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Final Report

APPLICATION OF HIGH TECHNOLOGY IN HIGHWAY TRANSPORTATION

by

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(The opinions, findings, and conclusions expressed in this report are those of the author and not necessarily those of the sponsoring agencies.)

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SUMMARY

Highway and traffic engineering practice is rapidly changing as communications technology and computer systems are being adopted to facilitate the work of the practitioners and expand their capabilities. This field has been an evolutionary one since the introduction of computers in the 1950s. In recent years there have been major breakthroughs in the application of interactive graphics for computer aided drafting and design, and in the use of microcomputers. Described in this report are current developments in the use of high technology in highway and traffic engineering. Also discussed is the extent to which state transportation agencies are availing themselves of the benefits of high tech. The report discusses the anticipated impact of high tech from the viewpoint of Virginia's highway transportation system and suggests seven areas where research and development could prove profitable. These areas are data base management and information systems; highway traffic operations and management; highway information systems and user communications; computerized design, analysis, and planning; laboratory and field data collection and analysis; construction management and quality control; and other applications such as robotics and expert systems.

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INTRODUCTION

The rapid changes in technology and computer-aided automation that have occurred during the past decade are having a major impact on every aspect of human endeavor. From the workplace to the home, in business and recreation, the effect of what is termed "high technology" is being felt and is changing the way we live and work. While the computer has been an integral part of science, engineering, business, and medicine for several decades, recent breakthroughs in miniaturization and data storage capabilities have resulted in completely new ways in which computers are being used. Office automation and microcomputers are two of the most dramatic of these recent developments. Following closely has been the creation of an extensive software industry which has produced a wide variety of programs for a multitude of applications.

Computers have become a familiar part of transportation operations in all modes -- airlines, transit, railroads, and trucking -- for tasks as diverse as scheduling, vehicle control, and data management. In highway and traffic engineering, computers have been used in traffic signal monitoring and data acquisition. As the potential for traffic control on a statewide basis is realized, there may be the opportunity for further improvements in safety and capacity on interstates and major highways, as developments in high-tech equipment applications occur.

Among the ideas being considered are the availability of onboard computers for vehicle guidance and control, which could revolutionize traffic engineering practice and the way we travel. As smaller computers become more powerful, they offer the potential for road, vehicle, and driver systems that could replace present methods which rely on manual vehicle control. In other areas of highway engineering, significant breakthroughs could occur in pavement management, photogrammetry, bridge design, construction management, and field or laboratory testing.

Transportation is ideally suited to benefit from developments in high technology because it represents a significant element in the use of society's resources and because this vast system, which is data intensive, should lend itself to increased productivity through automation. At the state level, the opportunities for introducing high technology into the design, management, and operations of the highway system could result in increased productivity, capacity, and safety.

PURPOSE AND SCOPE

The purpose of this report is to describe recent developments in high technology that could have impact on the highway system in Virginia. The report is intended to provide information on current applications and ongoing research which links high tech to the highway field and to discuss the likely impacts of these developments and appropriate strategies related to the state's highway system. The study approach has been in accordance with the activities discussed below.

The identification of current and future developments in high technology as they relate to highway transportation were investigated. A review was made of current literature describing recent project applications and situations in highway transportation where high-tech solutions may result in improved system performance or productivity. Examples were identified from proposed projects and ones recently started.

A major source of information was the Highway Research Information Service of the Transportation Research Board, which produced a file of 206 document records based on key descriptors. These records were analyzed, categorized, and reviewed. Other information was obtained from TRB sessions on high technology and traffic engineering and from the Federal Highway Administration (FHWA). The extent to which other states are involved with high technology applications was also investigated and information on their current activities was obtained.

CONDITIONS REQUIRED FOR APPLICATION OF HIGH TECH IN TRANSPORTATION

In order for a new technology such as computers to have a wide application in the transport field, other contributing factors are necessary. The applications of the new technology must have economic advantages over current methods, and should result in an improved product or performance. Investments in capital equipment are frequently justified in terms of savings in operating costs, including that for labor. High technology used as a means for automating routine tasks represents potentially significant cost reductions in the manufacture and processing of goods, and U.S. auto manufacturers are retooling factories with this savings in mind.(1)

Other external factors include the safety, health, environment, energy, and social impacts that high technology brings. Factory automation, for example, impacts on the work force and the quality of the working environment. In another high-tech field, nuclear power has not met its potential because of the safety risks inherent in this form of energy. More recently, chemical processing for pesticides has been receiving greater public scrutiny because of a tragic accident which cost thousands of lives.

In the transportation sector, environmental concerns have frequently limited the options available to officials for meeting growing travel demands. Similarly, energy shortages (or surpluses) have influenced the type and extent of the transportation systems and automobile designs in the United States. Finally, the attitude of management and labor toward change must be positive and this is often difficult to achieve, since change is disruptive and often viewed with fear and anxiety.

Other pressures for change that affect the highway industry are the need to adapt to revised missions and the need to be competitive. As technology is developed which permits an agency to carry out its mission in new and better ways, it becomes incumbent upon the agency to see that the technology is utilized. Of course, change has been the hallmark of this century, beginning with the inventions of electricity, the automobile, air transportation, telecommunications, and the like. So the process of introducing high tech -- computers and automation -- can be viewed simply as a continuation of this evolutionary process. What distinguishes this phase of development is the extent to which it touches all aspects of human endeavor. The "computer revolution" is going on in the home and workplace, in recreation and leisure, in sales and marketing, in industry, and in government.

A principal characteristic of computer technology that has influenced its wide adoption by industry has been the dramatic reductions in cost coupled with the impressive increases in performance that have occurred during the past 20 years.(2) Where only a few years ago computer usage was considered primarily in the domain of "white-coated" scientists who worked mysteriously behind closed doors in air conditioned rooms, today these images have vanished and in their place are "ordinary people" working with computers in their shops and offices, carrying out similar tasks on miniature desk top machines. This downsizing phenomenon shows no sign of abating, and as progress continues in the direction of lower costs and greater capability, further applications in the transportation field are to be expected. However, as these capabilities are extended, their applications will depend, to a great extent, on the ability of the system to modify in such a way that potential benefits are achieved. As an example, self-guiding vehicles are within the state of the art, yet they have not seen wide adoption into the highway system because other necessary elements to ensure workability have not been forthcoming. Thus, in a sense, a computer high tech solution can be seen as an improvement in a component of the system (suboptimization), but its

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potential will not be realized unless other system changes are made at the same time.

Other impediments to the introduction of high tech into the highway and traffic field are institutional, legal, and administrative. National laws limiting the degree of industry collaboration in the interest of maintaining a competitive environment have adversely affected the abilities of high-tech companies to develop products. These barriers apparently do not exist in other developed nations, most notably Japan, and are viewed by American industry as limiting factors in its ability to compete and innovate. This attitude on the part of the Justice Department appears to be changing and fewer antitrust actions are expected in areas where collaboration can have beneficial national effects. Also, the contrast in decision-making roles in this country as compared with Japan is striking. In the United States few technically trained people are in high positions in government, industry, or academia. This lack, it is claimed, impedes technological advances in this country, because decisions are made on institutional and political grounds, without due consideration to technical implications. In Japan, there is a basic recognition that for high-tech research to succeed, there must be close collaboration between all elements of the private sector as well as universities.

A final factor in assuring the success of high-tech innovations as applied to highway and traffic engineering, is the fact that this is a very diverse market whose suppliers typically are not high-tech oriented. Accordingly, firms are reluctant to develop products for a limited, diverse, and uncertain market. There is a role for state DOTs in carrying out research projects jointly with high-tech industry, and this is to test and develop new applications, to assist in defining user needs, to identify suitable suppliers, to test and evaluate new applications from a user's viewpoint, and to conduct economic analyses. Such joint product testing and development in this new and expanding area could serve to accelerate the process by which new ideas and techniques are incorporated into highway and traffic practice.

REPORT ORGANIZATION

The remainder of this report is organized into three major sections. The first part is a brief description of examples of high-tech applications in the highway and traffic field as reported in the literature. The second part describes recent experiences of state departments of highways and transportation in high-tech applications, and is based on information furnished by 46 of the 50 states. The questionnaire used to collect this information sought to determine the extent to which other states are investigating this topic and the types of projects in this field that have been proposed or that were recently gotten under way. The final section of the report contains conclusions, alternative high-tech projects in the highway and traffic field, and suggestions for several courses of action that could be adopted in Virginia.

EXAMPLES OF HIGH TECH IN HIGHWAY AND TRAFFIC ENGINEERING FROM THE LITERATURE

A review of the literature has indicated that applications of computer technology and automation in highway and traffic engineering can be considered in seven broad categories. These are: (1) data base management and information systems; (2) highway traffic operations and management; (3) highway information systems and user communications; (4) computerized design, analysis, and planning; (5) laboratory and field data collection and analysis; (6) construction management and quality control; and (7) other applications, including robotics and artificial intelligence.

The following sections identify and describe several typical situations in highway transportation where high-tech solutions could result in improved system performance or productivity. Examples are presented of projects that have been completed or recently started where information has been made available through the literature. The projects described are a limited sample of the many under way and are intended to illustrate situations where high technology has been applied. References should be consulted for details.

Data Base Management and Information Systems

Pavement management systems have been developed by many states. An example is the report prepared for the Ohio Department of Transportation concerning the establishment of a pavement management information and feedback system.(3) The report describes the basic concepts of pavement management, a summary of PMS activities in other states, and the current pavement data system in the state. Recommendations concerning the creation of a pavement data bank are included. Many similar reports and projects could be cited as this application of computer technology is being adapted on a widespread basis.

A similar research project at a national scale titled "Data Bank for Recycled Bituminous Concrete Pavements" is intended to establish a comprehensive, cross-referenced computer data bank on construction projects employing salvaged or recycled bituminous concrete materials, with provisions for continual update and expansion.(4) The research consisted of the design and establishment of a computerized information retrieval system that can be continually updated, expanded, and cross-referenced. The system is intended to be used to inventory the extent and characteristics of asphalt pavement recycling projects in the United States, with the potential to analyze the performance of pavements built with recycled materials. The research project involved the establishment of a data bank that contained extensive information about each recycling project, including laboratory samples of pavement cores taken from selected projects to obtain data essential for making the data bank useful in performance-related analyses, and, ultimately, the development of software to provide the means whereby data on past, present, and future recycling projects can be entered, stored, and retrieved on a continuing basis. Each project is described by many characteristics, and the software which supports entry of evaluation data is capable of providing predefined reports, cross-referencing between projects, and the generation of special output reports as required.

The Geographic Information System for Transportation (GIST), which is being developed for the Louisiana Department of Transportation, integrates digital graphic and computerized transportation information to provide a comprehensive transportation management information system.(5) GIST correlates a digital representation of the road network with transportation data. An automated digital mapping process is used to provide the road network base map and the transportation data for non-graphic attributes. Since highway engineering is "map-oriented," the creation of a graphic roadway network that is interfaced to non-graphic types of data has broad application in the transportation field. Special highway data include right-of-way width, pavement type, design sections, skid rating, node length, control devices, and maintenance ratings. The development of a transportation geographic data base which can link with the transportation non-graphic data file is a viable approach to handling a transportation agency's mass data problems. Transportation engineering is dependent upon the iterative nature of the analysis and decision process, and feedback from existing conditions coupled with GIST developed interactive graphics systems is intended to provide management and planners with modern high-technology tools. According to the developer of GIST, today's interactive graphic system (IGS) technology offers transportation management information capabilities previously not available. The unique capabilities of this system allow many aspects of computerized transportation data bases to be linked to the graphical map display of transportation networks and are awaiting useful implementation. Activities in which geographic data base concepts can be applied with significant benefit in the transportation field are data management, operational analysis, traffic management, and planning.

Highway Traffic Operations and Management

Many highway and freeway programs utilize high technology to improve the capacity and safety of these facilities. Among these is the New Jersey Turnpike, which is a limited access toll road containing over 1,000 lane-miles of roadway. The facility handles 144 million vehicles annually that generate 3 billion miles of travel.(6) Since its opening in 1951, the Turnpike has been one of the most modern highways in the nation, using the most recent technologies in the highway field. The Turnpike program to enhance safety and capacity includes consideration of the driver, the vehicle, and the roadway, including observations of motorist and vehicle condition throughout the system. High-technology applications are introduced into the Turnpike facility through an automatic traffic surveillance and control system. The system, which is comprised of over 850 detector loops, detection equipment, amplifiers, transmitters, 34 miles of buried cable, four computers, a dynamic map display, CRTs, and printers, continually monitors performance throughout heavily traveled sections of the Turnpike and implements changes to speed and warning signs or changeable message direction signs to maximize the roadway capacity. Computerized toll collection equipment is expected to replace electromechanical equipment, and it will provide faster and more reliable means of documenting toll transactions and furnish pertinent records for traffic forecasting and management.

Other high-tech innovations that have been implemented or are planned for the Turnpike include additional variable message signs and fog detectors. These laser detectors operate over a baseline of 250 feet, and telemeter information to a traffic operations center which can then arrange to lower traffic speeds. Ultimately, the fog detectors will be able to "talk" to the weather forecasting computer and thus enhance the accurate forecasting of limited visibility conditions.

Another application of high tech in traffic operations deals with the problem of incident verification and identification of traffic conditions at a particular site. The objective of this project, was to provide a means of transmitting adequate TV picture coverage of traffic flow over conditioned telephone circuits at a lower cost than that of wideband links (e.g., coaxial cable, fiber optics, or microwave), and to demonstrate the utility of the technique for the traffic community.(7) The new technology developed could reduce the cost of providing the incident verification and identification for many sites. It is intended for use in situations where a transportation agency wishes to add the capability of TV incident verification and identification without the need to purchase and install a dedicated communications system. It is not intended for traffic facilities that have or can obtain channels on future wideband communication. The technology was developed by the Jet Propulsion Laboratories and tested in cooperation with the Maryland Department of Transportation. The test results demonstrated that digitized TV image compression technology can be successfully brought from the laboratory and shown to be technically and economically feasible for certain traffic conditions. However, additional testing on a national basis is essential to allow urban freeway operations to assess the utility of the technology and gain familiarity with its potential use and application. The authors stress that a belief in the importance of high technology, coupled with innovation by the private and public sectors and changes in government and industry posture, are needed.

The New York State Department of Transportation has developed a Centralized Local Accident Surveillance System (CLASS) that combines modern technology and proven analytical techniques to allow every locality the benefit of a modern, efficient accident surveillance system.(8,9) The advantages of a centralized computerized system are that it saves on costs of redeveloping analytical procedures for many local governments and can permit the consideration of more variables in accident analysis with greater accuracy. The major elements of CLASS are (1) an accident site location map using interactive graphic techniques and a link-node coding scheme, where a node can be a railroad crossing or intersection, and a link is the artery between nodes; (2) a data base containing highway information and accident data oriented to the link/node system; and (3) a software system that allows the data base to be accessed, summarized, and analyzed, and permits communication between the graphic and non-graphic files.

Highway Information Systems and User Communications

The literature review revealed very little information dealing directly with current projects utilizing high tech to furnish information and communications for the highway user. Aside from advances in highway signs and traffic signals, little in the way of direct information is furnished to the road user -- aside from general radio bulletins about weather and traffic conditions. This appears to be an area where significant innovations could occur in the coming years as computers are made even smaller and more powerful.

An example of the current state of the art in user communications is a study of peak hour recreational traffic on the Maryland Eastern Shore.(10) A computer simulation of summer weekend travel indicated that the most cost-effective solution is route diversion of traffic during certain peak hours. The difficulty with this solution is the need to inform motorists of the alternatives and of the times when these routes should be used. At present, there is no high-tech means of directing each driver along the optimal path. Rather, the authors propose that route diversion information be furnished by variable message signs, prescheduling optimal assignments to serve as a guide for selecting sign messages, distributing leaflets with a sketch map at toll plazas with careful trailblazing of alternative routes, setting up traffic count stations, and using higher tolls at peak periods. While these suggestions are indeed practical and useful, they imply a considerable investment in labor. Were it possible to computerize the information system between the user and the roadway, then a more efficient route allocation would no doubt result. This technology is yet in the conception stage, and may represent an area where new and dramatic breakthrough could result.

A technology that appears to have promise for future automobile information and navigation is the Navstar Global Positioning System (GPS) developed by Magnavox.(11) The system is being developed to enhance military effectiveness. Civilian applications of GPS have always been presumed but these have a secondary consideration and do not influence developmental decisions. GPS satellites will be launched by space shuttle beginning in 1986, and by the end of 1987 there could be 12 operational satellites, which would be sufficient to provide continuous two-dimensional navigation worldwide. By the end of 1988, there could be 18 operational satellites that would permit worldwide, continuous, three-dimensional navigation, and would be needed for optimal aircraft and land vehicle applications. The plan is to place three "spare" satellites in orbit, so that 21 satellites may be operational in the future. Every user will be able to receive signals from 4 or more satellites simultaneously. By making time-of-arrival measurements on these signals, the user equipment will be able to determine four parameters: latitude, longitude, altitude, and time. The continuous availability of accurate global navigational information will be a true technological revolution.(12) The automobile industry has shown interest in navigation instruments, and Ford is demonstrating a transit satellite navigator combined with a computerized map display. Other automotive manufacturers have similar projects under way, and GPS appears to be well suited for this type of application. The coordinates of position must also be supplemented with a digital map that interprets the coordinates and plans the trip. This information is required by the driver in order to determine his location. Information is also required about the best route under prevailing traffic conditions. A visual display would work, but a voice synthesizer which would furnish information about present location and route directions is preferred. A digital radio link could provide corrections for great accuracy and provide hazard warnings or inform the motorist of recent changes in road conditions which would affect the selected route. Many of these components--radio, computers, and voice synthesizers -- are in use today. Their development for a highway transportation application, together with the GPS, is conceivable by the year 2000.(11)

A note of caution has been expressed as to the "user friendliness" of high technology for motorist information and guidance. This topic is discussed by R. E. Dewar,(13) who points out that traffic guidance hardware has advanced more rapidly than human skills. There is a tendency, he claims, to provide too much information for drivers. The problem of information overload is exemplified by too many signs, too much information on one sign, complex roadway geometry, confusing signal phases, etc. The overloading of drivers is accelerating as more information is being put into the vehicle. Thus, the driving task requires greater sensory attention and information processing, and decision making has replaced physical strength and stamina as controlling factors. Drivers must have sufficient intelligence to be able to process information rapidly and without error. Dewar questions whether we are providing drivers with more information than they need or more than they can use with ease. This question becomes even more valid as we move into the 21st century, in which a considerable portion of the population will be over 60. This aging group of drivers will represent a considerable challenge for traffic engineers, safety experts, and automobile designers. A solution to the problem of presenting information to the driver is the "positive guidance" approach proposal by Alexander and Lunenfield, which can be a useful checklist to assist the highway design engineer develop modern tools for route guidance.(14) The elements include (1) presenting information according to its relative importance, (2) furnishing the information where and when it is expected by the drivers, (3) using color and shape to highlight information, (4) repeating information at appropriate intervals, (5) not overloading the driver but spreading the information over space and time, and (6) anticipating what the driver may already know and avoiding furnishing unnecessary information.

Highway technology has been applied more slowly to problems in highway information systems and user communications than in other areas. One reason is that the technology required is extremely complex and costly, and all the components may not be developed until sometime in the 21st century. Another reason is the human factor involved. Other applications of high tech in highway engineering have little direct involvement with the motorist -- they are laboratory, design, or data management oriented. Introducing the human element creates a new set of problems that must account for the diverse characteristics of the motoring public. To be successful, the systems must be simple and easy to understand and use.

Computerized Design Analysis and Planning

The application of high tech in highway design, analysis, and planning has expanded considerably in recent years with the availability of computer aided design facilities and the development of the microcomputer. The applications are too numerous to describe here, as they span the spectrum of all highway design elements and are constantly changing.

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The FHWA has been active in the development of interactive graphics, a technique that represents a great opportunity for employee productivity in the highway design area.(15) Interactive graphics (often referred to as computer aided design), is the product of the evolution of the computer since the 1950s, when designs were done by "batch processing" of key punched data. The interactive feature permits instantaneous communication or response between the computer and the individual, and visual displays of the design permit the alteration of lines, symbols, and characters simply with the press of a key. Four of the principal areas of FHWA involvement with interactive analysis are described by Los.(15) They are (1) acquisition, installation, and use of three automated drafting/ mapping computer systems, (2) promotion of interactive graphics to state highway agencies, (3) development of an Interactive Graphics Aided Design System (IGADS) and (4) development of an interface system and graphics data exchange standard.

The Automated Drafting/Engineering System (ADES) is intended to replace the manual process of preparing highway contract plans and to augment the integrated highway design systems, such as the Roadway Design System (RDS), which use large computers for highway design. The initial project, was undertaken in Michigan in 1979, and in 1984 an interactive graphics system from Intergraph was installed in Arlington, Virginia; Denver, Colorado; and Vancouver, Washington. ADES,can be used to compile a map from aerial photography, update topographic maps, and modify produced plots such as profiles, cross sections, and mass diagrams into final highway contract plans. One workstation is dedicated to the preparation of bridge plans and bridge rehabilitation. The FHWA has been active in the demonstration of the effectiveness and efficiency of automated drafting and mapping techniques, using ADES, and in providing technical assistance to states interested in acquiring and installing such systems. As of June 1984, 17 states and the FHWA had interactive systems installed, 4 states had systems on order, 15 planned to acquire a system, and 5 expressed an interest in the system.

The development of an Interactive Graphics Roadway Design System (IGRDS) began with the work of the Texas State Department of Highways and Transportation, and is being completed as an HP&R pooled funded effort managed by the American Association of Highway and Transportation Officials (AASHTO). The purpose of this project is to develop and deliver interactive graphics design software to the AASHTO Subcommittee on Computer Technology using RDS. Among the functions to be available in IGRDS are horizontal alignment, vertical alignment, coordinate geometry, cross-section modification, RDS graphics file, and plot review. The firm of C. W. Beilfuss and Associates, which has had an ongoing relationship with the Texas Department of Highways and Transportation, was selected for the project. Thus IGADS began as a federal project in 1975, was further developed by the state of Texas, and now is being completed under a joint effort of 16 states.

The Virginia Department of Highways and Transportation is a cooperating agency in Support of the Interactive Graphics Road Design System (IGRDS) which will allow participating states to significantly advance their automated drafting/design capability. The Department feels that the interactive graphics project proposal that has been developed is an excellent and appropriate project as it will lend support for the utilization of a CADD system which has also been proposed for the Department. The CADD task committee of the Department has recently prepared a feasibility study for a CADD system.(16) The report states that "the benefits achieved through the use of a CADD system more than offset the investment in equipment that would be required to meet the immediate drafting needs of the Department. The acquisition of a CADD system would offer the Department an excellent opportunity to increase productivity, reduce costs and, over a number of years, possibly realize a net reduction in manpower requirements. Failure to acquire a CADD system would mean continued reliance on costly, labor-intensive, manual drafting and would only postpone, at best, the Department's entry into the computer graphics field at a time when efficiency in production is being sought and the solution obvious.

Computer graphics have been used in transportation for the past two decades. Applications have included transit planning, facility location, network analysis, network generation, editing and mapping, public participation simulations, and environmental impact analysis. The full potential of computer graphics is beginning to emerge as they are linked with powerful microcomputers.(17)

The use of microcomputers in transportation has occurred over the past 5 years and applications are now appearing in the literature. As this technology becomes mature, there will continue to be advances in this area. A recent study by M. J. Demetsky investigated areas where microcomputers can aid in the effectiveness of transportation engineering at state and local levels.(18) The report included a survey of microcomputer needs of transportation professionals and described sources of information on software. It recommended that a microcomputer support organization be established at the state level to assist transportation professionals in securing software for engineering problems.

Laboratory and Field Data Collection and Analysis

The TRIS search revealed that a number of studies and investigations are under way that will utilize high technology in laboratory and field investigations.

The Ohio Department of Transportation working jointly with the Department of Electrical Engineering at Ohio University, is investigating the automation of dynaflect deflection measurements using a microcomputer. By having the capability of recording measurements directly onto tape, the need for hand recording and hand keypunching of data is eliminated. This project illustrates an application of computers in field situations in which the recording of data is handled automatically, thus eliminating the possibility of human error and also reducing labor costs.

The Puerto Rico Department of Transportation and the Puerto Rico University at Mayaguy are developing a computerized data system to rapidly process and analyze laboratory data, thus providing management with up-to-date materials testing information. Similar projects are under way in other states, as reported in the survey described in the next major section of this report.

The Army Construction Engineering Research Laboratory in Champaign, Illinois is engaged in a project to evaluate the feasibility of using optoelectronics to detect surface deformations in pavements. Possible techniques will be identified for comparison and development of new techniques using the fundamental principles of optoelectronics.

The University of Texas Center for Transportation Research is investigating an automatic turning movement count system for signalized intersections. The objective of the study is to develop a practical automated process for making intersection turning movement volume counts. The project involves the following activities: (1) developing criteria for location, types, and numbers of vehicle or axle detectors, (2) developing a system of external logic which can predict turning movements from detector excitations with respect to time, (3) testing and evaluating, and (4) converting into a form suitable for full application. Finally, the project will require development of a microprocessor-based electronic instrument system that can be easily connected to a signal controller and easily programmed for on-site conditions.

Construction Management and Quality Control

The use of computers in construction management and quality control has been expanding rapidly, in parallel with developments in other areas of the highway industry. The principal uses are in construction project management, inventory control, bidding, estimating, and partial payment schedules.

A recent paper by Paul L. Los discusses the potential use of microcomputers for construction management.(19) He points out that most of the commercially available software programs are written for contractors, not construction managers. There are many systems for quantity take-off or estimating. Information on other microcomputer programs is published in Civil Engineering Magazine and Engineering News Record. Most agencies will either have to develop their own programs or adopt some of the commercially available spread sheet, word processing, data and file management programs, or get them from other agencies. A large selection of general purpose programs is also available through computer magazines.

Future Applications: Robotics and Expert Systems

The preceding discussion has briefly outlined topical areas in the highway and traffic field in which computer applications are being developed.

Two additional applications on the horizon deal with the use of robotics and expert systems in the highway field. Neither has reached a point of development such that highway agencies are utilizing this technology in practice. A recent report by William Zuk discusses the status of robotics in construction.(20) He points out that the use of programmable robots in manufacturing is well established but their use for tasks such as those in construction is still in the developmental stage. His report describes twenty types of highway construction activities where future uses of robots appear to be feasible.

Expert systems is a branch of artificial intelligence that attempts to recreate the knowledge base necessary for making decisions. For example, if a given set of information were available and were fed into a computer, then the correct course of action would be furnished. This technology is being applied in areas such as medicine, mining, chemistry, and a variety of business applications. The application to highway and traffic engineering is feasible, but to date little work is being done in this area.(21)

EXPERIENCES OF STATE DEPARTMENTS OF HIGHWAYS AND TRANSPORTATION IN THE APPLICATION OF HIGH TECHNOLOGY

Introduction

A survey questionnaire was sent to the chief administrative officer of each state department of highways and/or transportation in order to (1) determine the extent to which other states are investigating this topic and implementing high-tech solutions intended to improve system performance and productivity, and (2) obtain descriptions of specific projects that have been proposed or recently started that utilize innovative applications of computer technology. A letter was mailed on April 7, 1985, requesting a reply by April 30, and 35 states responded by that date. A follow-up letter was sent to the remaining 15 states requesting a reply by May 20, and 11 were received. See the Appendix for a list of the questions posed to the states. Thus the information reported is based on replies from 46 states. A list of the states responding and the individuals who completed the questionnaire is in Table A-1 in the Appendix.

How States Introduce New Technology into Practice

Each state was asked to characterize its organization's approach to introducing new technology into practice in one of the following three ways:

A. Leaders in the introduction of new products and ideas

B. Utilizers of new products and ideas after they have been generally accepted and tested by others

C. Incorporators of new products and ideas as appropriate to their needs and programs

As shown in Table 1, 13 states consider themselves to be leaders in the introduction of high technology into practice, 9 states indicated that they utilize new products and ideas only after they are generally accepted as state-of-the-art, and 24 states indicated a "middle ground" approach.

Table 1

Characterization of State DOTs' Approach to Introducing New Technology into Practice

Leaders in Introduction of New Products & Ideas	Utilize New Products & Ideas After Tested by Others	"Middle Ground" Incorporate New Technology As Appropriate
Arizona	Delaware	Alabama
California	Hawaii	Alaska
Colorado	Indiana	Arkansas
Florida	Mississippi	Connecticut
Michigan	Nebraska	Georgia
North Dakota	New Hampshire	Idaho
Ohio	North Carolina	Illinois
Oklahoma	Rhode Island	Kansas
Pennsylvania	Tennessee	Kentucky
South Dakota		Louisiana
Texas		Maine
Washington		Maryland
		Massachusetts
		Minnesota
		Missouri
		Montana
		New Jersey
		New York
		Oregon
		South Carolina
		Utah
		Vermont
		Virginia
		West Virginia

These results indicate that a large number of states have embarked on high-technology programs and are making significant attempts to incorporate new products and ideas into their organizations. Only 9 states (or 19.6% of those responding) take a more conservative approach by introducing new technology and utilizing new products and ideas after they have been generally accepted and tested by others. These latter states, with few exceptions, also indicated that they have no R & D high-tech projects under way and have not collaborated with universities or the private sector in the high-tech area.

Research and Development Projects

Each state was asked to describe any research and development projects under way in which computer technology was being evaluated, and if found successful, would replace current practice. (Question 3 of the survey.) Thirteen states reported that there were no R & D high-tech projects under way, whereas 33 states listed one or more projects. A total of 162 projects were reported. The average number of projects per state was 5, and the maximum number of high-tech projects for a single state was 12. Table 2 lists the states that reported active high-tech projects and the number of projects.

Table 2

Number of Research and Development Projects in Which Computer Technology is Being Evaluated

State	Number of Projects
Alabama	1
Arizona	9
Arkansas	5
California	6
Colorado	7
Connecticut	3
Delaware	2
Florida	6
Idaho	5
Indiana	3
Kansas	5
Kentucky	3
Maine	4
Maryland	4
Massachusetts	6
Michigan	6
Minnesota	12
Montana	3
New Jersey	4
New York	7
North Dakota	3
Ohio	8
Oregon	2
Pennsylvania	11
Rhode Island	1
South Dakota	2
Tennessee	1
Texas	10
Utah	2
Vermont	1
Virginia	7
Washington	12
Wisconsin	1
Total	162

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The current R & D projects in which computer technology was being evaluated and could, if successful, replace current practice are listed in Appendix Table A-2 under 7 categories. These are (1) Data Base Management and Information Systems; (2) Highway Traffic Operations and Management; (3) Highway Information Systems and User Communications; (4) Computerized Design, Analysis, and Planning; (5) Laboratory and Field Data Collection and Analysis; (6) Construction Management and Quality Control, and (7) Other. These are discussed below.

There were 30 projects from 21 states reported in the category of data base management and information systems. This area is one in which many departments of highways and transportation are developing new methods and techniques for the application of high technology. Project areas include specific applications in pavement and bridge management, traffic inventories, personnel records, materials, planning, and preconstruction record keeping. Many states are implementing pavement management programs and several are developing long-range plans for information systems within the department. The state of Pennsylvania has an extensive program in the data base management field that incorporates a wide variety of stand-alone data bases for roadways, maintenance operations, and resources and bridge data.

There were 39 projects from 20 states reported in the category of highway traffic operations and management. This is also a very active area and states are investigating a variety of innovative applications of computer technology in the traffic field. Project areas include freeway traffic control at on-ramps, traffic signal networks, development and testing of weigh-in-motion equipment for trucks, automated vehicle classification and counting, automated monitoring of toll booths, highway safety programs, traffic systems communications, and control of traffic through work zones. Many states are testing weigh-in-motion systems that will determine truck weights, classification, and identification without requiring the vehicle to stop, and several states are examining how computers can be used to update traffic counting programs. Ohio, Texas, Virginia, and Washington have several major projects in the traffic field in which computers are utilized, including traffic signal troubleshooting, use of fiber optics for traffic systems communications, real-time monitoring of major urban freeways, and telecommunications links between freeway surveillance centers and data analysis centers.

In the category of highway information systems and user communications, only 6 projects from 5 states were reported. Among these are surveillance control and driver information on Detroit freeways and an integrated motorist information system using detectors and variable message signs in New York. The relatively few numbers in this category may reflect some overlap with Category 2: Highway Traffic Operations. It may also serve to indicate that the area of highway information and user communications is one which has great potential for high-tech applications but will require the cooperative efforts of several industries and organizations. State DOTs can furnish information using variable message signs, signals, and high-tech signing. However, direct communication with the driver will require the development of on-board electronic equipment and computers for automobiles.

There were 36 projects from 26 states reported in the category of computerized design, analysis, and planning. This area is one in which states are making major commitments in computer technology as the drafting and design functions are being automated. The use of computers in highway engineering design is not new but the computerization of the entire design process has emerged within recent years. Many states reported that they are evaluating CADD systems and are introducing workstations both in central offices and in the field. Some states, notably Texas, Pennsylvania, and Minnesota, are farther along in this development than others. It is clear, however, that this development is revolutionizing the work of highway transportation agencies, and that it will have a profound effect on the numbers and qualifications of engineering professionals required in the future. The development of software is also reported by many states. Maine reports program development to prioritize highway and construction rehabilitation programs; Ohio is developing CAD software for maintaining road maps and the preparation of plans; and Washington has developed software for hydraulic design. Several states are participating in joint projects with the AASHTO to develop interactive bridge and road designs. Pennsylvania, as well as other states, has developed extensive libraries of computer programs for highway and traffic design.

There were 25 projects from 15 states reported in the category of laboratory and field data collection and analysis. This is an area where some states are investigating the applications of computer technology to field and laboratory studies of topics as wide-ranging as materials, surveying, pavement condition evaluation, bridge displacement monitoring, detection of ice on bridge decks, and noise. Some states report that they are completely automating their materials laboratories, including activities such as testing, data storage, quality control, and calculations. Connecticut is particularly active in the development of photologging for highway engineering data and the use of laser video discs and computer graphics for storing photolog records of roadway conditions.

In the area of construction management and quality control, 7 states reported some activity. Pennsylvania, Arizona, Minnesota, California, and Kentucky have initiated computerized management systems that automate the construction contract process. Microcomputers installed in district offices permit the direct preparation and maintenance of contract documentation as well as communication with central offices. The paucity of construction-related high-tech projects outside of the management area is

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probably indicative of the fact that construction work is usually contracted out, and since state DOTs do not have the prime responsibility for actual construction, they have little incentive to undertake R & D in this area. Again, improvements in methods and techniques will require participation of both the public and private sectors in research..

The category other was intended to capture a variety of projects that cut across all areas or that were particularly unique. Some states did indicate that they view high tech as going beyond computer technology and cited examples. Accordingly, these projects were also listed in the other category, and include projects such as noncorrosive winter maintenance, use of waste rubber and sludge in pavements, etc. The most predominant high-tech application has been the use of microcomputers as a substitute for mainframes. The availability of micros has created a new way of using computers at the local level. Among the states that reported expansion of their capabilities through micros were Colorado, Florida, Maryland, Massachusetts, Montana, and Pennsylvania. Several states reported experimentation with office automation, electronic mail, technology transfer, satellite surveying, and experimentation with the total automation of district offices.

Collaboration with Universities or the Private Sector

Each state was asked to describe situations in which the Department collaborates or has collaborated with the private sector or universities to jointly develop new products and/or applications of high tech in highway and traffic engineering. Fifteen states reported that their agencies had not collaborated with universities or the private sector in the high-tech area, whereas 31 organizations reported on the development of new product ideas, or projects that utilized the assistance of outside groups. A list of states that have utilized universities and private sector organizations and the type of projects or activity is furnished in Appendix Table A-3. In some instances the project examples overlapped with those listed in Table A-2, and these have not been repeated. Several interesting collaborative efforts that were reported are commented on below.

Use of universities for training and technology transfer. Several states indicated that universities are providing training assistance in computer applications for engineers and technicians, particularly in the use of new CADD systems. Universities are also being utilized to develop training materials and software for use by local transportation agencies.

Students are hired as interns. In association with local universities and faculty, students are hired to develop computer applications in highway projects such as highway needs models, automated field data collection, and special programming problems. The advantage to this

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approach is the availability of specialized expertise and the introduction of students to the highway transportation field.

The most common type of university-private sector collaboration reported involves the contracting out by state DOTs of specific project work in the high-tech area. Many of the projects that states reported as under way (see question 3) are being carried out by contractual arrangements. Among the projects listed in which universities and consultants are used are pavement management system development; evaluation of CADD options; development of complex software to be used with existing hardware; advanced laboratory testing techniques; conversion of existing bridge design programs to a user friendly format; bridge analysis, design, and testing; pavement and geometric design; computer programs for preconstruction project management; and field testing of bridge and pavement performance.

Several states have entered into collaborative arrangements with universities, and are working cooperatively in a variety of high-tech areas. For example, the Minnesota DOT has established the Cooperative Program for Transportation Research and Studies with the University of Minnesota. Pennsylvania actively involves universities and the private sector in the development and conduct of research on new high-tech materials, concepts, etc. The South Dakota DOT and the School of Mines have jointly developed a salt substitute for road deicing for which a patent has been issued and two are pending.

Several states work primarily with their in-house staffs, and seek outside collaboration in overload situations. For example, the implementation of new technology is adapted to local conditions in response to requests of the Arizona department's operations staff. When feasible it is performed with available staff and resources, and when these are not available then a university or private sector agency is selected.

Several states referred to collaborative efforts with other states through the AASHTO. The project to develop computer programs for bridge design is an example of this type of collaboration.

Collaboration with private industry in the development of new product ideas is under way in several states. The Maryland DOT is conducting a joint research effort with NASA and the Jet Propulsion Laboratory to develop software and hardware for compressing video pictures and transmitting them over telephone lines. The objective is to apply this implementation of space technology to freeway monitoring and traffic data collection. The system could be used for traffic counting studies and has the potential to identify traffic accidents on a near real-time basis. Another example is the Michigan DOT, which has worked with General Motors to develop a rapid travel profilometer that will test the roughness or ride quality of pavements. The Aeronautics Division of the

Arizona DOT has worked with other airport-oriented groups to develop equipment through their research project. Also the Oregon DOT is working closely with the trucking industry on automated vehicle identification.

Utilization of Computer Technology by State DOTs

A final question was intended to capture the extent of current usage of computer technology (in contrast with R & D projects) within state DOTs. The respondent was asked to simply indicate general areas where the organization is utilizing computer technology. The responses are shown in Table 3.

The most active topic, currently, is data base management, and 40 of the 46 responding states indicated that they have projects under way in this area. The second highest usage, 38 states, is for computerized design, analysis, and planning, and this is followed by laboratory and field data collection, 33 states, and highway information systems and user communications, 31 states. The last named category was most likely intended to include highway traffic operations and management. Table 4 lists additional areas of computer activity that were itemized separately under the "Other" category. Six states added eight new items -- three in the traffic engineering area, two dealing with field testing, and two with computer modeling -- and one state suggested a separate category for office automation.

For the items listed in Table 3, each state was asked which area it considered to have the highest potential for computer application. The results are tabulated in the last column. The item listed first is computerized design, analysis, and planning. This viewpoint possibly reflects the fact that many states are just in the implementation phase of CADD systems and are expecting that this investment will yield high future payoffs. The areas of data base management, highway information systems, and laboratory and field data collection and analysis were rated by fewer states, possibly indicating that the major potential may have already been achieved in these areas or that states are uncertain as to how these areas will be developed by the private sector.

Respondents were asked to briefly describe how computer technology was being used by the DOT organizations for each of the categories. An extensive list was provided that supplements the information in Tables A-2 and A-3. From these replies, it is evident that computer technology has permeated the activities of state departments of transportation in all areas where productivity gains are possible.

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Table 3

Areas in Which State DOTs Are or Will Be Utilizing Computer Technology

Area	Number of States: Utilizing High Tech	Number of States: High Potential Application
Data Base Management	40	22
Highway Information Systems and User Communications	31	18
Computerized Design, Analysis, and Planning	38	35
Laboratory and Field Data Collection and Analysis	33	14
Artificial Intelligence	0	1
Automated Sampling and Quality Control	9	2
Other (see Table 4)	6	

Table 4

Additional Areas in Which State DOTs Are
Utilizing Computer Technology

Office Automation (Florida)

Environmental Protection Modeling (Hawaii)

Analytical Models (e.g. HPMS, HIAP, etc.) (Idaho)

Nondestructive Testing of Bridges and Pavements (Minnesota)

Surveying Data Handling (Minnesota)

Communications and Real-time Traffic Control (Texas)

Traffic Management Systems (Virginia)

Signal Timing Plans (Virginia)

Potential Areas for High-tech Applications

Table 5 lists those areas which states indicated will have potential for high-tech application in the coming years. The list contains a wide variety of suggestions, which indicates that considerable R & D activity can be expected at the state level. Among the items suggested by one or more states are office automation, artificial intelligence, satellite transmission of data, robotics, traffic signal networks, highway information for traffic routing, monitoring climatic and field conditions such as fog and ice, and testing. High-tech applications in several of these areas -- for example, maintenance management and computerized design -- are already under way in some states.

Table 5

Future Areas of Application for High-tech
Suggested by State DOTS

Satellite transmission of computer data files

Satellite surveying

Ice detection

Monitoring reduced visibility (fog)

Identification of the chemical and physical characteristics of asphalt and their relationship to performance in highway pavements

Maintenance management systems

Office automation

Artificial intelligence

Automated sampling and quality control

Computerized design

Interdepartmental communications computer control of mechanical equipment to improve safety, precision, and productivity rates. Ultimately robotic applications

A moving, self-contained pavement recycle or rehabilitation "Train" semiautomated at first, but more automated as technology advances

Utilize newly available "high-technology" to test things in ways we couldn't test before and gradually replace less useful or less efficient tests

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CONCLUSIONS AND SUGGESTED ACTIONS

This study has investigated the extent of the present use of high technology in the highway and traffic field and the potential for future use. Each of the areas described, as well as the activities of many states, could easily warrant extensive discussion and documentation. However, based on the information gathered, several conclusions and suggested actions emerge. These are presented in the sections that follow.

Conclusions

Taken as a whole, the states have been very active in adopting computer applications in all areas of highway engineering and management. Some states have been more aggressive than others and have provided leadership in this area so that other states can follow. States in the forefront of high-tech development in transportation tend to be those with a strong commitment to industrial development and research and excellent university facilities (e.g.,California, Michigan, Pennsylvania, and Texas).

The most promising applications of high technology in highway and traffic are those in which technology is sufficiently developed so that it can be applied to specific problems within the agencies. An example is the use of data base management in a variety of highway contexts. On the other hand, the potential use of robotics or expert systems is not considered to be sufficiently well known to justify research and development by state transportation agencies.

The available literature dealing with applications of high technology in highway and traffic engineering is very diverse, and state administrators and researchers will have to rely upon material from suppliers and vendors, as well as site visits for up-to-date information. While there are many projects under way, documentation of these will require special efforts, personal correspondence, and discussions with the persons involved.

Collaborative efforts with industry, universities, and nonprofit organizations, with the goal of introducing new high-tech concepts into practice, are carried out by states in a variety of ways. The most common is through contracts for the performance of specific tasks such as software development or the preparation of training courses. In some few instances states have teamed up with a research organization to develop and test a new high-tech product.

There are certain categories of projects in which collaboration by states has been beneficial. These are research and development projects in which the results are generic and all agencies involved benefit. These tend also to exceed the cost that a single organization could bear. An example is the interactive graphics roadway design system that is being completed through the joint efforts of the states and being administered by the AASHTO.

Some states are pursuing the development of new technologies in collaboration with industry. However, the fragmented nature of the highway transportation industry, the need to be prudent and conservative with public funds, the political cost of failure, the possibility of litigation, and the difficulty in transferring the results from one agency to another tend to discourage this practice. The public sector operates under a different set of ground rules than does the private sector, and for this reason attitudes about research and development between these sectors are markedly different.

The areas which appear to have the greatest potential for the immediate application of computer technology in highway transportation are data base management and computerized design, analysis, and planning. These areas do not interface directly with the motoring public, but result in direct efficiencies within the organization.

The areas of highway information systems and laboratory and field data collection and analysis are seen as having lower potential from a state point of view. Breakthroughs in highway information systems will be dependent upon developments by the private sector (most notably the auto industry). Applications in this area carry high risks and require careful coordination with the motoring public if they are to be successful. Laboratory and field data equipment applications require that industry develop the systems. It will be motivated by the potential market and the likelihood that transportation agencies will adopt new products. Both of these areas represent opportunities for joint private sector-transportation agency collaboration.

Development of Alternative High-tech Projects

This report has described seven basic areas in which potential benefits may be gained through the application of high technology. These are listed below with examples of the types of projects, applications, or both, that are possible. Some of these areas are more fully developed

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than others. In some cases, it is simply a matter of applying proven technology; in others, considerable development will be required.

1. Data Base Management and Information Systems

   - Pavement Management Systems
   - Right-of-way Data
   - Technology Transfer Data Retrieval
   - Personnel Records
   - Transfer of Data Files
   - Pavement Performance Monitoring
   - Construction Project Data
   - Roadway Management Systems
   - Bridge Management Systems

2. Highway Traffic Operations and Management

   - Weigh-in motion
   - Traffic Signal Control
   - Vehicle Classification and Counting
   - Toll Collection
   - Traffic Materials Inventory
   - Traffic Surveillance
   - Freeway Monitoring and Control

3. Highway Information Systems and User Communications

   - Variable Message Signs
   - Detectors
   - Automated Routing
   - Global Positioning
   - Automobile Information Systems

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4. Computerized Design, Analysis, and Planning

   - Evaluation of CADD Systems
   - Network Analysis
   - Urban Transportation Models
   - Software Development for Design Applications
   - Bridge Design Programs

5. Laboratory and Field Data Collection and Analysis

   - Computer Automation of Materials Laboratory
   - Software for Mix Design Calculations
   - Photologging for Highway Data
   - Portable Microcomputers for Distress Data
   - Materials Reports
   - Automated Road Inventory and Condition Surveys
   - Bridge Dynamics and Testing
   - Nondestructive Testing
   - Computerized Survey Data

6. Construction Management and Quality Control

   - Microcomputers for Contract Documentation
   - Statistical Aggregate Quality Control
   - Automation of Bid, Contract, and Construction Process

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7. Other

   - Electronic Mail
   - Microcomputers
   - Satellite Positioning
   - Expert Systems
   - Robotics

Suggested Actions

The extent to which the Virginia Department of Highways and Transportation embarks upon expanded research and development in the high-tech area will depend upon factors such as cost, availability of trained personnel, program priorities, and need.

No attempt has been made to examine existing practices in all of the areas within the Department to determine how these could be improved and modified to reduce costs and personnel needs through automation. Accordingly, it is inappropriate to make specific recommendations. Rather, several courses of action which could prove to be beneficial are indicated. It is, therefore, suggested that the Department undertake the following:

1. Review and evaluate existing practices in each of the areas described to determine the extent to which contemporary techniques and equipment are being used, that take full advantage of high technology potential.

2. Encourage and support research that investigates ways in which high technology can be used to improve the performance of its highway system and organization.

3. Identify individuals or groups within the highway organization who will serve as computer technology specialists responsible for the introduction and development of this technology within the agency.

4. Consider working with other research organizations or governmental agencies (e.g., NASA) to develop equipment and software with specific application to the state's transportation system. With the concentration of high-tech industries in Northern Virginia, as well as the Department of Defense and the Center for Innovative Technology, the opportunity exists for

collaboration and leadership by the state in the highway transportation field.

5. Develop further training programs for its staff in the use of computers and their application in highway transportation. The opportunity to work with universities, vendors, and consulting firms in this area should be considered.

6. Work cooperatively with other states in the development of high-tech applications. The interactive graphics aided design project is one example of this type of collaboration. Other opportunities should be considered, as appropriate.

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APPENDIX

SURVEY QUESTIONS
SURVEY RESULTS

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Questionnaire

IMPACT OF HIGH TECHNOLOGY ON HIGHWAY AND TRAFFIC ENGINEERING AT THE STATE LEVEL

1. (a) Name of organization:

   (b) Name of person completing questionnaire:

2. Which statement best characterizes your organization's approach to introducing new technology into practice?

   (a) We consider ourselves to be leaders in the introduction of new products and ideas.

   (b) We utilize new products and ideas, but only after they have been generally accepted and tested by others.

   (c) We take a "middle ground" in the introduction of new products and ideas, and incorporate new technology as appropriate to our needs and programs.

3. Briefly describe any research and development projects in your organization in which computer technology is being evaluated, and, if found successful, would replace present practice.

   (a) There are no R&D high-tech projects under way at this time.

   (b) The projects under way are as follows: (Use separate sheets if necessary.)

4. Briefly describe situations in which your organization collaborates or has collaborated with the private sector, universities, etc., to jointly develop new products and/or applications of high tech in highway and traffic engineering.

   (a) Our agency has not collaborated with universities or the private sector in the high-tech area.

   (b) New product ideas developed jointly with our agency and outside groups are as follows. (Use separate sheets if necessary.)

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5. (a) For the following categories of high-tech applications in highway and traffic engineering, please check the areas in which your organization is utilizing computer technology.

    1. Data Base Management

    2. Highway Information Systems and User Communications

    3. Computerized Design, Analysis, and Planning

    4. Laboratory and Field Data Collection and analysis

    5. Artificial Intelligence

    6. Automated Sampling and Quality Control

    7. Other (please specify)

   (b) Which of the areas listed above do you consider to have the highest potential for computer application in your organization?

    1. 2. 3. 4. 5. 6.

   (c) What other areas do you feel have potential for high-tech application?

   (d) For those items in 5(a) which were checked, please briefly describe how computer technology is being used by your organization. (Use separate sheets if necessary.)

Table A-1

States Responding to Questionnaire on Impact of High Technology on Highway and Traffic Engineering at the State Level

State	Person(s) Completing Questionnaire	Title
Alabama	F. L. Holman	Research Engineer
Alaska	Donald D. Friend	State Traffic & Highway Safety Engineer
	Tom Weed	Supervisor of Technical Systems Support
Arizona	Frank R. McCullagh	Research Engineer
Arkansas	Jerry R. Westerman	Assistant Engineer of Materials and Research
California	Terry Abbott	Associate Transportation Engineer
Colorado	Joe Dolan	Executive Director
Connecticut	Charles E. Dougan	Director of Research and Materials
Delaware	David W. Matsen	Computer Support Manager
	Oscar L. Sebastian	Applied Technology Engineer
Florida	Murray S. Yates	Director of Cosntruction
Georgia	Samuel D. Volb	Senior Research Engineer

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Table A-1 (continued)

State	Person(s) Completing Questionnaire	Title
Hawaii	Patrick Hironaga	Compliance Testing Engineer
Idaho	Keith R. Longenecker	Management Services Manager
Illinois	Marvin L. Traylor, Jr.	Engineer of Physical Research
Indiana	John P. Isenbarger	Director
Kansas	James V. Bush Carl F. Crumpton Glen Anschutz William E. Watts Harold Benoit	Asst. to State Transp. Engineer Engineer of Research Asst. Dir. Engr. & Design Asst. Dir. Planning & Develop. Bureau of Traffic Engineering
Kentucky	Bruce D. Irvine	Information Systems Supervisor
Louisiana	Lacey A. Glascock	Director of Traffic & Planning
Maine	Kenneth M. Jacobs	Materials & Research Division
Maryland	A. Scott Parrish	Chief, Bureau of Research
Massachusetts	Michael D. Meyer	Director, Bureau of Transportation Planning and Development
Michigan	Martin L. O'Toole	Acting Engineer of Materials and Technology
Minnesota	Paul J. Diethelm	Research & Development Engr.
Mississippi	Sidney Q. Kidd	Assistant R & D Engineer
Missouri	Robert N. Hunter	Chief Engineer
Montana	Homer G. Wheeler William G. Salisbury	Ass't Adm., Engr. Div. Adm.-Cent. Svc. Div.
Nebraska	Dalyce Ronnau Dave Hughes	Ass't Engr., Trans. Plan. Div. Computer Systems Manager
New Hampshire	Richard A. Pucci	Administrator of Administration

Table A-1 (continued) 1153

State	Person(s) Completing Questionnaire	Title
New Jersey	D. W. Gwynn	Director, Division of Research and Demonstration
New York	James F. Carrigan	Exec. Assistant, Office of Engr.
North Carolina	M. P. Strong	Research Engineer
North Dakota	Allan Covlin	Traffic Operations Engineer
Ohio	Geno P. D'Ippolito	Engineer, Bureau of Traffic
Oklahoma	Ray L. West	Director, Data Processing
Oregon	Joseph N. Speight	Resources Engineer
Pennsylvania	David P. Buchek	Civil Engineer 5
Rhode Island	Joseph F. Arruda	Asst. Director of Transportation Planning
South Carolina	M. R. Sanders	Civil Engineer 3
South Dakota	Wallace L. Larson	Assistant for Administration
Tennessee	James A. Stewart	Central Services Officer
Texas	William R. Ratcliff	Division of Safety and Maintenance Operations
Utah	Douglas I. Anderson	Research and Development Engr.
Vermont	Frank E. Aldrich	Chief Engineer
Virginia	Fred F. Small	Ass't Division Head, Highway and Traffic Safety Division
Washington	A. D. Andreas	Assistant Secretary for Highways
West Virginia	Charles R. Lewis II	Planning and Research Engineer Traffic Engineering Division

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Table A-1 (continued)

Wisconsin	Russell Throndson	Supervisor, Transportation Systems Area, Bureau of Systems & Data Processing

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Table A-2

R & D Projects Currently Under Way Using Computer Technology

Category 1: Data Base Management and Information Systems

State		Description of Project
Alabama	.	Pavement management system
Arkansas	.	Data base system for storing, retrieving, and reporting results between Department's Material and Research Division and the Districts
	.	Establish data base system to maintain past and current Department rights-of-way by digitizing existing drawings and microfilmed rights-of-way plots.
	.	Reviewing feasibility of incorporating microprocessor base controls for use in all phases of Department's activity, such as traffic monitoring, loadometer studies, maintenance of highway inventories, and laboratory testing
California	.	Cal Trans is conducting a study to replace the existing manual records keeping system with an automated micrographics based records storage and retrieval system
Colorado	.	Create a data base of all research material available in Technology Transfer Section in Division of Transportation Planning
	.	Feasibility study to bridge between Colorado road information system data base and interactive graphics capabilities. This would allow English language queries to data base with graphical output on map
	.	Developing an information system long range plan for the Department
	.	Developing statistical programs (SPSS) to extract EEO information from State Personnel System data files
Florida	.	Software developed to assist top management in evaluating information contained in large data bases. Prototype is menu driven and displays information

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Table A-2 (continued)

	graphically. Intended to replace printed computer reports
Idaho	. Pavement management networks optimization using marginal analysis procedures
Kansas	. Pavement management system, under development since 1980
Maryland	. Pavement management system which runs on a microcomputer
	. Install and evaluate a hardware/software package developed in Europe to link the DOT Univac mainframe to the state government IBM mainframe to allow full transfer of data files and operations between the two systems
Massachusetts	. Developing an organization-wide project information system based on computer terminals
Minnesota	. Acquiring, storing, and processing technical and nontechnical data
	. Development of a pavement management system
New Jersey	. Resource allocation using highway performance monitoring system). Evaluations and sensitivity tests to determine extent of data needs to make system useful
	. Pavement management models are being evaluated and developed to program rehabilitation efforts on link and network basis
New York	. The management/analysis of geographic information using interactive graphics and associated data base
North Dakota	. Developing a records keeping system using D base III to take over entire construction record keeping system. To include all work associated with construction projects, quantity books, change orders, haul sheets, progress estimates, etc.
	. Pavement management system that will rely heavily on the use of mainframe and microcomputers

Table A-2 (continued)

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Ohio	.	Pavement Performance Monitoring System. Research project to design and implement a computer-based PMS to provide performance information on past pavement designs and project life and performance of new and existing highway pavements
	.	Pre-construction project monitoring system. Develop on-line computer system to provide input of preconstruction information regarding project scope, costs, work-to-date, projection of construction start dates, uncompleted tasks, project costs, etc.
Pennsylvania	.	Roadway management system. Incorporate a number of stand-alone data bases (pavement management, roadway inventory, railroad crossing, and highway performance measurement) into a comprehensive roadway information data base
	.	Maintenance operations and resources information system. Incorporates maintenance, materials, and equipment management activities into a comprehensive data base
	.	Bridge management system. Will incorporate a bridge replacement and rehabilitation system, bridge maintenance system, structure inventory record system, and bridge load capacity rating system
Texas	.	Computer-based pavement management system
Utah	.	Common data base combining the important parameters from safety, pavement condition, traffic, structures, geographical, and rail crossing files. Will add maintenance, construction, etc.
Washington	.	Pavement management systems for state and local agencies. Computer conversion of PMS to microcomputer

Table A-2 (continued)

Category 2: Highway Traffic Operations and Management

State	Description of Project
Arizona	. Comparative assessment of computer programs for traffic signal planning, design and operation
	. Implementation of on-ramp traffic control on the Black Canyon Freeway
California	. Testing a weigh-in-motion system to detect truck weights, classification, and identification, without requiring the vehicles to stop at weigh stations
Delaware	. Demonstration project to digitally control traffic signal networks
Kansas	. Weigh-in-motion equipment for weighing trucks at high speeds
	. Classification of vehicles in the traffic stream by type using electronic equipment instead of manual/visual means. 55 mph speed monitoring
Maine	. Weigh-in-motion system on the interstate highway system, with microprocessor on site and telephone line MODEM to mainframe computer
Maryland	. Weigh-in-motion system that uses a bridge weighing system. It is portable and collects and analyzes data on an IBM-PC
Massachusetts	. Exploring ways through telemetry and microcomputer analysis to update state traffic counting program
Michigan	. Truck weight monitoring thru the use of weigh-in-motion scales
	, System to monitor toll collections and compare to vehicles passing through toll booth
Minnesota	. Freeway traffic management
	. Vehicle weigh-in-motion and classification

Table A-2 (continued)

New Jersey	.	Centralized traffic counting system. Investigations to develop specifications for statewide traffic counting system. Counters will be polled by micro-computer over dial-up telephone lines
New York	.	Computerized urban traffic signal systems
	.	Automation of traffic data collection and analysis
North Dakota	.	Weigh-in-motion. Purchase of system for collecting truck weight data
Ohio	.	Inventory of traffic materials (parts and supplies) stocked at the sign shop and field districts
	.	Computer-based device to test all functions of traffic signal monitors
	.	Computer-based device to record events leading up to the failure of a signal installation, for "instant replay" and "troubleshooting"
	.	Fleet management system including parts management
	.	Highway safety program -- Traffic accident analysis package
Oregon	.	Weigh-in-motion
Pennsylvania	.	Value iteration process -- actuated signals. Developed a computer model to analyze and optimize traffic signal settings for various types of isolated intersections. Further research to enhance the program
Texas	.	Automatic turning movement counter
	.	Computer-enhanced slow scale television for traffic surveillance
	.	Fiber optics for traffic systems communications
	.	Freeway and corridor data collection, management, analysis, and real-time control
	.	Computer-aided safety analysis
	.	Automated issuance of permits for oversize and/or overweight vehicles

Table A-2 (continued)

Virginia	. Automated traffic count sampling program
	. Highway traffic records to integrate and interface traffic record data with management information system plan
	. Real time traffic monitoring and control stations on I-66, I-395, and tunnel control systems in Tidewater
Washington	. Freeway surveillance and control. Ramp monitoring, closed circuit TV, electronic data collection for traffic systems analysis
	. Telecommunications link between freeway surveillance center and data base system. Link traffic systems management center and UW data base management system for easy retrieval and analysis of volume and lane occupancy data
Washington	. Statewide data rationalization. Continuous monitoring of traffic trends and data utilizing permanent traffic recorders
	. High-tech flagging. Project to minimize exposure of flagging personnel to traffic.
	. Computerized vehicle classification and traffic counting data
	. Weigh-in-motion automated computerized system

Category 3: Highway Information Systems and User Communications

State	Description of Project
Arizona	. Visual display/MVD
Michigan	. Surveillance control and driver information on Detroit area freeways
New York	. Integrated motorist information system using detectors and variable message signs to improve traffic flow through ramp monitoring. Warning of congestion and suggestions for alternate routing

Table A-2 (continued)

Oregon	. Automated vehicle identification
Texas	. Portable travel information collection devices
	. Automated routing of oversize and/or overweight vehicles

Category 4: Computerized Design Analysis and Planning

State	Description of Project
Arizona	. Evaluation of Computer Aided Drafting and Design (CADD)
Arkansas	. Computer analysis of proposed changes to existing transportation systems and networks
California	. A pilot CADD project was completed in December 1984 with statewide implementation scheduled for fiscal year 1985/86
	. Computerized drafting aids are now being used in several drafting sections. They are capable of drafting stored symbols and text on highway plans
Colorado	. Evaluating MOSS (Modeling System Software), an earthwork computer program based on a 3-D model. Input to MOSS is directly from EDM machines in the field.
	. Division of Transportation Planning now executes all urban transportation models on microcomputers
Delaware	. Computer-aided design. Automated drafting system for roads and bridges. Bridge design computer-aided system to replace existing manual drafting of design plans
Idaho	. Coordinated USGS/state digitized mapping
Indiana	. CADD system is being investigated for implementation
	. Optimization and prioritization techniques in pavement management

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Table A-2 (continued)

Kansas	.	Feasibility of a CADD/CAM system with 12 workstations
	.	Computer-aided mapping
Kentucky	.	Develop design capability in roadway and bridge design utilizing the interactive graphics system
Maine	.	Development of software to prioritize highway construction and rehabilitation program considering such independent variables as ride, ADT, maintenance costs, cost/benefit ratios, etc.
Massachusetts	.	Research contracts with two universities to develop microcomputer analysis packages for planning and traffic analysis
Minnesota	.	Producing plans, maps, reports, etc., CAD and surveying for example. No hands data handling process from preliminary field survey through mapping, CAD, and out to construction field surveys
Montana	.	CAD and CAM
New Jersey	.	Refinement of existing statistical analysis techniques and development of new techniques in the form of interactive computer programs. Extensive use of computer simulation to demonstrate and validate new methods
New York	.	The complete highway design process from input of site data to the design of the highway to the production of contract plans using interactive graphics
Ohio	.	Computer-aided design software for maintaining road maps and for preparation of plans. Implemented on mainframe and PC's
Pennsylvania	.	CADD
	.	Bridge automated design and drafting. Development of an integrated software system that will combine and automate the design, analysis, and drafting steps for certain types of highway bridges
	.	Computer program to model the overloading behavior of a steel highway bridge

Rhode Island	. Participating in the AASHTO study, Joint Development of a Bridge Design System, to develop a standard bridge design using computers
South Dakota	. Purchase of equipment to implement computer-aided drafting, mapping, and design
	. Participating in the development of software for interactive bridge and road design
Tennessee	. Completed study of CADD in other states. In the process of acquiring CADD system
Texas	. Computer-aided design using interactive graphics
Utah	. CAD-interactive graphics being evaluated for adoption
Vermont	. Use of CAD equipment
Virginia	. Start-up phase of CADD operation
	. Hydraulic design -- Use of microcomputer in tele-communications to access mainframes of other agencies and interdependent micros for use by field hydraulic design personnel
Washington	. AASHTO cooperative project on interactive graphics in roadway design
	. Hydraulic bridge backwater program.
	. New program that simultaneously considers multiple factors in hydraulic design
Wisconsin	. CADD. Evaluating interactive graphics roadway design system

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Table A-2 (continued)

Category 5: Laboratory and Field Data Collection and Analysis

State	Description of Project
Arizona	. Automation of Materials Laboratory
Arkansas	. Program for designing, calculating, plotting Marshall mix designs for ACHM's
California	. The use of total station surveying equipment was evaluated with favorable results. Additional purchases are proposed for future fiscal years
Connecticut	. Use of photologging for highway engineering data and network-level pavement management distress rating. Image quality is sufficient for network-level evaluations. On-board micro monitors integrity of data
	. Use of laser video disc and computer graphics for photolog libraries and pavement management distress ratings
	. Portable microcomputers for use in field data collection. Use of Epson PX-8 microcomputer for entering pavement distress data directly in the field
Florida	. Microcomputer applications in the capture and analyses of test data for Bureau of Materials and Research which are labor intensive
	. Interim materials test reporting system
Idaho	. Automated road inventory -- Image analysis crack evaluation
	. Surface texture skid friction evaluation
	. Modular port of entry instrumentation and design
Indiana	. Use of automatic collection devices for condition survey, deflection, roughness and friction data. Automatic data collection supersedes past manual collection methodologies and is more cost-effective

Table A-2 (continued)

Maine	. The dynamics of a single-span bridge are monitored via microprocessor and data are transmitted by telephone line MODEM to a research facility
	. Suspension bridge with aerial-elastic instability problems is monitored for displacement under varying wind conditions and data transferred via telephone line MODEM
Massachusetts	. New microcomputer-based technology for non-destructive testing of pavement
Michigan	. Detection of ice on bridge decks
	. Michigan automated records system Vehicle to determine horizontal and vertical alignment of highways
Minnesota	. Automation of lab and field tests used for design data and quality assurance
	. Use of nondestructive testing for bridge inspection, pavement ride, and load capacity surveys
New York	. Automation of laboratory information
Pennsylvania	. Lab system. Gould computer in Materials Testing Division (MTD) which provides processing capability for laboratory calculations, sampling, quality control and materials testing. MTD computer will be linked to Central Office mainframe to permit interfacing of data files
Virginia	. Direct field data entry of survey data into a computer acceptable format
Washington	. Computerized pavement condition survey unit. Data collected in the field to determine on-site defect ratings of pavements, and stored in a form compatible with existing micro and mainframe systems.
	. Pavement acoustical study. Evaluate field data collected regarding relative noise level values for various pavement types, textures, and wear
	. Computerized film cataloging and laser disc storage for photogrammetry

Table A-2 (continued)

Category 6: Construction Management and Quality Control

State		Description of Project
Arizona	.	Construction Office microcomputer
California	.	Microcomputers are being installed in resident engineers' offices for preparing and maintaining contract related documentation
Florida	.	Evaluating existing aggregate control system to provide statistical test data in a more available and useful format
Kentucky	.	Computerization of inputting bid data to the construction contract bid letting process
Michigan	.	Lightweight concrete pavement roughness tester to be used the same or following day after a concrete pour is made
Minnesota	.	Computer-aided field construction project data processing to reduce errors and time spent by field inspection personnel on reports. This includes pay quantity and quality assurance documentation.
Pennsylvania	.	Contract management system. Complete automation of construction contract preparation, bidding, estimating, and payment functions. Plans are to computerize all field inspection and documentation activities and process data from micros installed in field offices and then to District and Central Office computers via telecommunication lines

Table A-2 (continued)

Category 7: Other

State		Description of Project
Arizona	.	Automated coordinatograph
Arizona	.	Protocol converters
Colorado	.	Study of Department's microcomputers showing a 26% annualized return on investment
Florida	.	Experiment with the total automation of a district office
	.	Evaluating microcomputers for compatibility with the Department's network. Purchase of 100 units is expected
Kentucky	.	Office automation, data collection, and computational independence are being developed utilizing a distributed processing system now being installed
Maryland	.	Installation of local area network by Office of Traffic, a multiuser microcomputer of 28 stations. It will be connected to the DOT mainframe and local governments will access via telecommunications and microcomputers
Massachusetts	.	Using microcomputers in 10 operating divisions of the department. an evaluation will be done to determine their impact
	.	Technology transfer program to teach local officials how to use microcomputer analysis for traffic problem solving
Minnesota	.	Noncorrosive winter maintenance technology
	.	Use of waste rubber and sludge in pavements
	.	Development of cathodic protection system for bridges and continuously reinforced concrete pavements
	.	Use of fabrics in construction

Table A-2 (continued)

Montana	. Numerous applications for use of micros
	. Electronic mail
New York	. Numerous applications for use of micros, on construction jobs, design, traffic and safety, and maintenance
Pennsylvania	. Enhance quality and productivity of the design, construction, and maintenance activities within district engineering offices through use of personal computers
	. Engineering program library. Consists of over 100 computer programs for geometry calculation, bridge analysis and design, environmental analysis, surveying and photogrammetrics, geotechnical analysis, traffic engineering, and hydraulic
Virginia	. Satellite survey positioning

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Table A-3

New Product Ideas Developed Jointly with State DOT's and Outside Groups

State	Type of Project or Activity
Alabama	. In collaboration with Auburn University, a program has been developed for Maintenance management for local transportation agencies.
	. In collaboration with a consultant, a computer-aided design system has been implemented in the Design Bureau of the Alabama Highway Department.
Arizona	. The Aeronautics Division has worked closely with several software producers in testing and developing software for Apple computers. They are also planning to work with radar and other airport-oriented groups to develop their equipment and are working with the private sector on incorporating their ideas into their program. The high-tech committee has and is seeking private sector ideas and involvement.
Arkansas	. Development of a microprocessor controlled system for use in inventorying the Department's highway system.
	. Developed a microprocessor controlled data acquisitions system for stress-strain analysis of highway pavement and bridges.
	. Developed a microprocessor controlled pavement surface friction analyzer
	. Built a microprocessor controlled variable speed and variable path rapid wear track.
California	. In the process of contracting with local universities for developing and conducting training in computer applications for engineers and the new CADD system.

Table A-3 (continued)

Colorado	. New technologies developed or adopted to local conditions in response to requests of the Department's operations staff. When feasible to perform this activity with available staff and resources, it is done in house. When resources are not available a university or private sector agency is selected. This represents approximately 20-30 percent of the Department's program.
Florida	. Development of a construction quality reporting system.
	. Development of a pavement management program.
	. Development of microcomputer application for traffic operations data collection and analysis.
	. Determine current vehicle noise levels for highway noise computer models.
	. Development of guidelines for implementing computerized timing designs at traffic actuated signals.
	. Development of a systematic procedure for contract time determination.
Idaho	. Work closely with Boise State University in the development of new technologies. On-going student intern program that employs math and computer science majors for projects such as highway needs models, highway investment analysis models, pavement management, highway performance monitoring, automating dynaflect, road meter, skid meter, 16 mm photolog, programs to receive Telac communications, special programming, etc.
Indiana	. Joint Highway Research Projects performed through Purdue University use computers in connection with their research and reports.

Table A-3 (continued)

Kansas	. The pavement management system is being developed jointly with Woodward Clyde Consultants. During early development, a contract was also entered with the University of Kansas for computer services.
	. The Division of Planning and Development has worked with universities and consultants. The objectives of these efforts focused on complex software development to be used with existing computer hardware rather than the development of new products.
Maine	. Research is under way to improve traffic signal reliability and development for activated signs. Signs are being tested in 8 or 10 sites.
Maryland	. Conducting a joint research effort with NASA and the Jet Propulsion Laboratory. This study developed the software and hardware to compress video pictures and transmit them over voice-grade telephone lines. The objective is to apply this implementation of space technology to freeway monitoring and traffic data collection. It can be used for traffic counting, vehicle classification, speed monitoring and to study traffic patterns and vehicle weaving. It also has the potential to identify traffic accidents on or near real-time basis.
	. Acoustic emission detection projects jointly with University of Maryland. Develop procedures for analyzing acoustic emission signals from bridge-deck components in controlled laboratory conditions to determine crack initiation, location, and propogation. Field evaluation to monitor acoustic emissions of structural members of Woodrow Wilson Bridge.

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Table A-3 (continued)

	. Development and testing of an interactive real-time computer-based system for statewide hydrologic analysis.
	. Development and installation of CADD system.
	. Development of a consolidated road inventory system.
	. Microcomputer-based analytical model to analyze pavement life cycle costs for a variety of design, maintenance, and rehabilitation strategies.
Massachusetts	. R & D projects previously described. University research grants are the major means of collaboration.
Michigan	. Rapid travel profilometer. A vehicle to test the roughness or ride quality of pavement with General Motors.
	. Ice detection system with Surface Systems, Inc.
	. Michigan automated records system with Tech West, Inc.
	. Solar powered rest area with Michigan State University.
	. Flexible pavement design with MSU.
	. Evaluation of SCANDI with MSU.
	. Evaluation of wooden guardrail posts with Michigan Technological University.

Table A-3 (continued)

Minnesota	. Established the Cooperative Program for Transportation Research and Studies with the University of Minnesota. Collaborations include: (1) Real-time infrared vehicle detection system in lieu of pavement loop detectors; (2) use of sewerage disposal plant effluent as a source of acetic acid to make CMA, a noncorrosive deicing material; (3) macroscopic freeway simulation program for microcomputers; (4) simulation of intersection reconstruction sites; and (5) vacuum impregnation technology to mend shattered concrete.
Montana	. Have contracted with Montana State University to develop asphalt chemistry analysis using high pressure gel permeation chromatography.
	. Contracted for technical training in the operation of nuclear densiometers.
New Hampshire	. Contracted with the University of New Hampshire to develop user friendly programs from the highway department, a process that involves the conversion of existing programs to a user friendly format. Programs are being used by the Bridge Design Department in rigid frame and continuous beam analysis. Other programs include retaining wall design, rock stability, bridge deck analysis, storm sheet runoff, detention pond and culvert design.
New Jersey	. Slow growing grass. A joint effort with Rutgers has resulted in the development of a sturdy slow growth grass that is being used under field test conditions.

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Table A-3 (continued)

	. Snowplowable raised pavement markers. The Federal Highway Administration participated in developmental and evaluative effort to provide roadway delineation for snowbelt states.
North Carolina	. The Department's structures design unit has recently collaborated with North Carolina State University School of Engineering in activities relating to the transfer of computer technology to the design and construction of highway bridges. The School of Engineering was selected as a contractor by the U. S. Department of Transportation for this project.
North Dakota	. Exchange information, ideas, and programs with local government agencies within the area and to some extent with consultants.
Ohio	. Several of the projects referred to in question 3 are done through contracts with universities and other researchers.
Oklahoma	. Participate in a joint computer development program with other state departments of transportation through AASHTO.
	. Have worked jointly with OSU and OU in developing new methods for better highways, but not in the computer area. The Department has always been ahead of most universities in computer applications.
Oregon	. Working closely with the trucking industry on automated vehicle identification.
	. Working closely with Oregon State University on a technology transfer program.

Table A-3 (continued)

Pennsylvania	. Pennsylvania activity involves universities and the private sector in development and conduct of research on new high-tech materials, concepts, etc. The Department of Transportation utilizes both university and private consultant contracts to conduct a wide variety of related research. Projects include: overload behavior of steel-highway bridges (Lehigh), development of cost effective bridge systems (Lehigh), Ongoing cycles of pavement related testing at Pennsylvania State test track. Development of comprehensive bridge posting policy (Byrd, Tallamy & Assoc.). Bridge deck polymer impregnation (Penn State). Cause and repair of deformation - induced cracking in steel bridges (Lehigh). Runaway truck escape ramp technology (Penn State).
South Carolina	. Computer programs are being developed by a consultant under contract to provide a preconstruction project management system.
South Dakota	. South Dakota School of Mines and Technolgy and the Department of Transportation have jointly developed a salt substitute for road deicing. One patent has been issued and two are pending.
	. SDSM&T and SDDOT are jointly developing software for final analysis of existing bridge structures to more accurately determine their load carrying capacity.
Texas	. Several items listed in question 3 were developed in collaboration with universities.

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Table A-3 (continued)

Utah	. Crack sealing materials -- Test sections were established and suppliers were invited to install products for evaluation. The producers were responsible for handling and placement at sites and Department was responsible for evaluation and correlation with lab test results. Product improvements have resulted.
	. High-pressure liquid chromatography for asphalt evaluation. Montana State and Utah DOT have compared asphalt performance with results of MPLG results. This is a pooled fund study with a number of states involved.
	. Numerous new products have been evaluated through an experimental features program. Special provisions are established for a construction project to include the project or process and federal funds are available to evaluate the features.
Virginia	. Bridge and Location and Design Divisions' CADD study was a joint effort with the Virginia Highway and Transportation Research Council and the Department of Civil Engineering, University of Virginia.
	. Photogrammetry is being utilized for the development of geographic data base information for use in automated plotting of features controlling roadway design. Microcomputers have been utilized for data collection within this unit for the past eight years.
	. Also see response to question 3.
Washington	. Computerized Pavement Condition Survey Unit
	. Electronic Traffic Counting and Classification System for Roads and Intersections

Table A-3 (continued)

- Microcomputer Software for Pavement Management System
- Telecommunications Link between University of Washington and Freeway Surveillance Center in Seattle
- Highway Advisory Radio
- Changeable Message Signs
- Computerized Road Roughness Meter
- Traffic Signals -- Type 170 w/built-in Microcomputers
- Vehicle Classification Procedures
- Computerized Data Acquisition and Analysis System

Wisconsin

- Two projects sponsored by AASHTO and multi-state efforts:
- Interactive Graphics Roadway Design System will allow bridge and highway engineers sitting at a graphic workstation to perform interactive design functions. Our intent is to provide capability to the engineer to create a set of highway or bridge plans using a full range of design functions such as horizontal and vertical alignment, design template modifications, right-of-way limits, earthwork quantities, etc.
- Bid Analysis and Management System would be used to analyze highway bids and monitor contractors' bidding activities.

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