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Information Technology in Transportation
Key Issues and a Look Forward

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State-of-the-art computer technology has undergone an almost incomprehensible transformation, analogous to the evolution from Morse code to e-mail. Although the rudimentary scope, goals, and objectives of the transportation community have not changed significantly, the challenges of technology today are greater than ever before. Within a generation, computers have transformed the everyday tasks of the workforce—computer use has infiltrated almost everywhere. Data management capabilities have greatly enhanced resource management. However, accompanying the positive effects are the challenges of implementing, supporting, and funding these technologies in the world of transportation.

Narrowing the gap between cutting-edge technology and its applications, as well as identifying the missing links for applying technology in transportation will be the ongoing challenge. This paper briefly documents the state-of-the-practice in information systems and technologies for transportation, as well as the developing role of information technology (IT) in the 21st century. This assessment points to potential solutions for technological challenges in such areas as

- Applying information systems and technology in the transportation field;
- Applying system-user interfaces (e.g., interactive graphics) as well as data management and data sharing;
- Using web technologies (Internet, intranets, and extranets) in transportation;
- Prioritizing research, development, and demonstration programs to augment work presently under way;
- Encouraging the use of common information system and information technology semantics and standards in the transportation field;
- Facilitating and monitoring technology transfer as a "user advocate" among transportation organizations, vendors, and universities; and
- Evaluating the impact of computer technologies on transportation organizations, including gains in productivity.

The growing concerns about the application of advanced computer technology in transportation involve the following issues:

- IT,
- Management,
- Data sharing and interoperability,

- Transportation applications, and
- Information dissemination.

IT ISSUES

Transportation Applications of Web Technologies

In applying web technologies, the focus in the new millennium will be on advances in real-time technologies, such as "zero-latency" and push technologies.

Internet, Intranet, and Extranet Information Technologies

The transportation community should emphasize the applications of the Internet, intranets, and extranets in the design, construction, and operation of transportation facilities, specifically in the following areas:

- Data exchange and communication over the Internet or extranets;
- Cross-platform integration of transportation information sources;
- Dynamic generation and presentation of transportation information on the Internet;
- Information dissemination and management using organizations' intranets; and
- Integration of transportation databases with the Internet, intranets, and extranets.

Anticipating Future Revolutions in IT

The transportation community should identify and prepare for future revolutions in IT that will have an impact on transportation. One revolution is the likely "near future" transition to 64-bit "Wintel" systems. This transition will have a tremendous impact on distributed computing (such as the web) and on data management applications. Many organizations were caught off-guard and were unprepared or unwilling to make the initial investment in the 32-bit Windows 95 revolution and have lagged behind ever since.

Mobile Computing

The market penetration of hand-held and in-vehicle computers will provide a platform for many transportation applications. How can we take advantage of these new technologies?

Virtual Reality

Virtual reality may be useful for facility design and prototyping and should be investigated further.

High-Bandwidth Wireless Networks

How can high-bandwidth wireless networks be used effectively in transportation technology?

Consumer Electronics Explosion

The consumer electronics (CE) market is poised for explosive growth. Market-ready products supporting mobile computing and electronic commerce, and wireless communications supporting E911 locations, smart cards, and the like have made their debuts already. What impact will they have on public and private transportation services? Which CE technologies offer major opportunities for reengineering? For example, how can motor vehicles exploit e-commerce? We barely understand the dynamics of the boundary between the public and private sectors and are about to be overcome by technologically savvy consumers.

New Philosophies and Techniques for Systems Development

The interaction among interoperability, consumer electronics, and in-house software development is already undermining the entire concept of "enterprise" computing. Where is the transportation enterprise in a globally connected, consumer-driven, component-based universe? Enterprise solutions are just more "stovepipe" thinking, as isolating ultimately as the stovepipe applications they were intended to replace. What new philosophical and technical foundations will guide the development of new systems? Is the whole concept of "system" artificial and self-limiting? How should the ideas of nonlinearity, complexity, autopoeisis, and cybernetics be introduced into transportation systems? Institutions of higher education and the National Aeronautics and Space Administration (NASA) are exploring these areas. New applications derive from nonclassified military air and space technologies. The gathering of transportation data (for vehicles, rail, and aircraft traffic), analytic processing, and information presentation to transportation operation centers might be vital in the 21st century. Many of the large companies that have contracts with the military and NASA, such as Boeing, Northrop Grumman, and Lockheed-Martin, can be resources for the transportation community. This kind of engagement could allow research facilities, using U.S. Department of Transportation (DOT) grants, to develop processes, techniques, and management systems using high-altitude reconnaissance and ground surveillance aircraft equipment, geosynchronous satellite sensors, and data collection and telemetry programs. The Transportation Research Board should help develop consortiums among the states, universities, aerospace and aviation companies, and DOTs to discover solutions for tomorrow's needs.

Other topics and types of IT that will be of increasing interest to the transportation community include

- Software and hardware security,
- Mobile communications,
- Automatic equipment identification,
- Electronic data interchange,
- Global positioning systems,
- Geographic information systems (GIS),
- Visualization and animation,
- Electronic funds transfer,
- Voice recognition,
- Sophisticated bar-coding,
- Airborne ground surveillance,
- Satellite ground surveillance and tracking,
- Very large-scale computing,
- Distributive and client-server technologies, and
- Advanced analysis and modeling computing.

MANAGEMENT ISSUES

Standardized Methods for Benefit–Cost Analysis

It is important to develop standardized methods for benefit and cost (BC) analysis for the implementation of IT in transportation agencies. BC analysis traditionally has been

difficult for IT. Managers and politicians are less patient and less willing to accept the "intangible" benefits of IT.

Software Safety

As software becomes a more integral part of transportation systems, software safety issues arise. We must ensure that the software does no harm if it should fail. We do not want the equivalent of the Thorac X-ray machine accidents, in which several patients died due to defective software, to occur in transportation. But safety is not the same as security, although they are interrelated; safety goes beyond security. Safety considers such issues as "What happens if someone breaches the security barrier? Can the system still be safe?" Even without a security breach, software can fail because of a bug, hardware failure, or another similar internal problem. It is important to ensure that if the system software does fail, there is no resulting injury or loss of life. Some developers go even further, maintaining that it is important to ensure that the software does not cause any highly undesirable situations—for example, all the traffic lights turning green simultaneously as a result of a failure in the traffic management system. On the other hand, it also could be argued that all lights turning red at once also is unsafe—or at least highly undesirable.

Software Systems

With the good old days of "roll-your-own" software systems gone forever, how does an agency obtain new systems and components? How do you design and build systems from components? What new skills and roles does your information system (IS) staff need? How do you acquire, benchmark, deploy, operate, upgrade, and retire systems in this new environment? The last generation of systems managers witnessed the hardware "appliance." What is the software equivalent?

Standards and Guidelines

What are the specific standards and guidelines that IS leaders in the transportation world can rely on for practical application in a dramatically changing environment? The transportation community should support standards development—such as *Standards on Software,* Carnegie–Mellon's *Software Engineering Institute Capability Maturity Model, ISO9000-3,* the Project Management Institute's *Guide to the Project Management Body of Knowledge,* and other documents providing standards and guidelines.

Technical Concerns

What are the realistic, long-term costs and risks associated with enterprise resource planning implementations?

DATA SHARING AND INTEROPERABILITY

Management of Transportation Data

Management of transportation data from an IT point of view, or data storage and data delivery in a non-data-specific way should be considered.

Exchange and Sharing of Transportation Data Sets

The exchange of ideas and experiences is important in the advancement of transportation facilities. Good ideas and experiences can be exchanged through conference presentations and journal publications. These good ideas and experiences come mostly from analyzing or studying real-world data. These data sets, however, are rarely available. At present, even if authors who publish their work would like to share their data, there is no well-established

place to organize and disseminate them. Furthermore, data are expensive to collect. If we know that relevant data are available, we do not have to collect them again, or we only need to supplement the data that already exist. This would save both money and time. The transportation community should encourage the following activities related to exchanging and sharing transportation data sets:

- Determine what types of data are useful in terms of planning, design, operation, safety, and maintenance of transportation facilities. Determine how to classify the data.
- Determine the format and standard for publishing data sets. For instance, the data should be saved and published in standard formats. The data should then include a description of how they are collected, what and how to use them, where to get them, and so on. Since data are collected in the real world, we also might require each data set to specify at least one location reference suitable for GIS geocoding, making it possible find out what data a particular location has by clicking on a map.
- Define standards for disseminating the data.

Interoperability

Now that the "Holy Grail" of integrated systems has been abandoned, it looks like the next goal is interoperability. What is a good, working definition of interoperable? Is it practically achievable? How does interoperability differ from compatibility, interfaceability, and substitutability? What is the role of standards in achieving it? Which standards are we going to use? What is the difference between component-level interoperability and system-level interoperability? Where are the early examples of interoperability in transportation?

TRANSPORTATION APPLICATIONS

Aging and Disabled Drivers

The transportation community needs to investigate how IT could provide assistance to the increasing population of elderly and disabled drivers.

Intelligent Vehicles

How IT will affect the deployment of intelligent vehicles and how telematics will change the operations of transportation agencies and the behavior of motorists needs to be evaluated.

Vehicle and Highway Automation

Where do we go from here? How do we start with partial automation and advance to full automation?

Collision Warning and Avoidance Systems

The transportation community needs to evaluate how well collision warning and avoidance systems and crash mitigation systems could work, what percentage of the annual 40,000 accident deaths could be prevented by such systems, and whether such systems should be mandatory.

Information Dissemination

Public expectations about the transportation industry, particularly how the public interacts with government organizations, should be assessed. This is especially important as people

become accustomed to the availability of a high degree of timely information in their daily lives.

We also should consider how the timeliness of information applies to the following categories of people:

- End users traveling along the transportation infrastructure (en route IT);
- End users preparing to enter the transportation infrastructure (credentialing and trip planning);
- Government staff employing gathered information to improve the infrastructure (operations, planning, enforcement, etc.); and
- Governments communicating with each other.

BEYOND 2000

As we move into the 21st century, we need to identify the areas of transportation in which IT innovations might develop; we then can begin to solve problems and meet challenges proactively. By reviewing and assessing the state of the art in information systems and technologies, the transportation community might be able to predict directions that technology will take and to identify the skills that will be necessary to support the future expansion, integration, and productivity of transportation systems. We will see more advanced technologies with direct or indirect uses in transportation. It is important to provide trend forecasts for management, especially when the proposed changes require a long lead time and significant effort. One example is the need to rely increasingly on contracted work, which generates a need for effective contract management training and coaching for IS project managers.

To meet the IT challenges in the new millennium, we should increase awareness in state and local agencies of formal techniques to increase the margin of safety of the systems they procure. In the future, it will be possible to have considerably more intelligence in the infrastructure (for example, “smart highways” procured by state and local transportation agencies) and in communications between vehicles and the infrastructure.

In the new millennium, the transportation community should take a much more integrative and coordinating approach to IT applications for transportation, such as GIS, global positioning systems, and intelligent transportation systems. Finally, the transportation industry should strive to be a leader in IT. To do this, the transportation community must monitor developments in other sectors of the economy.