Recommendations routinely support the enhancement of the quality, interoperability, and dissemination of these data through coordinated activities at the national level and through partnerships with stakeholders. But because these reports have spanned the last decade and the findings and recommendations represent variations on the same theme, it appears that proponents have both underestimated the complexity of the task and failed to effectively communicate the fundamental need to the appropriate decision makers to make geospatial information not only a priority but a necessity. Partnerships exist to provide benefits for one or more parties. Identifying what benefits are for whom as well as what responsibilities are required of which stakeholders is an essential foundation for any data-sharing arrangement. Both the benefits and the responsibilities must be balanced in an equitable manner.

The work performed for this project and reports from previous studies indicate that the keys to successfully accomplishing the goal of an effective geospatial information infrastructure are to redefine and enable the roles of the stakeholders as partners; educate and demonstrate to decision makers the benefits of a comprehensive information infrastructure; and ensure that the technology, procedures, and best practices are made available to stakeholders to put the infrastructure in place.

The recommendations from this effort are divided into three categories:

- Institutional roles and responsibilities,
- Capacity and commitment building, and
- Geospatial information.

Each category is further divided into specific areas. Each area includes one or more recommendations for consideration by all levels and areas of transportation organizations, but in particular for the federal government and more specifically the U.S. Department of Transportation and its Bureau of Transportation Statistics.

Box 5-1
Previous Calls for Improved Geospatial Information

1991—*A National Geographic Information Resource: The Spatial Foundation of the Information Based Society*. Federal Geographic Data Committee.

1992—*Special Report 234: Data for Decisions: Requirements for National Transportation Policy Making*. Transportation Research Board, National Research Council, Washington, D.C.

1993—*NCHRP Research Results Digest 191: Management Guide for Implementation of Geographic Information Systems (GIS) in State DOTs*. Transportation Research Board, National Research Council, Washington, D.C.

1993—*Toward a Coordinated Spatial Data Infrastructure for the Nation*. National Research Council, Washington, D.C.

1995—*Promoting the National Spatial Data Infrastructure Through Partnerships*. National Research Council, Washington, D.C.

1995—*A Data Foundation for the National Spatial Data Infrastructure*. National Research Council, Washington, D.C.

1997—*Bureau of Transportation Statistics: Priorities for the Future*. C. F. Citro and J. L. Norwood (eds.), National Research Council, Washington, D.C.

2001—*National Spatial Data Infrastructure Partnership Programs: Rethinking the Focus*. National Research Council, Washington, D.C.

2003—*IT Roadmap to a Geospatial Future*. National Research Council, Washington, D.C.

2003—*Weaving a National Map: Review of the U.S. Geological Survey Concept of the National Map*. National Research Council, Washington, D.C.

Brief discussions of these reports are provided in Appendix C.

The recommendations are broad and will require leadership from the federal level to have a chance of meeting the goals set forth in this report.

Conclusion

Information, and the data and technologies that support and generate it, is not without cost. However, it should be viewed as infrastructure that is just as important and necessary as bridges, ports, runways, rails, and roads. Its cost is minimal compared with the potential for "billion-dollar bonehead decisions" that could occur without adequate information. To ensure the best decisions possible, the information infrastructure must be supported, or the means to make the necessary decisions will be unavailable.

Appendix A
Example of Geospatial Digital Information

Table A-1 provides an example summary of geospatial data used by a metropolitan planning organization (MPO). The table gives the types of data along with typical contents and possible sources for the data. In most cases, MPOs do not have the resources to collect comprehensive databases and must rely on participating stakeholders and state and federal agencies for their data. Users of the data are given with example applications. Some key issues and problems associated with the various databases are also provided.

TABLE A-1 Digital Geospatial Data Used by MPOs and Local Agencies

Data Type	*Typical Contents*	*Source*	*Applications*	*Users*	*Issues/Problems*
Geographic base files	Streets and roads Landmarks Political boundaries Address ranges Some natural features	Census Bureau Commercial vendors Locally created	Planning Map production Routing (transit, public safety) Traveler information	Virtually all MPOs Larger local agencies	Keeping information current Consistent registration Use restrictions (commercial products) Limited natural feature information Limited landmark information
Census geography	Census data Population Housing Economic information Noncensus socioeconomic Forecast data	Census Bureau Locally generated	Local and regional planning Social service delivery planning Analysis Transportation modeling Political districting Environmental justice/equity measurement	Virtually all MPOs Local agencies	No point data Aggregation for nondisclosure Infrequent update

(*continued*)

TABLE A-1 (*continued*) **Digital Geospatial Data Used by MPOs and Local Agencies**

Data Type	*Typical Contents*	*Source*	*Applications*	*Users*	*Issues/Problems*
Planning data sets	Land use data General planning/zoning Transportation model inputs Housing condition data Transit and highway networks	Cities and counties Regional agencies Transit operators Transportation agencies Private vendors	State, regional, local planning	Most larger MPOs Some larger local agencies	Difficult to acquire and maintain Expensive
Natural features	Vegetation Natural relief Fault lines Floodplain boundaries Soil types Watersheds	Federal agencies State agencies	Facility/corridor planning General planning and zoning Environmental analysis Habitat analysis Runoff/permeability analysis	Some MPOs use one or more data sets Limited use by large local agencies	Lack of uniformity Limited coverage Infrequently updated Highly variable data structures
Event-based operating data	Assessors' files Building permits Inspection information Incident type and locations Transit route/schedule data Residential/service locations	Operating agencies	Social service planning Housing planning Traveler information systems Public safety planning and analysis	Very limited use	Confidentiality requirements (statutory and policy) Lack of interagency coordination Multiplicity of file structures Lack of uniform coverage Lack of common data contents Definitional inconsistencies Lack of metadata
Continuous/real-time operating data	Performance/condition data	Operating agencies ITS vendors	Planning Performance measurement and analysis	Extremely limited use by nonoperating agencies	Unorganized Not time/date stamped Not archived Large data set size Unmapped data files Lack of metadata
Aerial imagery remote sensing	Registered, orthorectified imagery Digital elevation models	U.S. government Private vendors	Planning Environmental analysis Preliminary engineering Corridor analysis Change monitoring	Moderate use by MPOs Larger local agencies	High cost Relatively infrequent coverage Large data file size

Appendix B
The Process
Multimodal Transportation Requirements for Geospatial Information Infrastructure

Project Organizer: Transportation Research Board

The Transportation Research Board is a unit of the National Research Council, a private, nonprofit institution that is the principal operating agency of the National Academy of Sciences and the National Academy of Engineering. The Board's mission is to promote innovation and progress in transportation by stimulating and conducting research, facilitating the dissemination of information, and encouraging the implementation of research results. A committee (see Committee Member Biographical Information) was formed to address the mission and objectives of this project and to plan and conduct a series of three workshops.

Sponsor: Bureau of Transportation Statistics

The mission of the Bureau of Transportation Statistics (BTS) is to lead in developing high-quality transportation data and information and to advance their effective use in transportation decision making. BTS supplements the data collection programs of other agencies and serves as the lead agency in developing and coordinating intermodal transportation statistics. Dr. Ashish Sen, previous Director of BTS, noted that BTS is the lead agency for geographic information within the U.S. Department of Transportation (USDOT). He charged the steering committee at the outset of the project and was a participant in the workshops.

Cosponsor: American Association of State Highway and Transportaton Officials

The American Association of State Highway and Transportation Officials, which cosponsored the three workshops, is a nonprofit, nonpartisan association representing highway and transportation departments in the 50 states, the District of Columbia, and Puerto Rico. It is the only national public-sector association that represents all five transportation modes: air, highways, public transportation (bus and rail transit), rail, and water. Its primary goal is to foster the development, operation, and maintenance of an integrated national transportation system.

Mission

This initiative seeks to identify common issues among transportation modes and recommend areas where joint development of data, tools, and organizational capabilities could improve collective capabilities.

Objectives

- Characterize the current practice in geospatial information technologies in transportation organizations.

- Identify problems and opportunities in coordination, communication, and cooperation on geospatial information among transportation modes.
- Suggest mechanisms for the development, management, and coordination of geospatial information technologies throughout USDOT.
- Recommend approaches for enhancing geospatial information within transportation organizations.

Approach

The objective of this project (study) is to review current practice in geospatial information technology, examine the problems and opportunities among transportation modes, and seek ways to develop improved communication and coordination among transportation agencies. The intent is to shift the focus of transportation agencies at the federal, state, and local levels from their current emphasis on single modes to the performance of all modes. This approach is essential in accommodating expected growth in passenger and freight transportation.

The project was organized around workshops held in three cities during 2002. The first workshop, held in Chicago, Illinois, May 2–3, 2002, examined the role of geospatial data in the project delivery process. The second workshop, held in Seattle, Washington, June 13–14, 2002, focused on safety, security, and mobility. In each of these workshops, Ashish Sen, Director of BTS, provided guidance to the participants, committee members provided background material on the state of the art, and speakers representing the specific subject matter (including mode, organization, and discipline) were invited to present their perspective on the use of geospatial technology. The third workshop, held in Washington, D.C., October 22–23, 2002, reviewed current activities of the modal administrations within USDOT in utilizing the Global Positioning System, geographic information systems, and remote-sensing software. Representatives of each modal administration were invited to present their perspectives. Each workshop included ample time for discussion of the issues through breakout sessions designed to provide feedback to the committee.

The committee met December 3–4, 2002, to review the workshop results and draft a summary report to address the mission and objectives of the project. This document is the result of that meeting.

APPENDIX C

Previous Reports on Geospatial Data Infrastructure

During the past decade, several documents have recognized or evaluated the need for geospatial data as part of a comprehensive information decision-support environment. Findings from these reports consistently maintain the theme that the comprehensive data necessary for effective decisions at a national level or to be provided to state or local decision makers do not exist, except for very specific applications, and that integration across data sets has not been practical. Recommendations routinely support the enhancement of the quality, interoperability, and dissemination of these data through coordinated activities at the national level and through partnerships with stakeholders. The committee interprets the lack of success in meeting expectations as primarily a result of underestimating the complexity of potential partnerships and the difficulty of demonstrating specific responsibilities and benefits for various potential partnership arrangements. While progress has been significant, the committee suggests that each potential data-sharing arrangement be carefully analyzed by potential stakeholders. This appendix presents a summary of those reports and their recommendations. Recommendations from the current study are listed in parentheses in bold as they relate to these earlier recommendations.

Source: ***Special Report 234: Data for Decisions: Requirements for National Transportation Policy Making.*** Transportation Research Board, National Research Council, Washington, D.C., 1992.

- Provides independent assessment of the data needed for national transportation decision making.
- Concurs with the assessment of the Secretary of Transportation that the data to inform national transportation policy making are seriously inadequate and concludes that the organization of data activities in the department is not conducive to providing them. (**Relates to Recommendations 1a and 1b.**)
- The decentralized, modally focused data programs are appropriate for individual operating units, but they are not well structured to address strategic systemwide issues. (**Relates to Recommendation 1b.**)
- Calls for establishment of a transportation data center (TDC). (**Relates to Recommendations 2a, 3a, and 3c.**)
- Calls for development of a national transportation performance monitoring system by the center to track key indicators of the nation's transportation system and its environment from the viewpoint of markets and users.
- Calls for preparation of a biennial report by TDC on the state of the nation's transportation system. The report is to contain a summary and analysis of trends in system performance and impacts.

Source: ***NCHRP Research Results Digest 191: Management Guide for Implementation of Geographic Information Systems (GIS) in State DOTs.*** Transportation Research Board, National Research Council, Washington, D.C., 1993.

- Provides managers with a basic understanding of geographic information systems for transportation (GIS-T) and their benefits.
- Describes the factors involved in successful planning and implementation of GIS-T.
- Provides managers with cost–benefit considerations and metrics.

Source: ***Toward a Coordinated Spatial Data Infrastructure for the Nation.*** Mapping Science Committee, National Research Council, Washington, D.C., 1993.

- Mapping Science Committee concludes that a National Spatial Data Infrastructure (NSDI) needs to be established if the United States is to succeed as a highly competitive nation.
- Mapping Science Committee makes the following recommendations to accomplish the improvements:
  - Develop effective national policies, strategies, and organizational structures at the federal level for integration of national spatial data collection, use, and distribution. (**Relates to Recommendation 1a.**)
  - Continue and strengthen the Federal Geographic Data Committee (FGDC) as the working body of agencies to coordinate the interagency program. (**Relates to Recommendation 1a.**)
  - Establish procedures to foster ready access to information describing spatial data available within government and the private sector through existing networks. (**Relates to Recommendations 2a and 3a.**)
  - Establish a spatial data sharing program to (*a*) enrich national spatial data coverage, (*b*) minimize redundant data collection at all levels, and (*c*) create new opportunities for the use of spatial data throughout the nation. (**Relates to Recommendation 1a, 1b, and 1c.**)

Source: ***Promoting the National Spatial Data Infrastructure Through Partnerships.*** Mapping Science Committee, National Research Council, Washington, D.C., 1995.

- Viable partnerships will require focal points within the federal government for coordinating data production and partnership activities. (**Relates to Recommendations 1a, 1b, and 3a.**)
- Clear guidelines for cost sharing in partnerships need to be developed.
- States and other organizations must be involved in standards development, and only standards essential to NSDI objectives should be required in partnership agreements. (**Relates to Recommendation 1c.**)
- Incentives are needed to encourage partnerships that are designed to maximize use and benefits to the broader user community. (**Relates to Recommendation 3d.**)
- FGDC should investigate the extent to which federal procurement rules impede the formulation of spatial data partnerships and identify steps to ease them. (**Relates to Recommendations 1b and 3c.**)

Source: ***A Data Foundation for the National Spatial Data Infrastructure.*** Mapping Science Committee, National Research Council, Washington, D.C., 1995.

- The Mapping Science Committee recommends that geodetic control, orthorectified imagery, and terrain (elevation) data be considered the critical foundation of the NSDI.
- FGDC should be responsible for coordinating the development and certification of a foundation and for its maintenance and availability. Data partnerships should be a key component of this effort. (**Relates to Recommendation 3b.**)
- Specific spatial themes should be designated as framework data.
- FGDC should (*a*) coordinate identification of components of existing framework data through its clearinghouse, (*b*) encourage efforts to integrate those data with the foundation, and (*c*) identify gaps in data coverage and encourage programs that include partnerships to populate these framework data themes. (**Relates to Recommendations 3b and 3d.**)
- To accomplish the needed compilation, maintenance, quality control, and access of the foundation and framework data, additional research and development efforts are required.

Source: ***Bureau of Transportation Statistics: Priorities for the Future.*** C. F. Citro and J. L. Norwood, National Research Council, Washington, D.C., 1997.

- The Intermodal Surface Transportation Efficiency Act of 1991 established the Bureau of Transportation Statistics (BTS) as a statistical agency.
- BTS has the responsibility to set quality standards for data release and documentation, conduct evaluations and research on methods, develop key national indicators for policy use, and coordinate data collection to identify and fill gaps and reduce duplication and costs.
- BTS has focused primarily on compiling data and making them accessible.
- BTS should develop guidelines for data quality throughout United States Department of Transportation. (**Relates to Recommendation 1c.**)
- BTS should improve documentation of the transportation data it makes available. (**Relates to Recommendation 3c.**)
- BTS should develop a broad vision of a comprehensive transportation data system that can serve the information needs of users over the long term. (**Relates to this study.**)

- BTS should develop a long-term strategy with a structured implementation plan that specifies short-term, intermediate, and long-term activities and goals. (**Relates to this study.**)
- BTS should develop key national statistical indicators for the transportation system.

Source: ***National Spatial Data Infrastructure Partnership Programs: Rethinking the Focus.*** Mapping Science Committee, National Research Council, Washington, D.C., 2001.

Purpose of assessment: Was the NSDI developing according to plan, with FGDC partnership programs working to advance its goals, or was some degree of redirection appropriate?

- Found little evidence that the programs have
  –Reduced redundancy in geospatial data creation and maintenance,
  –Reduced the costs of geospatial data creation and maintenance, or
  –Improved the accuracy of the geospatial data used by the broader community.
- Recommendations:
  –Development of measures by FGDC that can be used to monitor long-term progress.
  –Adoption of a funding formula that provides resources to all participants on a noncompetitive basis, coupled with grants of sufficient size and duration to achieve expected outcomes. (**Relates to Recommendation 1d.**)
  –Funding of projects of sufficient scale to provide well-designed empirical tests of the hypotheses underlying the NSDI goals, and allowance for adequate documentation and dissemination of results. (**Relates to Recommendation 1d.**)

APPENDIX D

Descriptions of Workshops

Workshop 1: May 2–3, 2002, Chicago, Illinois

AGENDA, THURSDAY, MAY 2, 2002

8:30–10:00 a.m. Opening Session

WELCOME AND OVERVIEW
Ysela Llort, *State Transportation Planner, Florida Department of Transportation*

FEDERAL INITIATIVES IN SPATIAL INFORMATION INFRASTRUCTURE
Ashish Sen, *Director, Bureau of Transportation Statistics*

NEW DEVELOPMENTS IN GEOGRAPHIC INFORMATION SCIENCE
Harvey Miller, *Professor, University of Utah*

10:30 a.m.–12:30 p.m. Spatial Information Infrastructure in the Transportation Modes

MARITIME
Roger Johnson, *Acting Chief, Cartographic and Geospatial Technology Programs, National Ocean Service, National Oceanic and Atmospheric Administration*

RAIL
Sharon Austin, *Communications Director, Metra Railroad*

AIR
Randy Murphy, *Founder, Grafton Technologies, and Kevin Carlson, ANSP, Inc.*

TRANSIT
Michael Shiffer, *Vice President, Planning and Development, Chicago Transit Authority*

HIGHWAY
Brian Logan, *Cartography/GIS Manager, Kansas Department of Transportation*

1:30–3:00 p.m. Three Breakouts on Enhancing the Intermodal Use of Spatial Information

Participants will (*a*) summarize technical and organizational actions to improve the value of spatial information technologies in transportation organizations and (*b*) recommend strategies for enhancing interoperability of spatial information among organizations.

3:30–5:00 p.m. Report from the Panels on Intermodal Use of Spatial Information

Panels report findings on actions to improve the value of spatial information technologies and strategies to enhance interoperability.

AGENDA, FRIDAY, MAY 3, 2002

8:30–10:00 a.m. Critical Perspectives on Spatial Information Infrastructure to Support Multimodal Transportation Organizations

Moderator: Michael J. Shiffer, *Vice President, Planning and Development, Chicago Transit Authority*

STATE DEPARTMENT OF TRANSPORTATION OFFICIAL PERSPECTIVE
Brian Rowback, *Director of Region 5, New York State Department of Transportation*

LOGISTICS PERSPECTIVE
Bruce A. Ralston, *Professor and Head, Department of Geography, University of Tennessee*

LOCAL PERSPECTIVE
Ron Thomas, *Executive Director, Northeastern Illinois Planning Commission*

AIRPORT PERSPECTIVE: O'HARE AIRPORT
John Foggia, *ANSP, Inc.*

10:30 a.m.–noon General Session and Wrap-Up

SUMMARY, OPENING SESSION, MAY 2

FEDERAL INITIATIVES IN SPATIAL INFORMATION INFRASTRUCTURE
Ashish Sen, *Director, Bureau of Transportation Statistics*

Dr. Sen described the responsibilities that the Bureau of Transportation Statistics (BTS) has within the U.S. Department of Transportation (USDOT), including the lead role in meeting the Office of Management and Budget's mandate to complete standards for the transportation layer of the National Spatial Data Infrastructure by the end of 2002.

Transportation is inherently spatial, and geographic information systems (GIS) are the essence of transportation information. Viewing data geographically can often suggest new insights and clearly illustrate the potential of spatial data integration. Dr. Sen went on to note some of the GIS problems that must be solved to achieve that potential. He challenged the group to communicate, cooperate, and coordinate to move forward in the use of spatial data to solve multimodal transportation problems.

NEW DEVELOPMENTS IN GEOGRAPHIC INFORMATION SCIENCE
Harvey Miller, *Professor, University of Utah*

"GIS" refers to the technologies for capturing, storing, processing, and communicating geospatial information. "Geographic information science" (GISci) refers to the theories, models, and methods that underlie GIS. The distinction is originally due to Goodchild (1992).

GIS Trends

"Data Poor to Data Rich"

There are new modes for collecting georeferenced data, including automated, real-time data capture from intelligent transportation systems (ITS), location-based services (LBS), and environmental monitoring devices such as automated weather stations. Data storage costs have also collapsed over the past decade, leading to the development of massive enterprise databases and data warehouses. Spatial data infrastructures such as the U.S. National Spatial Data Infrastructure are facilitating the sharing and interoperability of spatial data, which is resulting in rapid growth of digital geospatial data. This involves not only increased volumes and expanded coverage (e.g., global databases) but also increased *spectrum*. In addition to the traditional vector and raster spatial data, it is possible to collect and store georeferenced multimedia, including text, sound, and imagery.

A critical development in GIS, particularly for transportation applications, is the development of position-aware technologies. As the name implies, position-aware devices can report their location in geographic space. These technologies often have wireless communication capabilities, either to the Internet or to a voice communication system such as a cellular telephone network. Positioning methods include Global Positioning System (GPS) receivers and radiolocation methods that "piggyback" on wireless communications. Vehicle-based and person-based inertial navigation systems that compute distance and direction from a known location are also possible. Some trends associated with these technologies include field-based GIS that allow the researcher to adaptively collect, edit, and analyze data in the field; ITS that require vehicle tracking; and LBS coupled with wireless Internet to provide information on the basis of location in space and time.

Increasing Use of Digital Imagery in GIS

Image maps are a convergence of imagery and mapping; the imagery has the geometric accuracy of a map. Included are digital orthophotoquads, which are expected to cover the entire United States within 10 years, and digital raster graphics, or digital images of

U.S. Geological Survey topographic maps. Remote sensing (RS) is also experiencing a major renaissance. Improvements in RS technologies are creating substantial increases in various types of resolution: spatial (1 meter and below), temporal (high revisit rates, geosynchronous, aerial platforms), and spectral (hyperspectral sensors that can collect 200 or more bands of spectral data). This is leading to new opportunities for socioeconomic and transport applications, including RS of vehicles and detailed urban morphology.

GIS will move beyond "raster or vector." The distinction between raster and vector will no longer be meaningful from the user's perspective: GIS will include automated intelligent conversion between these formats as necessary. Georeferenced multimedia sound and imagery will be increasingly important. The logical extreme is the virtual geographic environment, which allows users to immerse themselves in a photorealistic virtual reality environment (much like the "holodeck" on Star Trek—it may even be physically manipulable given nanotechnology!).

Development of Network and Mobile Computing

Network computing will lead to "information appliances" or special-purpose thin client/fat server computers where most computing and data processing occur remotely at a server or servers. Internet GIS will allow the deployment of web-accessible geographic data servers and geographic data warehouses. It will also allow computation to be distributed and spatial analytic tools to be shared. Mobile (wireless) technology will allow "ubiquitous computing" through handheld and wearable devices or possibly through devices embedded in infrastructure. This could permit GIS anywhere, anytime (within limits, of course: anyone with access to a wired or wireless telephone will have access to GIS). Mobile GIS can allow "augmented reality." For example, the analyst will be able to wear lightweight goggles and see a GIS data view imposed on a real view of some scene.

GIS Software More User-Friendly and Flexible

Better user interfaces are already evident: ArcGIS Version 8.1 utilizes the WIMP (windows, icon, mouse pointer) interface. Computer scientists are also trying to move beyond the desktop metaphor; for example, David Gelernter at Yale University is developing a "timestream" interface that maintains information and tools as a time-dependent flow of configurations and activities. "Wizards" and intelligent agents can help users through complex GIS processes (in the former case) or conduct the process automatically and in the background (in the latter case). The development of object-orientation and componentware means that software in general, and GIS specifically, will no longer have a wide range of vendor-supplied tools that try to do everything with limited success. Instead, it will become flexible. Flexibility is supported by the development of interoperable and open software architecture. GIS will probably cease to be independent, stand-alone software and instead become a tool kit linked to enterprise database systems.

GISci Trends

Among the many developments, three major trends that are especially relevant to GIS for multimodal transportation are highlighted. One of the biggest at the frontier of GISci is spatiotemporal GIS, that is, GIS representations and tools that can accommodate two- or three-dimensional geospace and time in an integrated manner. "Multidimensional GIS" tries to go beyond the "timeless space" of the map to include representation and analysis of four-dimensional information (Raper 2000). Some of these ideas have also been developed specifically for socioeconomic applications (Frank et al. 2001). There have been recent breakthroughs in spatiotemporal data modeling, including the event-based spatiotemporal data model, which maintains spatiotemporal data as a sequence of temporal events associated with a spatial object (Peuquet and Duan 1995), and the three-domain model (Yuan 2001), which treats time as a temporal object instead of an attribute to give the spatial, temporal, and semantic domains equal emphasis. The multidimensional location referencing system recently developed under the sponsorship of the National Cooperative Highway Research Program uses the three-domain model to develop a transportation data model that can reference facilities and events in three-dimensional geospace and time with respect to a transportation network.

Another research frontier is the development of methods for geographic data knowledge discovery (GKD). This refers to the search for patterns in massive geodatabases. Tools of geographic data mining include spatial cluster classification, exploratory spatial analysis using statistical methods, and geographic visualization. GKD will become more important in transportation as spatiotemporal data on network flows (through ITS) and on space–time trajectories through LBS become available. See Miller and Han (2001).

A final relevant trend is attempts to move GIS beyond place-based theories and methods. Place-based methods such as travel demand modeling, urban theory, and GIS in general are increasingly limited. In this high-mobility and information technology–based world, activities are increasingly being disconnected from place (for example, work can occur at an office, at home, at a coffee shop, or in a park). Some researchers, among them the author, are calling for a "people-based GIS," which will extend place-based GIS to encompass dynamic and mobile objects that perform activities within a dynamic geometry representing space. There are numerous theories and technologies to support a people-based GIS. Theories include time geography, which focuses on spatiotemporal constraints on behavior; activity theory, which examines how humans arrange activities in space and time and how transportation, telecommunication, and urban systems emerge from individual activities; and the aforementioned multidimensional GIS. Technologies that support a people-based GIS include position-aware technologies for data collection and GKD for massive, noisy space–time databases.

References

Frank, A. U., J. F. Raper, and J.-P. Cheylan (eds.). 2001. *Life and Motion of Socio-Economic Units*. Taylor and Francis, London.

Goodchild, M. F. 1992. Geographical Information Science. *International Journal of Geographical Information Systems*, Vol. 6, No. 1, pp. 31–45.

Miller, H. J., and J. Han (eds). 2001. *Geographic Data Mining and Knowledge Discovery*. Taylor and Francis, London.

Peuquet, D. J., and N. Duan. 1995. An Event-Based Spatiotemporal Data Model (ESTDM) for Temporal Analysis of Geographical Data. *International Journal of Geographical Information Systems*, Vol. 9, No. 1, pp. 7–24.

Raper, J. F. 2000. *Multidimensional Geographic Information Science*. Taylor and Francis, London.

Yuan, M. 2001. Representing Complex Geographic Phenomena in GIS. *Cartography and Geographic Information Science*, Vol. 28, No. 2, pp. 83–96.

SUMMARY, FIRST GENERAL SESSION, MAY 2

Maritime

Roger Johnson, *Acting Chief, Cartographic and Geospatial Technology Programs, National Ocean Service, National Oceanic and Atmospheric Administration*

The National Oceanic and Atmospheric Administration (NOAA) is the nation's principal advocate for ocean and coastal stewardship. It provides the scientific information management and leadership necessary to balance the environmental and economic well-being of the nation's coastal and economic resources. NOAA's mission is to describe and predict changes in Earth's environment and to conserve and wisely manage the nation's coastal and marine resources.

This task consists of seven strategic goals: to advance short-term warning and forecast services, implement climate forecasts, predict change, promote safe navigation, build sustainable fisheries, recover protected species, and sustain healthy coastal ecosystems.

Maritime spatial data received by the Office of Coast Survey is primarily used to promote safe navigation. About 3,500 ships are involved in incidents on the nation's waterways annually.

The stress on the nation's ports continues to increase substantially. During the past 50 years, the size of ships has doubled and the amount of oceangoing commerce has tripled. By weight, more than 98% of all cargo passes through U.S. ports and harbors. That represents more than $500 billion annually, and much of this cargo contains hazardous materials.

Currently, NOAA's primary product is the nautical chart, which shows the depths of water, aids to navigation, navigational dangers, and the adjacent land area that is of interest to the mariner. The charts are primarily intended for marine navigation. Nautical charts are verified and updated as part of an ongoing process to create a cartographic representation of the best available data collected through the years, employing a variety of collection techniques and delivered using various data types, formats, datums, scales, collections, and projections.

Charting material primarily consists of dredged channel data supplied by the U.S. Army Corps of Engineers, aids to navigation from the U.S. Coast Guard, and hydrographic and topographic surveys from NOAA itself. This material is supplemented with other surveys and information from other government and private organizations. All material needs to be critically examined with particular attention to the date of the survey, geographic datum, depth unit, plane of reference, and purpose and quality of the survey.

Two other new products of special interest to the geospatial data community are coastal maps and the extracted vector shoreline projects. The coastal map provides the hydrography and topography of all current edition nautical charts in a georeference raster format.

What challenges face NOAA? With more than 95,000 miles of coastline and 3.5 million square miles of open water, charting the United States is a substantial task. Daily challenges include the accurate horizontal and vertical datum transformations as well as data format conversions. The nautical chart is covered with information that was collected over numerous years with a variety of resolutions. Many of the data date back to the 1940s. Because of the Differential Global Positioning System, today's mariners are often capable of determining their position with a greater degree of accuracy than was the case when the data were collected. Improving positional accuracy is a major challenge.

Rail

Sharon Austin, *Chief Communications Officer, Metra Railroad, Chicago, Illinois*

Metra is a Chicago-area rail rapid transit system covering 3,700 square mile in northeastern Illinois. It is made up of 12 separate rail lines that radiate from the Chicago Loop and serves more than 100 communities and 241 rail stations. Metra runs 705 trains on weekdays and 484 on weekends over 546 route miles (1,189 track miles) and carries almost 300,000 passengers per day.

The presentation was focused on describing the GPS TrainTrac system, which is a computerized train-tracking system using GPS information to detect train locations and send concise information and announcements to customers. A test system was installed in two trains on one line in 1999, and after evaluation the decision was made to implement TrainTrac systemwide in April 2001.

The project goals were the following:

- Ability to monitor location and schedule performance of all commuter trains operating on Metra, Burlington Northern and Santa Fe, and Union Pacific;
- Automated station and emergency announcements on board;
- Automated reminders for customers needing special assistance;
- Ability to number trains, revise schedules, and generate and send announcements from a central location to any train;
- Ability to derive more timely information concerning operation and send it more quickly and efficiently to waiting customers; and
- Ability to evaluate operation in real time when decisions are being made during service changes or disruptions.

Implementation of Phase 1 of the system was completed in December 2001, and Metra is now preparing to implement Phase 2, which will develop an interface with existing station signs and audio equipment, develop and install technology for new cars, and make improvements to the existing system-based user experience.

In response to a question concerning ridership changes as a result of the improved customer service, Ms. Austin indicated that Metra has received positive feedback from weekend travelers on ease of using the service. However, Metra is primarily a commuter line with fairly stable weekday ridership, and increases have not been noted to date.

Air

Randy Murphy, *Founder, Grafton Technologies, and Kevin Carlson, ANSP, Inc.*

The purpose of this presentation was to provide an overview of how and why airports are applying spatial data and technologies. It was also intended to provide an industry overview that would set the context for the more specific application of spatial data and technologies at Chicago O'Hare International Airport.

Airports are not new to maps. Starting in the early 1930s, Elrey Jeppesen began hand-drawing charts for himself and his fellow pilots, many of whom flew airmail routes. By the mid-to late 1900s, computer-aided design (CAD) technology was flourishing as a tool to plan, design, build, operate, and maintain the facilities that make up an airport. Now GIS and CAD technologies are being used in numerous airport applications. Where this will lead in the decades ahead is the question and a challenge.

Most people are familiar with airports. They are complex environments encompassing aircraft operations, surface transportation, communication centers, weather stations, construction sites, maintenance, and fuel loading. Airports have also grown to include road networks, utilities, shopping malls, hotels, business centers, and shipping hubs. In many ways, airports can be thought of as minicities. The growth of airports is a long-term trend that is expected to continue for the foreseeable future, despite the terrorist attacks of September 11, 2001, and a recent economic slowdown. It has strained the existing aviation infrastructure and necessitated construction at airports throughout the country and, for that matter, the world.

GIS is being looked upon by many as a tool that can help the expansion and improvement of the aviation infrastructure.

The application of spatial data and technologies in the aviation sector has, however, lagged that in other transportation modes. It is estimated that aviation is approximately 9 years behind the other modes in applying GIS. Despite the need to catch up, a steep growth curve is expected because of demand. It will be facilitated by the lessons that can be learned from the other modes.

The challenge that lies ahead is to promote the sharing of experiences, data, and applications across modes.

Transit

Michael Shiffer, *Vice President, Planning and Development, Chicago Transit Authority*

Large urban transit organizations have challenging spatial data needs, and Chicago is no doubt representative of this. The Chicago Transit Authority (CTA) is the second-largest mass transit system in the United States, with

- 1,874 buses on 2,196 route miles;
- 12,858 bus stops;
- 1,190 rail cars on 222 route miles;
- 143 stations; and
- 1.56 million riders per day.

Given all of this, CTA has significant amounts of rolling stock and numbers of facilities and employees to keep track of; in addition, it must maintain an understanding of where riders are and where they wish to go. The spatial data needs of CTA are broken down into the following: strategic planning, service planning, scheduling, facilities, transit operations, maintenance, and capital program management. This paper will describe the spatial data needs of these functions and conclude by identifying some of the more general spatial information challenges that face large transit organizations.

Strategic Planning

The Strategic Planning Department strives to understand travel patterns within the metropolitan area. In doing this, a combination of census and land use data is critical in juxtaposition with the existing transportation infrastructure. Coordination of this information involves forming institutional links not only with the city of Chicago but also with the 38 local governments that CTA serves in the suburban area. The strategic planning group also relies on customer satisfaction surveys that frequently have an associated geographical element.

Another critical aspect is the need to manage the fleet of rail cars and buses and effectively allocate these vehicles among 8 bus garages, 11 rail terminals, and 12 rail yards. This fleet also requires tracking the capacity needs of individual routes so that CTA can better determine its needs for purchasing new vehicles. CTA must also keep abreast of strategies for dealing with emergency situations, which requires the maintenance of an effective information infrastructure to support contingency route planning in the event of extraordinary circumstances.

Service Planning

The Service Planning Department analyzes ridership patterns to incrementally adjust service to better match passenger demands. Key technologies that make this possible include automatic passenger counting mechanisms and fare collection technologies that record spatial coordinates. As CTA tracks its service, it must always be cognizant of equity considerations, because Chicago is a highly varied, multicultural city. Furthermore, service changes must be related to standards that have been put forth to the public.

Scheduling

The Scheduling Department is responsible for developing schedules that determine where and when vehicles serve the public. It must also determine the scheduling of thousands of employees who operate these vehicles and support CTA service. Some of the spatial aspects of this include having a geographical understanding of challenging logistical concepts (such as where employee washroom facilities are located throughout the city). The department also needs to maintain location-specific timetables so that customers can gain an understanding of when a bus or train will arrive.

Facilities Development

The Facilities Development Department must monitor street closures and construction timetables so that service can be rerouted with minimal disruption. In addition, the department maintains a spatial database of all 12,000 bus stops. Included in this information are characteristics of these stops, such as on which side of the street the bus stops, whether the intersection is signalized, and whether there are shelters for patrons. Other facilities issues in which spatial data play a significant role include how buses are turned and where vehicles can lay over between runs.

Transit Operations

Perhaps the most important application of spatial data in a transit system involves having information systems that allow effective monitoring of buses and trains. Such real-time management involves the support of field supervisors, the delivery of paratransit services, and current information on emergency reroutes. In addition, spatial data play a critical role in the management of medical, police, and fire services should they be required at any point in the system.

Of particular importance in Chicago is the issue of snowfall. CTA must keep rail stations and track alignments clear. In addition, CTA must coordinate snow removal efforts with those of the municipalities it serves to maintain clear bus routes, terminals, and stops.

Hundreds of other utility vehicles are used to support infrastructure (such as garages, warehouses, and elevated rail structures). Furthermore, it is important to understand the condition of this infrastructure, which of course has spatial needs.

Capital Program Monitoring

Finally, the management of the capital program requires tracking the progress of many concurrent construction efforts. In addition, an understanding of issues concerning real estate adjacent to CTA property is necessary.

Spatial information and emerging multimedia systems can play a pivotal role in both internal and public meetings where the many facets of CTA's capital programs are discussed.

Conclusions

Spatial data for transit properties present some interesting data-handling challenges. Some of these challenges arise because routes change by time of day and the alignment of some routes changes with the direction of travel. CTA also has routes that overlap on the same street, and some of Chicago's multilevel roadways add to this complexity.

Beyond these transit-specific challenges, CTA faces many of the same challenges that other public agencies must address. These include sharing information (both within the agency and with other agencies), the development of a spatial information infrastructure, and the development of the human capital necessary to maintain this infrastructure.

HIGHWAY
Brian Logan, *Cartography/GIS Manager, Kansas Department of Transportation*

Mr. Logan characterized the current practice in spatial information technologies in the Kansas Department of Transportation and the benefits derived from various applications. The specific examples included the development of the department's comprehensive highway program and the integration of disparate data sources for long-range planning and transportation modeling and as a decision-support tool in working with the governor, the legislature, local governments, and federal agencies.

Other examples cited were GIS web applications such as road condition reporting systems, construction and detour reporting systems, truck routing systems, and construction program status. Kansas has also used spatial data in multimodal applications such as rail–highway crossing improvements and in developing a statewide bicycle map.

Kansas has an active GIS clearinghouse that oversees development and use of spatial data. It works with federal, state, and local agencies and local utilities to coordinate collection of base data, including georeferenced imagery and base maps. It also maintains metadata records.

Mr. Logan offered the agency's perspective on the necessary infrastructure of spatial data, technical tools, and staffing. Critical issues included the conversion of legacy systems, the development of data standards, standardized location reference systems, and the integration of current remotely sensed imagery. Staff resources, well trained in spatial data technologies, are essential to successful application of GIS in state departments of transportation.

SUMMARY OF BREAKOUT SESSIONS

Workshop participants were divided into three groups and were asked to (*a*) summarize technical and organizational actions to improve the value of spatial information technologies in transportation organizations and (*b*) recommend strategies for enhancing interoperability of spatial information among organizations. To help structure their response, each group was provided the following topics:

- Key issues affecting modes today.
- How spatial data, tools, and technologies help address those issues.
- Barriers or constraints: securing the resources for new data, tools, and technologies.
- Critical pieces to ensure effective impact of technologies.
- Areas where sharing spatial data or cooperating on technology development would improve use of spatial information technologies.

Key Issues Affecting Modes

- Congestion/mobility within and across modes.
- Safety.
- Security/emergency response.
- Liability.
- Environmental impacts.
- International border crossings.

How Spatial Data, Tools, and Technologies Help Address Those Issues

Cross-Modal Analyses

Spatial technologies enable integration of information, which allows closer examination of the traditional split between modes for both passenger and freight. Such integration helps identify duplicative service and gaps that contribute to congestion and inefficient travel. For example, it allows assessment of travel time equilibrium between modes in critical transportation corridors.

Socioeconomic Analyses

The impact of transportation facilities and services on the community and environment can be assessed through the integration of data sets including demographic, environment, travel, and physical features.

Telling the Story

The public has been conditioned by the media to access and absorb information presented rapidly in a visual context. The medium is critical in delivering the message, and spatial data technologies enhance that capability. They are excellent tools for policy makers in communicating information on transportation programs and projects to funding agencies such as legislatures and to the affected public.

Meeting Emergency Needs

Spatial data technology enables rapid assembly and analysis of data to meet emergency situations affecting transportation facilities and services (e.g., floods, snowstorms, crashes).

Data Interfacing

The integration of disparate data sets such as user fees (e.g., gas tax), economic impacts (e.g., housing starts), and resource allocations are enhanced by spatial data technologies.

Improvement in Decisions Through Better Data Quality

Data integration via spatial technologies exposes bad data, which leads to corrections; hence, decisions are better informed.

Productivity

Spatial data tools and technologies improve the efficiency of organizations through better management of data collection, storage, analysis, and presentation.

Barriers or Constraints: Securing the Resources for New Data, Tools, and Technologies

Problem Definition

What is the multimodal problem that the use of spatial information will help solve? The first step in developing solutions is a clear definition of common problems that transcend modes. This, in turn, leads to cooperation across modes.

Organizational Issues

The roles of the federal, state, and local governments in accessing/acquiring data and sharing (giving up the data) are unclear. In addition, the stovepipe mentality and legacy databases within organizations hamper data sharing.

Lack of a Driver

Transportation modal agencies need a common purpose or issue to "rally around" or to "drive" intermodal cooperation and coordination. This involves identification of the critical stakeholder. The issue could be security, access to work sites, modal transfer points, and so forth. Conflicting objectives between modes and organizations lead to inefficient operations.

Access to Private-Sector Data

Core data sets often provide competitive advantage to the shipper/carrier of freight; hence, there is a reluctance to share.

Lack of Standard Data Sets and Definitions

- Precision and accuracy requirements of users vary
- Core data sets to meet common user needs are undefined
  - –NCHRP Project 20-27(1) GIS Report (University of Wisconsin)
  - –Jack Faucett report (NCHRP document)
  - –Saratoga Springs freight conference report
- Metadata standards are missing
- Georeferencing systems are inconsistent between organizations

Not User-Friendly

There is a need to make the tools and technologies easier to use.

Single Modal Focus

There is a lack of motivation to collect data other than those needed for business. Few service providers have broad multimodal operational responsibilities.

Funding Constraints

Data are expensive, and data acquisition and analysis capability is often the first area of the budget to be cut. This problem is compounded by the perception that data are secondary to transportation organizations, whose primary activities are construction and operation. The information infrastructure needs to parallel the physical transportation infrastructure.

Lack of Knowledgeable Staff

The need for knowledgeable staff extends from those who must understand the technology to those who must apply it to real situations. Also, technology is great, but it cannot replace the thinking process.

Critical Pieces to Ensure Effective Impact of Technologies

Involvement of Policy-Level Decision Makers

This will drive organizations to use spatial data technology.

Development of Best Practices

Development of best practices is needed in both the public and the private arenas to deal with data issues and process. It is particularly important for use in debating public policy issues. Cost–benefit examples from the private sector (FedEx) would be useful. This could include a pilot project in which a public–private partnership facilitates the movement of people or goods and has a clear benefit to a customer set.

Private-Sector Buy-In

This leads to cooperative actions in technology development and use between modes and organizations. For example, the ITS community has developed traffic data standards and procedures now in use by state and local governments.

Top-Down and Bottom-Up Approach

Policy-level actors (commissioners, CEOs) drive the use; planning and operations staffs develop the tools and technology.

Organizational Location

Spatial data elements must be incorporated within an organization's broader information technology plan. This is helpful in getting senior management approval and makes it less vulnerable to budget cuts.

Standards

Standards are necessary to make shared information useful across organizations and modes. Metadata standards and a "road map" to inform users about what is available should be included.

Liability and Privacy

Data provider and user comfort levels must be developed to ensure data sharing.

There should be integration with electronic media (Internet) to broaden the exposure of spatial technology applications.

Training

This is necessary to develop knowledgeable staff at all levels of government.

Identification of Common Data Sets

This allows agencies to focus on coordination in the funding, acquisition, and sharing of essential data without posing a threat to organizational roles and responsibilities.

Areas Where Sharing Spatial Data or Cooperating on Technology Development Would Improve Use of Spatial Information Technologies

Development of Standards

Common data sets and metadata standards should be developed.

Quantifying the Value of Sharing Multimodal Data

- How do the regional and local economies benefit?
- Examine linkages from demographics to jobs to mode.
- Examine relationships between modes and government (e.g., airport and city).

Partnerships with Other Disciplines Actively Engaged in Use of Spatial Technology

This could include the military (where possible), the space industry, and nontransportation arenas such as the real estate/housing industry.

Performance Measures

Governments at all levels and the private sector utilize performance measures to assess the impact of investment on the delivery of products and services. Spatial technology can assist in developing cross-modal measures.

Activity-Based Perspective

Organizations focus on the mode for which they have responsibility. Shifting the focus to the activity supported (e.g., journey to work, moving freight from one point to another) would highlight the importance and enhance the use of spatial technologies to integrate data sets. Transportation should be viewed as a service independent of mode. People and goods should move from one point to another in a seamless fashion. If transportation is viewed as a service, it might be easier for organizations and modes to seek (and find) information commonalities that could be supported or enhanced by spatial technologies.

Emergency Services

Clear demonstration of benefits in early response and subsequent recovery would enhance use of spatial technologies.

SUMMARY, SECOND GENERAL SESSION, MAY 3

State Department of Transportation Perspective
Brian Rowback, *Director of Region 5, New York State Department of Transportation*

Mr. Rowback is the Regional Director for New York State Department of Transportation's Niagara Frontier area, a four-county area in western New York. He is responsible for about 1,100 employees, split among operations, maintenance, engineering, and planning and development. His presentation covered three topics with respect to the use of spatial data: the integration of demographic and modal information, emergency response applications, and an approach to allowing executives and other management staff to review information on the capital program.

The first example focused on relating the assets of the Buffalo transit system to the demographics of the area. By geographically relating major employment centers to residential areas, the department was better able to analyze ridership and locate and construct bus shelters, sidewalks, and other pedestrian facilities. The availability of a spatially related asset management database to all local governmental agencies was instrumental in developing sound operational plans.

In the second example, Mr. Rowback described how the department used spatial data in managing state, local, and private resources in response to a major snowstorm. In December 2001 Buffalo received 84 inches of snow over a 2-day period, which effectively paralyzed the city. To direct the response, the department used a spatial database to identify roads closed to all traffic, roads open (plowed) with either one or more lanes, and snow dump areas. The up-to-date information was also posted on a website available to emergency management staff.

The final example was an illustration of the use of spatial databases in the capital construction program. Each project in the program contains a multitude of information that is critical to both the department and the public affected by the project. Critical milestones, schedules, detour routes, cost–benefit analyses, legislative districts, and other factors are in constant demand. A graphical representation becomes a valuable communication tool.

In response to questions concerning how BTS could assist a state department of transportation, Mr. Rowback stated that he lacked good information in certain areas, particularly origin–destination on freight movements. Issues include congestion at major choke points, international border crossings, and security.

Logistics Perspective
Bruce A. Ralston, *Professor and Head, Department of Geography, University of Tennessee*

This presentation focused on the logistics aspects of producing, storing, transporting, and marketing goods. Key questions are as follows:

- What modes are available at various locations?

- What are the costs, time, and capacity functions to capture intermodal movements?
- Is the infrastructure that makes the intermodal movements possible fixed or movable?

A model of the relationships between these factors along with several specific examples (grain storage in Osaka, jeans for Levi Strauss, CVS distribution chain) showed the value of spatial data integration in developing direct logistics costs.

The logistical perspective is both tactical (short term) and strategic (long term). It looks at things like facility location, transport and design, choice of mode and type of carriage, and inventory control. It works well at the operational level but needs further development and use of GIS technology for strategic decisions, particularly as it relates to supply chain optimization.

A supply chain consists of relationships between all actors: from the sources of raw materials, to the transportation providers, to distribution center operations, to delivery to the customer. Supply chain management is the practice that tries to coordinate these activities to increase customer value and is often based on interfirm relationships. It requires information sharing, cost–savings sharing, and chain visibility. There are "spatial brokers" that provide information via the web to support logistics and help run the emergent markets.

Supply chain approaches reflect emerging economic organizations. The shippers, carriers, and third-party information providers are learning how best to interact to build and use new business models. The swarm intelligence concept provides simple operational rules and allows businesses to evolve the best logistical approach. These trends highlight the need for dynamic spatial tools and technology.

Local Perspective
Hubert Morgan, *Northeastern Illinois Planning Commission*

The Northeastern Illinois Planning Commission (NIPC) is the regional planning agency for the six counties, including 272 municipalities and 8.1 million people, in the Greater Chicago area. Its primary responsibility is in land use planning and in working with transportation agencies such as the Chicago Area Transportation Study and CTA to relate community needs and public services. Mr. Morgan described the NIPC planning process, including the strong outreach to the public in identifying five regional issues areas: transportation and infrastructure, economic development, community development, natural resources and the environment, and quality of life.

GIS technology has been particularly useful in linking land use development patterns to employment and the transportation systems. The impact of proposed new developments on highway capacities and transit services can be more easily evaluated and presented to developers and the general public.

One of the challenges faced by NIPC is the difficulty in relating data collected by local governments under varying time frames and quality standards. NIPC is attempting to bridge these data gaps and overlaps by becoming the "spatial information broker" for the region. The use of spatial data technologies to demonstrate to local governments the value of coordinating the funding and collection of regional data has been very effective.

SUMMARY, FINAL GENERAL SESSION, MAY 3

The purpose of this session was to summarize ideas and develop proposals for enhancing the use of spatial information technologies in multimodal transportation organizations. Workshop participants were asked to refine the proposals and prioritize them on the basis of importance and ability to implement. The following issues/items were identified and discussed.

Catalog of Best Practices

Methods of acquiring and accessing modal data as well as examples of good cost–benefit analyses (e.g., FedEx) would be included. Transportation organizations in the different modes that can describe specific examples of best approaches to cost–benefit analyses should be identified.

Examples of the use of GIS by policy makers (Kansas Department of Transportation, CTA, and New York State Department of Transportation) to make strategic decisions or to engage the public in evaluating transportation issues should be included. (Consider Brian Rowback's pavement management example of using GIS as a "stovepipe" breaker, and how to use "discovery" as a technique to identify data sets often concealed with separate stovepipes.) Organizational and funding issues should also be addressed, including how to achieve buy-in at the top levels. Delivery could include brochures, a website, and training programs.

Standardization

Expanded use of spatial data technologies is hampered by lack of standards. A catalog (road map) of core data standards among modes should be developed. This would allow decentralized use of spatial data at all organizational levels. Standards could also be activity based to support point-to-point transportation, either person travel or freight movements. This approach would cut across modes. The American Association of State Highway and Transportation Officials (AASHTO), the Association of Metropolitan Planning Organizations (AMPO), and other representatives of the user community could be enlisted to help define the minimum level of data needs and commonalities. Several existing core data set sources exist.

Public–Private Partnerships

The expanded use of spatial technologies is dependent on their use in both government and private arenas. For example, the private sector is developing geospatial data standards for use in vehicles. The 511 system will provide a special communication network for publicly available information. Innovative uses of technologies such as this are driven by the marketplace and not by government declaration.

Companies such as FedEx and UPS have nationwide data on the reliability and performance of their transportation systems.

Transportation needs to seek out and engage critical private-sector modal leaders to develop strategies for sharing existing databases and developing spatial data tools and technologies. (A number of suggestions were raised in the last discussion session on working with private-sector agencies to access and share transportation data. A specific example cited was the lack of data sharing between airports and the surrounding communities that provide the landside access.)

Research

Gaps in spatial data tools and technologies need to be identified and a research program initiated to address these gaps. Coordination with other public-sector organizations and with the private sector is essential to the success of this effort.

Role Definition

Appropriate roles with respect to spatial data and technologies within USDOT and other federal agencies should be identified. This is first step in developing a hierarchy of responsible roles at other levels of government. The Transportation Research Board (TRB) also can have a role in advancing the state of the art and the state of the practice through directed research, identification of best practices, and subsequent outreach.

Clearinghouse

A clearinghouse capability with respect to spatial data tools and technologies would be beneficial. This should include information on current applications as well as developmental activities. (Often the developers of computer games lead the industry with respect to data integration and graphic displays.)

Pilot Project

A multimodal pilot/demonstration project to highlight the advantages of using spatial data tools and technologies would go a long way toward demonstrating the benefits and implementation issues. One or more real-life examples focused to address multimodal issues including both passenger and freight could be featured.

Service Delivery Concept

Transportation can be viewed as a service independent of mode. People and goods should move from Point A to Point B in a seamless fashion. Viewing transportation as a service might make it easier for organizations and modes to seek and find information commonalities that could be supported or enhanced by spatial technologies. This would also help identify the stakeholders who need spatial information, why they need it, and what the cost would be.

Problem Definition

The purpose of developing a multimodal transportation information system and sharing data must be clearly determined. There are logistics problems that have both transportation and nontransportation dimensions. These should be clarified before attempting to access and share data systems.

Freight Data Access

The movement of freight is a major contributor to congestion on the nation's transportation system. And it has major multimodal components. Access to and sharing of freight data—commodity flows, preferred routes or modes, or cost–benefit analyses—would be useful in identifying the best applications of spatial technology.

PARTICIPANTS

Sharon Austin, *Metra*
Carol Brandt, *Bureau of Transportation Statistics*
Kevin Carlson, *ANSP, Inc.*
Ed Christopher, *Federal Highway Administration*
Dean Englund, *Chicago Area Transportation Study*
John Foggia, *ANSP, Inc.*
James Hall, *University of Illinois*
Kathleen L. Hancock, *University of Massachusetts, Amherst*
Richard Harrington, *Pima County Department of Transportation*
Robert C. Johns, *Center for Transportation Studies, University of Minnesota*
Roger Johnson, *National Ocean Service, National Oceanic and Atmospheric Administration*
Steve Lewis, *Bureau of Transportation Statistics*
Ysela Llort, *Florida Department of Transportation*
Brian Logan, *Kansas Department of Transportation*
Xavier Lopez, *Oracle Corporation*
Harvey J. Miller, *University of Utah*
Randall J. Murphy, *Grafton Technologies, Inc.*
Thomas M. Palmerlee, *Transportation Research Board*
Roger Petzold, *Office of Intermodal and Statewide Planning, Federal Highway Administration*
Curtis Pulford, *Geospatial Systems Group, Wisconsin Department of Transportation*
Bruce A. Ralston, *Department of Geography, University of Tennessee*
Brian Rowback, *New York State Department of Transportation*
Ashish Sen, *Bureau of Transportation Statistics*
Michael J. Shiffer, *Chicago Transit Authority*
James Sims, *Southern California Association of Governments*
John Sutton, *Cambridge Systematics, Inc.*
Ron Thomas, *Northeastern Illinois Planning Commission*
Ronald W. Tweedie, *Consultant*
Wayne Watanabe, *King County Metro Transit*
Fred Laurence Williams, *Federal Transit Administration*
Francis Winters, *New York State Department of Transportation*

Workshop 2: June 13–14, 2002, Seattle, Washington

AGENDA, THURSDAY, JUNE 13, 2002

8:30–10:00 a.m. Opening Session

WELCOME AND OVERVIEW
Ysela Llort, *State Transportation Planner, Florida Department of Transportation*

FEDERAL INITIATIVES IN SPATIAL INFORMATION INFRASTRUCTURE
Ashish Sen, *Director, BTS*

NEW DEVELOPMENTS IN GEOGRAPHIC INFORMATION SCIENCE
Xavier Lopez, Oracle Corporation

10:30 a.m.–12:30 p.m. Spatial Information Technologies to Improve Transportation Security, Safety, and Efficiency
Moderator: Rick Harrington, *Technical Services Division Manager, Pima County Department of Transportation*

MARITIME
Carl Sobremisana, *Division of Ports, Maritime Administration*

RAIL
Raphael Kedar, *Deputy Associate Administrator for Policy, Federal Railroad Administration*

AIR
Theresa Smith, *Manager, Aviation Planning, Washington State Department of Transportation Aviation Division*
Fred Anderson, *AVN Business Manager, Federal Aviation Administration (invited)*

TRANSIT
Wayne Watanabe, *Supervisor of Infrastructure and Integration, King County Metro Transit*

1:30–3:00 p.m. Information for Critical Decisions in Transportation
Moderator: Harvey Miller, *Professor, University of Utah*

LEGISLATIVE VIEWS
Representative Fred Jarrett, *Washington State House of Representatives*

STATE DEPARTMENT OF TRANSPORTATION VIEWS
Brian Ziegler, *Washington State Department of Transportation*

PREPARING FOR REAUTHORIZATION: IMPLICATIONS FOR DATA
David Ekern, *Associate Director, AASHTO*

3:30–5:00 p.m. Critical Problems in Transportation: Challenges for Spatial Information Technologies
Moderator: Kathleen Hancock, *Associate Professor, University of Massachusetts, Amherst*

DISASTER RESPONSE
Ron Langhelm, *Federal Emergency Management Agency*

SECURITY
Catherine Lawson, *State University of New York at Albany*

SAFETY
Troy E. Costales, *Oregon Governor's Highway Safety Representative, Oregon Department of Transportation*

AGENDA, FRIDAY, JUNE 14, 2002

8:00–10:00 a.m. Breakout Panels on Enhancing Intermodal Use of Spatial Information

10:30 a.m.–noon Panel Reports and Wrap-Up

SUMMARY, OPENING SESSION, JUNE 13

FEDERAL INITIATIVES IN SPATIAL INFORMATION INFRASTRUCTURE
Ashish Sen, *Director, BTS*

BTS is the lead agency for GIS in USDOT. The administration has embraced geospatial data and technology, and GIS is one of the e-government initiatives. By the end of 2002 BTS will complete standards for a transportation layer of the National Spatial Data Infrastructure. This infrastructure is part of the Geospatial One-Stop to provide access to federal geodata from a single access point and make state and local geodata more accessible. Core standards will provide a common, consistent format for geospatial data.

BTS is working to develop GIS-based tools to identify potential bottlenecks and to study traffic congestion around airports. It has used GIS to assess public transportation in connection with welfare-to-work in the Boston metropolitan area. GIS can also be used to analyze other mobility problems, ranging from maritime cargo trade patterns to airport expansion possibilities. By linking GIS with GPS technology and satellite imagery, traffic flows over transportation networks can be tracked in real time.

Since the events of September 11, 2001, security has been a major concern of the federal government. The same spatial data technology used to assess congestion can also be used to track trucks and containers that could pose a security risk if misdirected. A GIS data platform can also bring diverse data together to address security issues.

Data are one of the most expensive investments that public and private organizations face. The continual issues of updating, maintenance, ownership, and stewardship of geospatial data created by many different organizations using different standards and technologies lead to inefficiencies and waste. BTS is taking the lead to reach compatibility through better communication, cooperation, and coordination.

New Developments in Geographic Information Science

Xavier Lopez, *Oracle Corporation*

The purpose of Mr. Lopez's presentation was to discuss the latest developments in spatial information technologies and tools. Four domains were presented: GPS technology, RS technology, static transportation data systems, and real-time systems. The key is the integration of all these technologies to address multimodal transportation issues.

The critical element in all these applications is location, and it is now being built into core information technology systems. And these systems are moving from desktop and client-server technology to the web, with spatial capability incorporated directly into the database. Internet computing also allows agencies to centralize services and deliver applications to a much larger customer base.

Mr. Lopez went on to describe several examples of the use of spatial technology. Among them are billing systems, a spatial database to manage mapping data across organizations in New York City, logistics applications, and location-based services.

Location-based services were described as the application of GIS technology in real-time systems with wireless technology. Roadside assistance, fleet management, remote vehicle diagnostics, and other field-based services are now available through this technology.

In conclusion, he stressed the importance of standards to location-based services, both in the geographic database and for the multimodal data systems.

SUMMARY, FIRST GENERAL SESSION

Moderator: Rick Harrington, *Technical Services Division Manager, Pima County Department of Transportation*

Maritime

Carl Sobremisana, *Division of Ports, Maritime Administration*

Mr. Sobremisana began his presentation with a brief history of the Maritime Administration and his experience on several projects. He then discussed the use of geospatial technology in the Ports of Los Angeles, Long Beach, New York, Oakland, and Seattle. Applications included a property lease management program, container tracking, a dredging management program, utility asset inventory, and the monitoring of construction sites. One of the most significant applications is cargo flow tracking. This has real-time impacts on other modes and geographic areas.

The potential for expanded use of spatial information technology in the maritime arena is particularly evident in international trade. Major port facilities in the United States are linked to foreign ports and, in turn, to land-based transportation corridors, both truck and rail. This includes the inland waterway system and the Great Lakes. The North American Free Trade Agreement and other economic incentives have increased the north–south cargo flows through the Americas.

The Federal Highway Administration, through the Office of Freight Management and Operations, has developed the Freight Analysis Framework. The use of this policy analysis tool will allow evaluation of current conditions, examination of future scenarios, and analysis of policies or strategic investments designed to improve freight productivity and mobility. Spatial technology will display the geography of market areas, the regional significance of corridors and nodes, and future simulated flows and changing traffic patterns resulting from differential regional growth. This will provide valuable input to developing national infrastructure investment levels.

GIS applications should be linked to critical policy issues concerning international and domestic trade. A clearinghouse should be created for better awareness and coordination of transportation-related GIS applications across all jurisdictional levels. The integration of GIS, GPS, and ITS technologies is imperative. Finally, freight container origins and destinations should be mapped for security, safety, and commercial purposes.

Rail

Raphael Kedar, *Deputy Associate Administrator for Policy, Federal Railroad Administration*

Mr. Kedar's presentation described the use of spatial data in the work under way at the Federal Railroad Administration (FRA). The railroad system for the United States has been geographically coded, and by using databases of rail shipments (the waybill sample), movements throughout the country can be simulated.

Spatial data applications are essential in four major areas: safety, policy analysis, defense/security, and international. The critical issue with respect to safety is the movement of hazardous materials. By simulating these movements, rail inspectors can be directed to the high-volume rail lines to optimize their inspection activities.

FRA is working with the Department of Defense and the Military Traffic Management Command to designate certain rail lines as essential to defense, a process similar to that used for the Strategic Defense Highway Network. The physical condition of these lines, which also connect military installations, would be paramount in the event of a national emergency.

FRA uses spatial data for policy analysis at national, regional, and local levels. An example cited was its use in analyzing railroad grade crossings. The decision to add protective hardware, close the crossing, or physically separate the rail line and the highway can have major effects on the railroad company, the highway system, and the surrounding community.

Potential rail mergers are analyzed extensively through GIS. The impact of these mergers is international in scope, yet also local. The FRA database includes both Mexico and Canada for analysis of cross-border impacts. The use of spatial information technology to illustrate the impacts to policy makers is invaluable.

Mr. Kedar touched briefly on the importance of wireless technology as a means to improve the accessibility of spatial information to operating agencies as well as the general public.

Air

Theresa Smith, *Manager, Aviation Planning, Washington State Department of Transportation*

The Washington State Department of Transportation is actively using GIS in working with cities and counties on airport/land use compatibility. This initiative originated with the Washington State Growth Management Act and is intended to protect airports from incompatible development in surrounding areas. The three issues of compatibility are height hazards, aircraft accidents, and noise.

The first step was to work with the airports and affected communities to define compatibility. Using a "stepped approach," the department met with jurisdictions to identify their needs, communicate clearly the airport needs, and then create policies and development regulations. With respect to height hazards such as a radio or cell tower, it explored the jurisdiction's liability associated with issuing a building permit in a known approach zone. With respect to safety, it examined aircraft accidents nationwide for patterns that could affect development adjacent to an airport. Noise contours were obtained from 14 CFR FAR Part 150. GIS were then used to create overlays of the compatibility issues on the areas surrounding the airport.

Several examples of community land use and airport development plans were shown. Commercial service airports and general aviation airports were included. Land use maps showing types of allowable uses within specific growth areas were combined with noise contours and accident safety zones. The result is better land use planning as a tool to reduce conflicts and improve compatibility between the airport and the affected community.

Early coordination and communication between partners can significantly reduce or eliminate the cost of future mitigation. Good, understandable data will enable informed decision making. Be creative in communication.

Fred Anderson, *AVN Business Manager, Federal Aviation Administration*

AVN has three main functions. It develops the instrument flight procedures in and out of airports, conducts the flight inspection program to ensure that the procedures are met, and prepares the public charts and specialized charts for air traffic controllers. It also supports the air traffic control systems with geospatial data.

The National Airspace System is currently being converted from ground-based navigational aids to a space-based GPS system. In 2003 the wide-area augmentation system, an enhancement to GPS to provide a low-cost vertical component, will be implemented.

Another major use of spatial data is the runway incursion component of Safe Flight 21. This program will develop detailed maps of the airport environment, taxiways, runways, ramp areas, and so forth to improve pilot visibility and help avoid runway incursion accidents. The program will also include a cockpit display that shows terrain data and potential flight obstacles in approaching the airport.

Mr. Anderson then described the advantages that light detection and ranging (LIDAR) technology can bring to the aviation industry. LIDAR uses a laser beam to develop a digital terrain model. Several examples of LIDAR accuracy in detecting ground obstacles such as radio towers—including guide wires—were shown.

Other promising RS technologies now under testing for use in commercial aviation include IFSAR (interferometric synthetic aperture radar) and hyperspectral imagery.

Finally, Mr. Anderson discussed airport layout plans, which are detailed maps that the Federal Aviation Administration requires of airports in order to receive grants. Geospatial data standards are needed to allow the sharing of this spatial information across modes and between the airport and adjoining jurisdictions.

TRANSIT

Wayne Watanabe, *Supervisor of Infrastructure and Integration, King County Metro Transit*

King County Metro Transit services an area of more than 2,100 square miles and 39 cities including Seattle and Bellevue, Washington, and has 100 million passenger boardings annually. It makes extensive use of spatial information in route planning, ridership analysis, and facilities management. An example cited was a welfare-to-work exercise to coordinate public transportation with job sites and employment centers.

Another application, called "bus time," enables the public to use an automated phone system to determine the status of buses approaching a specified bus stop. A regional trip-planning system allows potential users to specify an origin and destination, time, fare, and walk time to the bus stop and receive an automated itinerary for the trip. The system handles about 3,000 itineraries per day, the equivalent workload of about 10 people. The transit vehicles are automatically tracked via GPS for a real-time location capability. The ability to locate vehicles and communicate with drivers also assists in safety and security activities.

Metro Transit is currently demonstrating a transit signal priority project. The "smart technology" software is located at the intersection and is loaded with the bus schedule. The time status of an approaching bus is sensed and the signal time adjusted to increase the green phase if the bus is behind schedule.

Key data components for transit applications include the street network infrastructure, schedule data, bus stops, park-and-rides, ride-free areas, and service routes. Spatial information technology helps tie these characteristics together to meet customer needs.

SUMMARY, SECOND GENERAL SESSION

Moderator: Harvey Miller, *Professor, University of Utah*

LEGISLATIVE VIEW

Representative Fred Jarrett, *Washington State House of Representatives*

Mr. Jarrett began his presentation by describing his background and experiences as an employee of Boeing, mayor of Mercer Island, and more recently as a state representative. In these arenas one of the most difficult tasks is to understand the behavior and culture of the organization and public or market issues and to use that information to make sound decisions. One illustration was the planning and construction of Interstate 90 across Mercer Island. The ability to communicate across governmental levels was enhanced through the environmental impact statement, which clearly described the community effects of the project. The ability to see spatially the impacts allowed planners to achieve consensus on many of the construction details.

Spatial data technologies and tools also enable more extensive data mining. Through integration of various data sets, patterns otherwise invisible can be discovered and used to improve decision making.

Mr. Jarrett also touched on the issue of privacy. New information technologies have the capability of invading the lives of private citizens as well as commercial companies. The appropriate use of spatial information and related technology needs to be codified, and the process should be disciplined to protect users of the transportation systems. Trust relationships can also be helpful in sharing sensitive data. These relationships can be particularly effective if they result in time and cost savings.

In response to a question on performance measures, Mr. Jarrett described his experience in evaluating emergency services on Mercer Island. The key element was not time to the incident but survivability rate. In like manner, the key in transportation is not the facility, be it highway, rail, or air, but the mobility provided. Spatial information technology can assist in evaluating options and, through enhanced communication such as web-based systems, in providing real-time information to the public and decision makers.

Finally, Mr. Jarrett suggested that the development of spatial information technologies could be advanced by linking to security issues as they affect the transportation sector. His analogy was to the technology developments in the space program that evolved during the Cold War era. Technology is expensive, and opportunities for funding should be sought through agencies such as the Department of Homeland Security.

STATE DEPARTMENT OF TRANSPORTATION VIEWS

Brian Ziegler, *Washington State Department of Transportation*

Mr. Ziegler is the Director of Operations for the Washington State Department of Transportation. The focus of his presentation was on the changing role of state departments of transportation and how spatial technologies assist in meeting new information demands.

State departments of transportation across the country are moving from a transportation construction mode to an operations and maintenance mode. Congestion and safety issues are paramount to the customer, and real-time information on system condition is essential to efficient operation. In-pavement sensing systems and mounted cameras continually monitor traffic flows and, through operations centers, communicate up-to-the-minute traffic conditions to the public. By using GIS, the information is mapped and made available through the Internet, in websites and in public places. The systems also monitor pavement temperatures and weather conditions for maintenance purposes.

Operations centers are closely aligned with emergency response centers. This allows quick response of equipment and personnel in emergency conditions. High-accident locations and corridors are mapped for use in priority programming of remedial actions.

The entire state highway system is mapped through the use of digital orthorectified photos. They are linked to the video log system and used to view field situations in the office, thus reducing costly field trips.

Mr. Ziegler then illustrated the value of spatial information in assessing the impact of an incident (vehicle accident) on a Seattle freeway. The response to the incident by emergency personnel was captured on a video camera, and the resulting congestion was monitored by in-pavement sensors and mapped via GIS. The backup was approximately 8 miles at one point, and it lasted several hours after the incident itself was cleared from the roadway. More than one-half of all congestion is created by incidents, and careful analysis of these examples can help the department of transportation, police, and other emergency responders to minimize the impact on traffic flow and reduce potential accident situations.

Washington State is also using GIS to integrate modes. The department operates the nation's largest ferry system. Individual ferries are tracked via GPS, and real-time information is provided to users with respect to highway and transit connections. The database is available to share with other "owners of data" given certain data protocols.

Finally, institutional and organizational issues are the biggest obstacle to implementation of technology, and that is a good thing. Government is beholden to taxpayers and is generally risk averse. It must seek the greatest value, not the latest and greatest technology. It must provide better service to the public.

PREPARING FOR REAUTHORIZATION:
IMPLICATIONS FOR DATA
David Ekern, *Associate Director, AASHTO*

Mr. Ekern began his presentation by describing key transportation institutional trends that are affecting GIS data integration. They include a smaller and more diverse workforce, earlier retirements, increased use of the private sector, procurement reform, performance measurement initiatives, and the shift from building to operating transportation systems. These trends will affect the future of spatial information development and will become major factors in the success of reauthorization efforts.

AASHTO has developed a framework of major issues to focus its reauthorization proposals. Operations, safety, security, freight, and research are the most significant with respect to spatial data. The development of ITS at the state department of transportation and local government levels continues to lead to significant operational improvements. Mr. Ekern cited intergovernmental and cross-jurisdictional partnership demonstrations, reengineered project processing requirements, expanded procurement options, and streamlined standards development as examples of areas where improvements are still needed.

In the security area, AASHTO is concerned with defense mobilization efforts, asset protection, and emergency response preparation. The largest single reauthorization proposal within the AASHTO arena will be to advance technology to meet a series of general security provisions.

AASHTO also is advancing a major asset management initiative. This is essentially a strategic approach to managing transportation infrastructure with components that include a philosophy, a process, and a set of technical tools. Its main application is in resource allocation and utilization. Implications for the data world include the need for improved quality, new tools and data sources, new business models, and the commitment to long-term support. These factors lead to new relationships between the parties, innovative financing for data, integration across functional and modal stovepipes, and GIS training in the department of transportation culture.

The essential point is that data must emerge to achieve a broader set of goals: safety, security, and reliability.

SUMMARY, THIRD GENERAL SESSION

Moderator: Kathleen Hancock, *Associate Professor, University of Massachusetts, Amherst*

DISASTER RESPONSE
Ron Langhelm, *Federal Emergency Management Agency*

The primary mission of the Federal Emergency Management Agency is to provide quick response assistance in the event of disasters. In this presentation Mr. Langhelm discussed three examples and illustrated the value of GIS in responding to emergency situations.

The first example was an earthquake in the state of Washington. An earthquake model is used to assess the impacts and how to react. The model gives basic estimated numbers for factors such as economic loss, casualties, shelter requirements, and shake intensity. The Washington State Department of Transportation was able to use ground motion contour maps to focus bridge inspections to those likely affected by the quake.

The second example was Tropical Storm Allison, which had a major impact on Texas. GIS data on floodplains were helpful in assessing storm impact and economic loss.

The third example was the terrorist attack of September 11, 2001, on New York City. GIS technology was used at a detailed level to map the affected area and then to direct the search-and-rescue teams on a daily basis. Feedback from the teams provided near-real-time updates for use in tracking progress.

Emergency response is real time, and lessons are always learned. Data are collected rapidly from many sources with varying degrees of accuracy. Hence, core standards, particularly for geospatial data, would be highly desirable. Also, having a plan to warehouse the data for postemergency review and potential use would be helpful.

Coordination of remote-sensing data access is important. Federal, state, and local governments along with private-sector agencies provide data in response to emergencies. Ongoing working relationships among these groups are important in developing plans and procedures for sharing data for regular planning activities as well as for emergency response. Knowing that data are available helps avoid costly duplication and saves time.

Finally, the products made available through GIS were used extensively for advising the governmental officials responsible for managing disaster response. They were also used to educate the public on the scope of the disaster, the response, and how the public might be affected. Communication with all affected parties is critical to a successful response.

Security

Catherine Lawson, *State University of New York at Albany*

The relationship between transportation and security has been brought into sharp focus by the events of September 11, 2001. First, who is involved? The players include federal, state, regional, and local agency representatives and the private sector. What do they need to know? Activity patterns are key, but levels of detail and costs and benefits are important to both transportation and security. Where are things happening? These are time and space issues—the universal language has to be GIS. The missing feature is real-time or near-real-time updates of infrastructure information. This may require a new data framework that would enhance data sharing through a clearinghouse concept.

One of the interesting and useful concepts explored at the Saratoga Springs freight transportation conference was the development of a regional perspective using spatial data. The regional perspective fits well with security issues that cross state and even international boundaries. Universal licenses that facilitate data sharing across software packages would also be desirable.

Another concept raised by Dr. Lawson was the importance of self-describing, self-aggregating data. In the future world of regional security, GIS data must automatically identify themselves, their location, and the time. And volumes of largely redundant data must be condensed into usable summaries.

Coordination between transportation and security personnel at truck inspection sites can also lead to better data at lower cost. Through "snag and tag" technology, inspection surveys conducted by law enforcement agents could record truck cargo origins and destinations and make this information available for travel pattern analysis. E-seal technology now being tested in the Northwest can also be used to provide information on the performance of freight movements in the United States.

Dr. Lawson's recommendations for the spatial data community included a new regional geography of activities, wise and widespread use of data through trust agreements, cross-agency (security and transportation) data collection, and development of spatial connectivity across space and time.

Safety

Troy Costales, *Oregon Governor's Highway Safety Representative*

Highway safety offices are physically located in many different places for each state. About one-third are located in the department of transportation, one-third in the offices of public safety, and one-third in other state agencies. These offices are small and rarely have access to or knowledge of spatial information technologies. They work with law enforcement, health, the department of motor vehicles, driver education, and the legislature, which are unfamiliar with GIS. They are concerned more with the "why" of crashes than with the "where."

They are also concerned with lack of consistency in safety data from state to state, the need to integrate information from all roads (not just state highways), time delays in reporting crash information, and meaningful performance measures. All these factors make it difficult to make national or statewide comparisons and emphasize the need to develop some core national standards.

A significant challenge to the highway safety arena with respect to spatial information is how to integrate disparate safety data sets, which traditionally are not location based. These include public opinion surveys, child safety seat clinics, safety belt use (by age, location in car), arrests, court convictions, medical coverage by first responders, helmet use, law enforcement staffing, and other information for support of legislative changes. This is a rich mine of data waiting to be explored.

The future of highway safety is steeped in performance tracking and the smart use of data. States such as Oregon and Washington have active highway safety offices and are making progress in improving safety and reducing fatalities. States must work through their own sets of initiatives with the legislature, governor, state agencies, commissions, councils, neighborhood associations, and others. They need to pinpoint problem spots, emerging trends, issues that transcend typical data reporting, and other behavioral programs.

The highway safety program can be a strong partner in using GIS as a data reporting tool. Exposure to the opportunities is needed. Unique ways to link the needs of a safety office to reports or data relationships will be the turnkey for this field of professionals.

SUMMARY OF KEY POINTS FROM THE SEATTLE WORKSHOP

A summary of key points from the workshop breakout sessions follows. Each breakout group was asked to address the four topics listed below. The responses are summarized and related to the four objectives that define the mission of the project to enhance the use of spatial information technologies in multimodal transportation organizations.

Topic 1: Key Issues That Need Better Coordination of Spatial Data Across Modes

Major Categories

- Congestion
- Community and economic vitality
- Environmental quality
- Asset management
- Operations management
- Security/emergency response
- Safety
- Performance measures
- Intermodal connections

Crosscutting Issues

Privacy Public database use of private information must consider best ways to manage personal or commercial information to build a trust relationship.

Intermodal Data Exchange There are seams or gaps between the modes that can affect the efficiency and security of data transferability. These can be bridged by closer attention to media standards and transfer mechanisms such as "smart cards."

Intellectual Capital Simple reporting of spatial data for specific uses often creates "data stovepipes" that limit their application. The effective use of spatial data in multimodal applications can be enhanced through analysis that adds intelligence to the basic data.

Incentive to Share Modal organizations tend to have a single purpose and are often limited by charter and budget. The costs associated with data sharing may outweigh the benefits to be derived unless clear incentives can be identified.

Topic 2: Federal Transportation Responsibilities That Would Benefit from Better Spatial Information Technology Capabilities

Security

USDOT has a major responsibility to ensure security in the nation's transportation systems, both by individual mode (air travel) and in cross-modal situations (major transportation terminals). Transportation infrastructure is often a target. Spatial data technologies can be used to help protect the infrastructure as well as provide safe and efficient mobility to or from incidents.

Standards

The federal government has a major role in interstate and international travel and commerce. That implies the responsibility to establish standards and protocols for transportation elements that cross state and international boundaries and to provide guidance for developing cross-modal standards.

Clearinghouse

One-stop shopping for national and international spatial data as they relate to transportation is clearly a responsibility of USDOT. There are efficiencies to be gained, both in obtaining and in providing this information, through establishment of a clearinghouse at the USDOT level.

Topic 3: Actions That USDOT Could Take to Improve the Understanding and Use of Spatial Information Technologies Within the Transportation Community

Best Practices

Develop and distribute a catalog of best practices in the use of spatial data technologies in multimodal situations.

Clearinghouse

Establish a national clearinghouse of spatial data resources. This would include the concept of a "national data service" to match spatial data needs across modal and organizational boundaries. The use of regional facilitators to provide guidance and incentives to share data could also be included.

Value-Added Capability

The aggregation, integration, and analysis of data would provide an attractive package for use by modal organizations. The investment of intellectual capital in spatial data would enhance their use and encourage multimodal applications.

Coordination

As the lead agency in national transportation issues, USDOT should advance the establishment of federal, state, and local organizational structures that support spatial data sharing. It should also work closely with associations (e.g., AASHTO, AMPO) and the private sector to integrate data sources. International data sources and organizations should also be considered.

Resources

Spatial data cross all boundaries—local, state, regional, national—and are expensive to collect, analyze, and distribute. Although additional resources may be difficult to obtain, it is essential that existing resources at all organizational levels be coordinated to avoid duplication and identify data gaps.

Topic 4: Mechanisms for Development of Consensus-Based Improvement Initiatives Within the Transportation Community and Criteria for Prioritization of Initiatives

Models

Develop models that facilitate data sharing. These could be best practice models describing technology alternatives, organizational models for state or local government application, or relationship models for application with associations or the private sector. Licensing/contracting models that users can have in place so that resources and processes are available when needed could be included.

Research

The initial focus on identifying new spatial data elements and developing the resources to acquire, analyze, and deliver information at different granular levels should rest at the federal level. This can only be achieved by USDOT taking a leadership role in the research of spatial data opportunities.

Analysis Techniques

The spatial data infrastructure is static, yet the domain of transportation is dynamic, with real-time operational decisions increasingly taking precedence over capital investment decisions. Analysis techniques must be developed to support dynamic data management approaches. Moreover, operational data are universal in content, not sample based. Thus, new analysis techniques to support decision making are required.

Security Focus

The events of September 11, 2001, have shown the value of having immediate access to high-quality spatial data for use in response to incidents. Guidelines should be developed to sanitize or withhold data for security reasons yet have the data available for emergency response.

GIS Fire Drill

The value of having spatial data, tools, and technologies available for emergency application cannot be thoroughly tested under laboratory conditions. A field exercise under simulated conditions—a fire drill—should be undertaken to identify and correct deficiencies that could limit the effective use of spatial data during an emergency. It would also help showcase the value of spatial data.

Role Clarification

Is USDOT a "keeper of the data" or a librarian pointing to the best data source? Both roles are important, yet each requires a different level of intellectual capital investment to realize. In fact, the best approach would be a mix of the two roles designed to satisfy the existing and anticipated client base. Funding decisions will likely have a major impact on the outcome.

Organizational Outreach

Effective use of spatial data requires horizontal outreach across the modal administrations as well as vertical outreach to state and local governments, associations, and the private sector. This approach can raise issues concerning technology, core standards criteria, privacy incursions, security violations, and a myriad of real-time data concerns. Strong leadership at the federal level is needed to bring disparate organizations and issues to focus on common transportation problems.

PARTICIPANTS

Michael Alfultis, *U.S. Coast Guard*
Charles Frederic Anderson, *Federal Aviation Administration*
Carol Brandt, *Bureau of Transportation Statistics*
Troy Costales, *Oregon Governor's Highway Safety Representative, Oregon Department of Transportation*
Derald Dudley, *Bureau of Transportation Statistics*
David S. Ekern, *Minnesota Department of Transportation*
Mark Hallenbeck, *University of Washington Transportation Center*
Kathleen L. Hancock, *University of Massachusetts, Amherst*
Richard Harrington, *Pima County Department of Transportation*
Fred Jarrett, *Representative, 41st District, Washington State House of Representatives*
Roger Johnson, *National Ocean Service, National Oceanic and Atmospheric Administration*
Raphael Kedar, *Federal Railroad Administration*
Ron Langhelm, *Federal Emergency Management Agency*
Catherine Lawson, *State University of New York at Albany*
Ysela Llort, *Florida Department of Transportation*
Brian Logan, *Kansas Department of Transportation*
Xavier Lopez, *Oracle Corporation*
Harvey J. Miller, *University of Utah*
Randall J. Murphy, *Grafton Technologies, Inc.*
Thomas M. Palmerlee, *Transportation Research Board*
Ashish Sen, *Bureau of Transportation Statistics*
Michael J. Shiffer, *Chicago Transit Authority*
Terry Simmonds, *Washington State Department of Transportation*
James Sims, *Southern California Association of Governments*
R. Todd Slind, *CH2M Hill, Seattle Office*
Theresa Smith, *Washington State Department of Transportation Aviation Division*
Carl Sobremisana, *Maritime Administration*
Ann Sulkovsky, *U.S. Coast Guard*
Ronald W. Tweedie, *Consultant*
Wayne Watanabe, *King County Metro Transit*
Fred Laurence Williams, *Federal Transit Administration*
Francis Winters, *New York State Department of Transportation*
Brian Ziegler, *Washington State Department of Transportation*

Workshop 3: October 22–23, 2002, Washington, D.C.

AGENDA, TUESDAY, OCTOBER 22, 2002

9:00–10:30 a.m. Opening Session

WELCOME AND OVERVIEW
Ysela Llort, *State Transportation Planner, Florida Department of Transportation*

INTRODUCTION OF PARTICIPANTS

PROJECT SPONSOR REMARKS
Ashish Sen, *Director, Bureau of Transportation Statistics*

INTERGOVERNMENTAL INITIATIVES IN SPATIAL INFORMATION TECHNOLOGIES
Anthony Frater, *Office of Management and Budget*

11:00 a.m.–noon New Tools and Techniques for Spatial Decision Support
Moderator: Michael J. Shiffer, *Vice President, Planning and Development, Chicago Transit Authority*

1:00–3:00 p.m. Modal Presentations
Moderator: Ysela Llort, *State Transportation Planner, Florida Department of Transportation*

FEDERAL RAILROAD ADMINISTRATION
Raphael Kedar, *Deputy Associate Administrator for Policy*

FEDERAL AVIATION ADMINISTRATION
Daniel J. Mehan, *Chief Information Officer*
Bob Niedermair, *Manager, Aeronautical Chart Automation Branch and Chair of the GIS Working Group*
Barry Davis, *Manager of Air Traffic Airspace Laboratory*

FEDERAL HIGHWAY ADMINISTRATION
Cindy J. Burbank, *Associate Administrator, Planning and Environment*
Regina McElroy, *Office of Asset Management*

3:30–5:00 p.m. Modal Presentations (continued)

FEDERAL TRANSIT ADMINISTRATION
William Wiggins, *Transportation Specialist*

MARITIME
Captain Nicholas Perugini, *Chief, Marine Charting Division, NOAA*
Raymond R. Barberesi, *Director, Office of Ports and Domestic Shipping, Maritime Administration*

Moderator's Summary of Key Themes

Discussion

Introduction to Wednesday's Discussion

AGENDA, WEDNESDAY, OCTOBER 23, 2002

9:00–10:00 a.m. Issues for Discussion

NEXT STEPS
Ysela Llort, *State Transportation Planner, Florida Department of Transportation*

OBSERVATIONS
Wayne Watanabe, *Vice President, Planning and Development, King County Metro Transit*
Randy Murphy, *President, Grafton Technologies, Inc.*

Group Discussion

10:30–11:30 a.m. Question 1: Current Status: Spatial Information Technologies in Transportation

11:30 a.m.–12:15 p.m. Question 2: Partnerships for Better Data

1:15–2:00 p.m. Question 3: Priorities for Coordination

2:00–2:45 p.m. Question 4: Building Capacity to Benefit from Spatial Technology

3:15–4:30 p.m. Question 5: Next Steps

4:30–4:45 p.m. Closing Comments

SUMMARY, MORNING SESSION, OCTOBER 22

Project Sponsor: Ashish Sen, *Director, Bureau of Transportation Statistics*

GIS are crucial to infrastructure management, national security, and disaster response. President Bush and

Secretary of Transportation Mineta have expressed support for technology and the use of geospatial data for decision making.

BTS has taken the lead in developing a data exchange standard for roads for the Geospatial One-Stop, part of the Bush administration's strategy for expanding Internet-based electronic government. BTS completed this standard through a cooperative effort with support from state and local governments, the private and academic sectors, and other federal agencies. As the lead federal agency for the transportation theme, BTS will also develop data content standards for air, rail, and transit. In sponsoring these three workshops in cooperation with AASHTO and TRB, BTS is continuing to reach out to the spatial information community with the intent to further increase the value and utilization of GIS.

Intergovernmental Initiatives
Anthony Frater, *Office of Management and Budget*

Mr. Frater is the government-to-government portfolio manager within the Office of Management and Budget (OMB). He is focused on working with state and local governments to bring more harmonization, better data integration, and more service to that customer segment. His presentation detailed why there is a need for intergovernmental work and increased collaboration.

The foundation for intergovernmental work over the past year has been homeland security and electronic government. State and local governments are critical partners in both these efforts. The goal is to harmonize efforts between government levels to improve information exchanges for critical decision making.

The vision for e-government is to expedite the use of digital technologies, such as GIS and spatial technologies, to help deliver customer or citizen programs. The federal government can play an important role to help integrate information for use at state and local levels. Mr. Frater then described some of the various e-government initiatives and others that are heavily dependent on spatial technologies.

Examples of e-government initiatives included disaster management, Project Safecom (wireless), Recreation One-Stop, online rulemaking, and Geospatial One-Stop. Throughout all these initiatives, OMB is working hard to reduce the burden on state and local governments. Standardized data sets and common federal and state spatial data architecture are helping to achieve this goal.

New Tools and Techniques for Spatial Decision Support
Michael Shiffer, *Vice President, Planning and Development, Chicago Transit Authority*

Mr. Shiffer's presentation was focused on his experience in ways to use information technology to better inform and engage the public in making transportation infrastructure decisions. The underlying theme is that spatial information helps avoid billion-dollar bonehead decisions. The cost of spatial data tools is a fraction of the cost of major infrastructure projects, especially infrastructure projects in the transportation sector.

The first step is to develop an overall spatial data strategy. This strategy includes a spatial data infrastructure augmented with annotation tools, navigational aids, analysis tools such as GIS, and representational aids. Information delivery techniques are also critical to the successful use of spatial data. The presentation tracked each of these elements in turn with specific examples in Chicago, Boston, and other locations.

Mr. Shiffer's presentation was followed by a panel discussion that focused on what it takes to capitalize on this technology in both public- and private-sector applications. The following were among the salient points:

- The importance of raising the awareness of spatial data technology capabilities for decision making.
- Development of common data specifications to reduce data collection costs and increase utilization.
- Coordination of data collection to meet various user needs.
- Delivery of spatial technology data and tools into the hands of practitioners.
- A balance between standards and control versus creativity and flexibility.
- Recognition that organizations are evolving from pure policy and infrastructure development toward providing information to decision makers, stakeholders, and the public so that partnerships develop in planning transportation infrastructure. This involves coordination across many organizations and across multiple modes.
- Consideration of investing capital funds in information technology to support infrastructure investment decisions (e.g., utilities).
- Consideration of whether the data should drive the applications or the applications should drive the data (the reality is both).

SUMMARY, AFTERNOON SESSION, OCTOBER 22: MODAL PRESENTATIONS

Federal Railroad Administration
Raphael Kedar, *Deputy Associate Administrator for Policy*

FRA is one of the modal administrations within USDOT. Its primary responsibility is to regulate safety in the U.S. railroad system. Current issues include mobility, security, safety, and capacity. GIS are a tool to address these issues.

FRA uses the waybill sample to track shipments from origin to destination. However, it does not track route; FRA uses a simulation process to do this. Its GIS uses 1:2,000,000 and 1:100,000 scale mapping to represent the rail system and store information. Examples include the tracking of hazardous materials throughout the United States. The Office of Safety uses its simulation of hazardous materials to allocate inspection resources to higher volumes of hazardous materials and more frequent shipments. Grade crossing safety improvements are also prioritized by using GPS and GIS tools.

Rail capacity has become a major problem because railroads have neither the funds nor the technical ability to invest in capacity improvements. How should private railroad and public funds be combined for investment in railroads?

One of the missing elements for FRA is application programs. It needs programs with real-time capability that are customized to specific problems and easily accessible. Often the data are available, but organizing them for problem solving is extremely difficult.

The FRA grade crossing inventory is built on voluntary participation by each state. Each state will voluntarily submit its inventory of grade crossings to FRA. FRA has developed a report format that it prefers the states to use. FRA has modified that format recently to request an X/Y coordinate of the grade crossing, when possible. Some states are more progressive than others. Some states have actually inventoried all their grade crossings by using GPS receivers. Therefore, the overall inventory is a mixed bag of good, mediocre, and poor data. The railroads definitely have GIS applications, mostly in the area of facilities management to control maintenance of the track, structures, bridges, yards, and so forth. By and large, they do not share.

FEDERAL AVIATION ADMINISTRATION
Daniel J. Mehan, *Chief Information Officer*

The Federal Aviation Administration (FAA) has regulatory responsibilities but also an operational function in that all the air traffic controllers report to them. FAA is involved in safety, certification, and regulation of the air industry and is responsible for all flight control. It manages about 30,000 commercial flights that move about 2 million passengers each day. Real-time information is critical in managing this system.

FAA has just finished its 3-year information technology strategy plan. The first of the three focus areas is information security including geospatial information. Safety and redundancy are the critical elements. FAA is particularly concerned about viral attacks that could jeopardize the security of the airlines. The second focus area is e-government, including data management, standardization, registration, and so forth. The third piece is business value, which is basically getting the most out of annual investment.

Combining efforts in cybersecurity, getting business value, and driving e-government are all enhanced through the application of geospatial information systems.

Bob Niedermair, *Manager, Aeronautical Branch, and Chair of the GIS Working Group*

FAA is responsible for managing air facilities within the United States. Customers include the Department of Defense, the air carriers, business aviation, general aviation, the Forest Service, and commercial shippers. FAA also provides information technology for the air traffic control systems communication center in Virginia, flight service stations, flight traffic control areas, RT centers, and terminal radar centers.

One of its GIS products is the radar video map (RVM), which uses several different radar systems. These systems do not have a common format, so it must run translators to certify the RVM on the radar screen. (Lack of common formats seems to plague everyone.) Mr. Niedermair went on to describe the development of other maps and charts for use in guiding aircraft both in the air and on the ground.

He also described work that FAA is accomplishing with the National Airspace System Information Architecture Committee (NIAC). NIAC works with governmental and private-sector organizations to encourage technology sharing. It helps develop standards for map features and other data such as how latitude and longitude should be defined. NIAC also participates in the Geospatial One-Stop with USDOT and encourages use of new radar systems such as STARRS.

Barry Davis, *Office of Airspace Management*

This presentation described how FAA creates and uses spatial information to ensure aircraft safety. An example cited was evaluation of an obstruction, such as the construction of a high-definition TV tower in the vicinity of an airport. An evaluation must be conducted to ensure that the tower does not interfere with any procedure, fixture, or terminal airspace.

Each evaluation requires assembly of data from many sources, including traffic flows, model information, base map thematic layers, and elevation data. Assembly can take 30% to 50% of the time, which leaves less time for analysis and value-added efforts necessary for decision making.

To help address standardization, FAA has embraced XML. It has also created internal partnerships to encourage data sharing and improve standards. By making data available internally, FAA is hoping to establish a national data set with intranet (not Internet) access. GIS has been helpful in resolving conflicts between data sets.

FEDERAL HIGHWAY ADMINISTRATION
Cindy J. Burbank, *Associate Administrator, Planning and Environment*

The Federal Highway Administration (FHWA) is responsible for ensuring that as state departments of transportation administer federal funds, important federal laws—environmental, safety, and so forth—are met. FHWA also encourages states to use these funds in ways that enhance mobility; are intermodal in nature; meet freight needs; and serve safety, national security, and environmental stewardship.

Its priorities are reduction of fatalities and injuries on the nation's highway system, congestion mitigation for both passenger and freight trips, and environmental stewardship and streamlining. GIS is important in all three areas but is particularly valuable in helping good projects move responsibly and quickly through the environmental process.

GIS is particularly useful in bringing together for analysis factors such as wetlands, air quality, historic properties, Native American lands, wildlife, and community impacts. The data can be assembled on a common base and shared across multiple jurisdictions among modes.

Ms. Burbank cited examples of the use of spatial information in improving the decision-making process in specific states. Among them were the Florida Department of Transportation's Efficient Transportation Decision-Making Process, which uses the University of Florida's Geoplan Center as a central database for various stakeholders; the I-69 corridor from Texas through Indiana to address North American Free Trade Agreement trade issues; the Maine Integrated Transportation Decision-Making Process; and a GIS database shared across multiple agencies in Arkansas to prepare environmental impact statements.

In response to a question, Ms. Burbank emphasized the importance of having a National Academy of Sciences panel make a strong statement in support of the need for federal agencies to work across both modes and disciplines to develop a common database of information and use it to make decisions. USDOT needs to invest in research and in staff time in working with states and local agencies to develop and use spatial information and technology.

Regina McElroy, *Office of Asset Management*

The mission of the Office of Asset Management is to ensure that the transportation infrastructure is adequate to support the nation's mobility needs. It defines critical research needs and facilitates the transfer of technology and funding to state and local transportation agencies.

Geospatial technology is used in various aspects of transportation construction and maintenance including pavement maintenance, bridge inspection, quality assurance, and data flows. It is particularly useful in context-sensitive design, a collaborative, interdisciplinary approach involving all the stakeholders in the transportation process. It attempts to fit a transportation facility to the physical setting while preserving scenic, aesthetic, historic, and environmental resources. It takes into account the purpose of the highway, as well as the needs of the community. By using GIS, transportation planners can relate land use plans, existing and future traffic demand, rights-of-way, soil conditions, population density, and various other design factors.

GIS is also a valuable tool for use in pavement and bridge management systems. The ability to overlay various data sets can highlight the impact of competing objectives and help clarify the decision-making process. FHWA has also incorporated GIS capability in the Highway Economic Requirements Model—State Version. This model computes the impact of a proposed highway investment on system condition, performance, and user cost. It then uses GIS to graphically display the results for decision makers.

One of the missing links is the connection between various project types (pavement, bridge, tunnel). Individually, the data sets provide valuable information, but the connectivity between sets is weak. Several states are now exploring how GIS can provide that linkage. FHWA's role is to help the states in this process through technology transfer, training, and education support.

FEDERAL TRANSIT ADMINISTRATION
William Wiggins, *Transportation Specialist*

The Federal Transit Administration (FTA) has launched a research effort to bring transit data from transit properties around the country to the national level. Approximately 600 transit agencies have provided information for the central database. This enabled FTA to provide Congress with a report of the transit mobility index for the nation. It also provided a livability index—that is, how close transit was to the population within a quarter mile walking distance from a residence and how frequently service was provided. This information proved valuable in 1995, when welfare-to-work and the need to match homes, jobs, and transit services came into place.

FTA implemented one program called job access. Unfortunately, it was dependent on data updates from local governments and transit providers, and current information was not readily available. This hampered the use of GIS for job access analysis. It also highlights one of the critical elements in using spatial data. Current, accurate data need to be available from all the participants. Partnerships are needed to make the process successful.

FTA is working to provide information on best practices in the use of GIS in transit applications. It has conducted a survey to identify what applications are needed in the transit industry. It has also initiated a guidebook, which is intended to create some standardization in delivery of information concerning spatial data. The guidebook will also contain information on the sharing of application software as well as accessing ITS systems.

MARITIME ADMINISTRATION

Captain Nicholas Perugini, *Chief, Marine Charting Division, NOAA*

The marine transportation system is the nation's network of oceans, lakes, rivers, canals, locks, and dams. The ports are particularly critical to the U.S. economy; 95% of all foreign trade passes through them. The marine transportation system supports 13 million jobs and contributes $742 billion to U.S. gross domestic product. Its impact was demonstrated in the 11-day longshoremen lockout on the West Coast, where 29 ports were closed and there was an estimated loss of $1 billion to $2 billion to the U.S. economy.

In September 1999 the Secretary of Transportation released the marine transportation system report, which indicated that the greatest safety concern of mariners is the availability of timely, accurate, and reliable information concerning the water. The widespread use of GPS by mariners has highlighted the inaccuracies of paper nautical charts and has led to many improvements in the process.

The Maritime Administration is responsible for producing the approximately 1,000 nautical charts that cover the coastal waters of the United States. It also maintains a framework of water-level gauges and the national space reference system, which gives integrity to spatial data available from NOAA's positioning experts.

U.S. ports are continually changing, with construction of new facilities, piers, disposal areas, and the like. The accurate positioning of shorelines, obstacles, channels, and other marine features is critical to safe and efficient water transportation. GPS, GIS, and other spatial information technologies are enhancing the capability of the Maritime Administration to deliver the required information.

Raymond R. Barberesi, *Office of Ports and Domestic Shipping, Maritime Administration*

The Maritime Administration has a legislative mandate to look at port development in the United States, monitor cargo movements, and investigate causes of congestion to see how they affect the U.S. economy. GIS technology could assist in meeting this mandate, but at present there are no portwide GIS cargo flow applications at major U.S. ports. The GIS applications deal primarily with infrastructure.

There are segmented GIS application and freight data management systems within USDOT, other federal agencies, and industry. However, there is no focal point within the federal government to create a synergy and sharing of freight transportation GIS-related data.

GIS projects should be linked to critical policy issues that deal with freight transportation and intermodal infrastructure, both domestic and international. GIS maps depicting existing and future capacity shortfalls should be readily available to U.S. ports, state departments of transportation, metropolitan planning organizations, and local agencies. Freight container origins and destinations should be mapped to help analyze markets, security issues, safety, and traffic congestion.

Finally, the Maritime Administration, FHWA, and FRA should collaborate in connecting truck, rail, and maritime cargo GIS mapping and freight and infrastructure data to commercial U.S. ports. BTS is the logical organization to coordinate this task.

SUMMARY, OCTOBER 23: KEY ISSUES

The second day a "conversation circle" was held to examine issues raised by Tuesday's presenters relative to the five issues shown below.

Current Status: Spatial Information Technologies in Transportation

What Are We Doing Well Now?

Data collection capabilities are advancing rapidly. Examples include ITS in many state departments of transportation. GIS are becoming ubiquitous and are used as specialty tools, like the microscope in many scientific fields. Spatial technology is outstripping the ability to use it productively.

Obstacles

Too many data are collected for a single purpose, when the data could be used in other areas and over time. While business processes drive the data collection, technology can break down barriers and enable more efficient processes. Practices need to be developed to institutionalize data maintenance and use. Policy makers may not be able to specify what they want, but they may know it when they see it.

Opportunities

Transportation infrastructure equates to spatial information. Engage states and local governments in understanding the relationship between their transportation mission and spatial information. One size does not fit all—partnerships are the key. USDOT is a partner but may not be the lead. State agencies deliver projects, which include spatial data on infrastructure, environment, boundaries, population densities, and so forth. Hence, a percentage of the funding for each project should be added for spatial data overhead. This would provide a continuing funding stream. State and local governments have much in common; hence the need for standard definitions.

Mapping of airport sites could be an opportunity for vertical and horizontal partnerships among local, state, and federal agencies. Typically, mapping is used by local airports and FAA only.

Roles

Technical folks need to deliver to a nontechnical audience. Partnerships should include the private-sector data providers. BTS could review metadata and assist in the budget process.

Members of academia are now partnering with transportation organizations to conduct research.

Good Examples

The Florida Geographic Data Library disseminates data via the web. Private-sector firms are beginning to "fit" their data so that the data can be disseminated from the library. All data sets have metadata.

NatureServe runs a clearinghouse operated on the web for biospatial data for each state. NatureServe "cleans up" local data for posting and encourages standardization.

The state of New Jersey provides funds to counties for standard data sets.

In North Carolina, consultants are required to feed data to an environmental data clearinghouse "hub."

Partnerships for Better Data

Opportunities

BTS operates within the USDOT/federal structure and thus is not able to fulfill industry needs. BTS could serve as a point of access/dissemination in addition to being a data source.

Partnerships to Support Business Objectives A successful partnership exists if there is "something in it" for each partner. Incentives need to be created for agency-to-agency and public–private partnerships that reward all participants.

Benefits of Common Data The Federal Emergency Management Agency acquires and disseminates certain base data sets to its community of users. The benefit is that all users work from standard data. This could be replicated by other agencies, either as outright provision of data/licenses or through creative cost-sharing arrangements.

Key Points

Data Standards While BTS is not a standards-setting body, it could consider taking a leadership role in the industry in identifying the needs and encouraging standardization.

Incentives Federal programs could be used to provide incentives for standardization and sharing of private-sector data with public agencies. Mechanisms are needed to provide data, dollars, and software for start-ups that are willing to develop and share data. There is a need for "sticks" as well as "carrots" to promote data sharing. USDOT could consider establishing requirements for data sharing as a prerequisite for appropriate funding programs. It could add development of procedures and programs for sharing transportation-related geospatial data to the emphasis areas for federally funding regional planning by metropolitan planning organizations.

Best Practices USDOT could develop programs to share applications, information about successful applications, and information about sharing data. BTS could consider sponsoring "highlight" demonstrations for other federal agencies on how technology could benefit program delivery and coordination with other government entities. Programs to share applications and information about successful applications are as important as information about sharing data.

Issues

Public Access to Data The issue of open records requirements and whether to charge for data is still unresolved and troublesome. Balancing the principle of public access to public data with the opportunity to recoup some of the high cost of data acquisition, management, and dissemination is difficult.

Public–Private Partnerships While public–private partnerships appear attractive, they are difficult to operationalize on a day-to-day basis. USDOT could take the initiative to work with the private sector. Finding appropriate public-sector incentives for private companies is difficult. USDOT and other transportation agencies are seen as "warehouses of data" by the private sector, but access to data is made difficult by bureaucratic requirements, the absence of data sharing as part of the mission of public agencies, and so forth.

Data Quality in Partnerships Public agencies also face the issue of when to withhold data that may be preliminary, incomplete, misleading, or subject to misinterpretation. Many agencies now make these decisions on an ad hoc basis. Successful data-sharing efforts must focus on the "lowest common denominator"—that is, on data that are needed by all members of the sharing community.

Priorities for Coordination

There is a need for partnerships with a common interest in solving a common problem area. This drives definition of common data sets. The interface for sharing intermodal data should be defined. Where the links (interfaces) are and what the interfaces need to be should be identified. There is a need to define the architecture of practices for the departments of transportation and GIS users.

The common policy issue across all transportation-related organizations is mobility or access. The priority should be to provide the spatial features and attributes needed for enhanced mobility.

The data needed for planning, policy, operations, and engineering may not be interchangeable. The focus should be on the interoperability across modes.

Building Capacity to Benefit from Spatial Technology

Training and Education

The need to provide continuing education to existing employees contrasts with the kind of education new employees need. Students knowledgeable about spatial information technologies are available, although frustration exists because some universities might only be teaching one platform while people need to learn to deal with several different software platforms. Continuing education—the ongoing education that short courses can provide—can help with this problem. Building capacity within organizations needs to be looked at from several levels. It must be reinforced at the top but must also include continuing education for existing employees. In addition, new employees bringing new skills are essential to reenergize the agency. The use of interns brings in new skills and provides feedback to the universities.

Engineers Versus Nonengineers

The civil engineering curriculum is tight right now. However, civil engineers have good skill sets, and many organizations are finding that they have a facility with GIS and can quickly pick them up.

Best Practices

Federal agencies should be involved in showcasing high-profile applications to agency leaders. As a funding agency, USDOT can use the carrot-and-stick approach to encourage state and local governments to partner in the application of spatial information technology. Associations could take a strong role in emphasizing some of these technologies and their capabilities so that leaders hear from their peers.

Next Steps

Security is an issue that will drive the exchange of spatial data.

Liability is likely to constrain data sharing. An example is crash data from state transportation agencies. Barriers to data sharing are often written into statute or contained in agency policy documents.

PARTICIPANTS

James Altenstadter, *Pima County Association of Governments*
Fred Anderson, *Federal Aviation Administration*
Raymond R. Barberesi, *Maritime Administration*
Nancy Blyler, *U.S. Army Corps of Engineers*
Carol Brandt, *Bureau of Transportation Statistics*
Cindy Burbank, *Federal Highway Administration*
Joedy Cambridge, *Transportation Research Board*
Bill Chang, *Bureau of Transportation Statistics*
Barry Davis, *Federal Aviation Administration*
David S. Ekern, *Minnesota Department of Transportation*
Anthony Frater, *Office of Management and Budget*
Hank Garie, *State of New Jersey*
David Gehr, *Parsons Brinckerhoff*
Kathleen L. Hancock, *University of Massachusetts, Amherst*

LCDR Robert Hennessy, *U.S. Coast Guard Office of Marine Safety, Information Resources Application Development Branch*
Jill L. Hochman, *Federal Highway Administration*
Kris Hoellen, *American Association of State Highway and Transportation Officials*
Shara Howie, *NatureServe*
Robert C. Johns, *University of Minnesota*
Roger Johnson, *National Ocean Service, National Oceanic and Atmospheric Administration*
Raphael Kedar, *Federal Railroad Administration*
Walt Kulyk, *Federal Transit Administration*
Ysela Llort, *Florida Department of Transportation*
Brian Logan, *Kansas Department of Transportation*
Xavier Lopez, *Oracle Corporation*
Ernest R. Lucier, *Federal Aviation Administration*
Richard Marchi, *Airports Council International*
Regina McElroy, *Federal Highway Administration*
Daniel Mehan, *Federal Aviation Administration*
Paul B. Mentz, *SYNTEK Technologies, Inc.*
Carolyn Merry, *University Consortium for Geographic Information Science*
Harvey J. Miller, *University of Utah*
Dan Moreno, *CH2M Hill*
Randall J. Murphy, *Grafton Technologies, Inc.*
Robert Niedermair, *Federal Aviation Administration*
Eugene Olig, *Titan Corporation*
John Palatiello, *MAPPS*
Thomas M. Palmerlee, *Transportation Research Board*
Cindy Paulauskas, *Navigational Technologies*
Linda Pearsall, *North Carolina Natural Heritage Program*
Captain Nicholas Perugini, *Chief, Marine Charting Division, National Oceanic and Atmospheric Administration*
Roger Petzold, *Federal Highway Administration*
Marshall R. Potter, *Federal Aviation Administration*
Robert Rovinsky, *Chief Information Officer's Office, Federal Aviation Administration*
Brian Rowback, *New York State Department of Transportation*
Asish Sen, *Bureau of Transportation Statistics*
Michael J. Shiffer, *Chicago Transit Authority*
Freddie Simmons, *Florida Department of Transportation*
James Sims, *Southern California Association of Governments*
Tom Smith, *Virginia Natural Heritage Program*
Carl Sobremisana, *Federal Maritime Administration*
Bruce Stein, *NatureServe*
Kathleen Stein, *Howard Stein-Hudson Associates, Inc.*
Dale Sterile, *U.S. Coast Guard Operations Systems Center*
James E. St. John, *Federal Highway Administration*
Ann Sulkovsky, *U.S. Coast Guard*
John Sutton, *Cambridge Systematics, Inc.*
Alexis Thomas, *University of Florida*
John Tizzy, *SYNTEK Technologies, Inc.*
Ronald W. Tweedie, *Consultant*
Lisa Vandemark, *National Research Council*
Tom Walker, *Delaware Valley Regional Planning Commission*
Wayne Watanabe, *King County Metro Transit*
Patricia A. White, *Defenders of Wildlife*
Fred Williams, *Federal Transit Administration*
Gary Williams, *Association of American of Railroads*
Francis Winters, *New York State Department of Transportation*
Leslie Wollack, *National States Geographic Information Council*
David B. Zilkoski, *National Geodetic Survey*s

Committee Biographical Information

Ysela Llort, *Chair*, is currently Assistant Secretary for Intermodal Systems Development at the Florida Department of Transportation. When she was appointed to the committee, she was the State Transportation Planner. As chief planner, she had oversight responsibility for the statewide and systems planning functions for the department. Her primary responsibilities included executive-level policy formulation and interpretation, and she worked with numerous transportation partners, including metropolitan planning organizations, to obtain consensus on needs and priorities for the state. She has broad experience on the issues that drive spatial information technology requirements. She is the Chair of the National Cooperative Highway Research Program Project Panel on Development of an Update to the 1977 AASHTO Redbook and a member of the Surface Transportation Environmental Cooperative Research Program Advisory Board, and she has been active in a number of Transportation Research Board (TRB) committees. Ms. Llort is a graduate of Duke University, where she earned a degree in economics, and has master's degrees from Clemson University in both city and regional planning and transportation engineering.

David S. Ekern is currently Director of the Idaho Department of Transportation. When he was appointed to the committee, he was Assistant Commissioner, Minnesota Department of Transportation. While he was with the Minnesota Department of Transportation, he was assigned to the American Association of State Highway and Transportation Officials (AASHTO), where he focused on initiatives and policy development that are changing the face of the nation's transportation agencies. At the Minnesota Department of Transportation, he served as Division Director of Engineering Services, Assistant Chief Engineer, and District Engineer. He has also held positions in environmental policy and planning, preliminary design, metropolitan and regional planning, and highway maintenance. Mr. Ekern brings to the committee extensive knowledge of transportation operations and management issues. He chairs the National Research Council (NRC) Steering Committee for the Conferences on Remote Sensing and Spatial Information Technologies for Transportation, which is organizing a series of three annual conferences. He is a Registered Professional Engineer. He received a bachelor of science degree in civil engineering from the University of Minnesota and a master's in business administration from the University of St. Thomas.

Kathleen L. Hancock is an Associate Professor in the Department of Civil and Environmental Engineering, University of Massachusetts at Amherst. Her interests include information systems for transportation including design and implementation of geographic information systems (GIS), spatial analysis, and intelligent mapping. Among her research projects are coordination of the GIS framework for national transportation policy and planning tasks and design and implementation of a spatial emergency management planning environment for hazardous materials incidents. She has wide knowledge of transportation applications of spatial information technologies. She chairs the TRB Committee on Spatial Data and Information Science and is a member of the Technical Activities Division's Group 5 Council. She is currently Associate Director, Center for Geospatial Information Technology at Virginia Polytechnic Institute and State University, and Associate Professor, Department of Civil and Environmental Engineering.

Robert C. Johns is Director of the Center for Transportation Studies at the University of Minnesota. Previously he served as the center's Deputy Director and Associate Director. Before joining the university in 1988, he worked in management positions at the Metropolitan Council of the Twin Cities Area, the Minnesota Department of Transportation, and the Atchison, Topeka, and Santa Fe Railway. He is chair of TRB's Committee on Strategic Management and a former member of the TRB Committee on Management and Productivity. In Minnesota, he administers the Transportation and Regional Growth Study and chairs the ITS Institute Board. He also serves on the Guidestar Board of Directors, the Minnesota Road Research Section Board of Directors, and the Minnesota Freight Investment Committee. He has a broad knowledge of management issues for transportation organizations.

Brian C. Logan has been the Cartography/GIS Manager for the Kansas Department of Transportation for 15 years. He is currently the Program Chair of AASHTO's Geographic Information Systems for Transportation Symposium and serves on the newly formed Spatial Information Task Force of AASHTO's Standing Committee on Highways. He served on the Technical Advisory Committee of the Kansas GIS Initiative and on its Policy Board. He has extensive knowledge of the use and challenges of spatial information technologies in a state department of transportation. Mr. Logan holds a master's degree in geography from Kansas State University.

Xavier R. Lopez is Director of Oracle's Location-Based Services group. He leads Oracle's efforts to incorporate spatial technologies across Oracle's database, application server, and e-business technologies. He has 12 years of experience in GIS and spatial databases. He holds advanced engineering and planning degrees from the University of Maine, Massachusetts Institute of Technology, and the University of California, Davis. Dr. Lopez has been active in numerous academic and government research initiatives on geographic information and is the author of a book on government spatial information policy. He provides the committee with knowledge of emerging spatial information technologies. He received a Ph.D. from the University of Maine in spatial information engineering and completed a Chancellor's Postdoctoral Fellow program at the University of California, Berkeley, in 1998.

Harvey J. Miller is Professor of Geography at the University of Utah. His research and teaching interests include GIS, transportation and telecommunication, spatial analysis, and geocomputation. He is coauthor, with Shih-Lung Shaw, of *Geographic Information Systems for Transportation: Principles and Applications*. He is currently North American Editor of the *International Journal of Geographical Information Science*, a member of the Board of Directors of the University Consortium for Geographic Information Science, Councilor-at-Large of the North American Regional Science Council, and a member of the NRC Committee on Identifying Data Needs for Place-Based Decision Making. He has extensive knowledge of the application of emerging spatial information technologies and their use in transportation. Dr. Miller is currently the Chair of the Geography Department at the University of Utah.

Randall J. Murphy is the founder of Grafton Technologies, Inc., a firm dealing with the implementation of spatial technologies within the aviation sector. His efforts have focused on the advancement of spatial data standards, the definition of spatial data needs to support aviation, the investigation of new data collection technologies, and the development of web-based systems to deploy spatial and related attribute data to end users. His clients include the Federal Aviation Administration (FAA), state aviation officials, and airports. Murphy is an active member of the GIS Committee of the American Association of Airport Executives and is Chairman of the FAA/DOT Liaison Subcommittee. Mr. Murphy is also a founding member of the GIS Working Group of FAA's National Airspace System Information Architecture Committee.

Michael J. Shiffer is on an extended leave from his position as Associate Professor of Urban Planning and Policy at the University of Illinois at Chicago while he serves as Vice President for Planning and Development at the Chicago Transit Authority (CTA). Dr. Shiffer spearheads CTA's overall strategic and operations planning efforts, including service scheduling and facilities development. He is responsible for a staff of 82 planners, architects, engineers, and other transit professionals in five departments. His academic research investigates the ways information technologies could better inform decision making, with a focus on spatial information and multimedia representational aids. He has taught courses in analytic methods, emerging technologies for planning and decision support, and urban public transportation. Dr. Shiffer blends a strong academic background with concern for implementing and maintaining spatial information technologies in an operating transit organization. He received a Ph.D. in regional planning from the University of Illinois at Urbana–Champaign in 1991.

James M. Sims recently retired. When he was appointed to the committee, he was Director of Information Services for the Southern California Association of Governments, where he was responsible for transportation modeling, GIS services, database management, and Internet services including management of the organization's website. He also had oversight responsibility for Southern California Rideshare, the nation's largest rideshare organization. Southern California Rideshare developed and maintains the world's largest rideshare and transit databases, covering all of Southern California. Mr. Sims has expertise in the development and use of spatial information technologies in a metropolitan planning organization and to support transit planning. He holds bachelor's and master's degrees from Auburn University.

Wayne Watanabe is the supervisor of King County Metro Transit's Infrastructure and Integration Section in Seattle, Washington. His responsibilities include GIS, network infrastructure, desktop and server support, application development, and database administration. He was the project manager for Metro's $2.4 million core GIS project completed in 1995. This core GIS now serves as a key data infrastructure layer for multiple automated transit information systems, including automatic vehicle location, automatic passenger counting, automated timetable information, and automated trip (itinerary) planning, as well as for supporting service and facility planning and safety and security functions. He has experience in developing, using, and maintaining spatial information technologies in an operating transit organization. Mr. Watanabe is a graduate of the University of Washington, with B.S. degrees in mathematics (numerical analysis) and psychology (behavioral) and an M.B.A. with an emphasis on quantitative methods and operations systems.

Francis M. Winters, Jr., heads the GIS Unit of the New York State Department of Transportation. He is responsible for GIS policies, standards, and application development. As an expert in the use of spatial information technologies for transportation, he brings an understanding of successful implementation strategies in a multimodal transportation organization. He has a master of science degree in geography from the University of Idaho, with concentrated study in cartography, computer science, and GIS.

TRB
TRANSPORTATION RESEARCH BOARD
500 Fifth Street, NW
Washington, DC 20001

www.TRB.org

ISBN 0-309-09468-2