NCHRP

SYNTHESIS 296

NATIONAL
COOPERATIVE
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PROGRAM

Impact of New Information and Communication Technologies on Transportation Agencies

A Synthesis of Highway Practice

TRANSPORTATION RESEARCH BOARD

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Impact of New Information and Communication Technologies on Transportation Agencies

A Synthesis of Highway Practice

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SUBJECT AREAS
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The members of the technical committee selected to monitor this project and to review this report were chosen for recognized scholarly competence and with due consideration for the balance of disciplines appropriate to the project. The opinions and conclusions expressed or implied are those of the research agency that performed the research, and, while they have been accepted as appropriate by the technical committee, they are not necessarily those of the Transportation Research Board, the National Research Council, the American Association of State Highway and Transportation Officials, or the Federal Highway Administration of the U.S. Department of Transportation.

Each report is reviewed and accepted for publication by the technical committee according to procedures established and monitored by the Transportation Research Board Executive Committee and the Governing Board of the National Research Council.

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PREFACE

A vast storehouse of information exists on nearly every subject of concern to highway administrators and engineers. Much of this information has resulted from both research and the successful application of solutions to the problems faced by practitioners in their daily work. Because previously there has been no systematic means for compiling such useful information and making it available to the entire community, the American Association of State Highway and Transportation Officials has, through the mechanism of the National Cooperative Highway Research Program, authorized the Transportation Research Board to undertake a continuing project to search out and synthesize useful knowledge from all available sources and to prepare documented reports on current practices in the subject areas of concern.

This synthesis series reports on various practices, making specific recommendations where appropriate but without the detailed directions usually found in handbooks or design manuals. Nonetheless, these documents can serve similar purposes, for each is a compendium of the best knowledge available on those measures found to be the most successful in resolving specific problems. The extent to which these reports are useful will be tempered by the user's knowledge and experience in the particular problem area.

FOREWORD

By Staff
Transportation Research Board

This synthesis report will be of interest to state transportation departments and their staffs, as well as to the consultants that work with them in the areas of changing technologies. Its objective was to examine the impact that information and communication (I/C) technologies are having on transportation agencies and to gather data to understand how agencies are dealing with these impacts. Four classes of technologies were examined: intelligent transportation systems, communication technology, software tools, and remote work arrangements. The synthesis was accomplished through a review of recent literature and a survey of representatives from state transportation agencies. Case studies in five state departments of transportation helped put the findings from the literature review and survey in context.

Administrators, engineers, and researchers are continually faced with highway problems on which much information exists, either in the form of reports or in terms of undocumented experience and practice. Unfortunately, this information often is scattered and unevaluated and, as a consequence, in seeking solutions, full information on what has been learned about a problem frequently is not assembled. Costly research findings may go unused, valuable experience may be overlooked, and full consideration may not be given to available practices for solving or alleviating the problem. In an effort to correct this situation, a continuing NCHRP project has the objective of reporting on common highway problems and synthesizing available information. The synthesis reports from this endeavor constitute an NCHRP publication series in which various forms of relevant information are assembled into single, concise documents pertaining to specific highway problems or sets of closely related problems.

This report of the Transportation Research Board documents the widespread use of many I/C technologies and a general enthusiasm for their value to transportation departments. At the same time, there seems to be an undercurrent of concern about the adaptations that rapidly changing technology demands of department of transportation staff and their organizations.

To develop this synthesis in a comprehensive manner and to ensure inclusion of significant knowledge, the available information was assembled from numerous sources, including a large number of state highway and transportation departments. A topic panel of experts in the subject area was established to guide the author's research in organizing and evaluating the collected data, and to review the final synthesis report.

This synthesis is an immediately useful document that records the practices that were acceptable within the limitations of the knowledge available at the time of its preparation. As the processes of advancement continue, new knowledge can be expected to be added to that now at hand.

CONTENTS

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This study was managed by Donna L. Vlasak, Senior Program Officer, who worked with the consultant, the Topic Panel, and the Project 20-5 Committee in the development and review of the report. Assistance in project scope development was provided by Stephen F. Maher. P.E., Manager, Synthesis Studies. Don Tippman was responsible for editing and production. Cheryl Keith assisted in meeting logistics and distribution of the questionnaire and draft reports.

Crawford F. Jencks, Manager, National Cooperative Highway Research Program, assisted the NCHRP 20-5 Committee and the Synthesis staff.

Information on current practice was provided by many highway and transportation agencies. Their cooperation and assistance are appreciated.

IMPACT OF NEW INFORMATION AND COMMUNICATION TECHNOLOGIES ON TRANSPORTATION AGENCIES

SUMMARY

With the Information Age proceeding at full throttle, new information and communication (I/C) technologies are exerting profound effects. These effects are particularly salient at the organization level, and transportation agencies are no exception. The rapid introduction and diffusion of innovative I/C technologies are creating far-reaching impacts on organizational structure and culture in departments of transportation (DOTs) and manifesting themselves in often unanticipated ways. With the proliferation of I/C technology expected to continue, knowledge of its impacts is more important than ever for managers who need to guide transportation agencies toward a successful future.

The objective of this synthesis report is to examine the impacts that I/C technologies are having on transportation agencies and to gather data to understand how agencies are dealing with those impacts. Although I/C encompasses a broad range of technologies, for the purposes of this study, four areas of technologies were examined:

- Intelligent transportation systems,
- Communication technology,
- Software tools, and
- Remote work arrangements.

This synthesis was accomplished through a review of recent literature, a survey of 61 representatives from 35 state transportation agencies, and case studies of specific I/C activities in 5 states. The literature provided primarily a qualitative perspective, focusing on issues, advantages and disadvantages, benefits, and other important but nonquantitative aspects of the impacts of I/Cs technologies. Responses to the survey questionnaire quantified the extent to which I/C technologies are in use among state DOTs and the impacts they are having. Interviews with DOT representatives from the states of Washington, Virginia, Wisconsin, Florida, Missouri, and Kansas provided in-depth reviews of how technologies were being used in specific areas and their impacts on the DOTs. The key findings of the study are summarized here.

Two classes of impacts were highlighted by the literature: the effects on internal operations and customer service impacts that focus on the users of DOT services. Internal operations have benefited from expanded access to and use of information that I/C technologies enable. Nevertheless, acquiring and managing information has put new pressures on the mission of the organization, relationships between transportation organizations, and demands on limited staff and budget resources.

I/C technologies are offering transportation organizations new and more effective ways of sharing information with their customers. Traveler information systems are an example

of how the use of our congested transportation roadways can be made more efficient by offering travelers access to better information about incidents, congestion, and construction.

The survey underscored the complexity of decision making when state transportation agencies acquire and deploy new I/C technologies. Respondents indicated that they take into account a wide array of criteria, with the most important being the availability of financial resources, the ability to demonstrate benefits, and having adequate staff.

State transportation agency use of I/C technologies was high, with 15 of the 27 surveyed technologies used by 50 percent or more of the DOT respondents' organizations. Not surprisingly, the Internet was one of the most commonly used technologies. For the most part, the less frequently used technologies reflect devices aimed at the driving public or at individuals, such as in-vehicle technologies like navigation systems, and more "personal" technologies, such as personal digital assistants.

The survey revealed a very favorable attitude toward the impacts that I/C technologies are having on state DOTs. Respondents saw consistently *positive* impacts on management practices, staff use of the technology, and overall understanding of what the technology can do resulting from the use of technologies such as the Internet, wireless communication, cell phones, and geographic information system devices. The Internet is widely used and offers many advantages, but a negative rating by the respondents given to security issues illustrates an on-going concern among transportation agencies.

Case studies in five state DOTs helped put the findings of the literature review and survey into context. The development and application of a long-term strategic plan dealing with I/C can guide the purchase and implementation of I/C technologies in a planned, purposeful manner that pursues specific implementation goals and assures compatibility. The case studies in Washington and Virginia underscored this point. The example of the Washington State DOT Traffic Management Center illustrates that technologies, purchased before the benefit of a long-term plan and not well integrated with the rest of the system, can cause further problems with equipment purchases and operator performance.

State DOTs often face critical skill shortages and staff training needs that are only exacerbated by the proliferation of the new I/C technologies. To benefit from these new I/C technologies, state and local transportation agencies must either retrain existing staff to upgrade their engineering and management skills or hire new staff with the requisite skills. The case studies illustrated that outsourcing, use of consultants, personal computer "seat management," and hiring bonuses are just some of the management tools that state DOTs are using to address staff shortages.

In conclusion, the synthesis report has documented widespread use of many I/C technologies and a general enthusiasm for their value to transportation departments. At the same time, there is an undercurrent of concern about the adaptations that rapidly changing technology demands of DOT staff and the organizations of which they are a part. This study has provided both a general sense of those impacts, coupled with a more in-depth view in five states. However, there is a great deal more to be learned as e-government (the use of the Internet for government functions) and other new applications of I/C technologies continue to stretch the boundaries of DOT practices.

CHAPTER ONE

INTRODUCTION

Information and communication (I/C) technologies are among the most significant developments in society today, because they are having a profound influence on the behavior of business, government, and individuals. Rapid innovation and adoption of new technologies are widespread and will continue if recent trends are any indication. These trends include (Cluett et al. 1997; Starr 2000):

- Equipment that is increasingly portable, powerful, and affordable;
- The increasing presence of computers at work and in the home;
- New services, products, and relationships from the merging of computers and telecommunications;
- Digital wireless and wireline communications of increasing bandwidth available from multiple suppliers;
- Heightened concern about the need for individual and corporate privacy and security surrounding these technologies;
- Human interface technologies easing interaction with equipment;
- Customization and personalization of technology;
- Automation of purchasing transactions; and
- Geo-locating of people and goods.

Transportation agencies are well aware of the technological changes taking place. Many of these same technological trends have the potential for impacting transportation agencies as profoundly as individuals and businesses. As transportation agencies use I/C to accomplish their missions, organizations and relationships are being transformed. This synthesis report examines the impact of four areas of technologies: intelligent transportation systems, communication technology, software tools, and remote work arrangements. Enabled by developments in these technological areas, new management approaches are emerging and new opportunities for customer service are being created as the relationship between agencies and their customers enters a new era.

The objective of this synthesis report is to examine the impacts that I/C technologies are having on transportation agencies and to gather data to understand how agencies are dealing with technological changes. These objectives are accomplished through a survey of the literature and through direct contact with transportation agency representatives. The methodology used is explained in more detail in chapter 2. Following the discussion of methodology is an analysis of the literature reviewed for this study (chapter 3). Results of a survey of representatives of transportation agencies are presented in chapter 4. Case studies that focus on particular aspects of technological impacts based on site visits and discussions with selected transportation agencies are presented in chapter 5. Chapter 6 summarizes the findings and makes recommendations for further study.

CHAPTER TWO

METHODS

This chapter describes the three methods used in this study: literature review, survey of transportation agencies, and case studies of transportation agencies. Each of these activities is described in more detail here.

LITERATURE REVIEW

A literature search was performed to identify possible sources that would provide useful perspectives on the topic of this synthesis study. Given the rapid changes taking place in I/C technologies, the search focused on post-1994 data sources to keep the analysis current. After a preliminary search to select the most useful databases, a final search identified the specific citations and abstracts to be obtained. Of the 63 documents identified in the search, 18 were considered the most relevant and are incorporated in the final review. Other sources known to the authors or recommended by the TRB Topic Panel were also included. Key findings of the focused literature review were summarized and incorporated into this report.

SURVEY OF TRANSPORTATION AGENCIES

An important component of this project was the development and implementation of a survey of state transportation agencies. The goal of the survey was to collect information on the current state of usage and impacts of new I/C technologies within transportation agencies.

The actual survey is shown in Appendix B of this report, and its final content reflects the literature review, recommendations from members of the TRB Topic Panel, and results of the pretest conducted on an earlier draft. The survey was distributed to state transportation agencies by the TRB staff. The study team followed up with the survey recipients by e-mail to encourage response. Sixty-one completed surveys were received from 36 states. The data analysis described below used these 61 surveys as the units of analysis.

CASE STUDIES OF TRANSPORTATION AGENCIES

Case studies were performed on selected transportation agencies. Although the literature review and survey activities provide valuable insights into the impacts of I/C technologies on transportation agencies, case studies have the potential to contribute additional depth and first-hand relevance to the information obtained. Agencies were selected and individuals were interviewed based on contacts made by the survey team and recommendations from the TRB Topic Panel.

CHAPTER THREE

LITERATURE REVIEW

Given the rapid pace of change in I/C technologies, it should be noted that the specific technologies discussed in the literature may be somewhat out of date. Nevertheless, the literature surveyed for this report does provide useful insights into the impacts of I/C on transportation agencies. The impacts described in the literature are primarily qualitative in nature, focusing on issues, advantages and disadvantages, benefits, and other important but nonquantitative aspects of the impacts of I/C technologies. Two classes of impacts of I/C technologies on state departments of transportation (DOTs) were revealed:

- Internal operations, the most frequently cited impacts; and
- Customer service impacts, which focus on the users of the DOTs' services.

IMPACT ON INTERNAL OPERATIONS

Among the 13 citations reporting operational impacts, the most frequently cited types of impacts and the number of times cited are listed here:

- Access to and use of information 7
- Mission and service delivery 5
- Organizational/interorganizational changes 4
- Resources (staff and budgets) 3
- Training 3
- Policy and procedures 2

The impact of I/C technologies on making data more accessible and useful to DOT internal activities is a common theme in the literature. For example, Iowa transportation officials are developing an electronic reference library that will automate document retrieval (Jahren et al. 1999). Critical and heavily used documents (such as design manuals and drawings needed in construction, standard forms, and phone directories) are currently in a variety of formats (often nonelectronic) that make accessing them time consuming and difficult. The electronic reference library will be compatible with Internet browsers and have links to the Internet and the Iowa DOT Intranet. In a study at the Connecticut DOT (Sime and Lohrey 1998), the challenge was to identify the best method for making the wealth of data on transportation innovations in TRIS (Transportation Research Information System), the TRB information repository, accessible to a diverse audience of users. Three methods were studied: a proprietary dial-up search engine, a CD-ROM subscription, and a website. The study assessed the advantages and disadvantages of each method based on the characteristics of each type of user, including local government officials; Connecticut DOT executives, managers, and staff in various sections; and transportation research engineers at universities. Given the overall movement toward web-based solutions, the other two methods have probably been eclipsed since 1998.

An Intranet-based system was developed and tested at the Office of Motor Carrier and Highway Safety (OMCHS) at the FHWA (prior to the Federal Motor Carrier Safety Administration being established) (Sienicki 1999). The tool was designed to provide quick and efficient access to a wide range of data. It was meant to help employees to effectively acquire, process, store, retrieve, and analyze data and to communicate, share, and process information with each other and with OMCHS customers (including state DOTs) and partners. The literature did not identify the success or difficulty of the ultimate system. Although the literature speaks to the benefits of such systems, industry experience has shown that they are not easily constructed because of problems of coordination and jurisdictional issues within an agency.

Maze et al. (1998) found that distance-information-sharing and distance-learning among state DOTs could provide opportunities for improving the efficiency of operations, but also pose barriers for implementation. Sharing information and intellectual resources are the benefits that can be realized using telecommunications and information technology such as videoconferencing and Internetworking. The barriers the authors identified are primarily institutional rather than technological, pertaining to the policies, procedures, budget priorities, and traditional ways of doing business. At the time of the study in 1998, the authors identified three technological trends that they thought might bridge the gap:

- Analog to digital transition,
- Rate of improvements in computing equipment capabilities, and
- Ubiquitous communications.

Participants at the Second National Integrated Transportation Management Systems (ITMS) symposium (Turn-bull and Henk 1997) cited several issues related to advanced technologies (such as networked computers, complex software, fiber optic and microwave communications, and other electronic hardware) used in transportation management that effect state DOTs. These technologies challenge DOTs to adapt their planning process, design, procurement and contracting, operations, and maintenance practices. Moreover, DOTs face critical staffing and training problems that are only exacerbated by new technologies. Interjurisdictional coordination in the use of technology-based systems for transportation management adds another dimension. Furthermore, organizational change may be required for ITMS in DOTs that have traditionally separated operations from maintenance functions.

The use of geographic information systems (GIS) has become a common method for information management and data retrieval at DOTs, and the impact of GIS is being felt in a number of ways. According to Ran et al. (1999), integrating Internet and GIS will provide an important means for transportation agencies and other transportation professionals to access spatially-based data. Applications cited by the author include transportation planning, traffic control design, infrastructure management, real-time traffic condition, and traveler information provision. GIS can also be applied to other areas, such as environmental assessment and safety management. Transportation agencies will be able to exchange planning or management information using Internet/GIS systems, and share that information with metropolitan planning organizations and local units of government.

In Detroit, Robinson (1999) reported that transit planning and marketing operations are benefiting from the use of a GIS-based system that supports key projects such as service reliability analysis, service change evaluation, route rationalization, and travel information. To date, the transportation agency in Detroit has used its system to help reduce delays, improve decision making, and enhance the public's access to information. Similarly, in Iowa a statewide coordinated GIS is being constructed as a means to improve performance-based planning (Schuman et al. 1998). A spatially-based design will be the basis for integrating data from diverse sources so that they can be used for more efficient decision making and for interacting with an ever-growing infrastructure. Because merging data into one system is impractical, a data warehouse architecture will be used. Internal DOT data (road, bridge, accident, and environmental data) can be linked to external data from the Department of Natural Resources, the U.S. Geological Survey, the Census Bureau, and elsewhere. Although the authors did not address the need for coordination and long-run stewardship of the system, three main implementation issues have been identified:

- Training and resources,
- Equipment acquisition, and
- Institutionalization of the project, which refers to the need to integrate the system into the daily workflow of employees.

The opportunities and challenges posed by the Internet and the Information Superhighway on California state and local transportation agencies were addressed in a 1996 study (Botha et al. 1996). Whereas it was found that agencies could potentially use the technologies to improve their processes, efficiency, and accuracy, agencies are likely to need major organizational change as well as commitment on the part of agency management and staff to be successful. Moreover, the authors believe that DOTs will need to place increased emphasis on marketing and public relations by agencies to manage the increased accessibility of information to the public.

DOTs need to be aware of the effect that I/C technologies will have on their customers' behavior and adapt DOT practices accordingly. For example, in reporting the results of a 1996 conference on the subject of telecommuting and other teleapplications, Day (1997) reports that these technologies are likely to require DOTs to assess their potential impact on demand for transportation services and the ability of DOT forecasting models to respond. DOTs will need to enhance the analytic and planning tools they are currently using that do not account for these technological impacts.

Finally, the pros and cons of the use of new technologies were weighed in an evaluation of mobile surveillance and wireless communication systems at the California Department of Transportation and the FHWA (Mastako and Klein 1998). A number of institutional issues were identified, including resource and information sharing. The main advantage was that personnel at both agencies learned more about the other's operations, but the high capital and operational cost of video equipment used in surveillance was seen as a major disadvantage.

IMPACT ON CUSTOMER SERVICE

I/C technologies offer new possibilities for state DOTs to provide new or enhanced services to their customers. Delivery of information was the principal type of improvement noted in the literature examined for this study. However, another indication of the potential of I/C technologies is in public safety, because state DOTs will be able to provide a better response to incidents and other emergency situations.

The ability of state DOTs to deliver information in a more timely and accessible manner is a major benefit of I/C technologies. In the Washington, D.C. region, new technologies (such as those represented in ITS) are part of the regional strategy for demand management, including the ability to provide pre-trip and en-route real-time information (National Capital Region Congestion and Mobility Task Force 1998). The Internet has greatly enhanced the ability of DOTs to disseminate transportation information to their customers. Shull (1996) examined five traveler information websites developed by state DOTs. These sites offer real-time and static multimodal information to the public. Shull identified several benefits in customer service. The public could access information any time of the day and could obtain the information they needed without assistance from the agency. The potential exists for DOT information reaching a wider audience than with traditional information dissemination methods. The websites also enable agency staff to answer e-mail inquiries, usually with greater ease and more efficiency than telephone responses, a potential savings for a DOT. However, these savings cited in the literature may prove elusive if the overall volume of customer contacts increases as DOTs become more accessible to the general public through electronic means; DOT staff workload per employee may increase rather than decrease.

The operational improvements cited previously often can be translated into DOT enhancements in customer service. Video technologies can increase the informational display possibilities for DOTs and the service they can provide to their customers. Perry (1996) describes how the Arizona DOT uses closed circuit television as part of an urban freeway traffic management system and at the same time provides the video images over the Internet and local television stations. Arizona continued to expand the use of communications and information technologies for traveler information services when it was chosen by the U.S. DOT as one of the ITS Metropolitan Model Deployment sites (Zimmerman et al. 2000).

GIS are another operational improvement that has value to a DOTs' external customers. As discussed by Ran et al. (1999), spatially-based data accessible over the Internet will be of great interest to transportation consultants and professionals. Moreover, geo-coded traveler information is of value to information content providers who want to provide digital information over the constantly evolving information delivery platforms, such as pagers, cell phones, handheld computers, and in-vehicle devices.

Wireless communications to vehicles will greatly expand the potential for greater customer service that DOTs can provide. Reed (1998) explored the safety implications of in-vehicle wireless communications. Of particular note is the potential development of automatic crash notification (ACN), which would automatically dial an emergency service provider in the event of a crash. Data recorders and global positioning systems (GPS) connected to wireless communications provide better and more efficient ways of collecting data, which may enable the driving public to achieve a whole new level of safety benefits with ACN. The impact of ACN on the DOTs will be not only the investment they will need to make in technology to receive the automatic notification, but also an investment in greater coordination among DOTs, emergency medical services, law enforcement, and others.

CHAPTER FOUR

SURVEY RESULTS

This chapter is based on the answers to the questionnaire provided by 61 DOT respondents from around the United States. A total of 36 states are represented in the results, and multiple respondents in some states replied to the survey. The affiliations of each respondent are shown in Appendix A, and the entire questionnaire is presented in Appendix B. Appendix C provides a detailed tabulation of all results. It should be noted that the results described in this chapter are not based on a statistical sample. Although the findings are suggestive, caution is advised when extrapolating to all DOTs and their staffs.

DEMOGRAPHIC RESULTS

The survey began with a series of questions about the respondents and their respective state transportation agencies. Tables 1–5 summarize the demographic data obtained from the survey.

TABLE 1

NUMBER OF PEOPLE IN RESPONDENT'S TRANSPORTATION AGENCY (Question 2)

Organization Size	No. of Respondents
State Level	
Fewer than 2,600	18
2,600–4,999	13
5,000 or greater	18
No response	12
Work Site	
Fewer than 500	19
500–999	14
1,000 or greater	19
No response	9
Department	
Fewer than 50	20
50–99	14
100 or greater	16
No response	11

Note: Sixty-one surveys were received from 36 states.

One-half of the respondents have been working in transportation for two or more decades, and nearly all currently serve in a supervisory or management role. The majority is responsible for decisions concerning the purchase of new technologies. The size of the organization was not a distinguishing characteristic. However, 80 percent of the respondents report that their transportation agency has a strategic plan, most of which include an I/C technology element. Thus, it can be concluded that the respondents to the survey are a seasoned group of professionals with responsibility in the I/C technology area.

TABLE 2

NUMBER OF YEARS RESPONDENTS WORKED IN TRANSPORTATION (Question 3)

Time (years)	No. of Respondents
5 or less	5
More than 5 to 10	6
More than 10 to 20	16
More than 20 to 30	18
More than 30 to 40	11
More than 40	1
Total	57

Note: Sixty-one surveys were received from 36 states.

TABLE 3

RESPONDENT'S PRIMARY JOB RESPONSIBILITIES (Question 4a)

Job Responsibility	No. of Respondents
Supervisory/Management	50
Support/Technical	6
Both	1
Total	57

Note: Sixty-one surveys were received from 36 states.

TABLE 4

RESPONSIBILITY FOR NEW TECHNOLOGY PURCHASES (Question 4b)

Decision Maker	No. of Respondents
Respondent	38
Others	19
Respondent/Others	0
Total	57

Note: Sixy-one surveys were received from 36 states.

TABLE 5

USE OF STRATEGIC PLAN FOR TRANSPORTATION AGENCIES (Question 5)

Use Strategic Plan	No. of Respondents
Yes	47
No	5
Don't Know	5
Total	57

Note: Sixty-one surveys were received from 36 states. Of those responding yes, 37 reported that their strategic plans included information and technology elements in particular, 6 did not, 3 did not know, and I did not answer this portion of the question.

Furthermore, the organizations they represent are engaged in strategic thinking about the role of I/C technologies. As indicated in Table 5, in those organizations that have a strategic plan, most such plans include an element dealing with I/C technology.

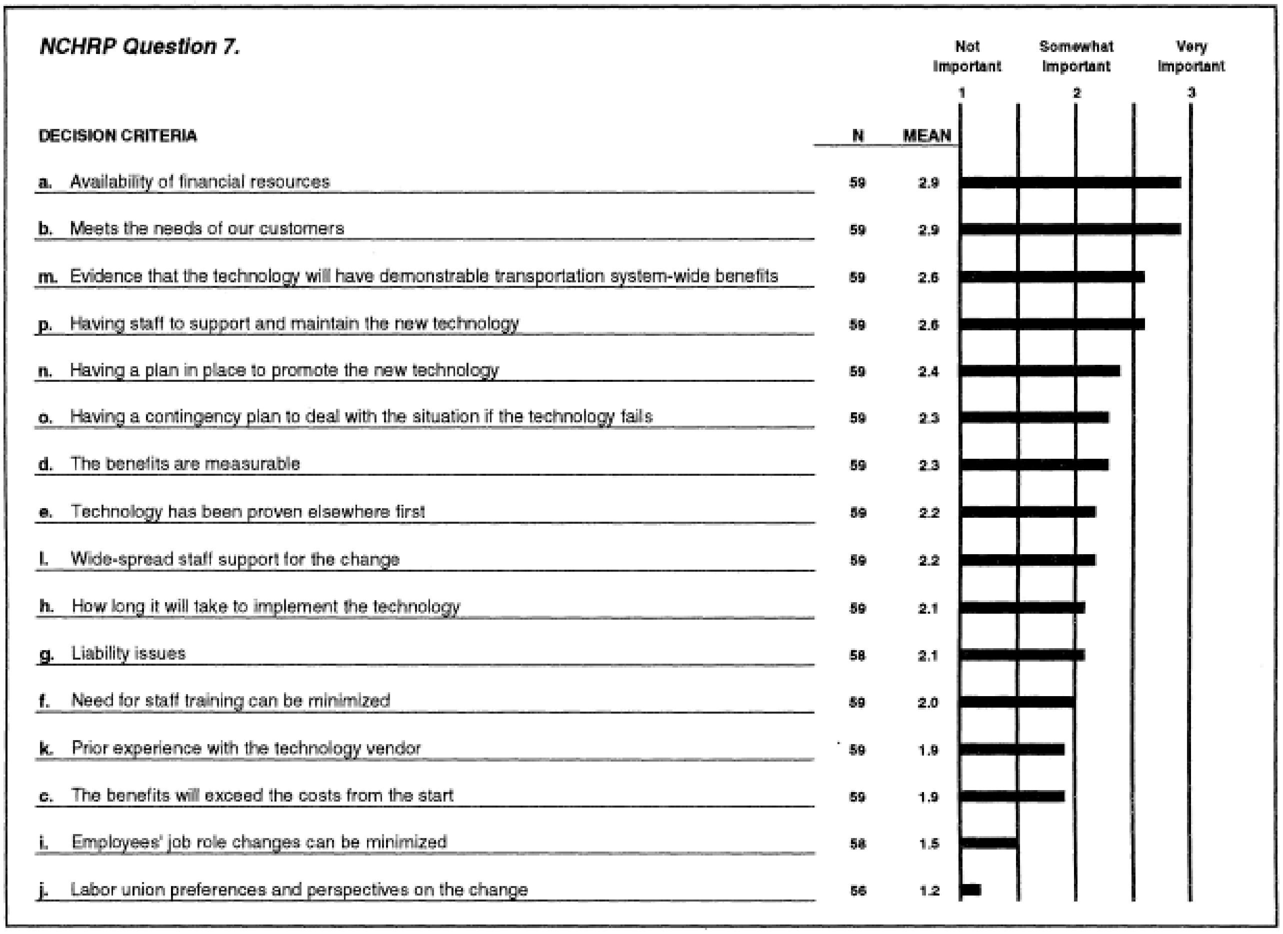

FIGURE 1 Relative importance of decision criteria for new I/C technology acquisitions.

ORGANIZATIONAL CONSIDERATIONS IN THE ADOPTION OF I/C TECHNOLOGIES

I/C Technology Acquisition Decision Making

There are many factors or criteria an organization may use in making decisions about whether to acquire new I/C technologies. The survey of transportation agencies and organizations asked respondents to rate the importance of various considerations in making a decision to purchase or deploy any of these new technologies. Figure 1 shows the results for 16 different decision criteria, as rated by the respondents, who were asked to think in terms of how their organization or department makes these kinds of decisions. The results in Figure 1 are presented in terms of a mean score for all respondents on each criterion, along with a graphic representation that shows how important respondents felt each criterion was as it would be applied in their organization or department. The responses are ordered with the most important criteria at the top to the least important criteria at the bottom. Responses range from "1" for "Not Important" to "3" for "Very Important," and the average (Mean) across all respondents who answered that question (N) reflects the relative perceived importance of that criterion for these respondents.

The top four criteria, with a mean response above 2.5 (half way between "Somewhat Important" and "Very Important"), reflect the importance of adequate financial resources, evidence that the new I/C technology is meeting customers' needs, evidence that the I/C technology will have system-wide benefits, and having adequate staff to support and maintain the new technologies. The least important criteria, with mean ratings below 1.5 (half way between "Somewhat Important" and "Not Important"), include minimizing employee job role changes and labor union issues. The majority of these various criteria, however, were rated at least "Somewhat Important." Thus, it is clear that decisions that transportation agencies and organizations are making about these new I/C technologies typically take into account a lot of different considerations. That is, these are evidently not simple decisions, but rather decisions that may occur after extensive deliberation, taking into account everything from financial and staff resources, to the ability to identify and measure benefits, to having contingency plans in place in case the I/C technology deployment fails to meet expectations.

The next step was to see whether the size of the organization, as measured by the number of employees in the state organization or in the respondent's department, had any effect on the responses regarding the perceived importance of the various decision criteria. That is, does organizational size, as measured by estimated number of employees, appear to be related to the importance of decision criteria? Table 6 provides data that bear on this question, both in terms of the overall estimated state organizational employment size (i.e., state DOTs) and by the number of employees at the department level.

The results presented in Table 6 show the average importance ranking for each of the decision criteria by the estimated size of the organization or department. Three size categories were defined, based on the observed distribution of organizational and department size across all respondents. Although no attempt was made to measure the statistical significance of these results (most would not pass such a test of significance), an attempt was made to discern any large differences between the two extreme categories, or linear change in either direction across the three response categories, to derive suggestive inferences about the possible relationships between organizational size and the relative importance of the various decision criteria associated with the acquisition of new I/C technologies.

Question 7c asked about the perceived importance associated with having evidence that the benefits from I/C technologies exceed the costs before the agency can decide to invest. Although this was not judged by the respondents as very important overall, those in the smaller state transportation agencies were more likely to cite this as important than those in larger agencies. The same relationship did not hold, however, when reviewing size at the department level. The same tendency can be observed for needing evidence that the I/C technology demonstrates system-wide benefits (7m) and that there is a plan in place to promote the new technology (7n). In the case of these two decision criteria, the same relationship can be observed at the department level. Although these are small differences, and the measure of organizational size is clearly not reliable, they suggest that organizational size may make a difference when it comes to decision making about new I/C technologies, a topic deserving further research.

Another question of interest is whether transportation agencies at the state level exhibit any differences in how they make I/C technology acquisition decisions, given how many I/C technologies they report having in place. That is, do the agencies that are in the forefront of I/C technologies in their state show any differences in the decision criteria they apply to acquire those technologies compared with agencies reporting few I/C technologies in place? Table 7 shows the results of this analysis. The number of technologies reported were grouped into three categories, low (2 to 6 technologies), mid (7 to 11 technologies), and high (12 to 17 technologies). When counting the number of reported technologies, duplication of technology types across the four categories of device type were eliminated. For example, “Internet” was only counted once for each respondent. Also, write-in technologies were not included in these analyses, because of the small numbers reported. Based on the technology options presented in this survey, respondents were limited to identifying a maximum number of 23. The highest number of unique technologies indicated was 17.

The data in Table 7 were examined to identify any change in mean score across the levels of technology acquisition. These data suggest that state transportation agencies that have acquired the most I/C technologies are likely to find the following decision criteria *more* important:

- Meeting customer needs (7b)
- Liability issues (7g)
- Having a plan in place (7n)
- Having a contingency plan in case of failure (7o).

They also are likely to find the following decision criteria *less* important:

- Prior experience with the vendor (7k)
- Having widespread staff support (7l).

Although these criteria could not be examined in more depth owing to the survey format, they reflect potential areas of concern or interest to DOT staff that may deserve further research.

Attitudes Toward New I/C Technologies

Survey respondents were asked to indicate their level of agreement with 17 statements that explore in further detail how transportation organizations think about the value and challenges that may be associated with their decisions to acquire and deploy these technologies. Although respondents were asked to describe their own perspectives and attitudes on these topics, their responses reflect on how their organizations and departments may view these technologies as well. The results are presented in Figure 2 in terms of a mean score for all respondents on each question, along with a graphic representation that shows the degree of agreement or disagreement with each question. The responses are ordered with the most agreement at the top to the least agreement at the bottom. Responses range from

TABLE 6

MEAN IMPORTANCE OF DECISION CRITERIA BY SIZE OF ORGANIZATIONAL UNIT (Question 7)

	Criteria															
No. of Employees	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p
State Level																
Fewer than 2,600	2.9 (18)	2.9 (18)	2.2 (18)	2.3 (18)	2.2 (18)	2.1 (18)	2.2 (18)	2.3 (18)	1.5 (18)	1.2 (16)	1.9 (18)	2.3 (18)	2.7 (18)	2.7 (18)	2.5 (18)	2.6 (18)
2,600–4,999	3.0 (13)	2.8 (13)	1.9 (13)	2.3 (13)	2.2 (13)	1.8 (13)	2.0 (12)	2.1 (13)	1.5 (12)	1.2 (13)	2.1 (13)	2.1 (13)	2.5 (13)	2.2 (13)	2.2 (13)	2.6 (13)
5,000 or greater	2.8 (18)	2.9 (18)	1.9 (18)	2.3 (18)	2.2 (18)	2.1 (18)	2.0 (18)	2.1 (18)	1.3 (18)	1.2 (18)	1.8 (18)	2.1 (18)	2.5 (18)	2.4 (18)	2.3 (18)	2.5 (18)
Department Level																
Fewer than 50	2.9 (19)	2.9 (19)	1.9 (19)	2.1 (19)	2.2 (19)	2.1 (19)	2.2 (19)	2.2 (19)	1.4 (19)	1.3 (17)	1.9 (19)	2.1 (19)	2.7 (19)	2.4 (19)	2.2 (19)	2.5 (19)
50–99	2.9 (14)	2.9 (14)	1.9 (14)	2.4 (14)	2.1 (14)	2.0 (14)	1.9 (14)	2.3 (14)	1.4 (14)	1.1 (14)	1.9 (14)	2.3 (14)	2.6 (14)	2.6 (14)	2.5 (14)	2.6 (14)
100 or greater	2.8 (15)	2.9 (15)	2.0 (15)	2.5 (15)	2.1 (15)	2.1 (15)	2.0 (15)	1.9 (15)	1.5 (14)	1.1 (15)	1.9 (15)	2.1 (15)	2.5 (15)	2.3 (15)	2.4 (15)	2.7 (15)

Note: Numbers in parentheses indicate number of responses. The criteria are listed in Figure 1 and Appendix Table C-1. Responses range from "1" for "Not Important" to "3" for "Very Important," and the average (Mean) across all respondents who answered that question (N) reflects the relative perceived importance of that criterion for these respondents.

TABLE 7

MEAN IMPORTANCE OF DECISION CRITERIA BY NUMBER OF I/C TECHNOLOGIES ACQUIRED (Question 7)

	Criteria															
No. of Technologies	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p
State Level																
2–6	3.0 (12)	2.8 (12)	1.8 (12)	2.3 (12)	2.3 (12)	2.0 (12)	2.0 (12)	2.2 (12)	1.5 (12)	1.3 (12)	2.1 (12)	2.3 (12)	2.5 (12)	2.3 (12)	2.0 (12)	2.5 (12)
7–11	2.9 (20)	2.9 (20)	2.1 (20)	2.4 (20)	2.3 (20)	2.0 (20)	2.1 (20)	2.2 (20)	1.6 (19)	1.1 (20)	2.0 (20)	2.2 (20)	2.8 (20)	2.4 (20)	2.3 (20)	2.6 (20)
12–17	2.9 (27)	3.0 (27)	1.9 (27)	2.2 (27)	2.1 (27)	2.0 (27)	2.2 (26)	2.1 (27)	1.4 (27)	1.2 (24)	1.9 (27)	2.1 (27)	2.5 (27)	2.5 (27)	2.4 (27)	2.6 (27)

Note: Numbers in parentheses indicate number of responses. The criteria are listed in Figure 1 and Appendix Table C-1. Responses range from "1" for "Not Important" to "3" for "Very Important," and the average (Mean) across all respondents who answered that question (N) reflects the relative perceived importance of that criterion for these respondents.

NCHRP Question 8.

Scale: 1 = Disagree Strongly, 3 = Neutral, 5 = Agree Strongly

STATEMENT	N	MEAN
i. Rapid technological changes make it increasingly difficult for public transportation agencies like ours to compete with the private sector for skills.	59	4.1
e. New I/C technologies have improved communication and integration across transportation organizations and agencies in our state.	59	4.1
k. The adoption of new I/C technologies by my organization has led to a substantial increase in information exchange with our public customers.	58	3.9
n. My organization's management believes that investments in new I/C technologies constitute a good use of the taxpayer's money.	58	3.8
p. Public expectations are a major factor that cause us to consider investing in new I/C technologies.	59	3.5
g. An impact of rapid I/C technology change is that management's expectations of staff performance are continually going up.	59	3.5
f. Technological change in our society now is so rapid and unpredictable that our organization has difficulty responding effectively.	59	3.4
c. The level of awareness in my organization about new I/C technologies is high.	59	3.4
j. The adoption of new I/C technologies by my organization has led to the formation of new public/private partnerships.	58	3.4
m. The use of new I/C technologies in our organization allows us to better manage travel demand.	55	3.4
l. New I/C technology use among transportation agencies in our state has directly led to improved communication across modal organizations.	56	3.3
o. The costs to maintain new I/C technologies and keep them up to date constitute a major barrier to adoption in my organization/agency.	58	3.0
q. Our Agency has a difficult time implementing new technologies because our state has a policy of centralizing and/or standardizing new technologies	59	2.9
h. Because of the introduction of new I/C technologies, my organization seems to emphasize speed and quantity over quality of our products and work.	59	2.5
b. Our available resources are so limited that we cannot afford to invest in new I/C technologies.	59	2.4
d. The reason we aren't doing more to adopt new I/C technologies is because people don't want to have to change the way they perform their job.	59	2.3
a. Management in my organization is reluctant to risk trying new technology applications.	58	2.2

FIGURE 2 Attitudes toward various aspects of new I/C technologies.

"1" for "Disagree Strongly" to "5" for "Agree Strongly," and the average (mean) across all respondents who answered that question (N) reflects the relative degree of agreement for these respondents on each question.

It is useful to look at those questions that elicited both the most agreement as well as the most disagreement. Respondents generally agreed with the following:

- Rapid technology change makes it hard for public transportation agencies to compete with the private sector for skills (8i).
- New I/C technologies have improved communication and integration within transportation organizations in the state (8e).
- New I/C technologies have improved information exchange with public customers (8k), although they do not seem to help the agencies manage travel demand more easily (8m).
- Investments in new I/C technologies are viewed as a good use of the taxpayer's money (8n).

Also, respondents tended to disagree with the following:

- New I/C technologies have caused my transportation organization to emphasize speed and quantity over quality (8h).
- My transportation organization cannot afford to invest in new I/C technologies due to limited resources (8b).
- My transportation organization is not adopting new I/C technologies because people are reluctant to change job performance requirements (8d).
- Management in my organization is reluctant to risk trying new technology applications (8a).

On average, respondents were neutral on the other 9 questions, neither agreeing nor disagreeing.

As with the questions pertaining to the importance of decision criteria, it was important to determine whether the number of employees in the state organization or in the respondent's department had any relationship to their responses regarding their attitudes toward these I/C technologies. Table 8 shows the results of this analysis. The most striking outcome is that the smaller organizations, as measured by number of employees at both the state and department levels, are more likely to agree strongly that limited resources are constraining their ability to invest in new I/C technologies. They are somewhat more likely than the larger organizations or departments to agree that

- It is harder for their organization to respond effectively to rapid technological change (8f).
- Maintenance costs are a major barrier to I/C technology adoption (8o).
- It is difficult for their agency to implement the new technologies because of a state policy requiring centralization and/or standardization of these technologies (8q).

They also are more likely than the larger organizations to disagree with the benefits of I/C technology.

- New I/C technologies have improved communication and integration across transportation organizations and agencies in their state (8e).
- Adoption of new I/C technologies has led to a substantial increase in information exchange with their public customers (8k).
- Use of new I/C technologies in their state has led to improved communication across modal agencies (8l).
- Use of these technologies has allowed for better management of travel demand (8m).

We also wanted to examine how these states might differ in their attitudes toward new I/C technologies depending on how extensively they have already acquired and are using them. As was discussed in the earlier analysis of Question 7, the technologies were grouped into three categories (low, mid, and high), eliminating duplicates across the device type categories in our survey.

The data in Table 9 show some large differences in agreement by number of technologies currently used by these state transportation agencies. Respondents were more likely to *agree* with regard to the following statements if they were using a lot of new technologies, compared with those states that were only using a few.

- Level of awareness about new I/C technologies is high (8c).
- It is hard to compete with the private sector for skills (8i).
- Public expectations cause us to invest in new I/C technologies (8p).
- Available resources are so limited we cannot invest in new I/C technologies (8b).

Those respondents from organizations using many I/C technologies also were more likely to *disagree* with the following statements:

- New I/C technologies have improved communication and integration (8e).
- Because change is so rapid, we have a hard time responding effectively (8f).
- Costs constitute a major barrier to adoption (8o).

Finally, responses to this survey have afforded an opportunity to determine how the total number of I/C technologies being used by the responding state agencies was related to the size of the agency, as measured by number of employees. We hypothesized that larger organizations would be more likely to use a wider variety of new I/C technologies compared with smaller state transportation agencies.

In the comparison of organization size to use of I/C technologies, the reader is reminded that the survey results are not based on a statistical sample and, therefore, should be viewed as suggestive of trends and relationships rather than a definitive quantification. For example, the number of technologies is based on the total number of unique technologies that each respondent checked off under the four sections of Question 9, and it is likely that many respondents were not aware of how other departments in their organization were using these technologies. Moreover, the number of employees is based on the figure provided by the respondents for their state transportation agencies. For the 13 states where more than one person responded, there was sometimes a wide variation in respondents' estimates of the total number of employees. For the purposes of this analysis, we selected the largest figure provided and assigned that estimate of the number of employees for each response record from that state. For the number of technologies, we assigned the sum of all unique technologies listed by all respondents (when more than one) for each of those states. Thus, Figure 3 contains 34 data points, one for each state responding to the survey, exclusive of two that did not include information on the number of employees at the state level.

The hypothesis is at best only very weakly supported, judging by the distribution of data points in Figure 3, which reveals no apparent relationship between the size of a state DOT and the number of new I/C technologies. However, given the measurement issues noted previously, this could be a useful line of investigation for future research.

In summary, it can be concluded that decision making for state transportation agencies with regard to the acquisition and deployment of these new I/C technologies is a

TABLE 8

AVERAGE (MEAN) LEVEL OF AGREEMENT ON ATTITUDE STATEMENTS BY SIZE OF ORGANIZATIONAL UNIT (Question 8)

	Statement																
No. of Employees	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q
State Level																	
Fewer than 2,600	2.2 (18)	2.7 (18)	3.5 (18)	2.4 (18)	3.9 (18)	3.6 (18)	3.8 (18)	2.5 (18)	4.1 (18)	3.8 (18)	3.9 (18)	3.1 (16)	3.3 (16)	3.8 (18)	3.1 (18)	3.7 (18)	3.0 (18)
2,600–4,999	2.7 (13)	2.5 (13)	3.4 (13)	2.5 (13)	4.2 (13)	3.1 (13)	3.3 (13)	2.6 (13)	3.9 (13)	3.2 (13)	4.0 (13)	3.5 (13)	3.2 (13)	3.7 (13)	3.3 (13)	3.2 (13)	3.1 (13)
5,000 or greater	1.9 (18)	2.2 (18)	3.6 (18)	1.9 (18)	4.2 (18)	3.4 (18)	3.7 (18)	2.4 (18)	4.1 (18)	3.5 (18)	4.1 (18)	3.4 (18)	3.7 (18)	3.9 (18)	2.7 (18)	3.9 (18)	2.7 (18)
Department Level																	
Fewer than 50	2.3 (19)	2.7 (19)	3.3 (19)	2.3 (19)	4.0 (19)	3.8 (19)	3.2 (19)	2.4 (19)	4.1 (19)	3.3 (19)	3.9 (19)	3.3 (19)	3.3 (18)	3.7 (19)	3.1 (19)	3.5 (19)	3.1 (19)
50–99	2.2 (14)	2.2 (14)	3.3 (14)	2.1 (14)	3.9 (14)	2.9 (14)	3.6 (14)	2.6 (14)	4.1 (14)	3.4 (14)	3.9 (14)	3.3 (12)	3.5 (13)	3.9 (14)	2.8 (14)	3.6 (14)	2.6 (14)
100 or greater	2.1 (15)	2.4 (15)	3.7 (15)	2.3 (15)	4.3 (15)	3.3 (15)	3.7 (15)	2.5 (15)	3.9 (15)	3.4 (15)	4.0 (15)	3.7 (15)	3.6 (15)	3.7 (15)	2.9 (15)	3.9 (15)	2.9 (15)

Note: Numbers in parentheses indicate number of responses. The statements are listed in Figure 2 and Appendix Table C-2. Responses range from "1" for "Disagree Strongly" to "5" for "Agree Strongly," and the average (Mean) across all respondents who answered that question (N) reflects the relative degree of agreement for these respondents on each question.

TABLE 9

AVERAGE (MEAN) LEVEL OF AGREEMENT ON ATTITUDE STATEMENTS BY NUMBER OF I/C TECHNOLOGIES ACQUIRED (Question 8)

	Statement																
No. of Technologies	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q
State Level																	
2–6	2.1 (11)	2.3 (12)	3.1 (12)	1.9 (12)	4.4 (12)	3.7 (12)	3.3 (12)	2.4 (12)	3.9 (12)	3.3 (12)	3.8 (12)	3.3 (12)	3.3 (12)	3.6 (12)	3.3 (12)	3.2 (12)	3.4 (12)
7–11	2.4 (20)	2.4 (20)	3.4 (20)	2.6 (20)	4.0 (20)	3.4 (20)	3.6 (20)	2.6 (20)	4.0 (20)	3.2 (19)	3.8 (19)	3.2 (18)	3.6 (19)	3.7 (19)	2.9 (19)	3.5 (20)	2.8 (20)
12–17	2.2 (27)	2.5 (27)	3.7 (27)	2.3 (27)	4.0 (27)	3.2 (27)	3.5 (27)	2.4 (27)	4.1 (27)	3.6 (27)	4.0 (27)	3.4 (26)	3.3 (24)	3.9 (27)	2.9 (27)	3.7 (27)	2.9 (27)

Note: Numbers in parentheses indicate number of responses. The statements are listed in Figure 2 and Appendix Table C-2. Responses range from "1" for "Disagree Strongly" to "5" for "Agree Strongly," and the average (Mean) across all respondents who answered that question (N) reflects the relative degree of agreement for these respondents on each question.

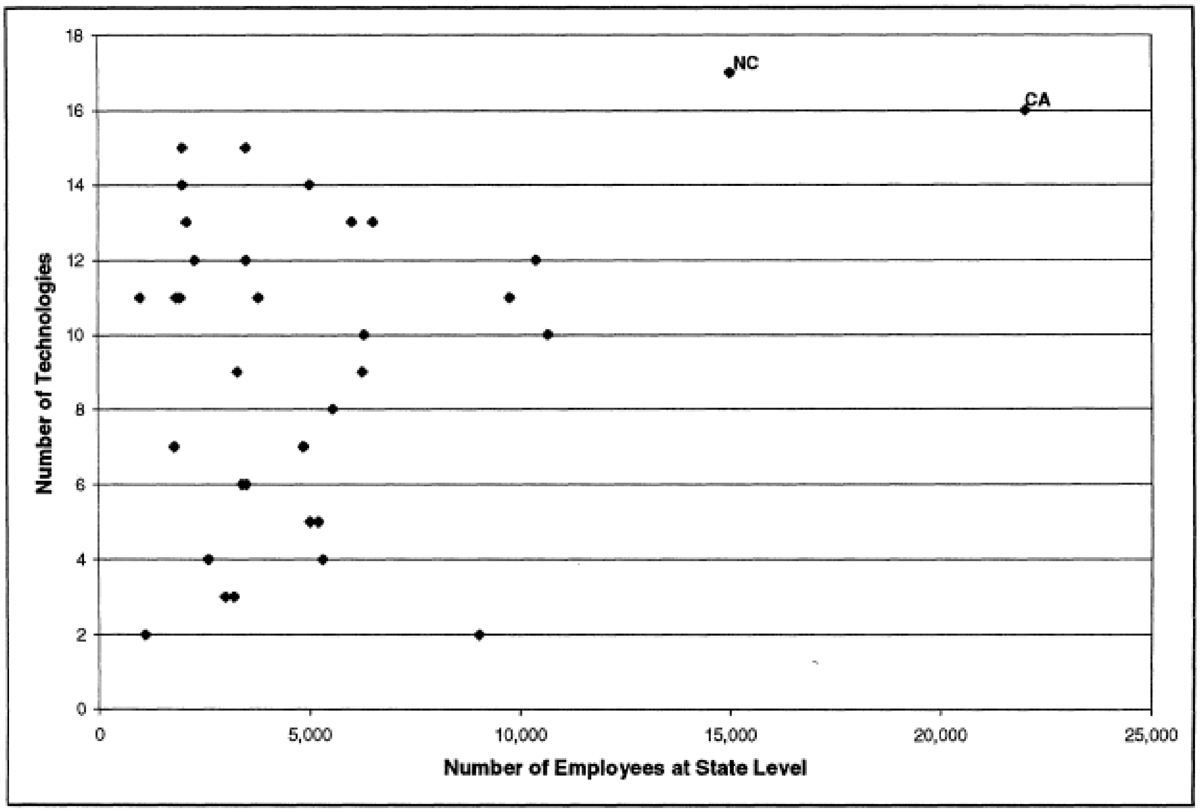

FIGURE 3 Relationship between transportation agency size and number of new I/C technologies.

complex process. The states that responded to this survey indicated that they take into account a wide array of different criteria as part of their acquisition decision process. There is weak but suggestive evidence that organizational size may be related to the kinds of criteria that are judged important in making new I/C technology acquisition decisions. These states also responded that they are not reluctant to take risks when investing in new I/C technologies (see 8a), but acknowledge that there are many issues that may affect decisions to adopt these technologies, such as availability of staff skills and an undercurrent of rapid technology change that is difficult to keep up with. Organizational size does not appear to be a good predictor of the likelihood to invest in new I/C technologies, but having the financial resources available, along with a customer focus and the ability to demonstrate system benefits, do emerge as important criteria used by these transportation agencies in making decisions to acquire and use new I/C technologies.

USE AND IMPACT OF I/C TECHNOLOGIES

State Transportation Agencies Use of and Experience with I/C Technologies

Question 9 listed four general categories of I/C technologies and asked respondents to identify the I/C technology categories (at least one category, but no more than two) for which they could provide the best insights into potential impacts of the technologies on their own transportation organization. The four categories were (1) ITS devices, (2) communication devices, (3) software tools, and (4) remote work arrangements.

TABLE 10
NUMBER OF RESPONDENTS FOR EACH OF THE FOUR I/C TECHNOLOGIES (Question 9)

I/C Technology	No. of Respondents
ITS Devices	30 (49%)
Communication Devices	24 (39%)
Software Tools	38 (62%)
Remote Work Arrangements	11 (18%)

Table 10 indicates the total number of respondents who replied to each of the four categories. The sum of the number of respondents in Table 10 is greater than our total survey response of 61, because survey respondents were allowed to indicate that they could provide insights into more than one (up to two) of the I/C technologies. However, two respondents answered questions for three of the four technology categories and four respondents answered for all four of the technology categories.

Table 10 indicates that the survey respondents were most familiar with the impacts of software tools on their organization, followed by ITS devices and communication devices. Only 18 percent of the respondents indicated that they could provide insight into potential impacts associated with remote work arrangements.

In the survey questionnaire (Appendix B), question 9A asked respondents to provide additional information on the impacts of specific ITS Devices on their organization. Table 11 provides some basic information on the use of ITS Devices and the overall impact of the technologies on the respondents' organizations.

Table 11 shows that four kinds of ITS Devices (out of eight) are used by a majority of the state transportation organizations represented by the respondents: infrastructure-based sensors (73.3 percent), real-time traffic information (63.3 percent), the Internet (96.7 percent), and global positioning systems (76.7 percent). Only one of these technologies, the Internet, was used by a majority (mean = 59.1 percent) of the staff within the respondents' organizations. One explanation is that most employees probably use the Internet for e-mail, websites, and other broad-spectrum applications. By contrast, the other ITS devices are more specialized and more likely to be used by fewer DOT staff. Regardless of use levels, the overwhelming majority of respondents (always above 90 percent) indicated that their organization's overall experience with ITS Devices was positive.

Question 9B asked respondents to provide additional information on the impacts of specific Communication Devices on their organization. Table 12 provides some basic

TABLE 11

SUMMARY OF RESPONDENTS' EXPERIENCE WITH ITS DEVICES (Question 9a)

I/C Technologies Associated with ITS Devices	Number (and Percentage) Indicating Organization Uses This Technology	Respondents Indicating a Positive Experience (%)	Respondents Indicating a Negative Experience (%)	Respondents Indicating a Neutral Experience (%)	Mean Percentage of Staff in Respondent's Organization Using This Technology
Infrastructure-Based Sensors	22 (73.3)	90	5	5	22.2
Real-Time Traffic Information	19 (63.3)	100	0	0	24.5
In-Vehicle Navigation Systems	2 (6.7)	100	0	0	7.5
Internet	29 (96.7)	100	0	0	59.1
Digital Satellite Photography	6 (20.0)	100	0	0	10.5
Voice-Activated and Voice-Recognition Systems	3 (10.0)	100	0	0	7
Global Positioning System (GPS)	23 (76.7)	95	0	5	9.3
Automatic Collision Notification Devices	0 (0.0)	0	0	0	0

Note: Variable message signs, highway advisory radio, and closed circuit television were added by one respondent.

TABLE 12

SUMMARY OF RESPONDENTS' EXPERIENCE WITH COMMUNICATION DEVICES (Question 9b)

I/C Technologies Associated with Communication Devices	Number (and Percentage) Indicating Organization Uses This Technology	Respondents Indicating a Positive Experience (%)	Respondents Indicating a Negative Experience (%)	Respondents Indicating a Neutral Experience (%)	Mean Percentage of Staff in Respondent's Organization Using This Technology
Wireless Communication	18 (75.0)	93.8	6.3	0	30.9
Cell Phones	22 (91.7)	94.7	0	5.3	21.2
Pagers	21 (87.5)	78.9	10.5	10.5	21.2
Global Positioning System (GPS)	14 (58.3)	83.3	0	16.7	6.5
Personal Digital Assistants (PDAs)	6 (25.0)	80.0	20.0	0	7.5

information on the use of Communication Devices and the overall impact of the technologies on the respondents' organizations.

Table 12 shows that four kinds of Communication Devices (out of five) are used by a majority of the state transportation organizations represented by the respondents: wireless communication (75 percent), cell phones (91.7 percent), pagers (87.5 percent), and GPS devices (58.3 percent). PDAs were only used by 25 percent of the organizations represented in the survey. Despite the widespread use of Communication Devices across transportation agencies, relatively few individuals within these organizations are using the technologies. Access to these technologies are likely to be restricted within the respondents' organizations. However, a majority of the respondents indicated that their organization's overall experience with the Communication Devices was positive, with “positive” ratings of between 78.9 and 94.7 percent across all five Communication Devices technologies.

Question 9C asked respondents to provide additional information on the impacts of specific Software Tools on their organization. Table 13 provides some basic information on the use of Software Tools and the overall impact of the technologies on the respondents' organizations.

Table 13 shows that five kinds of Software Tools (out of 11) are used by a majority of the state transportation organizations represented by the respondents: the Internet (97.4 percent), financial management software (55.3 percent), database software (76.3 percent), project management software (78.9 percent), and GIS software (78.9 percent). On average, however, only the Internet was used by a majority of the staff (57.0 percent) within the respondents' organizations. Database software was, on average, used by 39.3 percent of the staff within the respondents' organizations. The respondents' organizations' overall experiences with Software Tools has been positive, with “positive” ratings of between 66.7 and 97.1 percent across all 11 Software Tools technologies.

Question 9D asked respondents to provide additional information on the impacts of specific Remote Work Arrangements on their organization. Table 14 provides some basic information on the use of Remote Work Arrangements and the overall impact of the technologies on the respondents' organizations. The data presented in Table 14 should be viewed somewhat cautiously, because (see also Table 10 above) only 18 percent of the survey respondents (11 of 61) indicated that they could provide insight into potential impacts associated with Remote Work Arrangements.

Table 14 shows that two kinds of Remote Work Arrangements (out of four) are used by a majority of the state transportation organizations represented by the respondents: remote access (90.9 percent) and the Internet (81.8 percent). On average, however, only the Internet was used by a majority of the staff (55.7 percent) within the respondents' organizations. Recall that the Internet was included as an I/C technology in three of the four technology categories included in this survey. This reflects the basic nature of the Internet and the variety of ways in which the Internet can be used within transportation agencies. As seen in Tables 11, 13, and 14, the

TABLE 13

SUMMARY OF RESPONDENTS' EXPERIENCE WITH SOFTWARE TOOLS (Question 9c)

I/C Technologies Associated with Software Tools	Number (and Percentage) Indicating Organization Uses This Technology	Respondents Indicating a Positive Experience (%)	Respondents Indicating a Negative Experience (%)	Respondents Indicating a Neutral Experience (%)	Mean Percentage of Staff in Respondent's Organization Using This Technology
Internet	37 (97.4)	97.1	0	2.9	57.0
E-Commerce	11 (28.9)	80.0	0	20.0	13.9
Financial Management Software	21 (55.3)	81.0	4.8	14.3	27.9
Timekeeping Software	13 (34.2)	84.6	0	15.4	35.4
Literature Search Software	9 (23.7)	66.7	11.1	22.2	13.6
Database Software	29 (76.3)	92.6	0	7.4	39.3
Project Management Software	30 (78.9)	89.3	3.6	7.1	21.1
Construction Management Systems	17 (44.7)	82.4	0	17.6	14.0
Computer Models and Simulation	14 (36.8)	83.3	0	16.7	6.0
Geographic Information Systems (GIS)	30 (78.9)	82.1	0	17.9	13.4
Portable Pen-Based Database Systems	6 (15.8)	80.0	20.0	0	5.4

TABLE 14

SUMMARY OF RESPONDENTS' EXPERIENCE WITH REMOTE WORK ARRANGEMENTS (Question 9d)

I/C Technologies Associated with Remote Work Arrangements	Number (and Percentage) Indicating Organization Uses This Technology	Respondents Indicating a Positive Experience (%)	Respondents Indicating a Negative Experience (%)	Respondents Indicating a Neutral Experience (%)	Mean Percentage of Staff in Respondent's Organization Using This Technology
Remote Access (e.g., Telecommuting)	10 (90.9)	75	12.5	12.5	14.3
Internet	9 (81.8)	100	0	0	55.7
Personal Digital Assistants (PDAs)	4 (36.4)	50	25.0	25.0	21.3
Portable Pen-Based Database Systems	2 (18.2)	100	0	0	12.5

respondents' experiences with the Internet were very similar, but not identical, across the ITS Devices, Software Tools, and Remote Work Arrangements technology categories. The respondents' organizations' overall experiences with Remote Work Arrangements has been positive, with "positive" ratings of between 50.0 and 100.0 percent across all four Remote Work Arrangements technologies.

The results in Tables 11 through 14 can be summarized as follows:

- In general, state transportation agency use of the I/C technologies included in the survey was high. Across the four I/C technology categories, 15 of the 27 technologies listed were used by 50 percent or more of the organizations represented by respondents to the survey.

- There are clearly a number of I/C technologies that, reportedly, are not being used by the transportation organizations that responded to the survey. However, there seem to be some consistent trends across those I/C technologies that are not currently being used. Primarily, the nonutilized technologies reflect devices aimed at the driving public or at individuals, and include in-vehicle technologies such as navigation systems, voice activated/recognition systems, and collision avoidance devices. They also include more "personal" technologies such as PDAs and portable pen-based database systems.

- There are relatively few "high negative" ratings across Tables 11–14. However, some of the highest negative ratings seen in Tables 12, 13, and 14 are associated with PDAs and portable pen-based database systems. As noted above, these technologies were also associated with low use. It is not clear if the low use is a result of these somewhat negative experiences or if the negative experiences reflect a lack of time and effort in making the devices useful and valuable for individual agencies.

Impacts of I/C Technologies on State Transportation Agencies

To understand the potential impacts of I/C technologies, the survey results reported in this section focus on what seem to be the most important findings. Tables 15, 16, and 17 summarize the respondents' understanding of the various impacts of I/C technologies on their transportation agency, and all the results are available in Appendix B. Cell values in Tables 15 through 17 represent the percentage of respondents indicating a positive or negative response. Importantly, these percentages are based on the number of respondents who answered the question, not the total number of responses to the survey. In Table 15, for example, 29 respondents indicated having experience with and knowledge of the Internet as it relates to their transportation agency. Of these 29 respondents, 62.1 percent indicated that their agency's experience with the Internet had a positive impact on Management Practices. The data presented in these tables reflect a subset of all of the data obtained on potential impacts. The full dataset is presented in Appendix B, where it can be seen that the number of responses to some of the individual I/C technologies is quite small. In addition, many of the percentages representing either positive or negative impacts are also small, indicating low consensus among respondents.

To focus our efforts on those I/C technology agency impact combinations that reflect a reasonable subset of all state agencies, Tables 15–17 only present those I/C technologies for which at least 25 percent of our overall sample size (at least 15 responses from the sample) indicated that their organization had relevant experience with the potential impact. Furthermore, these tables only show potential impacts when the value of overall experience with the impact (either positive or negative) was 50 percent or greater.

The implications of the results presented in Tables 15–17 are as follows:

- Some consistent trends with respect to the impacts of I/C technologies on state transportation agencies can

TABLE 15

PERCENTAGE OF RESPONDENTS REPORTING SIGNIFICANT IMPACTS OF ITS DEVICES ON THEIR AGENCIES (Question 9a)

Potential Impacts	I/C Technologies			
	Infrastructure-Based Sensors (%)	Real-Time Traffic Information (%)	Internet (%)	Global Positioning System (%)
Management Practices			62.1	
Transportation System Planning	68.2	52.6		56.5
Education and Training of General Public		63.2	65.5	
Understanding What the Technologies Can Do		57.9	62.1	65.2
Staff Use of the Technology (Confusion, Errors)			58.6	
Understanding How the Technology Will Effect Traveler Behavior		57.9		
No. of Responses	22	19	29	23

Note: All entries reflect *positive* impacts. Table represents I/C technologies eliciting more than 15 responses and potential impacts with values of 50 percent or greater.

TABLE 16

PERCENTAGE OF RESPONDENTS REPORTING SIGNIFICANT IMPACTS OF COMMUNICATION DEVICES ON THEIR AGENCIES (Question 9b)

Potential Impacts	I/C Technologies		
	Wireless Communications (%)	Cell Phones (%)	Pagers (%)
Management Practices	83.3	86.4	76.2
Integration of New with Existing I/C Technology	50.0		
Understanding What the Technologies Can Do	50.0	50.0	
Staff Use of the Technology (Confusion, Errors)	50.0	59.1	
No. of Responses	18	22	21

Note: All entries reflect *positive* impacts. Table represents I/C technologies eliciting more than 15 responses and potential impacts with values of 50 percent or greater.

TABLE 17

PERCENTAGE OF RESPONDENTS REPORTING SIGNIFICANT IMPACTS OF SOFTWARE TOOLS ON THEIR AGENCIES (Question 9c)

Potential Impacts	I/C Technologies					
	Internet (%)	Financial Management Software (%)	Database Software (%)	Project Management Software (%)	Construction Management Systems (%)	Geographic Information Systems (GIS) (%)
Management Practices	67.6	81.0	58.6	86.7	64.7	70.0
Transportation System Planning						80.0
System Design and Acquisition			55.2			
Security Issues	–51.4					
Long-Term Financial		57.1				
Education and Training of General Public	54.1					
Integration of New with Existing I/C Technology	59.5		55.2			60.0
Understanding What the Technologies Can Do	62.2		51.7	50.0		60.0
Staff Use of the Technology (Confusion, Errors)	56.8					50.0
Cultural Changes with the DOT Agency	59.5					
No. of Responses	37	21	29	30	17	30

Note: Entries preceded by a minus sign (–) indicate *negative* impacts; entries without the minus sign indicate *positive* impacts. Table represents I/C technologies eliciting more than 15 responses and potential impacts with values of 50 percent or greater.

be discerned. For example, there are consistently *positive* impacts on management practices, staff use of the technology, and overall understanding of what the technology can do resulting from the use of technologies such as the Internet, wireless communication, cell phones, and GIS devices.

- Also, generally consistent *positive* impacts are seen with respect to transportation system planning and the integration of new with existing I/C technologies across a range of I/C technologies.

- The only *negative* impact noted in Tables 15, 16, or 17 (and consistent with our selection threshold) reflects security issues surrounding the use of the Internet.

- There were a number of potential impacts that were not consistently reported (in either a *positive* or a *negative* sense) by the respondents. These include organization of transportation agencies, short-term financial impacts, training and learning curves for DOT staff, traffic forecasting, allocation of internal resources, and outsourcing of jobs/functions.

CHAPTER FIVE

CASE STUDIES

Case studies provide an opportunity to "drill down" into the impacts of I/C technologies on state DOTs. Whereas the survey of DOTs gives the macro-view across the United States, case studies shed light on the context in which I/C technologies are being acquired and applied and the impacts that are being felt. Site visits were conducted with DOT staff in Washington State and Virginia, and telephone interviews were conducted with staff of DOTs in Wisconsin, Florida, Missouri, and Kansas. The information they provided is the basis of this chapter. The results are presented in seven sections. First, at the Washington State DOT (WSDOT), the focus is on I/C technologies at the traffic management center. In the second section, on Virginia, the organizational impacts of I/C technologies are examined. Wisconsin's e-government initiatives are discussed in section three. Section four describes new approaches to telecommunications being used to foster ITS in Florida. The experience of the Missouri DOT in implementing an information management system is presented in section five. Section six discusses activities in electronic signatures and document management at the Kansas DOT. In the final section, the staffing implications of I/C technologies are assessed.

USE OF I/C TECHNOLOGIES IN THE WASHINGTON STATE TRAFFIC MANAGEMENT CENTER

A site visit was made to WSDOT and the Seattle Traffic Management Center (TMC) to examine current status and practices at the TMC with respect to new I/C technologies. This center was chosen for the case study because Battelle had investigated a range of related issues at the Seattle TMC in 1995. Thus, past research provided a useful comparison with the current situation at the TMC. In particular, insights were developed into how Seattle has adapted to the availability of new I/C technologies, using the 1995 findings as a baseline.

Background

Within transportation agencies, I/C technologies are used to assist a variety of different operating groups, from administrative, financial, and planning organizations to service support and information dissemination organizations. However, state- and local-level TMCs represent a key component of any plan involving widespread deployment of I/C technologies, especially ITS devices. In particular, TMCs serve as the "nerve center" of metropolitan areas, deploying ITS technologies with responsibilities that include:

- Monitoring, collecting, and disseminating real-time road/weather, motorist, and public safety information;
- Controlling traffic signals;
- Controlling roadway surveillance cameras and monitoring incidents;
- Monitoring and operating special purpose (e.g., fire protection) surveillance and control systems;
- Operating highway advisory radio systems; and
- Composing and displaying safety-related information.

Recent expansion and upgrades of ITS technologies into metropolitan areas has provided TMCs with a range of new surveillance, communications, and control equipment. Although greatly increasing the TMCs' general abilities to reduce congestion, improve traffic flow, and increase motorist safety, these technologies have not always been appropriately integrated into existing TMC operations. ITS technologies are frequently deployed without sufficient consideration of actual TMC data needs, the impact of these technologies on TMC operators and other decision makers, or the need for standards for the use of ITS data.

February 1995 Status of ITS Technologies at the Seattle TMC

In February of 1995, a preliminary human factors review of the WSDOT TMC was conducted by Battelle. The review focused on a limited set of concerns and problems experienced by the TMC with respect to the use of ITS technologies. The Seattle TMC is one of the most advanced traffic management centers in the nation. Within the TMC, the Radio Communications Center (RCC) is responsible for issues involving public safety and highway maintenance that relate to the use of surveillance systems, phone systems, and radio communications. At the time, the proliferation of nonintegrated ITS technologies into the RCC had resulted in slowed traffic management operations, strained resources, and increased workload demands on TMC staff. Table 18 provides key examples of nonintegrated ITS technologies, the problems that these technologies had (in 1995) caused for TMC staff, and the operational consequences associated with these problems.

TABLE 18

1995 TMC PROBLEMS ASSOCIATED WITH THE ACQUISITION AND MANAGEMENT OF ITS TECHNOLOGIES AND DATA

TMC Problems	Examples of Nonintegrated ITS Technologies →	Problems Experienced by TMC Staff →	Consequences for TMC Operations
1	Different screen layouts, control designs, user interfaces, and operating procedures for ITS technologies	Stimulus-response incompatibilities. Confusion and frustration when switching between ITS technologies	Slowed response times and input errors
2	Multiple equipment performs similar or identical functions	For example, on radio communications equipment, RCC operators "walk over" one another	Garbled and missed communications; redundant operations
3	High degree of auditory clutter from communications equipment such as radios, CB scanners, police scanners, and printers	Unable to distinguish high-priority alarms from normal background sounds	Missed calls and auditory alarms and/or slowed response times to auditory messages
4	Lack of physical space at consoles and work areas due to proliferation of ITS-related equipment	No room for paper documentation; poor access to equipment by operators	Use of paper maps and other hardcopy cannot be properly performed at main consoles

July 2000 Site Visit to the Seattle TMC

As part of the present study of the impact of I/C technologies, a site visit was conducted to the Seattle TMC by Battelle on July 11, 2000. The goal of the site visit was to assess the agency's approach to acquiring and integrating ITS technologies into the center and, in particular, to compare current status and practices with those observed in 1995. The site visit took approximately 2 hours; during this time, we observed TMC operations in the main control room and conducted interviews with the lead engineer within the TMC. The following summarizes our observations with respect to various TMC characteristics as they relate to I/C technologies.

Approach to TMC Design

Over the past several years, long-term planning for the TMC has been more systematic and strategic than in previous years. Improvements to the TMC are made in relatively small steps and gradual changes. One aspect of TMC development that has led to a decrease in some of the problems seen in 1995 is the in-house design and development of TMC software.

Workstation Design and Layout

TMC operations are controlled from three primary workstations contained in the control room. Importantly, these three workstations have the same configuration and can perform the same functions. Thus, operators can move from workstation to workstation with confidence because the operations as well as the layout are the same, and the individual workstations provide redundancy with one another in case of equipment failure. Overall, the control room is free of unnecessary or unused equipment.

This presents a stark contrast to the situation in 1995, when the workstations in the control room did not have the same layout (resulting in confusion as operators moved from one workstation to another) and were not functionally identical. This focus on redundancy and ease-of-use did not come about by accident, but was accomplished by design, through a series of gradual changes involving removal of unneeded equipment and replacement of one-of-a-kind equipment with standard “swappable” workstation components.

The ease-of-use of the TMC workstations has improved so much over recent years that virtually all of the operators are part-time student interns from the University of Washington. These operators are trained to work the “hot seat”—the central workstation in the TMC—within 1–2 weeks. This workstation functions as a command and control center for the TMC and is the only workstation that is staffed during peak work hours.

Integration of Communications Activities

Communication and sensor technologies have become more integrated than in past years. A frequent problem faced by TMCs is verifying the correct nature and location of roadway emergency situations such as vehicle accidents or fires. Ironically, the widespread use of cell phones has proven to be a mixed blessing in such situations. That is, although cell phones have improved the public's ability to report emergency situations to the TMC and to state emergency response units, they have also led to an increase in the number of errors associated with emergency call-ins. In the Seattle TMC, infrastructure-based sensors, such as cameras, are used to verify the nature and location of emergency reports called in by the general public. Therefore, the TMC has been able to use one kind of I/C technology—roadway cameras—to address problems caused by another kind of I/C technology—cell phones.

In the Seattle area, the availability of cell phones has also led to a significant reduction in the need for roadside call boxes. Low-use call boxes are being removed from the roadsides, resulting in considerable financial savings to the state with respect to call box maintenance and replacement costs.

Conclusions

The 1995 and 2000 visits to the Seattle TMC have provided a unique "before and after" perspective on the impacts of I/C technologies on WSDOT. Based on these observations, several conclusions can be drawn.

- The purchase and implementation of I/C technologies should be done in a planned, purposeful manner. Some of the problems experienced by the Seattle TMC in 1995 could have derived from the purchase of I/C technologies that were not integrated and even incompatible. The subsequent application of long-term strategic plans has helped reduce and in some cases eliminate many of these problems.

- There are often unexpected interaction effects resulting from the implementation of I/C technologies. As seen previously, the widespread use of cell phones led to both negative and positive impacts associated with, respectively, errors in emergency situation reports and the continued need for roadside call boxes. To the extent possible, transportation planners should consider the possibility of interaction effects and avoid negative interactions and look for opportunities for synergistic (i.e., positive) interactions among I/C technologies.

- I/C technologies can have a significant financial impact on state transportation agencies. Nonintegrated technologies, or those purchased without the benefit of a long-range plan, can result in longer operator training times, poor operator performance, and errors in public information dispensed by the TMC. Alternatively, integrated I/C technologies can reduce training requirements, reduce operator skill requirements, and lead to the elimination of redundant or unnecessary equipment.

IMPACTS OF I/C TECHNOLOGIES ON THE VIRGINIA DOT ORGANIZATIONAL STRUCTURE AND FUNCTION

The Virginia DOT (VDOT) provides instructive examples of the impact that I/C technologies are having on the structure and function of DOTs as they seek to carry out their mission. The largest agency in Virginia and the third largest state DOT in the United States in miles of roads, VDOT currently employs 10,600 persons, down from a high of 13,000 in the 1990s. To deal with pressing transportation needs within the state, VDOT has seen its budget increase from $2.5 billion in fiscal year 1999 to $3.2 billion in 2000.

From an organizational perspective, the staffing and budget figures are indicative of the twin pressures to provide the transportation services needed while at the same time controlling the size of state government itself. I/C technology is recognized as offering solutions for achieving VDOT's missions; however, I/C technologies also challenge VDOT to manage the changes that I/C technology brings about.

During an interview with VDOT managers at their Richmond headquarters on August 24, 2000, the organizational aspects of managing I/C technologies were explored along with recent major initiatives, including the movement toward e-government, as the use of the Internet for government functions is called.

Changes in Organizational Structure of Information Technology

Primary responsibility for I/C technology lies within the Technology Directorate, whose assistant commissioner is in the second tier of management, below the VDOT commissioner (Figure 4). Management of information technology (IT) within VDOT has gone through a cycle of change over the last decade. In 1994, a study of management information systems was performed across all state government departments, which resulted in restructuring the management of IT. Within VDOT a new governing group was formed known as the TIMSC, the Technology and Information Management Steering Committee. Until then, management of IT within VDOT had taken place from a centralized division, whose customer service to the other divisions was found wanting. Funding for IT was distributed to the business units and away from the central IT group, which was left with a coordination role.

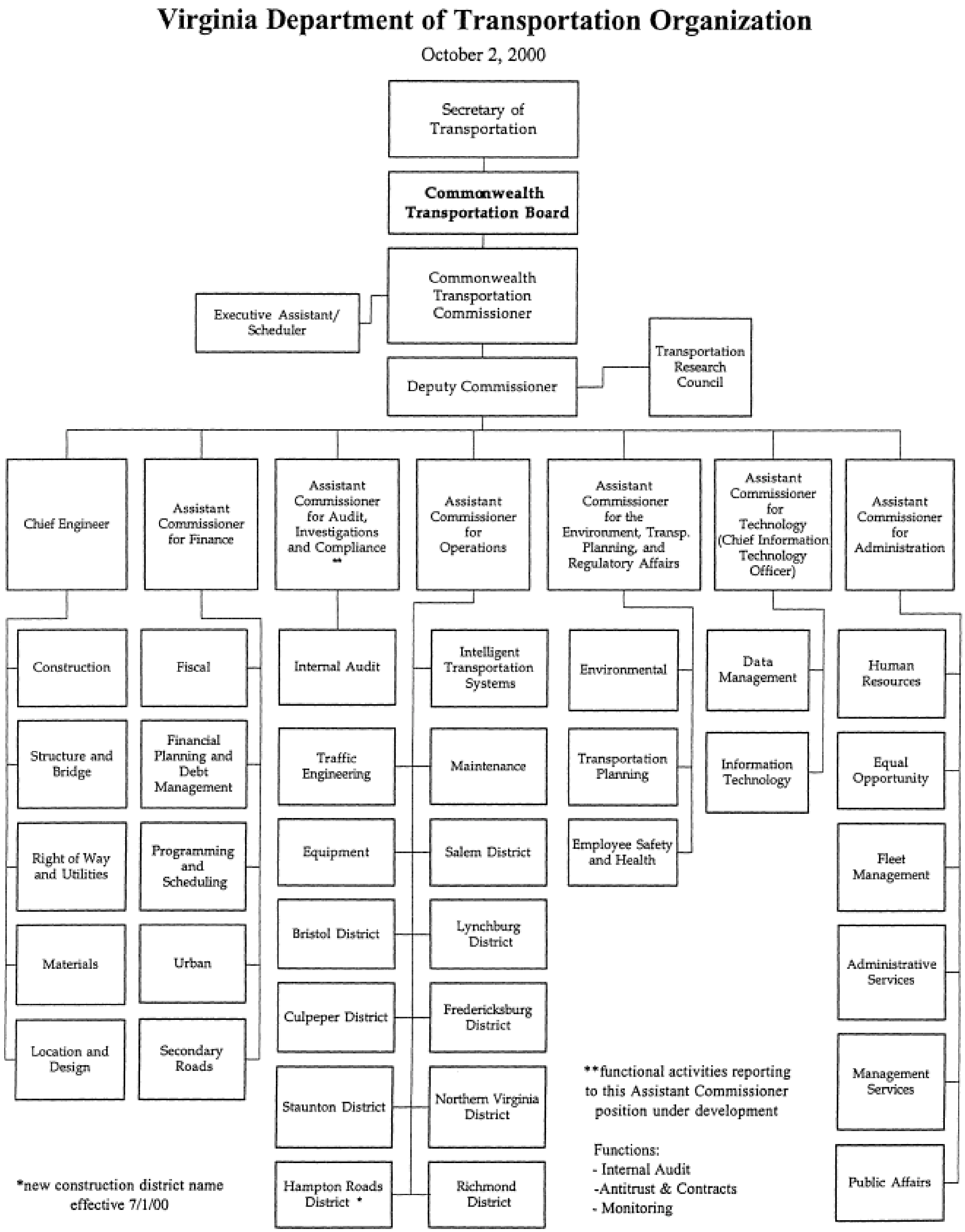

FIGURE 4 Virginia Department of Transportation organizational structure. *(Courtesy of VDOT 2001.)*

Within VDOT, management of IT started to move back from the business units to a more collaborative relationship with the IT group. To effect this change, a new executive level position, the Assistant Commissioner for Technology, was established. Business units still managed their own IT budgets, but now they needed approval. The process has been viewed as successful and has helped to provide the checks and balances to serve the IT needs of individual divisions while maintaining a degree of control across VDOT. Within the new IT management structure, a key function of the TIMSC is to set priorities on how resources will be distributed among the divisions. In October 1999, VDOT issued its first Technology and Information Management Program Strategic Plan (http://www.vdot.state.va.us/info/techplan99.html). The Strategic Plan documents VDOT's approach to selecting, planning, developing, and evaluating IT initiatives as a means to further its business objectives.

All business processes for managing IT have changed, and have been dealt with by bringing together the functional and regional organizations within VDOT to foster collaboration and coordination in solutions to IT problems. The transition has not always been smooth. In moving toward VDOT-wide standard software, resistance has sometimes arisen as individuals and organizations were required to abandon the comfort of the familiar and learn new applications. Consequently, there is competition for funds as organizations strive to see their priorities served.

The E-Government Vision for Virginia

IT is at the center of a key policy initiative in Virginia, and a Secretary of Technology was appointed in 1999 to implement the governor's vision for e-government. That vision includes creation of a web portal called “My Virginia,” which is intended to be a single site whereby Virginia citizens can interact with all levels of state government. This site also allows for customization to reflect each user's unique needs. The vision for internal applications of e-government is to unify systems such as payroll and travel so that they are standardized across state government agencies and available on the state's Intranet.

The potential impacts of I/C technologies are nowhere so apparent as in the implementation of the e-government vision. To manage the enormous scope of the task, the near-term focus at VDOT has been on achieving the governor's goal of having all VDOT forms available on the web by the end of the year. There are over 800 VDOT forms being converted to PDF format for downloading. In the long term, the vision for e-government will require dramatic IT and organizational changes to support interactive use of forms and for state agencies to transfer information among themselves and between state and local government agencies.

VDOT's current website is being transformed into a portal that will be connected transparently to the “My Virginia” portal, but VDOT will continue to maintain its own portal. Allowing users to customize the portal to reflect their own interests will enhance customer service. Additionally, many types of interactions will become webenabled, leading to greater efficiencies for both customer and VDOT personnel. For example, construction bidding has been a manual process. Now, however, notices of bids are available on the VDOT website. The next step will be to enable people to order bid packages via the Web and, eventually, bids will be submitted over the Internet.

The many potential web applications that may eventually be required by VDOT divisions have necessitated new development approaches and organizational relationships. Generic applications that can be customized and adapted to a particular division's needs will help ensure that scarce web development resources are efficiently deployed on the highest priorities. The process will also enable divisions to control their own web-related material and free them from relying entirely on the web developers for all new material on the VDOT portal. For example, a generic survey capability can be developed so that divisions can adapt it to their own needs. Approximately 12–15 people are in the VDOT web development group and many requests for their services are anticipated. Prioritization of projects and collaboration with other VDOT groups will be needed and that will require a breaking down of “cultural firewalls,” which will not always be easy.

E-Government Impact on Other IT Activities at VDOT

E-government is having ramifications beyond its immediate impact, because IT infrastructure needs to be in place to support e-government. Initiatives already underway have been given new urgency or are being looked at in a new way for how they relate to e-government, such as the following:

- *Seat Management*—VDOT has found that long procurement cycles are anathema to keeping computer technology current. Even when new hardware is procured, the disposal of obsolete government equipment becomes another problem. As an alternative to owning personal computers (PCs), VDOT has contracted with a firm that provides hardware, software, and support for all new PCs. Using a 3-year refresh cycle, 7,000 PCs have so far been supplied to VDOT employees, who receive a suite of standard application software. Depending upon the unique needs of particular divisions and individuals, the PCs have also been configured with additional software, such as CAD (computer-aided design) for the Location and Design Division. The advantage for VDOT is that employees are provided with the appropriate hardware with sufficient features and power to meet the evolving needs of the department.

The impact of seat management, as this approach is called, is to keep computer technology current so that VDOT is on a more level playing field with its contractors and customers than in the past. Although seat management will enhance both operations and customer service, this new model of PC management has, nevertheless presented challenges. For the individual PC user, seat management does require him/her to cede control of the PC, which may not always be easy. In addition, VDOT has undergone a learning process on how to manage the users' configurations as hardware and software products continue to change. These problems will fade and seat management is expected to continue to be the best solution to managing VDOT computers in a rapidly changing technological environment.

- *Geographic Information Systems*—GIS at VDOT admittedly lag behind the efforts of many other states, but current activities are intended to correct that situation. An initiative known as VGIN, Virginia Geographic Information Network, has been established to coordinate GIS activities between state and local governments. VDOT has the mission of providing the "transport layer" for GIS so that there will be consistency in information related to transportation across the state. However, there are several issues that need resolution and effort. First, a centerline for all roads in the state needs to be established for GIS to be applied. Second, currently available digitized maps are often simply geographic renderings and not spatially accurate for GIS use. Third, incorporation of business data, such as locations of stores, needs to have spatial references established. These will be potentially costly and time-consuming undertakings.

E-government provides further incentive for VDOT's GIS activities, as the Internet stimulates greater demand for and ease of access to transportation information. Having geo-coded information will be seen as increasingly necessary by other government agencies, transportation professionals, and the traveling public.

E-government is a prominent example of the many I/C technology initiatives underway at VDOT. Activities such as data warehousing and a laboratory for testing new products are other examples of VDOT's goal of putting I/C technologies to work for transportation in the Commonwealth.

Conclusions

From the experience of VDOT, several conclusions about the potential impact of I/C technologies can be drawn.

- The organizational structure to deal with I/C technologies is a reflection of the technologies themselves (PCs versus mainframe computers) and the operational and service imperatives of the DOTs (e.g., cost control and road building). Continuing evolution of I/C technologies will require adaptations in organizational structure.

- The Internet-equipped information society will require entirely new methods and levels of service for which DOTs are not well equipped. Management of scarce IT staff, equipment, and the budget to meet growing demands for services will require new forms of collaboration within DOTs.

- The impact of I/C technologies can have far-reaching ramifications. E-government, for example, requires not only the development of websites, but employees throughout the DOT who are equipped and trained to maintain them. Stimulation of new procurement practices may be needed, such as "seat management," or increased pressure on other I/C technology efforts, such as GIS, are likely to be felt.

WISCONSIN DOT'S E-GOVERNMENT INITIATIVES

The Wisconsin DOT is another state transportation agency that has embraced e-government. As in Virginia, the governor of Wisconsin gave added impetus to e-government by issuing an executive order in September 2000, laying the foundation for electronic delivery of state and local government services within the state (http://badger/state.wi.us/wistech). This executive order called for the creation of an Internet-based "service center" by January 1, 2001, where citizens could gain electronic access to core state government services. This statewide portal would expand over time to include the widest possible range of state and local government programs and to incorporate existing business systems of state agencies to promote overall efficiency. The executive order also requires that technologies, policies, and business practices be developed to ensure security and confidentiality for persons accessing e-government services.

In implementing the executive order, four major elements have been identified:

- Government to Citizen (G2C)
- Government to Business (G2B)
- Government to Government (G2G)
- Government to Employee (G2E).

Initial emphasis is on the G2C elements, in recognition of citizen demands for conducting some state activities on-line, such as vehicle registrations and hunting licenses.

About 50 percent of Wisconsin's population have Internet access, and increasing amounts of G2C business are anticipated. In the meantime, the state does not expect to save much in costs, because offices to serve the public will still need to be staffed. In trying to conduct G2C business another issue has emerged: how to charge for use of credit card payments. Legislation is needed to enable DOT and other state agencies to charge $2.50 to cover credit card processing for citizens wanting to pay on-line. Thus, embracing e-government could require new policies and procedures after the initial steps to organize the program. In addition, an overall architecture could be implemented, legislative action may be needed in addition to the credit card issue, and mechanisms need to be established to link to county and municipal governments. Within DOT and other agencies information systems it might be helpful to examine how changes in one data item (e.g., a license plate number) relate to another data item (e.g., vehicle registration number).

The Wisconsin DOT expects considerable cost savings as a result to G2B, in contrast to G2C. By reducing paperwork, such as putting construction drawings on-line, and by streamlining procurement through innovations such as reverse bidding that leads to the lowest price to the state, G2B should save time and lead to more cost-effective operations at the Wisconsin DOT. In the G2G arena, e-government is expected to produce improved communication between DOT and local governments within the state and also with other DOTs at the state and federal level. For example, G2G might facilitate fuel tax transfers between states or CVISN (Commercial Vehicle Information Safety Network). For the last e-government element, G2E, Wisconsin has already established a useful intragovernmental website for state workers. For example, employees can now obtain manuals electronically, and consistent information can quickly be communicated to all staff.

Despite the interest and enthusiasm for e-government initiatives in Wisconsin, there remain several e-government-related issues including:

- The use of private sector advertising on state websites. Attractive as a source of revenue, this can raise political and other difficult questions.
- Technical problems resulting from the rapid pace of technological change that underlie the Internet revolution and increase budget pressures. The state could establish standards for the hardware and software used in e-government.

The governance of IT is being handled by an IT Business Council within the DOT, which coordinates investment and policies across the agency and that will set the priorities through which e-government problems can be addressed.

NEW APPROACHES TO TELECOMMUNICATIONS AND ITS IN THE FLORIDA DOT

Technological and market developments in the telecommunications industry offer opportunities for the Florida DOT to escalate its deployment of ITS throughout the state. Following the Federal Telecommunications Act of 1996 the market for wireless and wireline services exploded, and telecommunications carriers required new sources of rights-of-way to construct their networks to serve the burgeoning demand. Recognizing its citizens' demand for telecommunications services, FDOT decided to open up its right-of-way through competitive procurements. For both wireless and wireline carriers, FDOT negotiated contracts that will have the added benefit of spurring the deployment of ITS technologies that will improve delivery of transportation services throughout the state. A single firm in the wireless market was awarded a 30-year contract to build communications towers on FDOT rights-of-way and act as the agent to lease space on the towers to wireless carriers. In return, FDOT will receive a portion of the gross revenues from leases. The contractor will convert the revenues to in-kind services by acquiring ITS hardware specified by the DOT, such as variable message signs or weather monitoring devices. FDOT will handle the installation and integration of the technology into its statewide ITS deployment.

On the wireline side, Florida will also be able to take advantage of a shared-resource arrangement with a fiber optic network firm. Under a 50-year lease, a firm was selected through competitive bid to install and maintain a fiber infrastructure on 2,200 miles of highway throughout Florida. In return, the DOT will have access to 48 dark fiber strands, regeneration buildings constructed by the contractor, and outside maintenance of the fiber network—an estimated $1.2 billion benefit to the state. For its portion of the network FDOT will assume responsibility for purchasing approximately $73 million in state-of-the-art electronics to light the fiber.

The rapid deployment of the telecommunications networks of the magnitude described are bound to be felt in various ways within the DOT. First is the expansion in use of outside expertise to supplement FDOT staff. For the management of its portion of the fiber backbone, FDOT decided to use an outside contractor, because DOTs often have difficulty competing for technical personnel with the private sector. The DOT has hired a general consultant to help with design and specifications for telecommunications, and a general consultant for ITS. Both general consultants will work with the district staffs to conduct concept studies in five corridors throughout the state. A second significant impact is that DOT districts, which have operated fairly autonomously in the past, will be required to collaborate. Because communications infrastructure passes through more than one district and because FDOT wants its telecommunications and ITS technology to adhere to a common architecture and use current and emerging standards, a collaborative approach among the districts is necessary for success. A third impact is that the state plans to construct its ITS using a "design, build, integrate" type of contract. The state will be able to take advantage of this new type of procurement, which could significantly speed up the deployment of ITS and achieve a greater degree of success than with traditional contracting approaches.

The rapidly expanding telecommunications market has afforded an opportunity for FDOT to take advantage of significant cost savings, to supplement its sources of funding for ITS deployment, and to have a statewide broadband telecommunications network available on an accelerated timetable. FDOT has been able to realize these advantages through innovative contractual arrangements involving public/private partnerships and through supplementing technical staff with outside expertise. FDOT recognizes that institutional adjustments are needed to succeed with new communications and information technologies. In particular, collaboration both internally and externally will be necessary. Although it is too early to tell what new stresses and strains will arise, FDOT's approach to telecommunications holds the promise of a solid foundation upon which its vision for ITS and other transportation applications can be based.

INFORMATION MANAGEMENT SYSTEM AT THE MISSOURI DOT: LESSONS LEARNED

In the mid-1990s, the Missouri DOT decided that the time was right for building a database that would standardize data across the entire department. The advantages were obvious: a single referencing system would enable analysts to readily access disparate information that would lead to better decision making and management of assets. For example, cross-referencing accident sites with pavement conditions and with road geometrics would provide valuable insights, which would help to identify problems and prioritize solutions.

What seemed simple has turned out to be a larger undertaking than originally envisioned. Starting with pavement and bridge databases in 1995, the plan was to incorporate safety and congestion data into the new system. Difficulties arose in trying to convert road referencing systems that had been used in separate databases. Whereas bridge and pavement geo-references were fairly straightforward, safety and congestion data were more complicated, especially where state routes cross city streets. Not part of state jurisdiction, city streets often had either no or different referencing systems in place. To address the problem the Missouri DOT put a tremendous amount of effort into non-DOT road referencing for safety and congestion data. Consequently, limited benefits were realized despite the considerable time and funding expended.

Undoubtedly the Information Management System will be of great value to the Missouri DOT when it is completed. In the pavement management area, for example, the system will enable the DOT to prioritize its construction and maintenance activities so that many factors can be used in determining when and on what road segments work gets done. Moreover, maintenance costs that previously were placed into a general accounting category will be linked to specific road segments.

Despite the benefits that will be realized when the project is completed, two important lessons have been learned about how the Information Management System might have been developed differently and produced results sooner.

- Tightly define goals in scope and time frame to allow for greater control.
- Implement an incremental development approach; that is, a system built in phases with resources focused on high priority areas that will result in the product being delivered more quickly. Such an approach also enables progress to be more clearly matched with scheduling and budgets.

As the system nears completion, it is clear that institutional challenges may be the next hurdle to overcome. The GIS capabilities of the system enable visual display of DOT data, often for the first time. Putting data in a new light can be very instructive, but it can also highlight deficiencies in the data that were not previously apparent. To combat the tendency to blame the Information Management System, management support is needed to confront negative reactions and to advocate the value of the system. Only with top level support will this new tool be integrated into DOT operations and produce the payoffs that were originally envisioned.

ELECTRONIC SIGNATURES AND DOCUMENT MANAGEMENT AT THE KANSAS DOT

The Kansas DOT (KDOT) is playing a leadership role in the movement toward electronic signatures so that state governments can conduct their business over the Internet. KDOT wants to achieve a state-of-the-art electronic document management system, and the electronic signature capability is needed so that engineering and other documents can be officially transmitted without paper. Kansas laws were changed so that electronic signatures are legally recognized, especially in their digital signature form. KDOT took a leadership role in issuing a request for proposal in 2001 to set up a digital signature system using Public

Private Key Infrastructure Technology. KDOT has been an active participant in this arena and participated in the August 2000, conference on digital signatures that brought together U.S. and foreign participants to discuss the next steps for state governments as a result of the federal Electronic Signature and Global Commerce Act (ESIGN), which became effective in October 2000.

The DOT's document management system itself has been prototyped, and the next steps are to expand it. The system is used to store legal documents and manage workflows such as executive correspondence, travel requests, accident forms, and bridge ratings and inspections. One of the major challenges is to integrate it into the corporate culture at KDOT. Within the DOT people are just beginning to understand what it can do, and it is too early to measure its ultimate impact. However, it will help in the cross-referencing of documents, which will lead to better information than is currently available, such as identifying all the correspondence on a particular topic. KDOT expects the document management system to improve effectiveness by enabling better decision making and to increase efficiency, especially among the clerical and administrative staff.

Kansas has introduced other practices to meet the challenges that I/C technologies pose to DOT operations. As in other states, KDOT has had difficulty staffing positions to support its initiatives involving I/C technologies. One approach being used to attract and retain job applicants is to offer a series of bonuses to compete with the lure of the private sector. These include signing bonuses, retention bonuses, and bonuses for skill acquisitions. Another innovation is contract programming, which has been in use for about the last 5 years. A line item in the budget has been established to provide a constant source of support in computer systems, analysis, training, and software. A committee of bureau chiefs who select projects according to the priorities that they face manages the funds. Projects range from simple, low-budget tasks to complex projects with costs exceeding hundreds of thousands of dollars. A work order process is used with vendors already under contract, which streamlines the process by focusing negotiations on the scope and price of the task. The process has five key steps.

- Description by KDOT of the task to be performed;
- Detailed analysis by the vendor of the task, including a fixed-price cost for each deliverable;
- Completion of the work;
- Acceptance of deliverables by KDOT; and
- Payment by KDOT of the lesser of the fixed-price or actual cost of the vendor.

Employees of the vendor often work on-site at KDOT to facilitate close collaboration with DOT staff. Moreover, training KDOT staff on the system or product being developed is a routine requirement, so that DOT staff are ready to use and maintain the system when it is turned over to them.

IMPLICATIONS FOR I/C STAFFING AND TRAINING: ITS CAPACITY BUILDING

The literature review on the role of new I/C technologies in organizations, coupled with the results of our survey of state transportation agencies, underscores the importance of staffing and training considerations. State DOTs often face critical skill shortages and staff training needs that are only exacerbated by the proliferation of the new I/C technologies. Respondents to our survey rated as *very important* "having staff to support and maintain the new technology," and they indicated *strong agreement* with the statement that "rapid technology change makes it hard for public transportation agencies to compete with the private sector for skills." To benefit from these new I/C technologies, state and local transportation agencies must either retrain existing staff to upgrade their engineering and management skills or hire new staff with the requisite skills. In addition, the rapid evolution in the marketplace of sophisticated I/C technologies calls for continuous improvement in the ability of staff to handle their changing job roles, to maintain high levels of performance, to learn new skills, and to overcome cultural and institutional barriers on the job that they never had to deal with before.

Federal Professional Capacity Building Program

The U.S. DOT's Joint Program Office has recognized the challenges facing state and local transportation agencies in this area of high technology staffing and training and is seeking to better understand and address the needs. Since 1995, the Office of Traffic Management and ITS Applications of the U.S. DOT has administered a Professional Capacity Building program "designed to develop and enhance the knowledge, skills and abilities of U.S. DOT Staff in the Federal Highway Administration (FHWA) and the Federal Transit Administration (FTA), state and local personnel, transportation professionals, and elected officials on ITS functions, opportunities, applications, designs, capabilities, and benefits. The key goal is to build a level of expertise of transportation specialists commensurate with their duties and responsibilities necessary to plan, design, build, operate, and manage current and future ITS projects (FHWA 2000)."

A report issued in December 1997 by the U.S. DOT that reviewed prior ITS education and training needs assessments and the results of field interviews with ITS practitioners, concluded that "alternative approaches to learning that are grounded in the use of new I/C technologies must be adopted." Thus, it has been apparent for a number of years that new I/C technologies not only are challenging state and local transportation agencies and organizations in terms of staff skills and training, but also are offering new mechanisms for delivering the very skills and training that are needed. The Professional Capacity Building program talks about needing and developing "a new breed of transportation professionals" capable of effectively managing and working with the range of new I/C technologies that are rapidly emerging.

The 1997 DOT study found that technical staff are currently insufficient and that the scientific and technical skills needed to take full advantage of the new I/C technologies are lacking in the transportation labor market. The study also found that training and education resources are typically insufficient to support the level of training and retraining that is required. The report offered guidance regarding a prudent course of action that included the following elements:

- Develop a more complete understanding of the full range of ITS skills and training needs. This would include attention to the less well-understood areas of transit and commercial vehicle operations, and would identify training priorities and detailed learning objectives linked directly to the needs of transportation agencies.
- Identify the gaps between critical skills and existing training courses.
- Establish a process to assure that training is focusing on emerging skill needs and keeping pace with the rapid evolution of new I/C technologies.
- Explore new ways to cost-effectively convey the needed skills and knowledge.

In the summer of 1998, DOT conducted about 200 interviews "to more systematically investigate the intelligent transportation systems (ITS) training and education needs of transportation professionals" (U.S. Department of Transportation 1999). This report reviews the technical and institutional challenges that are being faced today with the introduction and deployment of ITS systems, and these challenges get at the heart of the skills and training requirements for transportation agencies to effectively manage and work with the range of emerging I/C technologies. The technical challenges include the following (U.S. Department of Transportation 1999):

- ITS requires knowledge and skills across a range of highly technical topics. It requires expertise in information, communications, electronics, automation technologies, technology procurement and testing, and systems integration. Integration refers to the need for these new I/C technologies to work together in a system, for information exchanges to work smoothly, and for high technology applications to be able to "talk" to each other in a common language. Interviewees in the 1998 DOT study cited the need to know how to choose the most appropriate and cost-effective technologies, and to understand the capabilities, limitations, and risks of technology options.
- ITS also requires more extensive use of basic computer and software skills such as spreadsheets, database systems, word processing, or Internet applications.
- ITS deployment rests upon a foundation of multidisciplinary knowledge, skill, and abilities. Adopting new I/C technologies requires skill in understanding the needs of a wide range of users, including understanding how parts of an organization that typically are separate now may need to work closely together to operate a network of new information and communication systems or new cross-cutting technologies.
- Knowledge and skills must keep up with the continuous evolution of technologies and innovative practices. The ability of staff to adapt to rapid change was identified as a key need by respondents in the 1998 DOT study. Staff coming from different parts of an organization, often with very different disciplinary backgrounds, need to find effective ways to collaborate to manage and operate many of the new networked or integrated I/C technologies.

In addition to these technical requirements, new I/C technologies "also require unprecedented cooperation between public sector agencies as well as the public and private sectors, necessitating new skills in partnering, contracting, and negotiations." The DOT report goes on to say that in order to mainstream these I/C technologies, "transportation professionals will need to be able to affect organizational and cultural change."

Experlences In Selected State DOTs

Virginia

Discussions with VDOT provide an example of a state transportation agency where staffing for IT has been a challenge that has been further heightened by the e-government initiative. For PC software and web development skills, it has been exceedingly difficult to recruit and keep qualified staff. VDOT is finding itself stretched to compete with private sector salary levels. VDOT also needs to provide employees with interesting and challenging IT job content, given that the technical workforce is willing to move around in search of the best job opportunities available.

VDOT uses several coping strategies in staffing for IT. Retraining of current staff, although difficult in the web development area, is proving more successful for maintenance and trouble-shooting positions. A second strategy has been the establishment of a core group of employees with diverse skills who can serve many clients. A third strategy is the use of consultants and outside contractors to supplement VDOT staff. Participative management techniques represent yet another means to enhance job satisfaction and retain IT staff.

In addition, to increase the IT staff within VDOT in order to provide the support needed for e-government and other IT activities, IT has to compete with other staffing needs within the department. A strong case should be made for adding more staff for IT, especially when VDOT continues to have a ceiling on its number of employees. (As noted previously, KDOT has found targeted signing and retention bonuses to be an effective aid for IT staffing.)

Washington

Staffing and training issues were also discussed with the Director of ITS for WSDOT. Staffing for engineering positions in general, and IT in particular, is a constant challenge for WSDOT. On the plus side, engineering graduates are now increasingly being exposed to training in computers, software, and new communication technologies. Thus, one strategy is for WSDOT to seek out those entry-level job candidates who have more extensive exposure to this kind of training in school. WSDOT recognized more than 5 years ago that they faced a problem regarding IT skills in their organization. Initially, they drew on existing general engineering staff and tried enhancing their transportation IT skills. A special electrical engineering group was formed so that staff could learn from each other and become more effective at addressing network IT issues. WSDOT also began taking advantage of training opportunities in communications and technology. They have availed themselves of fiber optic training from a national training firm as well as accessing training opportunities offered by the U.S. DOT. For a time, while federal funds were available, WSDOT encouraged staff to get advanced (Master's) degrees, and later the state of Washington provided some financial support for this additional education. Although these programs are no longer available, WSDOT has established an intern program in cooperation with the University of Washington. There are typically one or two interns who work with more senior WSDOT staff while completing their engineering education programs at the university. This affords WSDOT access to individuals with the most current IT skills and also offers a seed bed for potential future employees.

As with other state transportation agencies, WSDOT has had a difficult time retaining skilled IT engineers. A big part of the problem involves maintaining a department pay scale that reflects the reality of the marketplace. Periodically, WSDOT is able to convince the state legislature to provide for a pay adjustment designed to help bring public sector salary levels for these skilled positions more in line with the private sector; however, this usually is not enough. Even when WSDOT is able to supplement these pay adjustments with their own internal funds, they routinely find themselves unable to provide a fair valuation of IT skills in the marketplace. Because they are never able to close the gap between public and private salary levels, the state relies on the attractiveness of their benefits packages to recruit and retain the highly skilled staff they need. In the final analysis, flexibility is limited and their success is only partial.

WSDOT has a unique relationship with the University of Washington, which is reflected in the Washington State Transportation Center known as TRAC. TRAC was established as a cooperative transportation research agency to link and coordinate state and commercial transportation research. The Executive Director of TRAC is also the Director of the Research Office of WSDOT. In an environment where it is difficult for WSDOT to invest in new staff or hire expensive consultants, TRAC offers a mechanism for conducting research on new technologies at reasonable cost to WSDOT, without having to fully commit to an expensive and untested technology. The collaboration fosters transportation IT expertise among the university faculty and helps keep WSDOT abreast of the latest technology developments and on the cutting edge of IT research. In addition, WSDOT staff invests time in speaking to university classes and participating in university sponsored career fairs. These kinds of activities broaden awareness among students of the opportunities available in the transportation field, and in particular the opportunities in the public sector.

In addition to the expertise needed to design, install, and operate new I/C technologies, state agencies like WSDOT are finding it particularly difficult to retain qualified people to maintain these systems. Highly specialized skills are required to properly maintain complex signal systems, remote cameras, and related I/C technologies currently in widespread use. WSDOT is losing maintenance personnel to other agencies and private companies that can pay better or offer more responsibilities. As indicated earlier with IT engineers, benefits and job security are what WSDOT can offer to counter the attraction of higher salaries. The agency has enough turnover through retirements and a wide enough diversity of jobs to provide opportunity and flexibility for employees, but it is unclear whether this, coupled with good health and vacation benefits, is enough to attract and retain the best IT maintenance personnel in the face of many attractive alternatives and a marketplace experiencing a shortage of the most qualified people.

CHAPTER SIX

CONCLUSIONS

This report has addressed the impact of I/C technologies on transportation agencies from three perspectives. First, a survey of the literature was conducted, and selected sources were reviewed to assess findings from previous studies. Second, a survey sent to representatives of state DOTs throughout the United States provided a broad, systematic view of the current state of I/C technologies in DOTs and the impacts they are having. Third, case studies in five state DOTs provided an in-depth understanding of particular aspects of I/C technology use and impacts. All three methods and sources of information help inform our understanding of this topic. The rapid introduction and diffusion of new information and communication technologies is being felt throughout society. This report can help transportation professionals anticipate I/C technology impacts and establish strategies for accounting for these technology effects in the mission of DOTs. Based upon this synthesis, a number of conclusions are discussed below.

Two types of impacts of I/C technologies evident in the literature provided useful categories for discussion: operational impacts and impacts on customer service.

- In the operational area, the literature uncovered broad themes, such as information access and use and staffing and training needs. However, it is unclear how representative the literature was in terms of the impacts that DOTs are addressing. Government transportation agencies generally lag behind other industries in the adoption of innovations. Therefore, information-intensive industries such as finance might provide lead indicators of additional impacts and ways to deal with them.
- In the area of customer service, lessons may be learned by examining I/C technology impacts in consumer and business-to-business marketing. Driven by competitive pressures, the private sector is likely to introduce new customer service technologies and processes that may be useful for DOTs.

Survey results indicated that state DOTs take into account a variety of different criteria in their decision process in making I/C technology investments.

- Although not reluctant to take risks investing in new I/C technologies, state DOTs clearly need to deal with many issues that affect decisions to adopt these technologies, such as availability of staff skills, in an environment of rapid technological change.
- Availability of financial resources, a focus on the customer, and the ability to demonstrate system benefits emerged as important criteria used by transportation agencies in making decisions to acquire and use new I/C technologies.

The overall use of I/C technologies is high at state transportation agencies, but use of certain I/C technologies is quite limited.

- Across the four I/C technology categories studied (ITS devices, communication devices, software tools, and remote work arrangements), a majority of the organizations responding to the survey (15 of 27) used 50 percent or more of the technologies.
- “Under-utilized technologies” can be classed as consumer or personal devices. Aimed at the driving public or at individuals, these devices include in-vehicle technologies such as navigation systems, voice activated/recognition systems, and collision avoidance devices. They also include more “personal” technologies such as personal digital assistants and portable pen-based database systems, with which DOTs rated their experience negatively. It is not clear if the low use is a result of these somewhat negative experiences or if the negative experiences reflect a lack of time and effort in making the devices useful and valuable for individual agencies.

DOTs are “pro-I/C technologies,” with respondents providing consistently positive ratings in their assessment of technologies and their impacts.

- Given the general enthusiasm for I/C technologies in the United States at the present time, this protechnology outlook can be expected.
- *Positive* impacts were cited on management practices, staff use of the technology, and overall understanding of what the technology can do resulting from the use of the Internet, wireless communication, cell phones, and GIS devices.
- Consistently *positive* impacts are seen with respect to transportation system planning and the integration of new with existing I/C technologies across a range of I/C technologies.

- The Internet is widely used and offers many positive impacts, but respondents' negative rating on Internet security illustrates a concern within DOTs.

The purchase and implementation of I/C technologies should be done in a planned, purposeful manner that pursues specific implementation goals.

- Many of the Seattle TMC problems in 1995 were due to the purchase of I/C technologies that were not integrated or even compatible with one another. Many of these problems have been reduced or eliminated through the development and application of long-term strategic plans.
- Financial implications of I/C technologies should be integral to the planning process and examined from multiple perspectives. Nonintegrated technologies, or those purchased without the benefit of a long-range plan, can result in longer operator training times, poor operator performance, and errors in public information disseminated by the TMC. Alternatively, integrated I/C technologies can reduce training requirements, reduce operator skill requirements, and lead to the elimination of redundant or unnecessary equipment.

There are often unexpected interaction effects resulting from the implementation of I/C technologies.

- For example, the widespread use of cell phones led to both negative and positive impacts associated with, respectively, errors in emergency situation reports and the continued need for roadside call boxes, as reported by WSDOT.
- Transportation planners need to recognize that deployment of I/C technologies might have unanticipated consequences to help avoid negative impacts and provide opportunities for positive interactions among I/C technologies.

New relationships with the private sector are developing around I/C technologies.

- As the Florida case study on shared telecommunications resources demonstrated, the interest of government and the private sector can converge and benefits to both parties can be realized through innovative partnerships.

Continuing evolution of I/C technologies will require adaptations in DOT organizational structure.

- Results of the case studies suggested that I/C technologies have the potential to shape the structure of the agency. For example, as computing power moves to the desktop and away from the centralized mainframe an agency can reorganize to reflect the new roles and responsibilities that the technology has enabled.
- E-government presents a vision of DOT service delivery and operational efficiency that is changing organizations. As the Virginia, Wisconsin, and Kansas case studies demonstrate, transitioning DOT function to e-government is a challenging task. From the conversion of paper forms to changing laws for electronic commerce, e-government is likely to impact many state organizations in order for the full vision to be realized.
- The Internet-equipped information society will require entirely new methods and levels of service for which DOTs are not well equipped. Management of scarce IT staff, equipment, and budget to meet higher customer expectations for services will require better collaboration within DOTs.

The impact of I/C technologies can have ramifications reaching far beyond their original intent.

- E-government, for example, requires not only staff to develop websites, but employees across the DOT equipped and trained to maintain them. E-government may provide additional stimulus for new procurement practices, such as “seat management,” or it may put increased pressure on other I/C technology efforts, such as GIS. DOTs will need to look beyond immediate impacts to how changes in one I/C technology area will affect other parts of the operation.

Finding and retaining the highly skilled staff needed to manage, implement, and maintain the suite of complex I/C technologies is a constant challenge.

- Both the VDOT and WSDOT case study inquiries into the implications of I/C technologies for staffing and training of personnel in state transportation agencies mirror not only the findings from the survey but also results of several years of federal DOT investigation into the efforts of states to build capacity for new technologies within their
- State transportation agencies find themselves competing with the private sector for scarce talent, and seeking new ways to train existing staff to assume new job roles and responsibilities. The adjustments required of these agencies are not only technical, but cultural and institutional as well.
- Use of outside expertise to supplement DOT staff in I/C areas is a typical solution to the staffing shortage. Rather than compete with the private sector, DOTs can look to consultants as valuable sources of skills needed in software, telecommunications, and other technical areas.

Based on conclusions from this synthesis study the following list contains suggested topics for future study:

- A systematic review of sources outside the transportation domain to understand the impacts of I/C technologies.
- Investigation of the complex process of decision making in the acquisition and deployment of I/C technologies.
- Study of the effect of further penetration and use of I/C technologies in DOTs to determine if their impacts are eased or exacerbated as they become more prevalent.
- Analysis of the coping strategies that DOTs are using to deal with the impacts of I/C technologies.
- Further investigation of state DOTs to identify models of organizational structure and management tools, and lessons learned from their application to the area of I/C technologies.

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APPENDIX A

Respondent Affiliations

TABLE A-1

RESPONDENT AFFILIATIONS

State/Agency*	Respondent's Work Group	Respondent's Position/Title
ALABAMA Department of Transportation (3)	Construction Bureau	Special Projects Engineer
	Multimodal Transportation Bureau— Special Programs Section	Special Programs Manager
	Transportation Planning Bureau	Transportation Planning, Bureau Chief
ARKANSAS State Highway and Transportation Department (1)	Construction Division	Civil Engineer IV, Construction Division
CALIFORNIA Department of Transportation (1)	Information Systems Service Center	Chief Information Officer
COLORADO Department of Transportation (1)	Information Systems Center	Information Systems Officer
CONNECTICUT Department of Transportation (3)	Highway Operations Section	Trans. Supervising Engineer
	Office of Information Systems	Administrator—Information Systems
	Property and Facilities	Telecom Engineer I
FLORIDA Department of Transportation (1)	Office of Information Systems	Chief Information Officer
GEORGIA Department of Transportation (2)	Information Technology Division	Information Technology Administrator
	Office of Planning	Planner 4
HAWAII Department of Transportation, Highways Division (1)	Materials Testing and Research Branch	Materials Engineer
IDAHO Transportation Department (2)	Division of Highways, Operations	Asst. Chief Engineer (Operations)
	Roadway Design	Roadway Design Engineer
ILLINOIS Department of Transportation (1)	Bureau of Information Processing	Bureau Chief of Information Processing
KANSAS Department of Transportation (1)	Research Unit	Engineer of Research
KENTUCKY Transportation Cabinet (1)	Division of Information Technology	Director
LOUISIANA Department of Transportation and Development (1)	Information Services	Information Technology Deputy Director
MAINE Department of Transportation (1)	Information Systems Division	Director, Information Systems Division
MARYLAND State Highway Administration (2)	Information Technology Division	Division Chief of Information Technology
	Research	Research Associate
MASSACHUSETTS Highway Department (1)	Highway Operations, Intelligent Transportation Systems (ITS) Programs Unit	Director ITS Programs
MINNESOTA Department of Transportation (2)	Metro Division—Traffic Management Center	Manager, Traffic Management Center
	Sustainable Transportation/Environmental Services/Telework Program	NA
MISSISSIPPI Department of Transportation (1)	Information Systems	Chief Information Officer
MISSOURI Department of Transportation (1)	Bridge Division	Structural Special Assignments Engineer
MONTANA Department of Transportation (3)	Communications Bureau	Communications Bureau Chief
	Information Services Bureau	Chief, Information Services
	NA	ITS Coordinator

NEBRASKA Department of Roads (5)	Communication Division	Communication Division Manager
	Information Systems Division	Information Systems Manager
	Intermodal Transportation Division	Intermodal Transportation Engineer
	Maintenance Division	Assistant State Maintenance Engineer
	Transportation Planning Division	Transportation Planning Manager
NEW HAMPSHIRE Department of Transportation (2)	Bureau of ITS	Administrator, Bureau of ITS
	Research Office	Research Engineer
NEW JERSEY Department of Transportation (1)	Bureau of ITS Coordination	Manager, Bureau of ITS Coordination
NEW YORK State Department of Transportation (1)	Transportation Research and Development Bureau	Transportation Research and Development Bureau Director
NORTH CAROLINA Department of Transportation (7)	Information Systems Technology (IST)	HICAMS Project Manager
	Division of Motor Vehicles	Commissioner—Division of Motor Vehicles
	Geographic Information Systems Unit	Assistant Director—Geographic Information Systems Unit
	IST	Deputy Director IST
	IST—New Technology Engineering	Application Development Supervisor
	ITS Operations Unit	State ITS Operations Engineer
	Photogrammetry Unit	Assistant State Photogrammetric Engineer
NORTH DAKOTA Department of Transportation (1)	Information Technology Division	Director of Information Technology Division, NDDOT
OKLAHOMA Department of Transportation (1)	Traffic Engineering/Management and Safety Branch	NA
OREGON Department of Transportation (2)	Information Systems, Technology Management	Manager, Architecture and Support, Technology Management
	Office of Project Delivery, Project Systems Unit	Manager, Project Systems Unit
PUERTO RICO Department of Transportation and Public Works (1)	Puerto Rico Highway and Transportation Authority	Director Materials Testing Office
SOUTH CAROLINA Department of Transportation (1)	ITS	ITS
TENNESSEE Department of Transportation (1)	Development	Assistant Chief Engineer
UTAH Department of Transportation (1)	Research Division	Engineer for Research and Development
VIRGINIA Department of Transportation (1)	Information Technology Division	Information Technology Manager
WASHINGTON State Department of Transportation (2)	Department: Traffic Operations— Workgroup: Advanced Technology Branch	Assistant ITS Program Manager
	MIS Infrastructure Services	Mgr. MIS Infrastructure Services
WISCONSIN Department of Transportation (1)	NA	Freeway Operations Engineer
WYOMING Department of Transportation (3)	Construction Staff	State Construction Engineer
	Telecommunications	Telecommunications Supervisor
	Traffic	State Traffic Engineer

NA = Not available.
*The number of responses is shown in parentheses in column 1.

APPENDIX B

Survey Questionnaire

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Project 20-5, Topic 31-08

IMPACT OF NEW INFORMATION/COMMUNICATION TECHNOLOGIES ON TRANSPORTATION AGENCIES

QUESTIONNAIRE

Name of respondent: ____________________

Title: ____________________

Agency: ____________________ *Telephone number:* ____________________

Fax number: ____________________ *e-mail:* ____________________

New information and communication (I/C) technologies are changing the ways in which transportation agencies view and accomplish their mission. Such technologies include:

- Intelligent Transportation System devices (e.g., sensors, in-vehicle devices),
- communication devices (e.g., cell phones, satellite technology),
- software tools (e.g., Internet, financial management, timekeeping, database management),
- remote work arrangements (e.g., telecommuting).

TRB Synthesis Project 31-08 is intended to investigate the impacts or changes that are taking place within transportation agencies as a result of these I/C technologies. This questionnaire provides key individuals in the transportation community with the opportunity to share their insights and experience in this area.

WHO SHOULD COMPLETE THIS SURVEY? We are seeking a range of perspectives. Please distribute to individuals

- In various functional organizations within the transportation department, such as planning, construction, and operations; highway and transit; finance and contracting;
- with experience in, and/or responsibilities for, the acquisition and use of new information and communication technology; and
- with supervisory and non-supervisory roles.

Your views are important to this study. Please take a few minutes to complete the survey items below. You may use the back of the sheets provided if you need more space to answer any questions—simply indicate which question. Please return the completed questionnaire and any supporting documents to:

Mary Winter
Battelle Human Factors Transportation Center
4500 Sand Point Way NE
P.O. Box 5395
Seattle, WA 98105–0395

If you wish, you may fax your response to (206) 528-3555. If you have any questions, please call Mary Winter at (206) 528-3265.

WE WOULD APPRECIATE YOUR RESPONSE BY: JUNE 15, 2000.
THANK YOU FOR YOUR TIME AND EFFORT!!

SOME QUESTIONS ABOUT YOU

1. What is the name (a) of your organization/agency and (b) of your particular department or work group?

   (a)____

   (b)____

2. How many people work in your transportation agency?

   (a) At the state level? ______________
   (b) At your work location or site? ______________
   (c) In your department? ______________

3. How many years have you been working in transportation? __________ years

4. (a) What are your primary job responsibilities? (check one)

   Supervisory or management_________ **OR** Support or technical role_________

   (b) With respect to the purchase of new technology...... (check one)

   I make decisions about new technology purchases ______________

   Others make decisions about new technology purchases ______________

QUESTIONS ABOUT INFORMATION AND COMMUNICATION (I/C) TECHNOLOGIES AND THEIR IMPACT ON TRANSPORTATION AGENCIES

5. Does your organization have a strategic plan? (circle one)

   Yes No Don't know

   – If yes, does it include information and communication technology elements in particular? (circle one)

   Yes No Don't know

6. What do you think are some of the key emerging information/communication technologies that will have an impact on state transportation agencies in the next 5 years?

   ____

   ____

   ____

7. When your organization (or department) is considering adopting a new information and communication technology, how important would you say the following considerations are in making a decision to support the acquisition of the new technology? **Please check one box on each line below**, indicating your sense of the importance of each factor in your organization. As needed, write-in and rate any additional decision criteria that are relevant to your organization in the blank space provided.

Decision Criteria	Not Important	Somewhat Important	Very Important
a. Availability of financial resources			
b. Meets the needs of our customers			
c. The benefits will exceed the costs from the start			
d. The benefits are measurable			
e. Technology has been proven elsewhere first			
f. Need for staff training can be minimized			
g. Liability issues			
h. How long it will take to implement the technology			
i. Employees' job role changes can be minimized			
j. Labor union preferences and perspectives on the change			
k. Prior experience with the technology vendor			
l. Wide-spread staff support for the change			
m. Evidence that the technology will have demonstrable transportation system-wide benefits			
n. Having a plan in place to promote the new technology			
o. Having a contingency plan to deal with the situation if the technology fails			
p. Having staff to support and maintain the new technology			
q.			

8. Below are some statements describing how you may feel about new Information and Communication (I/C) technologies and their possible effects on transportation agencies. For each statement, please circle a number between 1 and 5 to show how much you personally agree or disagree with the statement. As needed, write-in and rate any additional statements that are relevant to your organization in the spaces provided.

   1 = disagree strongly
   2 = disagree somewhat
   3 = neither agree nor disagree (neutral)
   4 = agree somewhat
   5 = agree strongly.

STATEMENT	DISAGREE STRONGLY		NEUTRAL		AGREE STRONGLY
a. Management in my organization is reluctant to risk trying new technology applications.	1	2	3	4	5
b. Our available resources are so limited that we cannot afford to invest in new I/C technologies.	1	2	3	4	5
c. The level of awareness in my organization about new I/C technologies is high.	1	2	3	4	5

STATEMENT		DISAGREE STRONGLY		NEUTRAL		AGREE STRONGLY
d.	The reason we aren't doing more to adopt new I/C technologies is because people don't want to have to change the way they perform their job.	1	2	3	4	5
e.	New I/C technologies have improved communication and integration across transportation organizations and agencies in our state.	1	2	3	4	5
f.	Technological change in our society now is so rapid and unpredictable that our organization has difficulty responding effectively.	1	2	3	4	5
g.	An impact of rapid I/C technology change is that management's expectations of staff performance are continually going up.	1	2	3	4	5
h.	Because of the introduction of new I/C technologies, my organization seems to emphasize speed and quantity over quality of our products and work.	1	2	3	4	5
i.	Rapid technological changes make it increasingly difficult for public transportation agencies like ours to compete with the private sector for skills.	1	2	3	4	5
j.	The adoption of new I/C technologies by my organization has led to the formation of new public/private partnerships.	1	2	3	4	5
k.	The adoption of new I/C technologies by my organization has led to a substantial increase in information exchange with our public customers.	1	2	3	4	5
l.	New I/C technology use among transportation agencies in our state has directly led to improved communication across modal organizations.	1	2	3	4	5
m.	The use of new I/C technologies in our organization allows us to better manage travel demand.	1	2	3	4	5
n.	My organization's management believes that investments in new I/C technologies constitute a good use of the taxpayer's money.	1	2	3	4	5
o.	The costs to maintain new I/C technologies and keep them up to date constitute a major barrier to adoption in my organization/agency.	1	2	3	4	5
p.	Public expectations are a major factor that cause us to consider investing in new I/C technologies.	1	2	3	4	5
q.	Our Agency has a difficult time implementing new technologies because our state has a policy of centralizing and/or standardizing new technologies.	1	2	3	4	5
r.		1	2	3	4	5
s.		1	2	3	4	5

9. The I/C technologies of most interest to this project can be organized into four categories: (A) ITS devices, (B) Communication devices, (C) Software tools, and (D) Remote work arrangements. Below, place a checkmark next to the I/C categories (**at least one category, but no more than two**) for which you can provide the best insights into potential impacts of the technologies on your transportation organization.

________A. ITS devices ________B. Communication devices

________C. Software tools ________D. Remote work arrangements

Pages 6 through 9 of this survey contain a series of tables with various information and communication (I/C) technologies listed in rows and potential impacts of these technologies listed in columns. Only fill in those table(s) [e.g., 9A, 9B, 9C, or 9D] for which you placed a corresponding check mark above.

The left-hand side of each table contains 3 additional columns labeled A, B, and C.

Column A: Use an "X" to indicate if your transportation agency uses each I/C technology listed. As needed, write-in additional I/C technologies in the blank rows of the matrix on pages 6 through 9.

Column B: For each I/C technology that you checked in Column A, use a "+", a "0", or a "-" to indicate whether your personal experience with the I/C technology has, overall, been positive (+), neutral (0), or negative (-).

Column C: For each I/C technology that you checked in Column A, indicate the percent of people in your organization (e.g., 25%, 50%, 100%) that use the I/C technology.

Remember, only fill in cells in Columns B and C for those I/C technologies that have been checked with an "X" in Column A.

In the "Potential Impacts" section of this table, use a "+" or a "-" to indicate if your agency has experienced each of the **impacts** listed. Use a "+" if your agency has experienced a generally positive impact, and a "-" if your agency has experienced a generally negative impact. Leave the cell blank if you have not experienced the impact listed. As needed, write-in additional potential impacts to this list in the blank columns provided.

TABLE 9A: ITS DEVICES

				POTENTIAL IMPACTS																
Used by your organization	Positive/negative experience	Percent in organization who use	I/C TECHNOLOGIES	Management Practices	Organization of transportation agencies	Transportation System Planning	System Design and Acquisition	Security Issues	Short-term Financial	Long-term Financial	Education & training of general public	Integration of new with existing I/C Technology	Understanding what the technologies can do	Staff use of the technology (confusion, errors)	Understanding how the technology will effect traveler behavior	Training and learning curves for DOT staff	Cultural changes with the DOT agency	Traffic forecasting	Allocation of internal resources (dollars, staff, equipment)	Outsourcing of jobs/functions
A	B	C																		
			Infrastructure-based sensors																	
			Real-time traffic information																	
			In-Vehicle Navigation Systems																	
			Internet																	
			Digital Satellite Photography																	
			Voice-activated and voice-recognition systems																	
			Global Positioning System (GPS)																	
			Automatic collision notification devices																	

Only complete this table if you checked "A" in Question 9.

TABLE 9B: COMMUNICATION DEVICES

				POTENTIAL IMPACTS																
Used by your organization	Positive/negative experience	Percent in organization who use	**I/C TECHNOLOGIES**	Management Practices	Organization of transportation agencies	Transportation System Planning	System Design and Acquisition	Security Issues	Short-term Financial	Long-term Financial	Education & training of general public	Integration of new with existing I/C Technology	Understanding what the technologies can do	Staff use of the technology (confusion, errors)	Understanding how the technology will effect traveler behavior	Training and learning curves for DOT staff	Cultural changes with the DOT agency	Traffic forecasting	Allocation of internal resources (dollars, staff, equipment)	Outsourcing of jobs/functions
A	**B**	**C**																		
			Wireless communication																	
			Cell Phones																	
			Pagers																	
			Global Positioning System (GPS)																	
			Personal Digital Assistants (PDAs)																	

Only complete this table if you checked "B" in Question 9.

TABLE 9C: SOFTWARE TOOLS

				POTENTIAL IMPACTS																
Used by your organization	Positive/negative experience	Percent in organization who use	I/C TECHNOLOGIES	Management Practices	Organization of transportation agencies	Transportation System Planning	System Design and Acquisition	Security Issues	Short-term Financial	Long-term Financial	Education & training of general public	Integration of new with existing I/C Technology	Understanding what the technologies can do	Staff use of the technology (confusion, errors)	Understanding how the technology will effect traveler behavior	Training and learning curves for DOT staff	Cultural changes with the DOT agency	Traffic forecasting	Allocation of internal resources (dollars, staff, equipment)	Outsourcing of jobs/functions
A	B	C																		
			Internet																	
			E-commerce																	
			Financial management software																	
			Timekeeping software																	
			Literature search software																	
			Database software																	
			Project management software																	
			Construction management systems																	
			Computer models and simulation																	
			Geographic Information Systems (GIS)																	
			Portable pen-based database systems																	

Only complete this table if you checked "C" in Question 9.

TABLE 9D: REMOTE WORK ARRANGEMENTS

				POTENTIAL IMPACTS																
Used by your organization	Positive/negative experience	Percent in organization who use	I/C TECHNOLOGIES	Management Practices	Organization of transportation agencies	Transportation System Planning	System Design and Acquisition	Security Issues	Short-term Financial	Long-term Financial	Education & training of general public	Integration of new with existing I/C Technology	Understanding what the technologies can do	Staff use of the technology (confusion, errors)	Understanding how the technology will effect traveler behavior	Training and learning curves for DOT staff	Cultural changes with the DOT agency	Traffic forecasting	Allocation of internal resources (dollars, staff, equipment)	Outsourcing of jobs/functions
A	B	C																		
			Remote access (e.g., telecommuting)																	
			Internet																	
			Personal Digital Assistants (PDAs)																	
			Portable pen-based database systems																	

Only complete this table if you checked "D" in Question 9.

APPENDIX C

Detailed Response Frequencies and Percentages for Questions 7, 8, and 9

Question 7. When your organization (or department) is considering adopting a new information and communication technology, how important would you say the following considerations are in making a decision to support the acquisition of the new technology? Please check one box on each line below, indicating your sense of the importance of each factor in your organization. As needed, write-in and rate any additional decision criteria that are relevant to your organization in the blank space provided.

TABLE C-1
RESPONSES TO QUESTION 7

	Actual Counts			% Based on Number of Responses (for each question)			
Decision Criteria	Not Important	Somewhat Important	Very Important	Not Important	Somewhat Important	Very Important	No. of Responses
a. Availability of financial resources	1	5	53	1.7	8.5	89.8	59
b. Meets the needs of our customers	1	5	53	1.7	8.5	89.8	59
c. The benefits will exceed the costs from the start	13	38	8	22.0	64.4	13.6	59
d. The benefits are measurable	2	39	18	3.4	66.1	30.5	59
e. Technology has been proven elsewhere first	3	40	16	5.1	67.8	27.1	59
f. Need for staff training can be minimized	6	47	6	10.2	79.7	10.2	59
g. Liability issues	10	33	15	17.2	56.9	25.9	58
h. How long it will take to implement the technology	4	43	12	6.8	72.9	20.3	59
i. Employees' job role changes can be minimized	33	23	2	56.9	39.7	3.4	58
j. Labor union preferences and perspectives on the change	46	10	0	82.1	17.9	0.0	56
k. Prior experience with the technology vendor	10	42	7	16.9	71.2	11.9	59
l. Wide-spread staff support for the change	9	30	20	15.3	50.8	33.9	59
m. Evidence that the technology will have demonstrable transportation system-wide benefits	0	24	35	0.0	40.7	59.3	59
n. Having a plan in place to promote the new technology	2	31	26	3.4	52.5	44.1	59
o. Having a contingency plan to deal with the situation if the technology fails	6	30	23	10.2	50.8	39.0	59
p. Having staff to support and maintain the new technology	4	17	38	6.8	28.8	64.4	59
q1. The benefits will be extended to a National coverage	0	0	1				1
q2. Agency executive understanding and support	0	0	1				1
q3. Directed at solving a problem—e.g., crashes or congestion	0	0	1				1
q4. Justifiable to political decision makers	0	0	1				1
q5. Legislative approval	0	0	1				1
q6. Having buy-in and support of senior management	0	0	1				1
q7. Partnerships available for support of technology	0	1	0				1

Question 8. Below are some statements describing how you may feel about new Information and Communication (I/C) techologies and their possible effects on transportation agencies. For each statement, please circle a number between 1 and 5 to show how much you personally agree or disagree with the statement. As needed, write-in and rate any additional statements that are relevant to your organization in the spaces provided.

1 = disagree strongly, 2 = disagree somewhat, 3 = neither agree nor disagree (neutral), 4 = agree somewhat, and 5 = agree strongly.

TABLE C-2

RESPONSES TO QUESTION 8

Statement	Actual Counts					% Based on Number of Responses (for each question)					No. of Responses
	Disagree Strongly		Neutral		Agree Strongly	Disagree Strongly		Neutral		Agree Strongly	
	1	2	3	4	5	1	2	3	4	5	
a. Management in my organization is reluctant to risk trying new technology applications.	10	33	7	7	1	17.2	56.9	12.1	12.1	1.7	58
b. Our available resources are so limited that we cannot afford to invest in new I/C technologies.	6	34	9	9	1	10.2	57.6	15.3	15.3	1.7	59
c. The level of awareness in my organization about new I/C technologies is high.	2	7	22	19	9	3.4	11.9	37.3	32.2	15.3	59
d. The reason we aren't doing more to adopt new I/C technologies is because people don't want to have to change the way they perform their job.	11	25	16	7	0	18.6	42.4	27.1	11.9	0.0	59
e. New I/C technologies have improved communication and integration across transportation organizations and agencies in our state.	0	1	9	33	16	0.0	1.7	15.3	55.9	27.1	59
f. Technological change in our society now is so rapid and unpredictable that our organization has difficulty responding effectively.	2	13	13	23	8	3.4	22.0	22.0	39.0	13.6	59
g. An impact of rapid I/C technology change is that management's expectations of staff performance are continually going up.	1	3	26	25	4	1.7	5.1	44.1	42.4	6.8	59
h. Because of the introduction of new I/C technologies, my organization seems to emphasize speed and quantity over quality of our products and work.	6	27	20	4	2	10.2	45.8	33.9	6.8	3.4	59
i. Rapid technological changes make it increasingly difficult for public transportation agencies like ours to compete with the private sector for skills.	0	6	7	24	22	0.0	10.2	11.9	40.7	37.3	59
j. The adoption of new I/C technologies by my organization has led to the formation of new public/private partnerships.	2	8	18	26	4	3.4	13.8	31.0	44.8	6.9	58
k. The adoption of new I/C technologies by my organization has led to a substantial increase in information exchange with our public customers.	0	2	12	33	11	0.0	3.4	20.7	56.9	19.0	58
l. New I/C technology use among transportation agencies in our state has directly led to improved communication across modal organizations.	0	11	20	22	3	0.0	19.6	35.7	39.3	5.4	56
m. The use of new I/C technologies in our organization allows us to better manage travel demand.	1	7	23	17	7	1.8	12.7	41.8	30.9	12.7	55

n. My organization's management believes that investments in new I/C technologies constitute a good use of the taxpayer's money.	1	3	12	34	8	1.7	5.2	20.7	58.6	13.8	58
o. The costs to maintain new I/C technologies and keep them up to date constitute a major barrier to adoption in my organization/agency.	2	22	13	17	4	3.4	37.9	22.4	29.3	6.9	58
p. Public expectations are a major factor that cause us to consider investing in new I/C technologies.	1	7	14	34	3	1.7	11.9	23.7	57.6	5.1	59
q. Our agency has a difficult time implementing new technologies because our state has a policy of centralizing and/or standardizing new technologies.	5	18	16	16	4	8.5	30.5	27.1	27.1	6.8	59

One person added the following statement: "My organization's management considers IT to be a vital function to accomplishing mission," and rated the response as "1—Disagree Strongly."

TABLE C-3

QUESTION 9: SURVEY TABLE 9A, ITS DEVICES

Used by your organization	Positive/negative experience	Percent in organization who use	I/C TECHNOLOGIES		POTENTIAL IMPACTS: Management Practices	Organization of transportation agencies	Transportation System Planning	System Design and Acquisition	Security Issues	Short-term Financial	Long-term Financial	Education & training of general public	Integration of new with existing I/C Technology	Understanding what the technologies can do	Staff use of the technology (confusion, errors)	Understanding how the technology will effect traveler behavior	Training and learning curves for DOT staff	Cultural changes with the DOT agency	Traffic forecasting	Allocation of internal resources (dollars, staff, equipment)	Outsourcing of jobs/functions		NUMBER OF RESPONSES
A	B	C																					
			Infrastructure-based sensors																				22
				Pos	40.9%	27.3%	68.2%	45.5%	4.5%	18.2%	40.9%	22.7%	45.5%	45.5%	36.4%	40.9%	22.7%	22.7%	45.5%	22.7%	22.7%		
				Neg	0.0%	0.0%	0.0%	4.5%	9.1%	22.7%	0.0%	0.0%	13.6%	9.1%	4.5%	0.0%	4.5%	9.1%	0.0%	9.1%	0.0%		
			Real-time traffic information																				19
				Pos	36.8%	21.1%	52.6%	42.1%	10.5%	10.5%	15.8%	63.2%	36.8%	57.9%	31.6%	57.9%	15.8%	26.3%	21.1%	10.5%	15.8%		
				Neg	0.0%	5.3%	0.0%	0.0%	5.3%	10.5%	10.5%	0.0%	21.1%	10.5%	10.5%	0.0%	5.3%	5.3%	5.3%	15.8%	0.0%		
			In-Vehicle Navigation Systems																				2
				Pos	50.0%	50.0%	0.0%	50.0%	0.0%	0.0%	0.0%	50.0%	50.0%	100.0%	100.0%	50.0%	100.0%	100.0%	0.0%	0.0%	0.0%		
				Neg	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	50.0%	0.0%	0.0%		
			Internet																				29
				Pos	62.1%	27.6%	44.8%	34.5%	13.8%	13.8%	20.7%	65.5%	37.9%	62.1%	58.6%	37.9%	41.4%	44.8%	0.0%	24.1%	13.8%		
				Neg	0.0%	0.0%	0.0%	0.0%	24.1%	3.4%	0.0%	3.4%	3.4%	3.4%	6.9%	3.4%	10.3%	10.3%	0.0%	13.8%	0.0%		
			Digital Satellite Photography																				6
				Pos	33.3%	16.7%	83.3%	50.0%	16.7%	16.7%	16.7%	0.0%	33.3%	33.3%	33.3%	0.0%	16.7%	33.3%	0.0%	33.3%	16.7%		
				Neg	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	16.7%	0.0%	16.7%	0.0%	16.7%	0.0%	16.7%	0.0%	0.0%	0.0%	0.0%		
			Voice-activated and voice-recognition systems																				3
				Pos	33.3%	33.3%	33.3%	33.3%	33.3%	0.0%	0.0%	33.3%	33.3%	33.3%	33.3%	0.0%	33.3%	33.3%	0.0%	0.0%	0.0%		
				Neg	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	33.3%	0.0%	0.0%	0.0%	0.0%		

Percentage based on number of responses per technology.

TABLE C-3

QUESTION 9: SURVEY TABLE 9A, ITS DEVICES (continued)

				POTENTIAL IMPACTS																		
Used by your organization	Positive/negative experience	Percent in organization who use	I/C TECHNOLOGIES	Management Practices	Organization of transportation agencies	Transportation System Planning	System Design and Acquisition	Security Issues	Short-term Financial	Long-term Financial	Education & training of general public	Integration of new with existing I/C Technology	Understanding what the technologies can do	Staff use of the technology (confusion, errors)	Understanding how the technology will effect traveler behavior	Training and learning curves for DOT staff	Cultural changes with the DOT agency	Traffic forecasting	Allocation of internal resources (dollars, staff, equipment)	Outsourcing of jobs/functions		NUMBER OF RESPONSES
A	B	C																				
			Global Positioning System (GPS)																			23
			Pos	30.4%	26.1%	56.5%	43.5%	4.3%	13.0%	13.0%	0.0%	34.8%	65.2%	47.8%	30.4%	43.5%	21.7%	8.7%	21.7%	4.3%		
			Neg	0.0%	4.3%	0.0%	4.3%	0.0%	8.7%	4.3%	0.0%	4.3%	0.0%	13.0%	0.0%	13.0%	13.0%	0.0%	8.7%	4.3%		
			Automatic collision notification devices																			0
			Pos	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%		
			Neg	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%		
			*VMS																			1
			Pos	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%	0.0%	0.0%	0.0%		
			Neg	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%		
			*HAR																			1
			Pos	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%	0.0%	0.0%	0.0%		
			Neg	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%		
			*CCTV																			1
			Pos	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%	0.0%	0.0%	0.0%		
			Neg	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%		

*Added by respondents.
Percentage based on number of responses by technology.

TABLE C-4

QUESTION 9: SURVEY TABLE 9B, COMMUNICATION DEVICES

A Used by your organization	B Positive/negative experience	C Percent in organization who use	I/C TECHNOLOGIES		POTENTIAL IMPACTS: Management Practices	Organization of transportation agencies	Transportation System Planning	System Design and Acquisition	Security Issues	Short-term Financial	Long-term Financial	Education & training of general public	Integration of new with existing I/C Technology	Understanding what the technologies can do	Staff use of the technology (confusion, errors)	Understanding how the technology will effect traveler behavior	Training and learning curves for DOT staff	Cultural changes with the DOT agency	Traffic forecasting	Allocation of internal resources (dollars, staff, equipment)	Outsourcing of jobs/functions		NUMBER OF RESPONSES
			Wireless communication																				18
				Pos	83.3%	33.3%	33.3%	33.3%	38.9%	22.2%	22.2%	16.7%	50.0%	50.0%	50.0%	33.3%	44.4%	33.3%	22.2%	22.2%	0.0%		
				Neg	0.0%	0.0%	0.0%	5.6%	0.0%	5.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	5.6%	0.0%	0.0%	5.6%	0.0%		
			Cell Phones																				22
				Pos	86.4%	22.7%	13.6%	9.1%	31.8%	9.1%	4.5%	4.5%	40.9%	50.0%	59.1%	36.4%	36.4%	45.5%	9.1%	31.8%	0.0%		
				Neg	4.5%	0.0%	0.0%	0.0%	9.1%	4.5%	4.5%	0.0%	0.0%	0.0%	0.0%	4.5%	0.0%	0.0%	4.5%	4.5%	0.0%		
			Pagers																				21
				Pos	76.2%	19.0%	4.8%	9.5%	19.0%	9.5%	4.8%	0.0%	38.1%	42.9%	42.9%	14.3%	33.3%	38.1%	0.0%	19.0%	0.0%		
				Neg	4.8%	0.0%	0.0%	0.0%	4.8%	0.0%	0.0%	0.0%	0.0%	4.8%	9.5%	0.0%	0.0%	0.0%	0.0%	4.8%	0.0%		
			Global Positioning System (GPS)																				14
				Pos	50.0%	28.6%	50.0%	57.1%	14.3%	14.3%	28.6%	0.0%	50.0%	50.0%	28.6%	14.3%	35.7%	21.4%	7.1%	14.3%	0.0%		
				Neg	7.1%	7.1%	0.0%	0.0%	0.0%	28.6%	0.0%	0.0%	14.3%	0.0%	14.3%	0.0%	7.1%	14.3%	0.0%	7.1%	0.0%		
			Personal Digital Assistants (PDAs)																				6
				Pos	33.3%	16.7%	16.7%	16.7%	16.7%	16.7%	16.7%	0.0%	50.0%	50.0%	33.3%	16.7%	33.3%	66.7%	0.0%	16.7%	0.0%		
				Neg	16.7%	0.0%	0.0%	0.0%	33.3%	0.0%	0.0%	0.0%	16.7%	16.7%	33.3%	0.0%	16.7%	16.7%	0.0%	16.7%	0.0%		

Percentage based on number of responses per technology.

TABLE C-5

QUESTION 9: SURVEY TABLE 9C, SOFTWARE TOOLS

A: Used by your organization	B: Positive/negative experience	C: Percent in organization who use	I/C TECHNOLOGIES		POTENTIAL IMPACTS: Management Practices	Organization of transportation agencies	Transportation System Planning	System Design and Acquisition	Security Issues	Short-term Financial	Long-term Financial	Education & training of general public	Integration of new with existing I/C Technology	Understanding what the technologies can do	Staff use of the technology (confusion, errors)	Understanding how the technology will effect traveler behavior	Training and learning curves for DOT staff	Cultural changes with the DOT agency	Traffic forecasting	Allocation of internal resources (dollars, staff, equipment)	Outsourcing of jobs/functions		NUMBER OF RESPONSES
			Internet																				37
				Pos	67.6%	32.4%	32.4%	32.4%	21.6%	13.5%	18.9%	54.1%	59.5%	62.2%	56.8%	40.5%	48.6%	59.5%	18.9%	16.2%	8.1%		
				Neg	8.1%	0.0%	0.0%	5.4%	51.4%	8.1%	2.7%	0.0%	0.0%	5.4%	10.8%	2.7%	10.8%	5.4%	0.0%	16.2%	8.1%		
			E-commerce																				11
				Pos	54.5%	36.4%	18.2%	27.3%	27.3%	36.4%	45.5%	45.5%	63.6%	45.5%	18.2%	9.1%	18.2%	54.5%	0.0%	27.3%	36.4%		
				Neg	9.1%	0.0%	0.0%	9.1%	36.4%	9.1%	0.0%	0.0%	9.1%	9.1%	0.0%	0.0%	18.2%	9.1%	0.0%	9.1%	0.0%		
			Financial management software																				21
				Pos	81.0%	14.3%	38.1%	28.6%	23.8%	42.9%	57.1%	0.0%	19.0%	19.0%	23.8%	0.0%	23.8%	33.3%	0.0%	33.3%	0.0%		
				Neg	4.8%	4.8%	0.0%	19.0%	23.8%	19.0%	0.0%	4.8%	14.3%	9.5%	28.6%	0.0%	28.6%	9.5%	0.0%	19.0%	4.8%		
			Timekeeping software																				13
				Pos	92.3%	30.8%	15.4%	30.8%	23.1%	15.4%	23.1%	0.0%	15.4%	23.1%	38.5%	0.0%	23.1%	30.8%	0.0%	30.8%	0.0%		
				Neg	0.0%	0.0%	0.0%	0.0%	7.7%	7.7%	0.0%	0.0%	0.0%	7.7%	7.7%	0.0%	23.1%	0.0%	0.0%	7.7%	0.0%		
			Literature search software																				9
				Pos	22.2%	11.1%	22.2%	33.3%	0.0%	0.0%	0.0%	11.1%	0.0%	33.3%	0.0%	0.0%	0.0%	11.1%	0.0%	11.1%	0.0%		
				Neg	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%		
			Database software																				29
				Pos	58.6%	27.6%	44.8%	55.2%	37.9%	17.2%	24.1%	6.9%	55.2%	51.7%	41.4%	3.4%	41.4%	34.5%	24.1%	31.0%	10.3%		
				Neg	0.0%	0.0%	0.0%	3.4%	3.4%	3.4%	0.0%	0.0%	6.9%	6.9%	10.3%	0.0%	17.2%	0.0%	0.0%	6.9%	0.0%		

Percentage based on number of responses per technology.

TABLE C-5

QUESTION 9: SURVEY TABLE 9C, SOFTWARE TOOLS (continued)

A	B	C	I/C TECHNOLOGIES		POTENTIAL IMPACTS: Management Practices	Organization of transportation agencies	Transportation System Planning	System Design and Acquisition	Security Issues	Short-term Financial	Long-term Financial	Education & training of general public	Integration of new with existing I/C Technology	Understanding what the technologies can do	Staff use of the technology (confusion, errors)	Understanding how the technology will effect traveler behavior	Training and learning curves for DOT staff	Cultural changes with the DOT agency	Traffic forecasting	Allocation of internal resources (dollars, staff, equipment)	Outsourcing of jobs/functions		NUMBER OF RESPONSES
Used by your organization	Positive/negative experience	Percent in organization who use																					
			Project management software																				30
				Pos	86.7%	33.3%	33.3%	36.7%	16.7%	30.0%	36.7%	3.3%	30.0%	50.0%	33.3%	0.0%	36.7%	33.3%	3.3%	26.7%	10.0%		
				Neg	3.3%	0.0%	0.0%	3.3%	0.0%	3.3%	0.0%	0.0%	16.7%	6.7%	26.7%	0.0%	23.3%	26.7%	0.0%	13.3%	0.0%		
			Construction management systems																				17
				Pos	64.7%	23.5%	23.5%	35.3%	17.6%	29.4%	35.3%	0.0%	23.5%	23.5%	29.4%	5.9%	35.3%	23.5%	5.9%	29.4%	17.6%		
				Neg	5.9%	0.0%	0.0%	5.9%	11.8%	0.0%	0.0%	0.0%	23.5%	11.8%	5.9%	0.0%	5.9%	5.9%	0.0%	5.9%	0.0%		
			Computer models and simulation																				14
				Pos	42.9%	14.3%	64.3%	35.7%	7.1%	0.0%	21.4%	21.4%	35.7%	42.9%	42.9%	7.1%	14.3%	14.3%	35.7%	0.0%	0.0%		
				Neg	0.0%	0.0%	0.0%	0.0%	0.0%	7.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	7.1%	0.0%	0.0%	0.0%	0.0%		
			Geographic Information Systems (GIS)																				30
				Pos	70.0%	40.0%	80.0%	43.3%	13.3%	13.3%	16.7%	23.3%	60.0%	60.0%	50.0%	23.3%	33.3%	46.7%	33.3%	26.7%	6.7%		
				Neg	0.0%	0.0%	0.0%	3.3%	6.7%	3.3%	0.0%	0.0%	3.3%	3.3%	16.7%	0.0%	16.7%	10.0%	0.0%	10.0%	3.3%		
			Portable pen-based database systems																				6
				Pos	50.0%	33.3%	16.7%	33.3%	33.3%	33.3%	50.0%	16.7%	33.3%	16.7%	33.3%	0.0%	33.3%	33.3%	0.0%	16.7%	0.0%		
				Neg	0.0%	0.0%	0.0%	0.0%	0.0%	16.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%		

Percentage based on number of responses per technology.

TABLE C-6

QUESTION 9: SURVEY TABLE 9D, REMOTE WORK ARRANGEMENTS

Used by your organization	Positive/negative experience	Percent in organization who use	I/C TECHNOLOGIES	POTENTIAL IMPACTS																		NUMBER OF RESPONSES
				Management Practices	Organization of transportation agencies	Transportation System Planning	System Design and Acquisition	Security Issues	Short-term Financial	Long-term Financial	Education & training of general public	Integration of new with existing I/C Technology	Understanding what the technologies can do	Staff use of the technology (confusion, errors)	Understanding how the technology will effect traveler behavior	Training and learning curves for DOT staff	Cultural changes with the DOT agency	Traffic forecasting	Allocation of internal resources (dollars, staff, equipment)	Outsourcing of jobs/functions		
A	B	C																				
			Remote access (e.g., telecommuting)																			10
			Pos	60.0%	40.0%	30.0%	30.0%	60.0%	0.0%	0.0%	10.0%	50.0%	50.0%	70.0%	30.0%	60.0%	50.0%	10.0%	40.0%	10.0%		
			Neg	20.0%	0.0%	0.0%	0.0%	30.0%	10.0%	10.0%	0.0%	20.0%	0.0%	20.0%	0.0%	30.0%	20.0%	0.0%	10.0%	0.0%		
			Internet																			9
			Pos	55.6%	33.3%	44.4%	55.6%	55.6%	0.0%	0.0%	55.6%	55.6%	66.7%	66.7%	66.7%	66.7%	55.6%	33.3%	22.2%	0.0%		
			Neg	11.1%	0.0%	0.0%	22.2%	22.2%	0.0%	0.0%	0.0%	11.1%	0.0%	11.1%	0.0%	11.1%	11.1%	0.0%	11.1%	0.0%		
			Personal Digital Assistants (PDAs)																			4
			Pos	75.0%	25.0%	25.0%	50.0%	25.0%	25.0%	0.0%	0.0%	75.0%	75.0%	100.0%	0.0%	50.0%	75.0%	0.0%	0.0%	0.0%		
			Neg	0.0%	0.0%	0.0%	25.0%	25.0%	0.0%	0.0%	0.0%	25.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	25.0%	0.0%		
			Portable pen-based database systems																			2
			Pos	50.0%	50.0%	100.0%	50.0%	50.0%	0.0%	0.0%	0.0%	100.0%	50.0%	100.0%	50.0%	50.0%	50.0%	50.0%	0.0%	0.0%		
			Neg	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%		

Percentage based on number of responses per technology.

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The mission of the Transportation Research Board is to promote innovation and progress in transportation by stimulating and conducting research, facilitating the dissemination of information, and encouraging the implementation of research findings. The Board's varied activities annually draw on approximately 4,000 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.

The National Academy of Sciences is a 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. Upon 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 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, encouraging 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, upon its own initiative, to identify issues of medical care, research, and education. Dr. Kenneth I. Shine 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 Academies and the Institute of Medicine. Dr. Bruce Alberts and Dr. William A. Wulf are chairman and vice chairman, respectively, of the National Research Council.