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COVER:
The North Carolina Department of Transportation's Wildflower Program, implemented in 1985 to beautify the roadsides, has grown from the original 12 acres (4.86 hectares) to include more than 1800 acres (729 ha) across the State. Wildflowers need little water, fertilizer, or maintenance (especially costly mowing), and they help control soil erosion, proving they can be functional as well as beautiful.

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Perspectives on the New Intermodel Transportation Program

by Bruce E. Cannon

This article was adapted from a speech given by Bruce Cannon to "Working Together to Move Minnesota" on October 29, 1992.

Introduction

A major focus of the Federal Highway Administration (FHWA) is the Intermodal Transportation Program (ITP) because that is basically what the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) prescribes. ISTEA is the legislation, but it is ITP we are working to carry out.

The book, *Reinventing Government*, encourages government managers and leaders to be "steerers" as well as "rowers" of their program "ships." I think that this analogy is particularly fitting for ITP. It is easy to become absorbed in the "fire-fights" and, as a result, risk losing sight of ITP's "big picture." I think that it is crucial to occasionally look at the entire puzzle—not just a few pieces.

With some help from colleagues and encouragement from top management, the FHWA's Office of Policy Development took some time to reflect on ITP in a broad fashion—its central guiding principles, challenges, and opportunities. We also thought about what these principles meant to FHWA, the States, and the transportation community. In thinking about ITP and its significance, we wanted to do what we could to make sure that its principles did not get buried in a mountain of paperwork or in a barrage of buzzwords. While we all know the importance of understanding key provisions and sound documentation in implementing legislation, we wanted to look at the broad view of the new ITP resulting from that legislation.

This expanded view could serve multiple purposes, such as:

- Provide a framework for understanding the overall ITP.
- Serve as a checklist for all of us in developing policy guidance to implement individual programs.
- Bridge the gap between the narrow confines of words in a section of legislation and the broader intent of the legislation.
- Facilitate discussion between transportation officials.
- Serve as a means of evaluating whether we are truly changing our ways of doing business.

ITP Guiding Principles

ITP has 10 guiding principles: implement intermodalism, use ITP flexibility, be more efficient, apply engineering principles, limit red tape, enhance the environment, promote safety, innovate, promote creative investments, and develop plans and programs.

Implement intermodalism

Before ITP, surface transportation thinking was very parochial. People often saw only their own narrow area of responsibility.

The new ITP now directs highway professionals to think about the interface with mass transit, rail, aviation, and shipping. This is the meaning of intermodalism. It means that all different

Protecting, and even enhancing, the environment is one of the guiding principles of the Intermodal Transportation Program.

modes of transportation must come together to form a seamless transportation network that will allow people and products to move from one mode to the other smoothly, with minimal congestion or interruption.

Use ITP flexibility

Flexibility means that the States and local communities can design their programs to meet their own transportation needs. If that means transit instead of highways—no problem—because then they can use highway funds on transit. The reverse is also true.

And there are many other options available in choosing how to spend highway funds. Transportation enhancements, operating costs for traffic control management, and seismic retrofit of bridges are just a few of the items on the expanded list of eligibilities. Flexibility under ITP also means funds can be transferred from one category to another to meet transportation priorities.

Be more efficient

A major philosophy underlying ITP is the effective and efficient use of limited resources. This is reflected in the six management systems and the use of the performance-oriented life cycle cost principles. It is also promoted in the planning process, which requires a balance of transportation needs and financial constraints. Efficiency is supported in efforts to preserve right of way for future transportation facilities, something that we must do if we are to keep pace with metropolitan area growth.

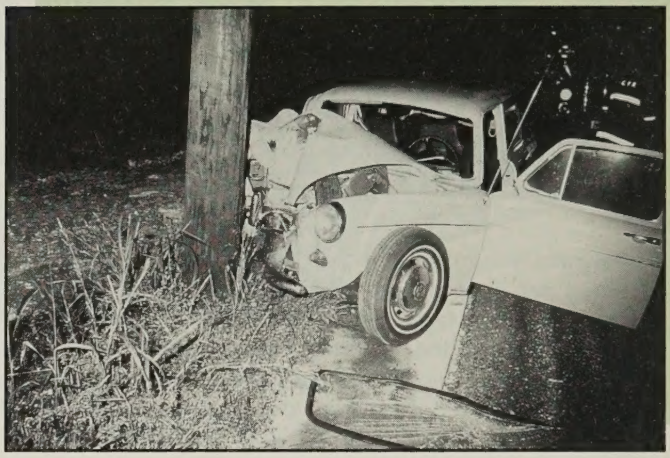
Apply engineering principles

ITP encourages pavement and bridge programs that recognize least total annual costs. It also stresses traffic system management and demand management initiatives for addressing traffic congestion.

Limit red tape

Congress recognized how many good non-Federal professionals there are running the State and local programs and decided to give them more responsibility in handling the federally assisted highway programs. Under ITP, State and local communities can assume FHWA oversight responsibilities on certain types of projects.

FHWA is directed to streamline program administration by reducing regulatory and administrative requirements and develop efficient coordination processes with other agencies (e.g., one stop environmental clearance). This will include efforts to improve financial management systems, thereby enhancing efficiency and accountability.



Reducing traffic accidents, which cost more than 40,000 lives and $130 billion annually, is a primary concern.

Enhance the environment

This legislation had its ear tuned to the environment at almost every turn, and this is reflected in ITP through: (1) New programs—Congestion Mitigation and Air Quality (CMAQ), Scenic Byways, and Congestion Pricing Pilot program. (2) New uses of funds—transportation enhancements, wetland banking, and mitigation of adverse impacts to wildlife, habitat, and ecosystems. (3) And overlaying it all, a planning process that must consider land use, environmental and social effects, and be coordinated with the Water Pollution and Clean Air Acts' plans and programs.

Promote safety

ITP certainly does not back away from the commitment of the Federal Government to improve safety on our highways. From safety in work zones to a new program encouraging the use of motorcycle helmets and seat belts, safety is still a primary concern. The 1990 $137 billion price tag on motor vehicle accidents, many associated with substance abuse, is a tremendous challenge facing all of us.

Innovate

This is a future-oriented program. Epitomizing this best is the substantial funding for the development of the Intelligent Vehicle-Highway Systems (IVHS). The States are urged to embrace, share, and use IVHS and other existing technologies.

Promote creative investments

The $155 billion provided by ISTEA sends a message that investment is important. But the way we spend is critical. We must maintain and enhance our Nation's international competitiveness and create new wealth. Now, that will require creativity on all our parts, and we must not be limited to traditional approaches. Public/private solutions are worthy of exploration and implementation.

Develop plans and programs

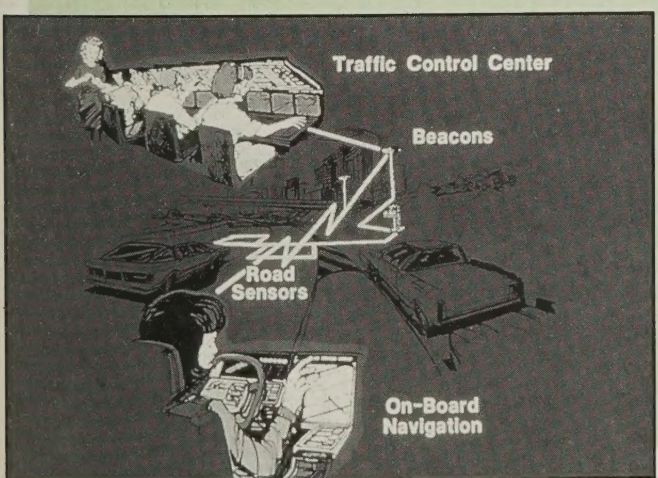
Finally, I come to what should really be first in having good transportation in America—sound transportation planning or, better yet, comprehensive planning that embraces transportation. I cannot overemphasize the importance of planning. The key element in this is intergovernmental cooperation—the States, Metropolitan Planning Organizations (MPO's), the Federal agencies, elected officials, and various interest groups must (not should) work together.

Critical Issues

Now, let's look at some selected principles and focus on a critical issue or two related to the principle.

Intermodalism

The challenge is to think more broadly about transportation in terms of how modes, systems, structures, finances, and other components fit together. Intermodalism challenges us to actualize these components around transportation outcomes, not modes or organizations.



The Intelligent Vehicle-Highway Systems Program will encompass innovative and creative solutions to many of our highway problems.

Single-mode biases cause us to think in terms of highway, transit, truck, or rail solutions to transportation problems. In the past, it caused us to compete against each other for budget resources and to guard "our" trust funds from "them."

Now we have a new program that challenges that old thinking. It requires a new way of thinking. ITP says "we do not care about your vested interests, institutional arrangements, and all the other trappings of your world. If clinging to those things means that you will not be able to move people, goods, and services the way the public needs, you need to redirect your efforts." Intermodalism must be more than a buzzword.

The market place has been moving in the intermodal direction for some time. I would venture to say that business leaders who are moving grain, forest, mining, and manufactured products to domestic and foreign markets know a great deal about intermodal transportation (or a lack of it). Our most effective, most competitive modal operators, transportation providers, and shippers think intermodally. Cargill and Federal Express are companies that come to mind. We must learn to think intermodally and improve our intermodal systems if we are going to compete globally.

The new ITP gives transportation officials the opportunity to seek flexible, market-driven solutions to our transportation challenges. It does so through the visionary emphasis on intermodalism by requiring active State and local participation in the formulation of policies tailored to local needs, and in the final decisions about funding priorities.

We are challenged to work together to develop Intermodal Management Systems that will increase integration of all of a State's transportation systems, including methods of increasing productivity and encouraging the use of innovative marketing techniques.

We are challenged to develop a seamless transportation system that relies on all modes of transportation, and ensures that major ports, airports, railroad transfers, and other transportation facilities have direct access to the new National Highway System (NHS).

We are challenged to identify International Trade Corridors and focus attention on various associated modal and intermodal facilities. These transportation systems are key to facilitating U.S. competitiveness in international markets. This effort will probably be reinforced by the North American Free Trade Agreement (NAFTA).

These trade corridors are going to contain not only part of NHS, but also major ports, waterways, railways, and airways. These facilities working together will be the main arteries of our international trade transportation system.

Flexibility

The important thing to recognize is that the best transportation solutions do not necessarily emanate only from Washington, DC, or from the State transportation buildings. ITP's flexibility provisions say to transportation officials that the "ball is in your court." Flexibility challenges us to trust others to do what is best, and it empowers them to do so. Flexibility under ITP reflects a trend in management that seeks to put decision-making responsibility and money in the hands of the people who are really on the "firing line." Thus, flexibility is the philosophical opposite of previous program characteristics with centralized management. Let us take a quick look at some of the flexibility provisions:

- Expanded use of project eligibility.
- Use of highway funds for transit and capital rail projects.
- Liberal transfer of funds between highway programs.
- Flexibility to involve the private sector in investments.
- Increased design and construction delegated responsibility for all non-NHS and certain NHS programs.

The opportunity is to make all this flexibility work for transportation. States have the flexibility to use their Federal funds on a far greater range of projects. ITP allows use of Federal funds for the best mode or combination of modes.

The challenge here, of course, is to come up with the innovative and responsive solutions to our transportation problems. Both at the State and Federal level we must identify and eliminate those barriers that stand in the way of finding the best solutions to our problems. Although we have made good progress, I venture to say that barriers exist at the Federal level and in every State. Of course, time and experience will help to eliminate many barriers to fully using ITP flexibility.

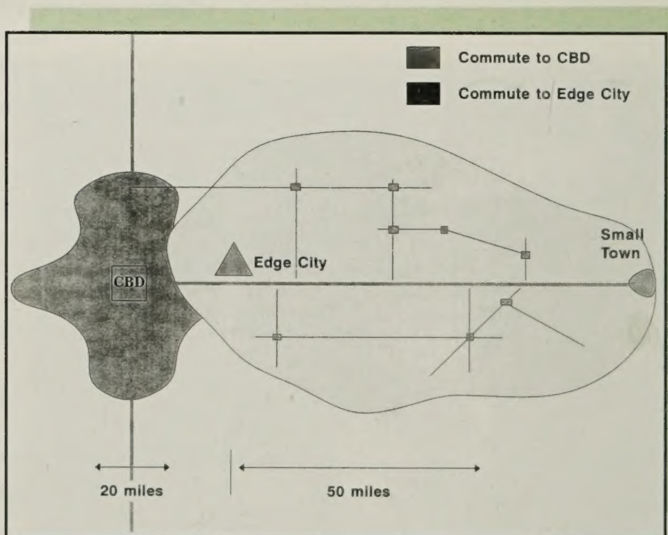
System efficiency

Joel Garreau wrote a very thought-provoking book entitled *Edge City*. The premise of the book is that most cities in this country are growing like Los Angeles, with multiple urban cores, or "edge cities." Mr. Garreau defines an edge city with two key variables: (1) at least 5 million square feet (465,000 square meters) of leasable office space, and (2) at least 600 thousand ft^2 (55,800 m^2) of retail space. Many believe that the edge city phenomena is the single largest revolution in 100 years in how we build our cities. Whether we like them or not, edge cities are a fact of life, and their growth has a phenomenal impact on transportation. For instance, much of the 30-percent increase in Vehicles Miles of Travel (VMT) that has occurred between 1983 and 1990 results from such edge cities through increased highway trip lengths and reduced ridesharing. The explosive increase in urban needs, also is at least partly attributable to this edge city phenomena.

This leads me to systems efficiency and what we should be doing with the transportation management systems ITP requires. What do we do about a VMT that is growing six times more quickly than the population? What do we do about urban needs that are doubling every 7 years? We know that we cannot build our way out. But part of the answer rests with the use of the management systems:

- Highway pavement.
- Bridges.
- Highway Safety.
- Traffic Congestion.
- Public Transportation.
- Intermodal Transportation Facilities and Systems.

I think that there is a great challenge for FHWA, the States, and local governments to make these systems work. Coordination between the six management systems is a must. The traffic con-



"Edge cities"—multiple urban cores that encourage many workers to work and reside farther from the metropolitan Central Business District—have a phenomenal impact on our transportation systems.

gestion, public transportation, and intermodal management systems appear to be the most closely related. Look at the big picture and think in terms of transportation outcomes. Cooperation among States, MPO's, and local officials is necessary. For years, we measured how well we were doing by the size of the appropriation we got at the State and Federal level or by the number of miles put into service. The concept of efficiency demands more than this. The conceptual framework for the organizations of the future will be how "smart" it is and how capable it is of understanding subtle relationships. To us, this means making systems efficient.

Another system efficiency challenge is developing an effective balance of transportation needs within a framework of probable financial constraints. At every State level, I anticipate one can find a mismatch of needs and financial resources. We must either find additional financial resources or manage the needs or both. Financial resources involve the traditional taxes or nontraditional private sector financing—value capture, toll financing, development assessments, and the like. In the needs management arena, we must identify the root causes of a problem and address them.

For example, the root causes of urban congestion are probably transportation-related only indirectly. In most cases, urban congestion is not the real problem, but only a symptom of a development management problem.

Let me illustrate using the edge city as an example. The edge city geographic area as determined by commuter patterns is very large. Commutes of 40 to 50 miles (65-80 kilometers), predominately through rural or low density, suburban countryside on farm-to-market roads are not uncommon. These long commuting trips are primarily due to the lack of affordable housing near the edge city.

Some cities, States, and metropolitan areas have recognized the edge city-transportation-affordable housing issue. Oregon, Florida, and other States are attempting to address this issue by managing infrastructure needs through growth management. Growth management has land-use implications such as better land development configurations and closer alignment of housing and employment centers.

Until we understand the underlying causes of urban congestion, we cannot begin to deal with it. If we don't begin to address the growth management-transportation issue, we are going to leave many unmet and expanding transportation needs for our children and grandchildren.

Engineering efficiency

We must do things differently. We need to bring technology on line more rapidly. This requires a real commitment to research and development and technology transfer. Another is to privatize where that makes sense.

The management systems and the balancing of needs and finances previously mentioned demand engineering efficiency. The pavement management system provides a great opportunity to achieve this efficiency. When we dovetail this management system with least annual cost principles, which include not only construction costs but also maintenance and user costs, we will probably make substantial modification in our pavement design and rehabilitation strategies. User costs associated with delays and accidents through construction zones or detours on high-volume highways increase rapidly and, if they are included in the least annual cost analysis, will probably result in more urban highway pavements being designed and/or rehabilitated for 30- to 50-year maintenance-free life.

Another engineering efficiency aspect has to do with maximizing the effective use of our transportation facilities. This includes: (1) stabilizing the flow on our freeways and arterials, thereby minimizing congestion and (2) increasing the auto and transit ridership. Projects involving High Occupancy Vehicle (HOV) lanes, ramp metering, ramp metering with HOV bypass lanes, freeway traffic control systems, areawide traffic control signal systems, changeable message signs, and roadside radio are all examples of projects where technology is available for implementation. Simple ramp metering and freeway traffic control systems can improve vehicle through-put on congested freeways in the peak hour as much as 50 percent.

Program administration efficiency

ITP gives States the opportunity to assume FHWA's oversight role for most projects not on the National Highway System. The evolution for this change in stewardship has been ongoing for many years. By focusing Federal efforts on NHS and allowing States to assume responsibility for other projects, ITP moves both FHWA and State DOT's more closely to our respective core missions.

Oversight of design and construction is really only the tip of the iceberg in terms of the possibilities that exit for achieving program efficiencies. A year ago, I worked on a Regulatory Review Task Force that sought to streamline unnecessary Federal regulations. This was part of the Administration's effort to reduce regulations and achieve regulatory reform. The experience was quite an eye-opener for me. We found plenty in the Code of Regulations for Title 23 (CFR 23) that could be streamlined or be made to work better. So, the challenge for States is twofold: (1) look at State regulations and requirements (can they be streamlined and made more efficient?) and (2) challenge the Federal rulemaking activities. FHWA should not regulate by telling you or its field offices in an over-prescriptive manner how to do something, but rather should regulate in an "empowerment" fashion, specifying the product or performance expected and not "how to do it."

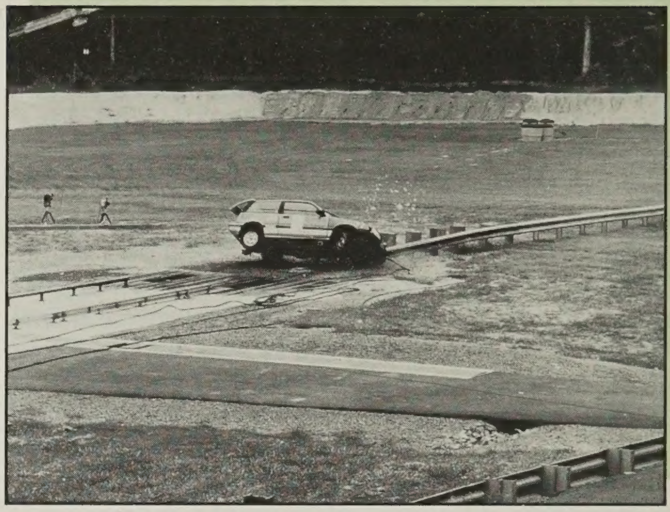
Closing

ITP challenges transportation professionals and the transportation industry to build and manage efficient, safe, cost-conscious, and environmentally sound, surface transportation facilities. These principles cannot be viewed as mutually exclusive; all must be factored into transportation decision-making at all levels of government and at every stage of the program and project development.

The final question becomes "how do we get there?" This requires money: Money for the 50-year pavement designs. Money for the international trade facilities. Money for the traffic operation systems. Money for the edge cities. Money to meet the expanding urban ground transportation needs. Money for the environmental enhancements. Money just to maintain existing transportation performance and condition levels.

But first, think about ITP and what it has done. ITP has set in motion a total restructuring of our program, how we think, act, and plan in the transportation arena. The transportation world and the general public are willing to accept these changes, but only in an atmosphere of rising funding. Full funding of ITP is vital to accomplishing changes that are embodied in ITP (as well as supporting economic vitality).

The investment portion of ITP may be the most difficult principle to achieve. The FY 1993 Federal-aid Highways obligation ceiling provides only about $4 for every $5 in ISTEA authorizations. This, in spite of an administration budget that called for nearly full ITP funding. Congress also earmarked budget authority for over $1 billion of demonstration projects that will not be delivered this year, so rather than the $18 billion Congress budgeted being spent in FY 1993, only $17 billion will be spent.



More research to develop safer highways is a priority.

The challenge and the opportunity rests with us. It begins now with making effective use of the resources we have. We must collectively stake our claim on future financing, which is at least fully funded ISTEA authorizations.

Bruce E. Cannon is the chief of the Legislation and Strategic Planning Division in the Office of Policy Development for the Federal Highway Administration. He has 40 years of experience with FHWA as an engineer and an administrator. His previous assignment was FHWA Division Administrator in Sacramento, California. He received the Federal Highway Administrator's Award. He has a civil engineering degree from Washington State University and a master of public administration degree from The American University in Washington, DC.

ISTEA

Where Are We After a Year?

On December 18, 1992, which was the first anniversary of the signing of the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) by President Bush, the Federal Highway Administrator Dr. Thomas D. Larson testified before the U.S. Senate Environment and Public Works Committee. This article is principally a summary of his official statement and remarks about the first-year efforts of the Federal Highway Administration (FHWA) to implement the legislation.

Summary of ISTEA

ISTEA is a comprehensive transportation act providing authorizations for highways, highway safety, and mass transportation for the next 6 years. Total funding of about $155 billion will be available in fiscal years 1992-1997. The purpose of the act is "to develop a National Intermodal Transportation System that is economically efficient, environmentally sound, provides the foundation for the Nation to compete in the global economy and will move people and goods in an energy efficient manner." *(1)*[1]

ISTEA has frequently been described as the most important legislation pertaining to transportation and national infrastructure since the creation of the Interstate Highway System during the Eisenhower administration. Undoubtedly, when fully implemented, ISTEA will significantly affect virtually every person living in the United States.

Intermodalism is the interface of highways, mass transit, rail, aviation, and shipping. It means that all different modes of transportation must come together to form a seamless transportation network that will allow people and products to move from one mode to the other smoothly with minimal congestion or interruption. *(2)*

Most of the ISTEA funding is earmarked for surface transportation—primarily highways. Authorizations of $121 billion are provided through programs, generally administered by FHWA, that have been dramatically restructured from previous highway law. *(1)*

Introduction

ISTEA offers a comprehensive approach to transportation problems—an approach that breaks with all precedent. It represents a change in how we do surface transportation in the United States of America. ISTEA is revolutionary because it places new emphasis on intermodalism and it affords greater flexibility to States and localities to be the primary determinants of how transportation priorities are set and how transportation monies are spent.

It is important to recognize that ISTEA requires that institutional changes take place—that old ways of doing business give way to a flexible intermodal approach that preserves the environment, enhances the safety and quality of our infrastructure, and promotes mobility. This new approach represents a paradigm shift in transportation programming where the central element moves from a concept of a "one size fits all" approach to a more flexible intermodal approach.

Change takes time; however, FHWA is aggressively moving forward to implement all the mandates of ISTEA. In spite of the massive rearrangement of programs, in fiscal year (FY) 1992 and with only 9 months available after ISTEA adoption, we had the largest obligation of transportation funding in our history—approximately $19.6 billion.

During the past year, we have had numerous outreach efforts involving State and local governments, transit operators, industry groups, environmental and citizen groups, private interest groups related to transportation, officials of toll facilities, and academic institutions. Indeed, hundreds of events have occurred in all 50 States covering all aspects of the ISTEA. In addition, we have communicated on numerous occasions with all the governors, assuring them of our cooperation in making full use of the ISTEA authorizations.

[1]Italic numbers in parenthesis identify references on page 141.

DECLARATION OF POLICY: Intermodal Surface Transportation Efficiency Act

It is the policy of the United States to develop a National Intermodal Transportation System that is economically efficient and environmentally sound, provides the foundation for the Nation to compete in the global economy, and will move people and goods in an energy efficient manner.

The National Intermodal Transportation System shall consist of all forms of transportation in a unified, interconnected manner, including the transportation systems of the future, to reduce energy consumption and air pollution while promoting economic development and supporting the Nation's preeminent position in international commerce.

The National Intermodal Transportation System shall include a National Highway System which consists of the National System of Interstate and Defense Highways and those principal arterial roads which are essential for interstate and regional commerce and travel, national defense, intermodal transfer facilities, and international commerce and border crossings.

The National Intermodal Transportation System shall include significant improvements in public transportation necessary to achieve national goals for improved air quality, energy conservation, international competitiveness, and mobility for elderly persons, persons with disabilities, and economically disadvantaged persons in urban and rural areas of the country.

The National Intermodal Transportation System shall provide access to ports and airports, the Nation's link to world commerce.

The National Intermodal Transportation System shall give special emphasis to the contributions of the transportation sectors to increased productivity growth. Social benefits must be considered with particular attention to the external benefits of reduced air pollution, reduced traffic congestion and aspects of the quality of life in the United States.

The National Intermodal Transportation System must be operated and maintained with insistent attention to the concepts of innovation, competition, energy efficiency, productivity, growth, and accountability. Practices that resulted in the lengthy and overly costly construction of the Interstate and Defense Highway System must be confronted and ceased.

The National Intermodal Transportation System shall be adapted to "intelligent vehicles," "magnetic levitation systems," and other new technologies wherever feasible and economical, with benefit cost estimates given special emphasis concerning safety consideration and techniques for cost allocation.

The National Intermodal Transportation System, where appropriate, will be financed, as regards Federal apportionments and reimbursements, by the Highway Trust Fund. Financial assistance will be provided to State and local governments and their instrumentalities to help implement national goals relating to mobility for elderly persons, persons with disabilities, and economically disadvantaged persons.

The National Intermodal Transportation System must be the centerpiece of a national investment commitment to create the new wealth of the Nation for the 21st century.

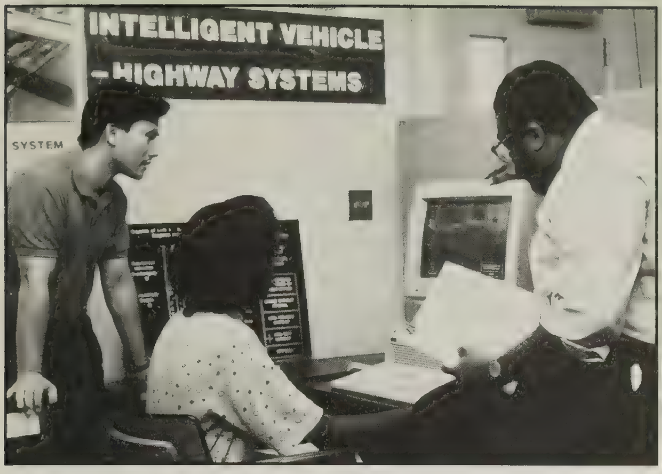
The following initiatives are critical to the success of this landmark, surface transportation legislation.

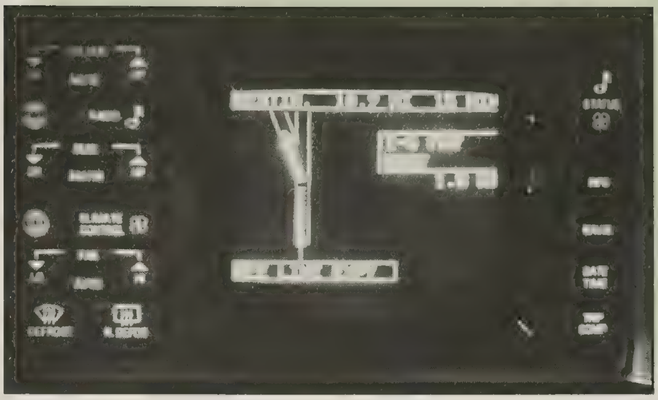
ISTEA Funding

In the year since enactment, a total of $16.9 billion of ISTEA-authorized highway funds have been obligated. The combination of this increased funding with the new intermodal flexibility provided in ISTEA will focus resources on those projects that provide us the most "bang-for-the-buck" in terms of moving people and products. Transfers in FY 1992 from highways to transit total $302.4 million.

Innovation

While increased funding is a major element of ISTEA, I must also stress ISTEA's promise for greater innovation. Over history, transportation innovation has paced major societal advances. Now—after too long a period of underemphasis on research and innovation—ISTEA is bringing progress:





IVHS will include technologies that will enhance the mobility, efficiency, and safety of the Nation's highway system.

- The United States is gaining Intelligent Vehicle-Highway Systems (IVHS) global leadership in IVHS technology and in public/private applications. (The Act established an IVHS Program, authorizing approximately $660 million over the 6-year authorization period. The IVHSProgram will include research, development, and operational tests of innovations and technologies that will enhance the mobility, efficiency, and safety of the Nation's surface transportation system.) *(3)* Major new international private markets are in the offing.

- Through global technology sharing, we are gaining technologies ranging from seismic design to pavement materials and design.

- Breakthroughs appear imminent in air quality sensors, global position satellite application, and other technologies to be transferred from the national labs.

- Highway Trust Funds are being used to support the high-speed rail transportation programs.

- Opportunities for innovative financing through tolls and public/private partnerships have been made available to States.

Reduction of Accident Rates on Highways

Transportation safety is the Department's highest priority. In 1991, approximately 41,500 people were killed in traffic-related accidents—an intolerable loss of human life. In the areas within our jurisdiction, the Department of Transportation (DOT) is working hard to reduce fatalities, injuries, and property damage caused by vehicle-related accidents. We are pleased to report that the fatal accident rates (per 100 million miles of travel) for combination vehicles, medium and heavy trucks, and all other vehicles have been continuously declining since 1980. Along with our colleagues in the National Highway Traffic Safety Administration (NHTSA), we are encouraging the development and implementation of programs in each State that have a high potential to reduce accident rates on our highways. We hope to contribute to this by enhancing safety through a number of broad-based initiatives, such as improved safety management systems mandated in ISTEA, the commercial drivers license program, stricter drug and alcohol enforcement, deployment of IVHS technology, designation of high-speed rail corridors to eliminate hazards of rail crossings, and an enhanced Motor Carrier Safety Assistance Program.

Bureau of Transportation Statistics

Secretary Card officially created the Bureau of Transportation Statistics as an independent operating administration within the Department. The Bureau is being organized around the major ac-

Transportation safety is DOT's highest priority. In 1991, more than 41,000 people were killed in traffic accidents.

Santa Teresa Border Crossing Intermodal Facility Feasibility Study

This is a jointly funded (Federal Highway Administration-$250,000; Federal Rail Administration (FRA)-$25,000; and Federal Aviation Administration (FAA)-$25,000) feasibility study of a new border crossing at Santa Teresa, New Mexico. Santa Teresa is located about 20 to 30 mi (32-48 km) west of El Paso, Texas and will relieve congested rail and highway facilities in El Paso and possibly at other locations along the Texas border. The Santa Teresa port of entry is intended to be a prototype facility using a high-tech design to accommodate the shipment of air, rail, and highway goods between the United States and Mexico.

The study is being managed by the New Mexico State Highway and Transportation Department (NMSH&TD), which has contracted with Sandia National Labs in Albuquerque, New Mexico to do the study. A steering committee has been formed to oversee the effort. It includes representatives from the NMSH&TD, FRA, FAA, FHWA, railroad interests (Santa Fe, Southern Pacific, Union Pacific, and the Ferrocarril Nacional de Mexico (FNM)), and trucking interests.

The first phase is a feasibility analysis which will look at required infrastructure costs and potential benefits and revenues to determine if the facility is financially feasible. The analysis will include expected commodity flows, general requirements of an intermodal facility, preliminary design and associated costs, revenue sources such as bonds, public and private investment, funding mechanisms, and expected revenue sources from user fees. One alternative being considered would be for the State to set up a port authority for financing and operating the facility.

The first phase was initiated in October 1991.

tivities identified in Section 6006 of ISTEA. The Bureau is working closely with other parts of the DOT and other Federal agencies to prepare an inventory of existing data resources, conduct the multimodal commodity and passenger flow surveys, design the Transportation Statistics Annual Report, represent the transportation community in planning for the year 2000 census, develop a data element dictionary for DOT, initiate the Section 6008 study with the National Academy of Sciences, and examine the data implications of ISTEA management systems.

National Highway System

The National Highway System (NHS) will be the keystone of our surface transportation network, now and for the foreseeable future. Identification, designation, and improvement of this system are essential to our economic vitality, and, more abstractly, to national unity. This is not a continuation of the Interstate era; the NHS will build on that system and will promote an even greater economic and social unification of our society than what has developed since the Interstate System was defined a half century ago. I can do no better than to cite Thomas Jefferson, as he is quoted by Merrill D. Peterson in "Thomas Jefferson and the New Nation:"

> By these operations, new channels of communication will be opened between the states; the lines of separation will disappear; their interests will be identified; and their union cemented by new and indissoluble ties. Roads and canals would knit the Union together, facilitate defense, furnish avenues of trade, break down local prejudices, and consolidate that "union of sentiment" so essential to the national polity. . .

FHWA has issued guidelines for developing a national highway system with port, airport, public transportation, intermodal facilities, and border-crossing connectivity. This connectivity is absolutely a primary function of whatever the highway system becomes for the future. Significant progress is being made to improve border crossings with Canada and Mexico. We are working on a specific project in New Mexico that would be a multimodal air, rail, and truck crossing point to accelerate crossings into Mexico.

Let there be no mistake, the NHS will not succeed unless the concept is widely endorsed. We are on track to meet the ISTEA directions of this critical program.

Intermodalism

As legislated by ISTEA, DOT established a new independent Office of Intermodalism within the Office of the Secretary, headed by the Associate Deputy Secretary of Transportation, that serves as a high-level focal point for intermodal transportation planning, both within DOT and the transportation community.

The marketplace is already moving in the intermodal direction. Our most effective, most competitive transportation companies today are integrated intermodal operators. Our surface transportation programs should be similarly evolutionary. ISTEA provides the mechanism we need to seek flexible, market-driven solutions to our intermodal transportation problems. It does so through the visionary emphasis it provides on intermodalism, by requiring active State and local participation at every stage in the formulation of policies tailored to local needs, and in the final decisions about funding priorities.

DOT wants to make certain that our institutions, regulations, and policies at the State, local, and Federal levels facilitate further movement in overcoming obstacles to intermodalism. We intend to support and pursue the efficiencies inherent in intermodal systems as a key to well-functioning and competitive American markets.

Flexibility

ISTEA is customer oriented. It provides funding flexibility to the States to spend transportation dollars on those programs, projects, and modes that are significant to the States and local governments, while focusing the Federal effort on the National Highway System. Americans want and deserve as much choice in meeting their transportation needs as can be provided. Simply put, the transportation priorities of Idaho differ from New York's priorities. Diversity among sections of our country has made this Nation great; however, this creates a significant challenge when designing a national transportation program. I believe our Nation will suffer unless we permit the States to pursue the maximum flexibility provided in ISTEA. Flexibility allows States and local governments to design and implement Federal-aid programs that meet their needs. Flexibility also means embracing opportunities to allow private sector involvement in all phases of developing, financing, constructing, owning, and operating highway facilities. We seek to foster public-private partnerships that will take advantage of the private sector's efficiencies and market-responsive innovations. Flexibility further requires that we develop a seamless intermodal transportation system.

To nurture and instill this flexibility, FHWA has created a new Intermodal Division; simplified procedures for transferring Surface Transportation Program (STP) funds between highways and transit have been developed; and an intermodal transportation research program to improve state-of-the-art intermodal passenger and freight transportation planning has been established. In FY 1992 we transferred $302.4 million of STP, Congestion Mitigation and Air Quality Improvement Program (CMAQ), and other funds from highways to transit.

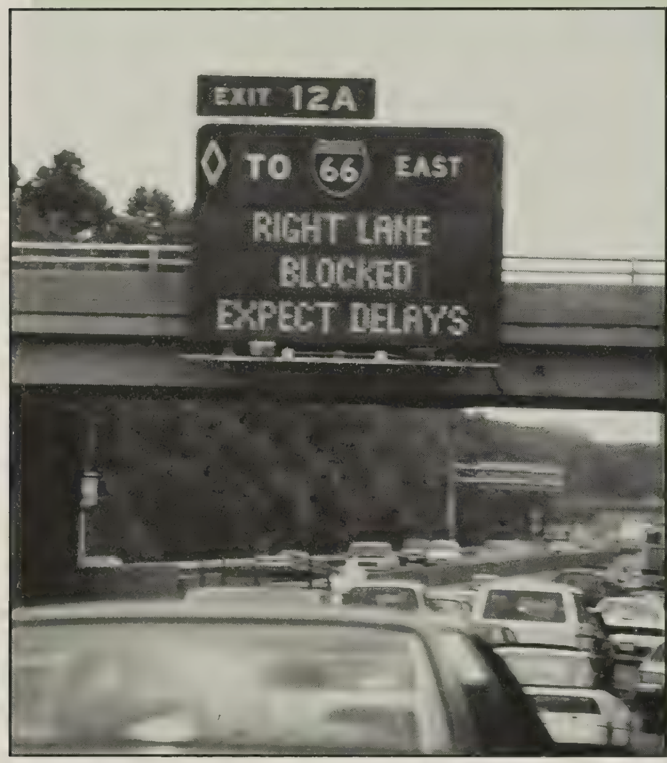
Improving Urban Mobility

"Edge Cities" are where people are increasingly living and where new centers of economic activities are developing. As anyone who commutes to work knows, in this "Edge City" era where urban centers merge with suburbia, reaching and often invading the outer edges of rural America, neither transit nor highways serve passenger and freight movements efficiently. Commuting 40 to 50 mi (65-80 km), predominantly through rural or low density suburban areas, is not uncommon for "Edge City" employees. Between 1983 and 1990, the total vehicle miles of travel (VMT) increased by approximately 30 percent even though population growth increased by only 5 percent. Much of the VMT growth, about 65 percent, is related to modal trip length, and reduced ridesharing, and is attributable to the "Edge City" phenomenon. We are encouraging an expanded research effort in this area. We believe that effective implementation of management systems and financially realistic metropolitan planning organization (MPO) transportation plans are critical to responding to "Edge City" transportation needs.

The last four FHWA biennial "Highway Conditions and Performance" reports show that rural capacity and rural urban pavement deficiencies have stabilized, reflecting sound management in these areas. Urban capacity deficiencies, however, have increased from about $15 billion annually in 1983 to over $30 billion in 1989. We believe that ISTEA's initiatives are beginning to address and promote intermodal mobility and will permit metropolitan areas to tailor solutions unique to each individual area's mobility concerns. However, crucial to this mobility and to air quality is effective management of these overwhelming urban needs. We realize that we cannot build our way out of urban congestion; we, therefore, welcome and are giving priority to the transportation management initiatives provided in ISTEA.

Congestion Mitigation and Air Quality Improvement Program

A safe, environmentally sensitive, intermodal transportation system, which reduces congestion, provides superior pavement and bridges and promotes public transportation and air quality, is the legacy that we must leave to the post-Interstate generation. ISTEA established a Con-



Reducing traffic congestion is a key to developing a safe, efficient, and environmentally sensitive intermodal transportation system.

gestion Mitigation and Air Quality Improvement Program that advances those projects or programs that are likely to contribute to the attainment of the National Ambient Air Quality Standards. In February 1992, FHWA issued interim guidance (57 Fed. Reg. 14880), and areas are already implementing a wide array of congestion mitigation and air quality projects. Other ISTEA funds may be used for these purposes.

FHWA and the Environmental Protection Agency (EPA) have a memorandum of understanding to work closely together to advance clean air and mobility. The public will never settle for a choice between clean air or mobility; they will demand both. FHWA and EPA are working to assure that the public gets both, and this may well be the biggest challenge because we are an urban society where nearly 80 percent of our people live in urban areas.

Improving Quality of Transportation Systems

Clearly we believe that improvements to the quality of our transportation systems are critical to building an enduring infrastructure in the post-Interstate era. Quality requires a continuing commitment to research. FHWA has an effort underway, termed the National Quality Initiative, which is promoting commitment to improving the quality of our Nation's highway system. As part of our commitment to quality, last month in Dallas, the American Association of State Highway and Transportation Officials (AASHTO) and FHWA cosponsored with ARTBA, AGC, American Concrete Pavement Association, National Asphalt Pavement Association, American Consulting Engineering Council, and National Ready Mixed Concrete Association, a CEO Seminar on "Partnerships for Quality." Participants agreed that, for government, product quality leads to citizen satisfaction and, for private enterprise, product quality leads to profitability.

Public/Private Partnership

ISTEA encourages States to develop new cost-sharing partnerships with the private sector. For example, ISTEA now removes barriers to use of tolls and permits tolling of most free non-Interstate Federal-aid facilities subsequent to reconstruction. Federal funds can now be leveraged with toll-based finance, and private investment can also be introduced. These opportunities to mix Federal loans and grants with various forms of toll-backed debt financing and private equity provide a range of new financial mechanisms to support a variety of improvement projects—public or private, State or local, toll or non-toll. The view that highway infrastructure is solely the responsibility of the government is changing (as it has changed several times over history). A significant number of private sector interests, including major engineering and construction firms, financial investors, and toll road operators, are seeking opportunities to take advantage of this provision and take a larger role in all phases of developing, financing, constructing, owning, and operating highway facilities.

DOT has conducted a series of conferences and seminars attended by representatives of all levels of government, academic institutions, and the private sector, and DOT produced a brochure on public-private financing that has given wide visibility to these innovative partnership opportunities to implement these new financing provisions. States must take deliberate steps to establish State transportation programs that incorporate these new tools. Several States (Arizona, California, Colorado, Florida, Missouri, Texas and Virginia) have enacted enabling legislation that permits public-private partnerships and clearly identifies the responsibilities of both the State and private parties.

Challenges

There are some particular challenges in implementing ISTEA. The Act created some extensive and significant new requirements for States and MPO's. While States and MPO's are working very hard to address the ISTEA initiatives, inadequate personnel resources and a lack of technical expertise and often minimal experience in working together could pose significant problems for the States and MPO's. Of particular concern are the abilities of States and MPO's to update their transportation plans in a comprehensive and timely manner and to develop financial resources that will enable them to implement the transportation plans. The projection of future revenues and costs appear to be especially difficult. FHWA and FTA, through our research and technical assistance programs, have initiated efforts to assist them in these areas.

In nonattainment areas, the Clean Air Act looms large and will make the task even more difficult. Changes in travel behavior may be necessary to meet air quality goals and urban mobility requirements. Finally, transportation decision-makers will have to make tough decisions on controversial Transportation Control Measures (TCM's). Strategic choices to enhance the long-term urban transportation system will be difficult but clearly essential. The easiest, short-term actions are many times not consistent with adopted longer-term objectives.

Conclusion

While many challenges in implementing ISTEA remain, the DOT is aggressively meeting these challenges and so addressing the Nation's transportation needs into the 21st century. At FHWA, we have empowered ourselves through FHWA 2000, our organizational blueprint and internal roadmap to the future. This reborn institution will help meet the nation's highway needs for safe, efficient, and environmentally sound movement of people and goods. In closing, after one year of experience we are convinced that ISTEA provides a proper roadmap leading to a sound surface transportation future for America's 21st century.

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Dr. Thomas D. Larson was the Federal Highway Administrator from August 1989 to January 1993. He also co-chaired the development and writing of the National Transportation Policy, introduced on March 8, 1990. Prior to FHWA, he served as professor and administrator at the Pennsylvania State University. He was Secretary of Transportation in the Commonwealth of Pennsylvania from 1979 to 1987. He served as president of the American Association of State Highway and Transportation Officials and chaired the National Governors' Association Task Force on New Federal Transportation Legislation. He has received numerous awards and honors including the Secretary of Transportation Gold Medal Award for Outstanding Achievement and recognition as Outstanding State Cabinet Official by the National Governors' Association. He received his B.S., M.S., and Ph.D. in civil engineering from the Pennsylvania State University, and he completed post-doctoral studies at Oklahoma State University and the Massachusetts Institute of Technology.

Pan American Partners: The Pan American Institute of Highways

by Gregory C. Speier

The Pan American Institute of Highways (PIH) is an international network of 30 technology transfer centers serving the needs of the highway community of the Americas. These centers, located in 13 countries, are working together to solve the technological needs of the Americas. The centers provide technical support to national and local governments, universities, road associations, and individuals.

Technology transfer, or technology exchange, is not easy. It is much more than a series of classes or lectures. It takes time, and it costs money. But the success of PIH demonstrates its value as a model for future international cooperation and partnerships.

This article reviews the origin and development of PIH, briefly describes some of the relationships of the centers, explains some of the needs for technology in Latin America, and considers some ways to work together.

In 1986, a number of the leaders of the highway community of the Americas met at the XVth Pan American Highway Congress (PAHC) in Mexico City, Mexico. The participants were painfully aware that the developing countries of the Americas were being buffeted by economic inflation, institutional and social stagnation, infrastructure deterioration, and technological isolation. This was the "lost decade of the 80's." Every day they were falling further and further behind their contemporaries in Europe, the United States, and Asia. Something needed to be done! They passed a resolution creating the Pan American Institute of Highways.

PIH is modeled after the Rural Technical Assistance Program (RTAP) with the objective of sharing information, documentation, and technology.

The Permanent Executive Committee of PAHC asked the Federal Highway Administration (FHWA) to take the lead to set up PIH. Under the guidance of then Federal Highway Administrator Ray Barnhart, some technology transfer specialists from the Americas and Europe met at a "Founders Conference," and a charter was established. PAHC in Montevideo, Uruguay in 1991 formally approved these actions, and FHWA agreed to serve as headquarters for the next 4 years.

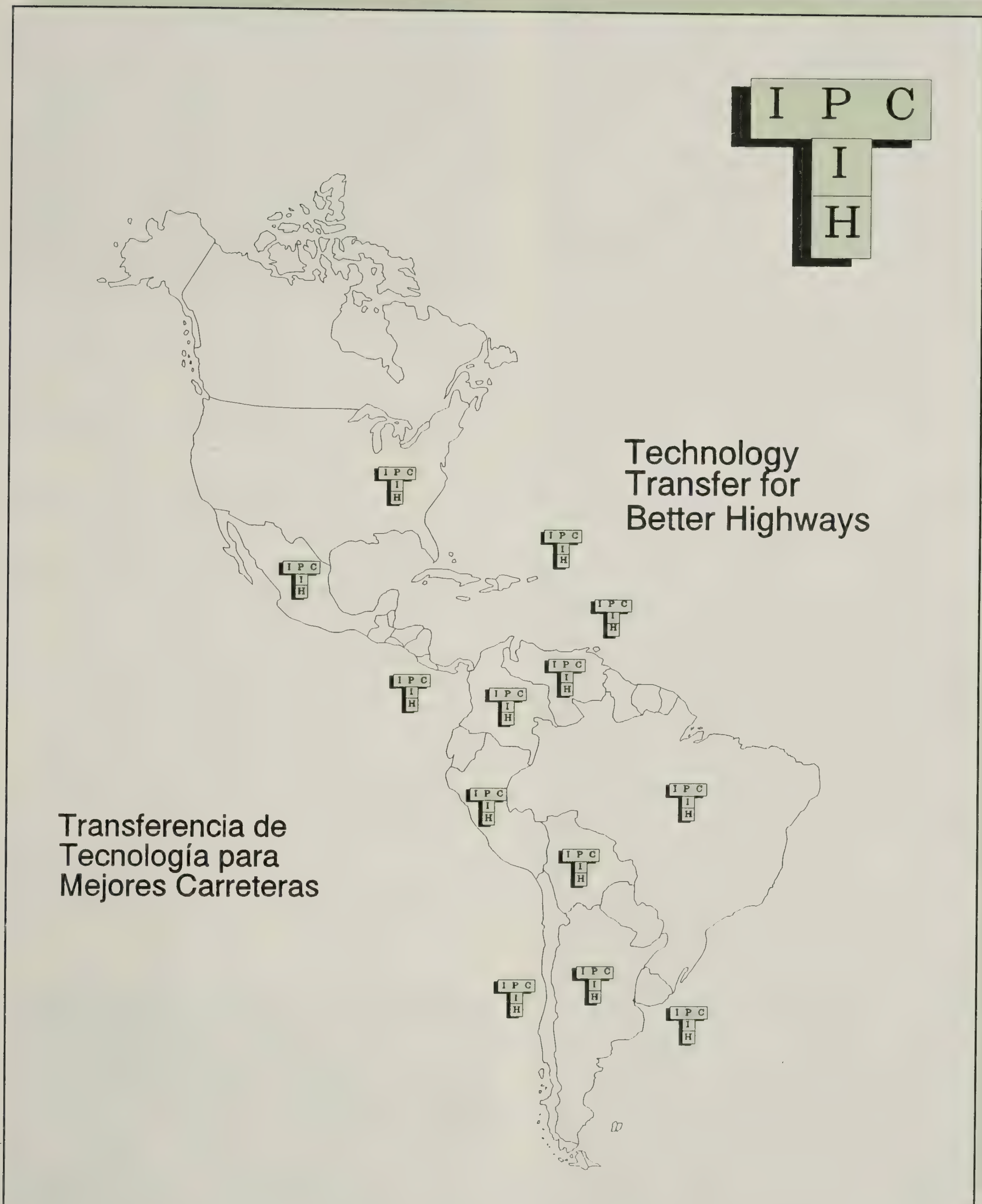
The headquarters is located at the Turner-Fairbank Highway Research Center in McLean, Virginia. The staff includes:

- Director General, FHWA, part-time (currently George Shrieves).
- Executive Director, FHWA, full-time (Gregory Speier).
- 2 Special Advisors, FHWA, part-time (William Brown and William Williams).
- 4 Technology Transfer Specialists, Contract, full-time.

The goal of PIH is to be a world-recognized, transportation-related technology transfer network serving the highway community of the Americas through the promotion and sharing of technology, materials, equipment, computer software, documentation, videos, courses, seminars, technical advice, and consultations. Thus, PIH brings the hemisphere a little closer together every day.

The centers are the backbone of PIH. The centers have laboratories, experts, document centers, and actually conduct or arrange technology transfer activities. There is a sense of community among these centers; they work together.

The centers differ in capabilities and strengths, but all make significant and complementary contributions. Some centers have experience with designing roads in mountain regions. Some have experience with environmental concerns. Some are doing research on the World Bank's



The United States and 12 Latin American countries participate in PIH.

Highway Design and Maintenance-Version III-model (HDMIII). Others are experienced in short course preparation and presentation. Some of the centers are within university settings. Some are part of the national or State highway agency. Some are road associations, and others are institutions such as cement or asphalt institutes.

PIH's bylaws allow for special recognition for centers that meet certain criteria. These centers are known as certified centers. Presently, 10 centers are certified by PIH. Certified centers must:

- Have a program of activities.
- Publish a newsletter.
- Maintain a resource list.
- Have a mailing list.
- Participate actively in the PIH network.
- Conduct an annual self-evaluation.

At first glance, it might seem like a lot of work to become a certified technology transfer center. But, certified centers are better able to serve their clients, and that is where technology transfer takes place.

PIH's goal for this year is to certify 10 more centers, but only the best centers will be certified. Certified centers are given priority for many PIH programs.

PIH is guided by an advisory committee composed of members from 10 countries. The 10 advisors represent a variety of fields of expertise within the highway community. The president of the committee is Julio Cesar Caballero, former Federal Highway Administrator of Argentina.

Technology exchange within the framework of PIH involves a number of difficulties. The Americas include 34 governments; each has its own currency, standards, and customs. There are cultural differences, immigration limitations, customs problems, and other obstacles. Communication is difficult, if not impossible, at times because PIH has four official languages—English, Spanish, French, and Portugese—requiring translation and interpretation of courses, documents, correspondence, and conversation.

Long distances must be traveled, and travel by government employees to another country often requires significant bureaucratic manuevering, sometimes including approval by the president of the country.

Training is a major element of the PIH family of activities. For example, a short course on Pavement Management was recently held in Honduras. The instructors were two young Uruguayan engineers who have been studying in Phoenix, Arizona.

PIH sent a concrete specialist from Cordoba, Argentina to San Jose, Costa Rica to share Argentina's experience with roller-compacted concrete. A geotechnical expert from Texas went to a number of countries to explain slope stability and slide restoration. When a maintenance need is identified, PIH sends a specialist to share knowledge.

The PIH course catalog lists 115 courses and seminars from 16 centers in 10 countries. These courses are ready to be used. For example, re-

The Mendoza (Argentina) to Santiago (Chile) Highway has 17 hairpin curves.

Engineers from PIH headquarters, Uruguay, and Chile discuss reinforced-earth concepts in New York.

Greg Speier examines a specimen from a project conducted by the University of West Indies in Trinidad and Tobago to test timber bridge components.

cently, PIH sent a team of specialists from Chile and Colombia to share their experience in a seminar in Venezuela. The catalog, printed in Spanish and in English, is available from PIH headquarters.

A second way to use the course catalog is to contact the responsible person listed for each course and to send one or two people from your organization to the place where the course is to be taught. Most of the centers will not charge a registration fee for an international participant. In fact, it is frequently the case that technical visits can be added to the trip agenda.

One other way to use PIH experts is to have them train others how to teach the material. For example, the center in Rosario, Argentina is conducting a course on drainage structures. PIH sent an expert from FHWA to share computer applications related to this subject. He shared his knowledge with the students, and he also taught professors at the university how to use the programs and how to teach the material. In this way, PIH enhances its ability to transfer technological information more efficiently.

In 1993, PIH plans to conduct more than 40 training sessions.

A popular program is the "Loaned Staff Program." In this program, young engineers, and some not so young, are sent for assignments of 1 to 12 months at other centers. The host center is responsible for living expenses, and the releasing center is responsible for salary. Presently, an engineer from Brazil is learning highway safety with FHWA, and an engineer from Uruguay is working with one of the U.S. technology transfer centers. An engineer from Costa Rica worked with PIH headquarters learning how

Bridge construction in Chile.

to organize and conduct training activities in an international arena, and an engineer from Colombia is learning highway information systems management. Exchanges of this nature bring us closer together and help us to solve mutual problems in new and different ways.

One of the technology transfer centers in Chile has agreed to operate a video lending library for all of PIH. This center will publish a list of available video tapes dealing with all aspects of highway maintenance. PIH members will only have to write, requesting a copy of the video in which they are interested. This method of sharing technology is a very productive and low-cost approach to solving our maintenance problems because the videos can be shown to many audiences in many locations. The equipment for editing and duplicating video tapes was provided by the International Road Federation. Presently, FHWA has a contract with the University of Texas to translate into Spanish a number of the most popular maintenance videotapes used in the United States.

This unique bridge is in Uruguay.

PIH has its own newsletter. This newsletter includes a calendar of events of interest to PIH members. The mailing list includes over 1,000 engineers and technicians.

Many of the PIH centers are involved in research activities, and PIH is conducting a survey to determine which research should be done and what is needed to enhance the research already underway. A report on this activity will be prepared in March.

What is needed in our countries today? PIH is attempting to devote 40 to 60 percent of its efforts to enhance maintenance of existing infrastructure. Traditional maintenance technologies can be taught to engineers and technicians through short courses, seminars, video courses, and on-the-job training. This type of training is never finished because new methods are developed and new staff are employed.

Mid-level managers need to be trained in the management technologies, and these technologies need to be implemented as soon as possible because these, in the long run, will save money. Among these are maintenance management, equipment management, bridge management, and highway information management technologies. PIH will try to devote from 20 to 40 percent of its training funds to this endeavor.

Whatever is left, perhaps 15 to 25 percent of the efforts, should be directed towards new technologies including personnel management, marketing, environmental and safety considerations, and new construction techniques.

Technology transfer is in itself a technology. It is not an easy task to organize, conduct, evaluate, and manage a series of technology transfer activities. Look at the more successful organizations of the world, and find out how much money they spend on training and preparing their employees. Should highway organizations be any different?

"Absurd" has been defined as "to continue acting in the same way, over and over again, expecting different results." PIH is an agent of change. Therefore, training opportunities must be provided for maintenance forces, making it possible for the young managers of our organizations to learn new management technologies. Top-level managers must be shown what can be done differently and how that will provide different results.

One problem for engineers is that they are trained to solve problems, and often they try to solve problems that have already been solved. For example, six countries were researching the World Bank HDMIII model. They were not aware that each of the other countries was doing the same research to adjust values to country-specific conditions. They are now sharing their results. Similar things happen in pavement design and structure design. We need to share what we are doing and to stop reinventing the wheel!

To do this, we must encourage contacts with other agencies and other countries. We must entwine our institutions. Initially, this will cost money, but in the long run it will be cost-efficient.

PIH is not a large building or infrastructure. PIH belongs to the members. Although PIH is headquartered at the Turner-Fairbank Highway Research Center, the headquarters' records and equipment belong to PIH and can be moved to a different headquarters in any of the countries at any time. PIH is an agent of change dedicated to working together to manage the transfer of technology.

Roller-compacted concrete test section in Cordoba, Argentina.

Individual membership is $10 per year, and institutional membership is $100 per year. Sponsoring members can contribute as much as they want. For a brochure on PIH and how to become a member, contact Enrique Ordoñez, HHI-20, 6300 Georgetown Pike, McLean, Virginia 22101-2296.

What does PIH offer to the highway community of the Americas? PIH offers excellence. PIH courses are offered with a money back guarantee of satisfaction. PIH offers the opportunity to interact with colleagues from all over the Americas, solving problems together, learning from each other, and helping each other. PIH provides its members direct access to the highway community of the world through its contacts with the International Road Federation, the Permanent International Association of Road Congresses, the Organisation of Economic Co-operation and Development, and others. Working together we can save resources and enhance our work and success.

Gregory (Greg) C. Speier, P.E., has been the executive director of the Pan American Institute of Highways for 4 years. He is a career highway engineer with the Federal Highway Administration. For 5 years, he worked in FHWA's Office of International Programs, during which time the plan for establishing and implementing PIH was developed in cooperation with the Latin American countries. He served overseas as an engineer in Puerto Rico and Vietnam. He earned his Bachelor of Science degree in Civil Engineering from the University of Puerto Rico in Mayaguez, and he is registered as a professional engineer in Kentucky.

Highway Applications of EXPERT SYSTEMS

by James A. Wentworth

Introduction

Expert systems have gained acceptance in many fields, ranging from aerospace engineering to finance, but they have not gained widespread application in highway engineering. There are many areas where expert systems could be of substantial value in highways. This article will attempt to briefly summarize what expert systems are, current applications in highway engineering and operations, make observations about expert systems and their applications, and comment on current research and future use of expert systems.

Expert systems are computer programs that incorporate: (1) reasoning and problem-solving processes of human experts (heuristic problem solving) and (2) specialized knowledge of experts (experience). The goals of expert systems are usually more ambitious than those of conventional or algorithmic programs because expert systems frequently perform not only as problem solvers but also as intelligent assistants and training aids. Expert systems have great potential for capturing the knowledge and experience of current senior professionals (many of whom are approaching retirement age) and making their wisdom available to others in the

Table 1.—Conventional programs vs. expert systems *(1,2,3)*[1]

Conventional Program	Expert System
Stated equations that can be proven. If correct numerical data is provided, a correct answer will result.	Usually based on rules of thumb (or other knowledge-representation schemes) that are generally reliable, but not always correct. These are concepts that cannot be reduced to formulas or numbers.
Provides answers only.	Can explain its logic and reasoning.
Needs all data called for to operate.	Can function with incomplete data.
Often developed by programmers in isolation from domain experts and users.	Development team includes knowledge engineers, domain experts, and usually end users by definition.
May be extremely difficult to examine imbedded knowledge.	Provides capability to examine knowledge base.
Problem solver.	Problem solver, intelligent assistant, and trainer - all interactive.
Need for computer resources is well defined.	Need for computer resources is less clearly defined but may be significantly greater than for conventional program.

[1]Italic numbers in parentheses identify references on page 152.

form of training aids or technical support tools. Applications include design, operations, inspection, maintenance, training, and many others.

Existing operational expert systems have already demonstrated the feasibility of highway applications. These systems include FRED (Freeway Realtime Expert System Demonstration), which is a real-time prototype for managing nonrecurring congestion on urban freeways in Southern California, and ERASMUS, a pavement assessment and rehabilitation system that is operational on 35 sites in France. Other developed systems such as FASTBRID (Fatigue Assessment of STeel BRIDges) and WZTS (Work Zone Safety Training System) show that fully integrated decision-aid/training systems are both possible and practical.

Description of the Technology

Expert systems differ from conventional programs in the way they store and use information. In a conventional program, the operations never vary as they are predetermined by the programmer. The conventional program contains precisely defined logical formulas and data, and if any data element is missing, the program will not run. The expert system, like the human expert, contains heuristic information and can function with incomplete information. Some of the major differences between conventional programs and expert systems are shown in table 1.

Current Applications in Highways

While applications in highway design, engineering, and operations have not gained the wide acceptance that expert systems have achieved in other fields, they are increasing in use. The results of a recent survey, conducted by the Organisation of Economic Co-operation and Development (OECD) in Paris, provided information on 90 expert systems in various stages of operation and development. This survey represents only a portion of expert systems actually developed.

The systems included in the OECD survey are classified by function in four very broad groups:

- *Traffic management and control*—systems developed to advise or assist with traffic management and control operations, such as diagnostics of traffic problems from sensor data, incident detection, signs, and signals.

- *Traffic impact and safety*—systems for evaluating ways of reducing the impact of traffic, such as noise control, safety work zone layout, accident investigation, etc.

- *Highway design and planning*—systems designed to assist with roadway design and to analyze roadway needs and problems, such as geometrics, landslide forecasting, and drainage.

- *Highway management*—systems to assist with roadway maintenance, operation, and decision-making, including pavement maintenance, bridge deck repair, and bridge painting strategies.

The systems reported were also grouped according to the category of problem. For the purposes of this report the categories were: *(2)*

- *Diagnosis/monitoring.* The basic goal of diagnosis/monitoring is to catalog a system's characteristics (deterioration, malfunction, etc.) into a specific cause or set of causes and from this develop solutions, i.e., what is wrong and what should be done about it. Monitoring can be considered to be real-time diagnosis. They are similar in terms of the problems and the complexities involved in developing the expert system.

- *Interpretation/classifying.* This class of system compares a situation with a set of known conditions and looks for matches. Expert systems that solve problems in this area are designed to model the pattern-matching ability of someone who is an expert in identifying features or characteristics in the problem domain.

- *Prediction/forecasting.* The goal of this class of system is to forecast future conditions based on existing conditions and a knowledge of past conditions.

- *Design/planning.* This type of system specifies how something should be built (design) or a prescribed set of actions to meet a goal (planning). In most examples developed to date, this consists of providing detailed specifications for a generic design or plan.

Table 2 shows the systems grouped by category and function. This table depicts expert systems that are in active use, in test and evaluation, or in development in 12 different OECD countries. All of the systems represented are either successful operational systems or potentially useful systems under development.

The heavy emphasis on highway management with diagnosis/monitoring systems and on highway design and planning with design/planning systems is apparent. This does accurately reflect needs in the highway community where

Table 2.—Reported expert systems

CATEGORY / FUNCTION	(a) Diagnosis/ monitoring	(b) Interpretation/ classifying	(c) Prediction/ forecasting	(d) Design/ planning
I. Traffic Monitoring and Control	5	6		4
II. Traffic Impact and Safety	3	7	3	3
III. Highway Design and Planning	2	5		16
IV. Highway Management	23	8		5

funding and staff are often inadequate and the problems cannot be ignored or deferred.

Several observations and conclusions can be drawn from the responses to the OECD questionnaire.

- The expert systems reported appear to be more developer-driven than user-demanded. This is to be expected in any relatively young technology; however, there is gradual acceptance of expert systems by the user work force.

- PC-based expert systems are far more common than workstation- or mainframe-based systems. There are very few Macintosh-based systems. The reason for this situation is obviously the availability of PC's and PC-based development tools. There are, however, increasing numbers of expert systems being developed on higher level workstations and then being ported to PC's. Of the systems reported, about 80 percent were PC-based with the balance divided between workstations and mainframes (15 and 5 percent, respectively).

- The integration of knowledge-based expert systems with algorithmic systems and data bases and other technologies is firmly entrenched as a practice. Many of the existing systems are hybrid systems where the knowledge-based expert system interacts with external programs and data bases or is only one component of a larger system.

From the OECD survey *(4)*, major expert systems conferences—in Paris *(5)*, Espoo, Finland *(6)*, Avignon, France *(7)*, and Montreal *(8)*—and other sources, several additional observations can be made:

- Currently available development tools are adequate for building expert systems in both basic and complex technical areas of highway engineering and operations.

- Fully integrated decision-aid/training systems are both possible and practical by combining expert systems with interactive videodisc training systems and other conventional media.

- The time and cost of developing and implementing expert systems is high compared to the time and cost required for developing and implementing algorithmic systems of a comparable magnitude. The time and cost are expected to decrease as development tools mature and as procedures for the verification, validation, and evaluation of expert systems are refined.

Observations more specific to the problems faced during the development, testing, and application of expert systems include:

- Structured planning is recommended for the successful development of a system. This should include the problem/need and the system's *benefits, organizational risk factors, technical risk factors,* and *user risk factors.*

- Management support in the institution sponsoring the development of the expert system is necessary. This support must include the commitment of both staff and financial resources to successfully develop and implement the system. Full knowledge and understanding of the costs, benefits, and risks is essential.

- The end user is pivotal to the development of expert systems and must be involved from the planning through the field evaluation stages. The end user provides definition of the skill level of the user community, information on how problems are addressed in practice versus the prescribed solutions, advice on how the system must function (interact with the user) to be accepted by the user community, and a cadre of supporters to test and promote the system once it is completed.

- Knowledge from the experts is vital throughout the development of the expert system. It is vital both in terms of building the system and for maintaining interest and continuity throughout the project.

- Reliability and ease of maintenance must be considered in all phases of the system development. Since the maintenance will probably not be performed by the developers, the system structure must be clear and straightforward. Logical and understandable names should be used for objects and knowledge structures within the system. Clear and complete system documentation is required for effective maintenance.

- The selection of the development tool for an expert system project should be performed by a qualified knowledge engineer or expert systems developer. This is critical because the tools have significant differences that are not explained in available literature and because an application should be keyed to the specific knowledge-handling and operational characteristics of a development tool.

Future Directions

Several of the expert systems currently under development should further demonstrate the value of expert systems and the variety of problems that can be addressed using them. For example, a small expert system is under development to diagnose signals from an inductive loop detector tester; when completed, the system will demonstrate the practicality of imbedding an expert system in testing hardware. Other current applications range from bridge rail retrofit design systems to pavement management systems to freeway incident management systems. There are numerous potential applications in the Intelligent Vehicle-Highway Systems (IVHS) Program.

One of the technical factors slowing the development and fielding of expert systems is the difficulty in testing these systems. There is little agreement among experts on how to accomplish verification (Is the system built right?), validation (Is it the right system?), and evaluation (Is the system valuable?) of expert systems. C. Green and M. Keys describe the vicious circle where "nobody requires expert system validation and verification, so nobody does it. Since nobody knows how to do it, nobody requires it." *(9)* One of the causes for this lack of agreement, and thus lack of accepted methodology, is the "combinatorial explosion" of possible solutions resulting from the execution of an expert system. The six-step solution proposed by J. Geissman and R. Schultz offers an approach to the validation and verification of expert systems, but it does not really address the complexity of the solution state space and offer processes to design field tests. *(10)* Fundamental research on these issues has been conducted through NASA, and applied research is being initiated by FHWA. *(11)*

New series of tools, including expert systems as one component, are in the planning phases. One example of such a hybrid system is a voice-actuated tool to assist the construction inspector. The system will use a highly portable (wearable) PC as the host and incorporate a voice data input module, a visual display, a voice-generation module, and a report generator. The system is also expected to provide a pre-inspection refresher course to the inspector based on information contained in the expert system and stored graphic images.

Two areas of opportunity that are not receiving adequate attention are expert systems as training aids and intelligent data bases. The increasing potential for such systems, especially intelligent data bases, is generating a great deal of interest.

For a variety of reasons, not all of which are technical, expert systems have not achieved their potential in highway engineering and operations. However, the outlook for expert systems is quite optimistic, and the possibilities for greatly increased productivity are astounding.

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Benefit-Cost Analysis of Lane Marking

by Dr. Ted R. Miller

Abstract

Pavement markings save lives and reduce congestion. This article, based on a study funded by The American Glass Bead Manufacturers Association, presents a benefit-cost analysis of edgelines, centerlines, and lane lines. The analysis considers markings applied with fast-drying paint or thermoplastic, the most frequently used marking materials in the United States. A literature review and telephone survey suggested striping with fast-drying paint costs $.035 per linear foot ($.11 per meter) in rural areas and $.07/lin ft ($.23/m) in urban areas. Thermoplastic lines cost more than painted ones, but can have lower life-cycle costs; in areas where snowplowing is unnecessary, they have longer lives.

Published literature suggests that existing longitudinal pavement markings reduce crashes by 21 percent, and edgelines on rural two-lane highways reduce crashes by 8 percent. Applying these percentages to published aggregate crash costs by roadway type yields the safety benefits. The analysis assumes markings improve traffic flow during the 6 a.m. to 7 p.m. period on arterials, freeways, and Interstate highways, increasing average speeds by 2 mi/h (3.2 km/h).

On average, each $1 currently spent on pavement striping yields $60 in benefits. The benefit-cost ratio rises with traffic volume. The urban ratio is double the rural ratio. Sensitivity analysis shows the benefit-cost ratios are robust. Where striping reduces congestion, the travel time savings alone yield a positive benefit-cost ratio for striping. Most highways already have a full complement of lines. Rural two-lane highways, however, sometimes lack edgelines. Edgelines on these roads will yield benefits exceeding their costs if an average of one nonintersection crash occurs annually every 15.5 miles (25 km) of roadway.

Introduction

Driving down a dark road on a misty night is never pleasant. The only comfort comes from centerlines and edgelines. These pavement markings, along with lane lines, are important driving aids. The driver's manual advises watching the edgeline when blinded by oncoming headlights. Lane lines organize vehicles into efficient lanes on multilane roads. Centerlines help oncoming vehicles to avoid collisions. Even in daylight, pavement markings make it possible for vehicles to travel more safely and quickly. They reduce congestion and raise roadway capacity.

This article probes the costs and benefits of roadway pavement markings. It restricts itself to edgelines, centerlines, and lane lines—the longitudinal lines that run parallel to traffic. It shows

Because of beads in the paint, light is reflected back to the driver. Note the double yellow centerline and left edgeline show up well; the right edgeline does not show up either because it is not marked or it too worn to reflect light.

This is a typical two-lane road with good centerline and edgeline markings.

that existing markings on different classes of roads have benefit-cost ratios ranging from 21 to 103. Most roads already have a full complement of lines. Some rural two-lane highways, however, lack edgelines; a few even lack centerlines. Edgelines would be cost-effective on a mile of rural two-lane highway if one crash occurred outside the roadway every 15.5 years.

Marking Media

Longitudinal pavement markings typically are applied using a liquid marking medium or binder that is visible during the day. The medium binds glass beads that make the lines visible when headlights shine on them at night. The principle underlying night visibility is retroreflectivity. Retroreflection means light reflects off the binder-coated backs of the beads and is returned to its source. Because the beads are almost perfectly round, the retroreflected light is concentrated in a small angle of return, making the marking conspicuous.

Existing binders include fast-drying, high-solvent paint; latex paint; thermoplastic; epoxy; and polyester. Some markings also are applied using preformed tape. This article computes benefit-cost ratios for the marking media that historically captured the largest market shares: high-solvent paint and thermoplastic. Other media, especially latex paint, have gained market share recently.

Fast-drying, high-solvent paint has dominated the U.S. market for many years. It is inexpensive to buy and apply. Because it dries very quickly, a trailing vehicle moving at 10 to 15 mi/h (16-25 km/h) can prevent traffic from tracking the newly applied paint. High-solvent paint has two drawbacks: a short life, often as little as 6 to 12 months, and environmentally damaging solvent emissions during application.

The newer latex paints are water-borne rather than solvent-borne. Thus, they avoid emission problems. Most latex formulations dry more slowly than high-solvent paint; typically, application proceeds at 5 mi/h (8 km/h).

Thermoplastic has captured roughly one-eighth of the U.S. striping market. Although costly to buy and apply, it has a long life—4 to 7 years. Thermoplastic lines are much thicker than painted lines, which makes them more vulnerable to snowplow damage. Contractors apply most of the thermoplastic in most States.

Benefit-Cost Equation

The benefit-cost ratio computed in this article equals the monetized benefits from pavement marking divided by the marking costs. Let B equal the benefits expected per year from pavement marking and C equal the annualized marking costs. Then the benefit-cost ratio is:

(1) $BCR = B/C.$

The benefits include both increased safety and reduced travel time benefits.

The next section of this article discusses marking costs. Subsequent sections describe the safety benefits, the travel time benefits, and benefit-cost ratios by roadway class.

Unit Costs of Marking

Pavement markings rarely require maintenance between reapplications. Their useful life can range from 6 months to 7 years depending on the marking medium, traffic volume, location (with lane lines and centerlines requiring more frequent replacement than edgelines), and snowplowing (with plowing to bare road causing rapid deterioration). The annualized application costs are:

(2) $C = M + P + E + ADMIN,$

where M = annualized materials costs, including binder, beads, and fuel.
P = annualized personnel costs, including wages, fringe benefits, and per diem when crews are absent from home overnight.
E = annualized costs of equipment and storage facilities.
ADMIN = annualized contract letting, monitoring, and other administrative costs.

Table 1.—Costs per foot for pavement marking (inflated to December 1990 dollars using the Consumer Price Index, all items)

Source	Year	High VOC Paint		Thermoplastic	
		Avg.	Range	Avg.	Range
Henry et al. *(15)*, 14 States	1988	$.035	$.02-.055	$.35	$.17-.60
Aurand et al. *(11)*, 9 States, 6 manufacturers	1988	.035	.17		
Hughes et al. *(16)*, State survey	1983	.035	.02-.07		
Attaway et al. *(17)*, NC	1988		.03-.045		.28-.40
Mendola *(18)*, NJ	1988				.15-.28
DePaulo *(19)*, Ohio	1988	.035	.035-.04		
SASTHO *(20)*, 14 States	1991	.035	.02-.05	.24	.12-.40
California	1990	.035	.10 Contr	.26	
Colorado	1991	.04	.055 Contr	.40	
Florida	1991	.04	.08 Contr		.25-.35
Illinois	1991	.02		.37 Chicago	
Los Angeles, CA	1991	.06		.28	
Maine	1991	.035			
Maryland/Virginia Contractor	1991	.32			.30-.50
Montana Contractor	1991		.04-.045		
North Carolina	1991	.03	.09 Contr	.35	
Phoenix, AZ	1991	.07	.085 Contr	.29	
Texas	1991		.035 Rur, .07 Urb	.35	.22-.45

The annualized costs include multiple applications where the useful life is less than 1 year. The annualization multipliers used were capital recovery factors computed using the formula in *Economic Analysis for Highways. (1)*[1] The analysis used a discount rate (present value factor) of 4 percent. That rate is recommended for use in analyzing highway safety countermeasures with lives less than 5 years. *(2)* Sensitivity analysis examined the benefit-cost ratio at a 10-percent discount rate.

This article drew data on marking costs from a literature review and a telephone survey. Table 1 summarizes the cost estimates per application. The top panel in the table shows published estimates; the bottom panel shows estimates from our telephone survey. Typically, the installed cost of high-solvent paint is $.035/lin ft ($.11/m) of 4-in (101.6-mm) stripe in rural areas and $.07/lin ft ($.23/m) in urban areas (in 1991 dollars).

Thermoplastic costs vary widely, ranging from $.15 to $.40/lin ft ($.49 to $1.31/m). The average is $.32/lin ft ($1.05/m). Reasons suggested by the telephone survey for the wide variation include:

- Thermoplastic lines range from 60 mils to 120 mils in thickness (with corresponding differences in materials cost and useful life).
- The war-related surge in oil prices at least temporarily raised materials costs.
- Contractor availability varies. Prices are higher where contractors are scarce.
- Thermoplastic is produced primarily in southern and western factories. Shipping it elsewhere is costly.
- Thermoplastic costs are sensitive to propane costs, which vary regionally. (The propane is used to heat and agitate the thermoplastic.)

Rural-urban variation

Most published costs are State averages. They mask substantial variability. Costs are low in suburban and rural areas where day-long striping will not disrupt traffic significantly. Urban striping costs often are higher. Reasons suggested by the telephone survey for higher urban costs are:

[1]Italic numbers in parentheses identify references on page 162.

- The striping day is short to avoid delaying rush-hour traffic.

- Striping roads with day-long congestion requires extra staff and equipment to control traffic.

- More time and care are required because the longitudinal pavement markings have to mesh with numerous crosswalks, stop lines, and other special markings.

Comparing costs between striping media requires caution. The costs for high-solvent paint in table 1 assume lines will retrace existing lines. Such restriping generally is done by State forces. Striping after repaving or chip sealing requires premarking to establish line locations. This costs perhaps $.005 to $.01/lin ft ($.016 to $.033/m). The paving contract generally includes premarking and striping. Since striping usually is subcontracted, contract costs include two tiers of administrative expenses and profits. Unlike painting contracts, thermoplastic contracts often are first-tier contracts.

The contract paint and thermoplastic costs in table 1 exclude the costs of contract letting and monitoring. The Texas Department of Transportation (DOT) estimated these costs at 5 percent of the contract price. The North Carolina DOT, which inspects more extensively than most, estimated the costs at 7 percent.

Values used

The analysis uses the following marking costs and material lives:

- $.035/lin ft ($.11/m) rural and $.07/lin ft ($.23/m) urban for high-solvent paint, with restriping every 6 months on Interstates, other freeways, and major urban arterials and annually on other roads. At a 4-percent discount rate, the annualized costs per mile are $381 ($236/km) for rural Interstates, $192 ($119/km) for other rural roads, $762 ($473/km) for urban freeways and major arterials, and $385 ($239/km) for other urban roads. For striping plus premarking by contractors every 7th year, the cost is $.09/lin ft ($.30/m), implying an annualized premarking premium of $49/mi ($30/km) rural and $18/mi ($11/km) urban. Including the premarking cost, for example, the annualized costs per mile on most rural roads total $241 ($150/km). These costs assume all lines are solid single stripes. The sensitivity analysis examines an alternative assumption.

- $.26/lin ft ($.85/m) rural and $.33/lin ft ($1.08/m) urban for thermoplastic, with restriping every 5 years. Where climate is appropriate for thermoplastic, State materials choices suggest its life cycle costs are competitive with high-solvent paint if average daily traffic exceeds roughly 2,500. The annualized costs per mile are $308 ($191/km) rural and $391 ($243/km) urban.

Miles striped

The miles striped by roadway type and land use were computed using data on number of lanes by roadway mileage. *(3)* Undivided highways require one edge or lane line per lane plus a centerline. For example, a four-lane highway requires two edgelines, two lane lines, and a centerline; a six-lane highway requires two additional lane lines. Each side of a divided highway requires one edge or lane line per lane plus an additional edgeline. Line mileage was computed using the following assumptions:

Table 2.—Line miles and crash costs by roadway functional class and land use, excluding local streets (costs in millions of December 1990 dollars)

Road Type	Urban Line-Miles	Urban Costs	Rural Line-Miles	Rural Costs
Interstate	84,520	$12,230	201,525	$10,489
Other Freeway	51,187	6,602	0	0
Major Arterial	238,852	58,260	303,499	23,102
Minor Arterial	270,822	41,963	460,750	23,094
Major Collector	245,512	17,136	1,321,942	30,330
Minor Collector	0	0	886,192	14,642
Total	890,893	$136,191	3,173,908	$101,657

1 mi = 1.61 km

- Divided Interstate highways with more than four lanes have an average of seven lanes in urban areas and six lanes in rural areas.

- Other divided urban freeways with four or more lanes averaged five lanes. Divided major arterials averaged 4.5 lanes.

- Almost all other divided roads with four or more lanes had four lanes.

- Undivided roads with more than two lanes averaged four lanes.

The first column of data in table 2 shows the line-miles by roadway functional class (excluding local streets, which rarely are wide enough or traveled heavily enough to stripe) and rural-urban land use. Rural roads, primarily major collectors, account for more than 75 percent of the line-miles.

Benefits of Marking

The benefits of marking, B in equation (1), are the present value of the sum of the annual benefits. The benefits for a 1-mi road segment are:

(3) $B = A*R*CS + V*T*(1/S_o-1/S)$,

where
- A = crashes per year on the road segment.
- R = fractional reduction in crashes expected due to marking.
- CS = cost savings per crash prevented.
- V = annual traffic volume on the road segment.
- T = the value of one vehicle-hour of travel time.
- S_o = average speed on the road segment before marking.
- S = average speed on the road segment after marking.
- * = multiplication sign.

Cost savings of crash prevention

Safety benefits—the crash cost savings were adapted from *The Costs of Highway Crashes. (4)* They include medical, emergency services, workplace, legal, property damage, travel delay, and administrative costs, as well as lost wages/household production, pain and suffering, and lost quality of life. The benefit values were derived using the method dictated by the Federal Highway Administration (FHWA) and the U.S. Office of Management and Budget for valuing life-saving benefits. *(5,6)*

The analysis by roadway functional class (e.g., rural Interstate, urban arterial) uses total crash costs by road type and land use from *The Costs of Highway Crashes. (4)* Total crash costs equal A*CS. The second data column in table 2 summarizes the costs. The cost savings equal these costs times R.

To analyze striping benefits for rural two-lane roads in more detail, the nonfatal injury benefits were tailored to the injury distribution for related crashes. These include crashes with first harmful events outside the roadway, plus head-on crashes. The injury distribution was computed using 1984 National Accident Sampling System data.

The related crashes are costly. The average benefit per related crash prevented, including fatal crashes and property damage only (PDO) crashes, is $95,000 (in December 1990 dollars). The benefits are $3,079,000 per fatal crash prevented and $154,000 per injury crash prevented. By comparison, *The Costs of Highway Crashes* reports that the average benefits of crash prevention are $48,000 for a police-reported crash and $79,000 for a police-reported injury crash. *(4)*

The safety benefits are for a 4-percent discount rate. For sensitivity analysis, benefits at 10 percent were taken from unpublished tables. *(4)*

Table 3 compares the costs per injury by police-reported severity at 4-percent and 10-percent discount rates. The nonfatal injury costs with a 10-percent discount rate are higher—an apparent anomaly. This occurs for two reasons. First, the value placed on the sum of lifetime earnings and quality of life is computed independently of the discount rate, using the method prescribed by the Office of Management and Budget. The sum equals $2.5 million in December 1990 dollars. Although earnings losses are less at a higher discount rate, because the sum is a constant, the value placed on lost quality of life rises by an offsetting amount. Second, to value the lost quality of life resulting from nonfatal injury, the discount rate was applied to compute a value per life year for lost quality of life. At a 4-percent discount rate, the loss per year equals the total loss divided by 20.8; at 10 percent, it equals the total divided by 10.2. Since nonfatal injuries predominantly affect quality of life in the year of the injury, the much higher value for a year of lost quality of life yields a higher average injury cost, even though costs in future years have a lower present value at the higher discount rate. *(4,6)*

Table 3.—Costs of an injury by police-reported severity and discount rate (inflated to December 1990 dollars) *(4)*

Police-Reported Severity	Cost by Discount Rate 4%	10%
K - Fatal Injury	$2,392,742	$2,360,330
A - Incapacitating Injury	169,506	190,069
B - Evident Injury	33,227	43,770
C - Possible Injury	17,029	27,757
O - Property Damage Only	1,734	1,734

Percentage reduction in crashes attributable to pavement markings

A literature review on the percentage of crashes prevented by longitudinal pavement markings revealed several studies that used treatment and control groups. It also revealed some studies without well-matched controls and values from some studies without proper bibliographic references. Table 4 summarizes all the percentages. Most studies supplemented existing centerlines with edgelines.

Average effectiveness was computed for all the studies and for several subsets. The subsets included:

- Studies of edgelines only.
- Edgeline studies excluding the highest effectiveness estimate and the lowest estimate.
- Studies that were examined and judged sound.

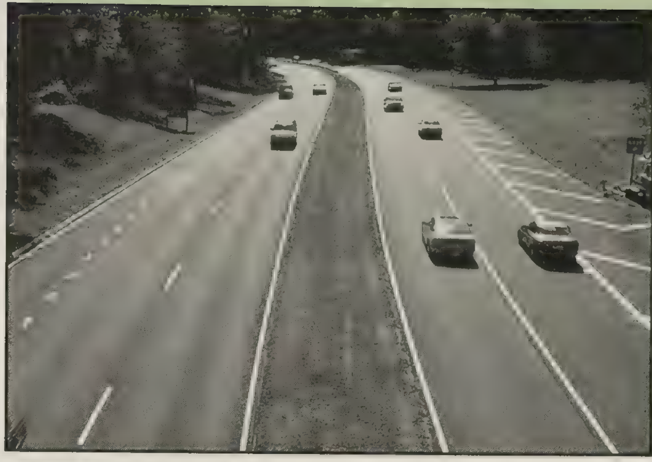
The averages ranged from 20 to 21 percent. The average for sound studies examined was 21 percent. This article assumes that roads already are marked, meaning the present crash levels are 21 percent less than the levels without marking. Expressed in terms of current crash rates, the percentage reduction in crashes attributable to striping is 100*.21/(1-.21) = 26.5 percent.

The best American effectiveness study is *Cost-Effectiveness and Safety of Alternative Roadway Delineation Treatments for Rural Two-Lane Highways*, which examines rural two-lane roads. This 10-State study includes more than 500 sites. Each site either had a significant and adequately maintained, nonexperimental change in delineation 2 or 3 years prior to the study or an undelineated, matched control site. Data

Table 4.—Percentage reduction in crashes due to long lines

	%	Reference
Centerlines		
United States	29%	*(7)*
Bavaria	10%	*(21)*
Edgelines		
United States		
Nationwide	8%	*(7)*
Kansas	16.5%	*(2)*
Kansas	14.5%	*(23)*
Ohio	19%	*(24)*
Illinois	21%	*(23)*
Idaho	16%	*(23)*
Utah	38%	*(23), (25)*
Arizona	60%*	*(23)*
Michigan	3%*	*(23)*
United Kingdom		
East Sussex	18%	*(26)*
South Yorkshire	30%	*(26)*
Cornwall	26%	*(26)*
Northamptonshire	12%	*(26)*
Hertfordshire	22%	*(26)*
France		
Lorraine	27%	*(27)*
West Germany		
Hesse	20%	*(21)*
Lower Saxony	25%	*(21)*

Driving on a road without proper lane markings can be very dangerous.



Proper lane markings facilitate the smooth flow of traffic and let traffic go faster on busy roads.

were obtained on crash experience for 2 to 3 years at each site (at least 2 years before and 2 after delineation for the sites with delineation added). The study finds adding both edgelines and centerlines reduces crashes by 36 percent. Adding edgelines to an existing centerline yields an 8-percent reduction. These percentages were used in the more detailed analysis of marking rural two-lane roads. *(7)*

Using the percentage reduction in crashes to compute safety benefits should yield conservative estimates. Several of the published studies suggest the percentage of injuries and fatalities reduced is greater than the percentage of crashes reduced.

Travel time savings

The benefit-cost ratios by roadway type include travel time saved because edgelines and centerlines let traffic go faster on busy roads. The analysis assumes:

- Travel time was saved during the 6 a.m. to 7 p.m. peak period. Eighty percent of vehicle-miles of travel occur during this period. Weekend and weekday travel generate roughly the same percentage of travel miles per day. Furthermore, trips are heavy in all hours from 6 a.m. to 7 p.m. with a range from 5.4 percent to 6.3 percent of all trips in each peak hour before 4 p.m. and after 6 p.m. and with 8.1 percent between 4 and 6 p.m. *(8)*

- Pavement markings raised speeds—thus saving travel time—only on Interstate highways, other freeways, and arterials.

- The average 56 mi/h (90 km/h) speed on these roads would fall to 54 mi/h (87 km/h) during

Table 5.—Annual vehicle-miles of travel (vmt) and benefit-cost ratio (BCR) for longitudinal pavement markings by roadway functional class and land use, excluding local streets (vehicle-miles in millions) *(3)*

Roadway Class	Urban		Rural		All
	VMT	BCR	VMT	BCR	BCR
Interstate	258,662	74.1	181,284	46.3	58.3
Other Freeway	116,965	63.4	0	—	63.4
Major Arterial	319,286	102.0	160,253	105.2	102.9
Minor Arterial	231,786	125.8	151,783	68.9	97.1
Major Collector	99,245	52.2	183,507	28.6	34.2
Minor Collector	0	—	46,985	20.6	20.6
Total	1,025,944	90.6	723,812	40.1	60.0

Table 6.—Benefit-cost ratios by rural-urban land use, showing the effects of alternative assumptions and marking media

	Rural	Urban	Combined
Using High-Solvent Paint (Base Case)	40.1	90.6	60.0
Using a Paint Cost That Is $.005			
Higher	36.2	82.6	54.4
Lower	45.0	100.5	67.1
Uniform 9-Month Striping Cycle	33.4	96.3	54.6
Effective Only for 9 Months Except on Minor Rural Collectors	31.6	80.1	50.7
Costing VOC Damage To Environment	36.7	85.7	55.6
Using Thermoplastic			
$.26/ft rural	32.9	130.0	58.9
$.22/ft rural	38.8	130.0	66.4
Adjusting Paint Use for Unpainted Parts of Lane Lines and Double/Skip Parts of Centerlines	41.6	99.3	63.6
Costing VOC Damage and Adjusting Paint Use	38.1	94.0	58.9
Including Crashes Not Reported to Police	51.2	114.5	76.0
Omitting Travel Time Savings	38.1	81.9	54.9
Ignoring Higher Cost At Repaving	49.7	93.5	69.1
Applying a 10% Discount Rate	38.8	93.5	59.9

the peak travel period if the roads lacked lane lines, edgelines, and centerlines. *(3)*

The analysis uses travel time values of 60 percent of the wage rate for the driver and 45 percent for passengers. These values are recommended by *The Value of Time and Benefits of Time-Saving*, which critically reviews the literature. *(9)* They also are used in the FHWA's Highway Economics Requirements System model. The average vehicle has 0.7 passengers. *(8)* Time of day and day of week do not unduly affect occupancy. *(8)* Therefore, it is reasonable to use this occupancy for peak hour trips.

The value of travel time saved per vehicle is 91.5 percent (60 percent + 45 percent * .7) of the wage rate. The average nonsupervisory wage in 1990 was $9.66/h. *(10)* Thus, a vehicle-hour of travel time (T in equation 3) is worth $8.84.

Table 5 shows the annual vehicle miles of travel (vmt) by roadway class (V in equation 3).

Benefit-Cost Ratios by Roadway Type and Land Use

Applying equation 3 to the data given above yields benefit-cost ratios by roadway type and land use. Table 5 shows the benefit-cost ratios for high-solvent paint (as well as vmt).

Nationally, pavement striping has a benefit-cost ratio of 60. On average, each dollar spent on longitudinal pavement markings yields $60 in increased safety and reduced congestion benefits. It saves $3 in medical care costs. The benefit-cost ratio is highest on arterial roads. The urban ratio is more than double the rural ratio. Annual benefits average $19,226/line-mi ($11,940/km).

Sensitivity analysis showed that the benefit-cost ratios were robust. The ratios by land use were not greatly affected by choice of marking medium, changed assumptions, or introduction of additional cost considerations. Table 6 summarizes the ratios.

Varying the paint cost affects the benefit-cost ratios but does not change their order of magnitude. Assuming a uniform restriping frequency of 9 months lowers the rural benefit-cost ratio but raises the urban ratio. Wear and tear, especially in the winter, probably reduces nighttime marking effectiveness to 9 months except on lightly traveled minor rural collectors. Because the effectiveness studies involved annual restriping, the effectiveness estimates already should incorporate this temporal decline. Assuming that they do not would reduce the benefit-cost ratio by 15 percent.

Typically high-solvent paint releases 69 lb of volatile organic compounds (VOC's) per mile (19.5 kg/km) of solid 4-in (101.6-mm) stripe. *(11)* VOC's oxidize, creating ozone that can cause respiratory distress for sensitive people. They also are suspected carcinogens. *An Analysis of Selected Health Benefits from Reductions in Photochemical Oxidants in the Northeastern United States* suggests valuing the short-term health effects of VOC's at $620/ton (562/Mg) (inflated to December 1990 dollars). *(12)* For each restriping, the cost is $21/mi ($13/km) of solid stripe. This value is primarily for the Northeastern United States, but A.J. Krupnick suspects it is also a reasonable national average. *(13)* The value does not consider the long-term cancer risk or any effect on plants and animals.

The environmental costs suggest latex paint would be more cost-effective than high-solvent paint if its applied cost was $.004 more per linear foot ($.013/m) or $1.30 more per gallon ($.34 more per liter). The better durability of some latex paints might justify an even greater cost. These conclusions apply only to latex paints with fast drying times.

In climates where thermoplastic markings are practical, their long life makes their life-cycle cost competitive with painted markings. They are especially competitive on high-volume urban roads. For ease of comparison, the ratios for thermoplastic were computed as if it could be used nationwide.

The benefit-cost ratios presented so far assumed all longitudinal pavement markings are single, solid lines. In reality, centerlines often are doubled, and they are dashed in passing zones. The industry rule of thumb is that a centerline on a two-lane road takes 1.3 times as much paint as a solid line. Conversely, lane lines are dashed. Typical lane lines are 10-ft (3.05-m) stripes separated by 30-ft (9.15-m) gaps in rural areas and 9-ft (2.75-m) stripes with 12-ft (3.66-m) gaps elsewhere. Applying these ratios to the estimated line-miles marked yields paint-miles. Costing with paint-miles raises the benefit-cost ratio slightly. Table 6 shows the revised ratios both excluding and including environmental damage.

The benefit-cost ratio of 59 with environmental damage and paint-miles may be more accurate than the ratio of 60 for the base case. Considering these additional costs raises the urban benefit-cost ratio but lowers the rural ratio.

Another possible model refinement would assume that longitudinal pavement markings are as effective at preventing unreported crashes as preventing reported crashes. Applying the underreporting estimates from *The Cost of Highway Crashes* yields substantially higher benefits. *(4)* It raises the benefit-cost ratio for all roads to 76.

Omitting the travel time savings affects the benefit-cost ratios only for congested roads. On these roads, savings in travel time alone would justify longitudinal pavement markings. On major rural roads, the benefit-cost ratios for these markings range from 6.4 to 10.2 if only reduced congestion is considered. On major urban roads, they range from 8.0 to 18.3. Where pavement markings will ease congestion, they almost surely will be cost-beneficial.

Ignoring the extra cost of contract pavement markings at repaving would raise the benefit-cost ratio. Using a 10-percent discount rate would affect the benefit-cost ratio minimally.

Edgelines on Rural Two-Lane Roads

The lowest benefit-cost ratios for longitudinal pavement markings are for edgelines on rural two-lane highways. This section examines the benefit-cost ratio for these lines in more detail. It again uses equations (1) through (3). The analysis is by average daily traffic (ADT) volume. It ignores any travel time savings.

Cost-Effectiveness and Safety of Alternative Roadway Delineation Treatments for Rural Two-Lane Highways finds edgelines prevent 0.72 crashes per million vehicle-miles (0.45 per million vehicle-km) of travel on rural two-lane roads. *(7)* Multiplying this value times the ratio of fatal crash rates per million vehicle-miles of travel on rural Federal-aid secondary roads in 1978 and 1988 suggests 0.48 crashes would be prevented today. This estimate is conservative, since nonfatal injury rates probably fell less than fatality rates. *(14)* The low quality of the nonfatal injury data precludes their use in adjusting to present crash rates.

This road has no edgelines; edgelines can help to prevent accidents.

Figure 1 shows the benefit-cost ratios. Even at 500 ADT, edgelines on rural two-lane roads yield $17 in safety benefits for every dollar invested.

Edgelines reduce crashes by 7.9 percent on rural two-lane roads with lane widths of 11 ft (3.36 m) or more. *(7)* Using that estimate, the number of crashes per year needed to justify striping (A) can be computed as:

(4) A = C/(CS*R) = 2 edgelines * 240/mi / ($95,074/crash * .079) = .064

Edgelines are justified on a rural two-lane highway with .064 or more crashes/mi/yr (.04/km/yr). Interpreting this number conservatively, edgelines are justified if an average of one nonintersection crash occurs annually every 15.5 mi (25 km). However, edgelines are not recommended if lane widths are less than 11 ft (3.36 m).

Conclusion

Existing longitudinal pavement markings yield benefits far greater than their costs. They increase safety and reduce congestion. Much of the safety benefit is achieved during periods of poor visibility. That suggests checking roadway retroreflectivity regularly and restriping promptly when retroreflectivity drops below recommended levels.

Edgelines may not be used often enough on rural two-lane roads in some States. The number of nonintersection crashes needed to justify edgelines is quite small. Rural collectors have far higher crash costs per million vehicle-miles of travel than other roads. *(4)* Wider use of edgelines on these roads may be a cost-effective way to cut the crash toll.

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Ted R. Miller directs the Safety and Health Policy Program at the National Public Services Research Institute in Landover, MD. He has more than 20 years of experience in safety economics and benefit-cost analysis. He developed the highway crash costs used by the Department of Transportation. He holds a Ph.D. in regional science (economics) and a master of urban planning degree from the University of Pennsylvania.

"Along the Road" is a hodgepodge of items of general interest to the highway community. But this is more than a miscellaneous section and more than a dumping ground for bits and pieces of information with no other home; "Along the Road," especially as it evolves, is the place to look for information about current and upcoming activities, developments, and trends. Your suggestions and input are welcome. Let's meet along the road.

South Central Electric Vehicle Consortium

On November 18, 1992, the South Central Electric Vehicle Consortium (SCEVC) hosted a regional Electric Vehicle Symposium for the States of Texas, Louisiana, Arkansas, Oklahoma, and New Mexico in Austin, Texas. Governor of Texas Ann Richards declared the day Electric Vehicle Day Technology Day.

The event, attended by more than 150 key decision-makers and leaders of both State and National agencies and of both private and public industries, featured a General Motors electric sports car, which can reach 60 mi/h (97 km/h) in 8 seconds with a top speed of 120 mi/h (193 km/h) and a range of 120 mi (193 km). Also displayed was a novel charging mechanism that only takes 15 minutes to recharge a vehicle.

Kate Carroll and Bill Craven of the SCEVC examine GM's Impact—an electric vehicle capable of accelerating from 0 to 60 mi/h in 7.8 seconds and with a range of 120 miles. Beside the vehicle are inductive charges.

The purpose of the symposium was to promote an information exchange about electric vehicles (EV) within and parallel to the industry to commercialize EV and its services. Symposium participants were able to drive an EV. General Motors will have the electric sports car on the market in two years.

Texas aims to become the alternative fuels capital of the world, according to the Governor's proclamation. The State encourages public and private ventures, including universities, to develop commercial applications for new technologies.

SCEVC is a part of the Texas Engineering Experiment Station at Texas A&M University.

—Texas Engineering Experiment Station

ISTEA—Boost to Mass Transit

The following is from an article—entitled "Unsweetened ISTEA" by Jean Dimeo—which was published in the December 1992 issue of *American City & County:*

ISTEA gave mass transit a big boost, doubling its budget to $32 million, and authorizing MPOs (metropolitan planning organizations) to spend any part of their surface transportation dollars on mass transit. In addition, the law increased the proportion of mass transit funds that comes out of the mass transit account of the Highway Trust Fund.

In June, DOT announced a new policy to send federal transit dollars to municipalities. Previously, federal funds could only be spent in conjunction with local matching funds, but now communities can spend the entire federal portion before they spend their own money. Local matching funds are required to pay for the last 20 percent of the project.

"This new policy will make it possible to provide more federal money, put it to work faster, create more jobs and improve transit in our cities," Transportation Secretary Andrew Card said in a statement. Under the policy, DOT's Federal Transit Administration will provide more than $3 billion this year.

But, although Congress failed to fulfill ISTEA's 1993 mass transit promise, transit officials say last year's landmark legislation has spurred communities to pursue non-road projects. A survey by the American Public Transit Association (APTA) shows that 85 percent of the officials surveyed said that ISTEA has influenced long-range planning in their communities, 71 percent said transit projects were being added to current programs and 27 percent said that flexible dollars were being moved to transit.

Coaching the Maintenance Vehicle Operator Program

The National Safety Council, a private, nonprofit public service organization chartered by Congress, has developed the "Coaching the Maintenance Vehicle Operator Program," a defensive driving program for public works, roads, and other personnel who operate heavy equipment. The complete in-house classroom program takes about 4 to 5 hours to complete but can be broken down into 1-hour segments for easy administration.

The program was developed to help roads departments reduce accident and injury claims. It teaches drivers to identify the risks that cause accidents and the vehicle and job characteristics that contribute to accidents and dollar losses. Contact Joe Potaczek, Director of Government Services for the National Safety Council, toll-free at 1-800-621-7615, extension 2258, for more information.

—National Safety Council

OECD Seminar on Strategic Planning for Road Research Programs

WHAT: The Federal Highway Administration is hosting an Organisation for Economic Co-operation and Development seminar to explore the applications of strategic planning to road research programs.

WHY: There is no question of the importance of strategic planning for road research programs in this era of intermodal transportation and international cooperation. Anticipation of future problems and the timely development of corrective and/or preventive measures can have significant economic benefits for the entire road community and users. The annual cost of motor vehicle fatalities and injuries in the United States is more than $137 billion. Research and technology that reduces this toll by only 1 percent would save almost ten times the total cost of federally supported research and development (R&D) programs; it would also save lives and the enormous amount of grief, pain, and suffering that results from motor vehicle deaths and injuries.

WHO: The seminar is for R&D decision-makers, researchers, and planners in Government, industry, and academia who are involved in assessing transportation research needs and trends and/or determining future technological requirements.

HOW: This seminar will:

- Assess the need for continual strategic planning and analysis of road research programs.
- Identify methodology, skills, and timeframes required for strategic planning.
- Compare applications of research planning by member nations.
- Recommend appropriate approaches, functions, and organizations to meet identified strategic research planning needs.

WHEN, WHERE, and ACTIVITIES: The program begins on **Monday, October 4, 1993** and ends on **Friday, October 8, 1993**. The first activity is a pre-seminar orientation to the U.S. research and technology program and budget process; this orientation will be conducted **Monday at the Turner-Fairbank Highway Research Center (TFHRC) in McLean, Virginia** and will include presentations about TFHRC and a tour of facilities. The seminar opens on **Tuesday afternoon in Williamsburg, Virginia**. The agenda includes discussion of:

- Critical national issues, environment for research, development of the national research agenda, and identification of short-term and long-term priorities.
- Research organization, management, and budgeting and finance.
- Cooperative research—public/private, regional, national, and international.
- Research customers and involvement.
- Research program evaluation.
- Observations and conclusions (round table).

FOR MORE INFORMATION about the seminar (registration fee U.S. $295), the program, lodging, transportation, related and supplementary activities, etc. contact by May 1:

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Safety Good News

Favorable news of reductions in highway fatalities is coming from all over the country. One of the best reports is from Wisconsin, where preliminary statistics show a 19 percent decline from 1991, and the 643 fatalities in 1992 was the smallest number in Wisconsin since World War II. When combined with the estimated 3.5-percent increase in vehicle travel for 1992, the State's provisional fatality rate is 1.36 per 100 million vehicle miles of travel, the lowest in State history and making Wisconsin's roads among the Nation's safest.

New Jersey reports the lowest number of fatalities in 32 years. There were 1,355 fatalities in New Jersey in 1973, which was the highest year ever. Last year, there were 597 fewer fatalities, or a 44-percent reduction from 1973. This is significant because the number of drivers is up over a million and vehicles have increased by more than 1.5 million. Vehicle miles of travel are up more than 10 billion in the last 20 years.

Alabama had just one fatality over the New Year's holiday; this is the lowest number for that period in the State's history.

—FHWA Public Affairs

DOT Report to Congress on the Status of the Nation's Highway, Bridge, and Transit Systems

In January, then Secretary of Transportation Andrew H. Card Jr. said a report sent to Congress indicates that there has been significant improvement in the condition of the Nation's highways and bridges over the past decade.

In issuing the Department's 1993 biennial report entitled *Status of the Nation's Highways, Bridges and Transit: Conditions and Performance*, Card said, "These improvements are a result of concerted Federal and State efforts that began 10 years ago. Full funding of the highway programs in the landmark Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) should allow State transportation agencies to continue that improvement trend."

The statutorily required report was prepared by the Federal Highway Administration and Federal Transit Administration. The report estimates transportation demand, finance, conditions, and performance of the nation's highway and transit systems. It shows capital investment requirements to meet specified engineering standards.

Pavement conditions continue to improve. In every category of road—from rural collector to urban Interstate—the portion of roads categorized in the top-ranked "good condition" increased, while the portion of roads in "poor condition" declined. The portion of mileage in poor condition in 1991 was approximately 7.5 percent for all non-local functional systems and 7.6 percent on the Interstate system, compared to 10 percent and 9.3 percent, respectively, in 1989.

The report notes that bridge conditions have stabilized and shows a reduction in structurally deficient bridges. Of about 575,000 bridges on all local and non-local roads, 20.6 percent were rated as structurally deficient in 1992, down from 23.3 percent in 1990. Structurally deficient means that a bridge is not capable of accommodating the loads that it is expected to carry; load restrictions keep these bridges usable. The higher order highway systems, those that carry the bulk of interstate commerce, have a much lower proportion of deficient bridges. For example, only 6.8 percent of Interstate system bridges were found to be structurally deficient in 1992, down from 7.2 percent in 1990.

Congestion in the Nation's metropolitan areas moderated between 1989 and 1991, consistent with a slowdown in the rate of growth in highway travel over that period. Congestion actually declined on the urban arterials that carry over 50 percent of travel on non-local urban highways, and slightly increased on the Interstate and other freeways in urban areas.

The report finds that in 1991 all levels of government provided $26.4 billion for highway capital improvements related to conditions and performance on non-local roads. Federal funds accounted for 48 percent, and State and local government funds 52 percent. The average annual capital cost to all levels of government and the private sector to maintain 1991 highway and bridge conditions and performance through the year 2011 is $47.2 billion, and $62.6 billion would be required to improve conditions by eliminating backlog deficiencies. Explicit benefit-cost considerations have not been applied in developing these cost estimates. While efforts have been made to use new construction only as a last resort, environmental, social, or cost considerations may further limit the new highway construction assumed in the estimates. These estimates represent investment and performance benchmarks to support further policy and budget analysis.

The report says that the average age of transit buses exceeds the federally recommended average usable age by 20 to 35 percent. Between 20 to 30 percent of rail transit facilities and maintenance yards are rated in poor condition, while approximately half of commuter rail cars and locomotives are in good condition. About 7 percent of track is in poor condition.

The average annual capital cost to all levels of government and the private sector to maintain the nation's transit systems in their current condition would be $3.9 billion through 2011, with an annual $6.6 billion investment required to eliminate the transit backlog and expand services. Total capital investment in transit systems in 1990 was $4.3 billion. The Federal share of that capital spending was 60 percent.

Prior to this year, there was a report on mass transit separate from the highway and bridge report. The reports were merged because of the complementary nature of these modes of transportation, consistent with the Department's emphasis on intermodalism.

For copies of the report, contact the Federal Highway Administration, Office of Public Affairs, HPA-1, 400 Seventh Street, S.W., Washington, DC 20590.

—FHWA Public Affairs

Robotic Road Workers

Today, high tech robots help maintain U.S. roads by moving concrete barriers, painting highway lines, and controlling the movements of road-surfacing machines. In the future, such "robo road workers" may place traffic safety cones, pick up garbage, fill potholes, or seal cracks in pavement, according to experts who spoke on this subject at the 72d Annual Meeting of the Transportation Research Board in January.

In an effort to cut construction costs while minimizing unsafe conditions for human workers, robotic or automated road systems are now being developed by private companies, universities, government laboratories, and highway departments around the world, said Carl Haas of the University of Texas.

"Few, if any, of these machines will look like the science fiction robots many people picture, or even like the robots working in automobile and manufacturing plants," Haas noted. "But many of the machines will have sensors and computer brains that rival the most sophisticated factory robot."

For example, he said, one new prototype robot—developed at Carnegie Mellon University and the University of Texas with support from the Strategic Highway Research Program—uses high tech sensors and a plotting mechanisms to locate and seal cracks in road pavement.

David R. Martinelli of West Virginia University discussed the technical and economic feasibility of automating the reinforcement of bar fastening on bridge decks—a concept that may reduce worker injuries related to this difficult task.

Yvan J. Beliveau of Virginia Polytechnic Institute and State University described a laser-based, three dimensional positioning system designed to precisely control the position and motion of road construction machinery. Beliveau's work could make it possible to more accurately and efficiently construct highway ramps, curbs, and culverts.

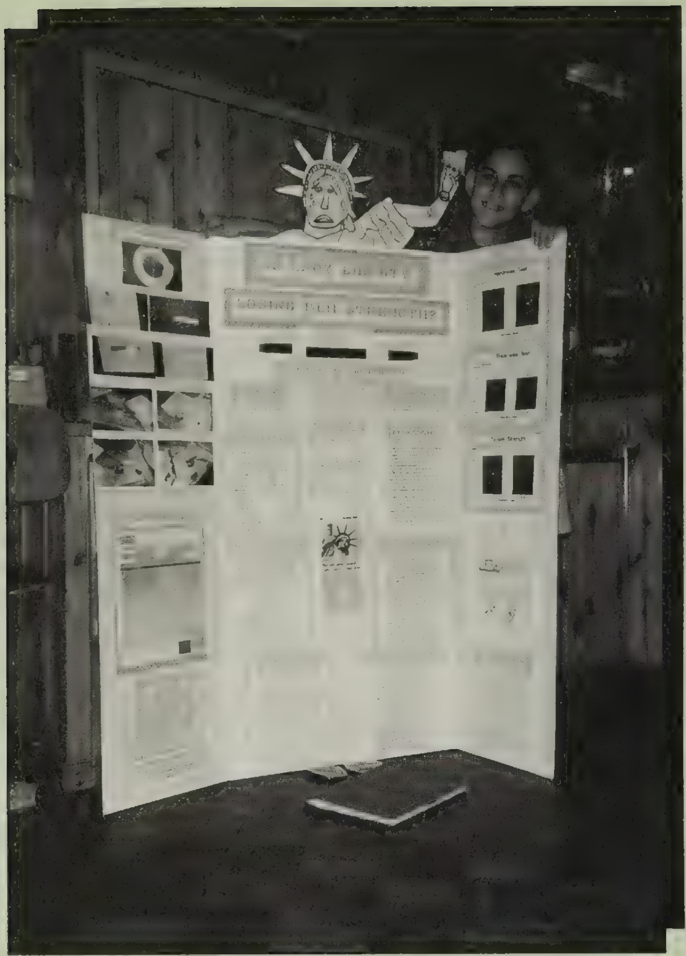
Other researchers described a broad range of new technologies, from methods for recycling asphalt pavement in real-time to a Finnish technique for leveling pavement overlays.

—Transportation Research Board

Award-Winning Young Scientist

Last year, Danny Friedman, then a 5th grader from Davie, Florida, was intrigued by the discoloring of the copper skin of the Statue of Liberty. After reading about the research of Dr. Richard A. Livingston, who was then a geochemist at the University of Maryland and is now a research chemist in the Office of Advanced Research at the FHWA's Turner-Fairbank Highway Research Center, Danny wrote to Dr. Livingston, asking for information about his research on the relative effects of acid rain and salt water on the color changes of the Statue's green-colored skin. That was the start of what has become a 2-year, and possibly continuing, study by Danny.

Danny's entry in this year's science fair at Nova Middle School in Davie won first place and will be entered in the Broward County Science Fair. For his experiment, Danny submerged a strip of stainless steel #316 L from the Statue of Liberty



Dan Friedman, a 6th grader at Nova Middle School in Davie, Florida, shows his award-winning science fair project.

Restoration Project in salt water for a year; the submerged strip was tested and compared to an original piece of unsubmerged stainless steel #316 L. His hypothesis was that the submerged steel would retain its strength as well as the original unsubmerged piece. Danny kept a written log and took pictures to document his findings. The results of his study supported his hypothesis and the findings of the Statue of Liberty Restoration Committee that the Statue was holding up well with her new stainless steel #316 L armature. Danny wrote in his report, "This is important because the Statue must be safe for visitors and must hold up in the Harbor's aggressive environment."

Danny says he is seriously thinking about doing more research on copper using the information sent by Dr. Livingston.

Danny's paper describing his experiment shows that he went far beyond the typical middle school science project. He conducted a major literature search; he used actual samples of stainless steel, copper, and iron from the Statue of Liberty Restoration Project; he used a handheld Rockwell Tester to test the hardness of the samples and a micrometer to test the thickness; he sought the advise of several engineers and industry representatives; and he was very descriptive in his log entries.

Describing a container with iron and copper in salt water, Danny wrote in his log 1 week into the experiment, "The solution in #1 is brownish and there is a residue starting to collect at the bottom of the jar." A month later, he wrote, "It looks like brownish tomato juice and you cannot see through it at all." Another month later, "The iron and copper solution started to smell before I even got the lid off. The liquid is dark brown and is thick as watery mayonnaise." Then 2 weeks later in his final entry, Danny said, "The iron and copper solution in #1 has an odor like vomit. It looks like spaghetti vomit without the lumps. The color is red, brown, orange and gray. It is as thick as sour milk. It has stained the plastic container. The piece of copper is light orange. It has many dark spots and its shine is gone. The piece of iron has a thick black coating of scum on it. The strips of metal cannot be seen through the solution. It is so thick."

Oh, what a researcher will endure in the name of science! Danny, congratulations and best wishes for continued success with this project and with your future projects.

Dr. Larson Wins TRB Distinguished Service Award

At the 72d Annual Meeting of the Transportation Research Board in January, Dr. Thomas D. Larson, outgoing Administrator of the Federal Highway Administration, was presented with the TRB's W.N. Carey, Jr., Distinguished Service Award. The award, named after the TRB executive director from 1967 to 1980, recognizes individuals who have provided leadership and distinguished service to transportation research and to the Board.

Dr. Larson's career is an outstanding record of service and contribution to the highway research community. In addition to serving as Federal Highway Administrator, he was president of the American Association of State Highway and Transportation Officials from 1985 to 1986. He chaired the TRB study committee that recommended the establishment of a strategically targeted program of highway research, resulting in the creation of the Strategic Highway Research Program (SHRP), and he also chaired SHRP's first executive committee. From 1980 to 1984, he served as a member of the TRB executive committee, and in 1981, he was chairman of the executive committee.

—Transportation Research Board

NEW RESEARCH

The following new research studies reported by the FHWA's Office of Research and Development are sponsored in whole or in part with Federal highway funds. For further details on a particular study, please contact Richard Richter, (703) 285-2134.

NCP Category A—Highway Safety

A.6: Human Factors Research for Highway Safety

Title: Investigation of Older Driver Freeway Needs and Capabilities

Objective: Identify the needs of older drivers in light of freeway use. The identification will be completed through an extensive literature review, an accident analysis, and extended focus group sessions with older drivers.

Performing Organization: Center for Applied Research

Sponsoring Organization: FHWA

Expected Completion Date: October 1994

Estimated Cost: $204,999

NCP Category B—Traffic Operations/ Intelligent Vehicle-Highway Systems (IVHS)

B.2: Advanced Traveler Information Systems

Title: Rural Applications of Advanced Traveler Information

Objective: Investigate applying ATIS functions in non-urban areas. The study will include a system design and address such issues as communications, implementation costs, potential benefits, and perceived utility. A cooperative operation test incorporating the design will be implemented.

Performing Organization: JHK

Sponsoring Organization: FHWA

Expected Completion Date: June 1995

Estimated Cost: $1,373,501

NCP Category D—Structures

D.4: Corrosion Protection

Title: Sacrificial Cathodic Protection Systems Project (III)

Objective: Develop sacrificial cathodic protection technology as an alternative to impressed cathodic protection for both reinforced concrete (R/C) and prestressed concrete (PS/C) bridge components. The contractor will investigate the development of sacrificial anode systems for substructure and superstructure in the laboratory and install the developed anode systems in the field to protect both R/C and PS/C bridge components.

Performing Organization: Construction Technology Labs

Sponsoring Organization: FHWA

Expected Completion Date: December 1997

Estimated Cost: $368,979

RECENT PUBLICATIONS

The following are brief descriptions of selected publications recently published by the Federal Highway Administration, Office of Research and Development (R&D). The Office of Engineering and Highway Operations R&D includes the Structures Division, Pavements Division, Materials Division, and Long-Term Pavement Performance Division. The Office of Safety and Traffic Operations R&D includes the Intelligent Vehicle-Highway Systems Research Division, Design Concepts Research Division, and Information and Behavioral Systems Division. All publications are available from the National Technical Information Service (NTIS). In some cases, limited copies of publications are available from the R&T Report Center.

When ordering from the NTIS, include the PB number (publication number) and the publication title. Address requests to:

National Technical Information Service
5285 Port Royal Road
Springfield, Virginia 22161

Requests for items available from the R&T Report Center should be addressed to:

Federal Highway Administration
R&T Report Center, HRD-11
6300 Georgetown Pike
McLean, Virginia 22101-2296
Telephone: (703) 285-2144

Advances in Weigh-In-Motion Using Pattern Recognition and Prediction of Fatigue Life of Highway Bridges, Volume I: Final Report and Volume II: Data Report, Publication No. FHWA-RD-92-046 and -045

by Structures Division

The two main objectives of this study were to: (1) demonstrate the advantages of using the Weigh-In-Motion and Response system (WIM+R) to evaluate the fatigue life of existing bridges and, (2) introduce pattern recognition methods in the analysis of WIM+R data. Four steel girder bridges were instrumented to obtain strain data at fatigue critical details, and at sections of maximum strain to compute the gross vehicle weight (GVW) of each truck. Two were simple spans, and two were continuous spans. A comparative study of the four alternatives suggested by AASHTO showed that the fatigue life computed with direct measurements of the stress ranges were greater than those computed with the simplified approaches. The damage equivalent secondary cycle factor for fatigue was defined. The applicability of three pattern recognition methods for WIM was investigated. The dynamic time warping, hidden Markov model, and feed forward neural network methods can classify trucks with the measured strain patterns.

This publication may be purchased from the NTIS. (PB No. 93-123594/AS, price code: A06 and PB No. 93-123628/AS, price code: A21.)

Impact of Truck Characteristics on Pavements: Truck Load Equivalency Factors, Publication No. FHWA-RD-91-064

by Pavements Division

This study was undertaken to evaluate various types of primary pavement response derived load equivalency factors. These use pavement response measurements such as strain and deflection to estimate the equivalent damaging effect of any axle loading condition. These types of factors are also expressed in terms of a relative number of equivalent standard axle loads.

A number of primary response equivalency factor methods were evaluated, and several were selected for further study. Deflection and strain pavement response measurements were evaluated over an experimental factorial of axle type, axle load, tire pressure, speed, pavement thickness, and pavement temperature. Primary response load equivalencies were calculated using the selected methods, and a number of statistical comparisons were made.

Results indicate that the concept of primary response truck load equivalency factors is viable and can be extremely useful for estimating load equivalence for pavement design and research purposes. Results also indicate which of the vehicle and pavement factors studies most significantly affect the estimate of load equivalency.

This publication may be purchased from the NTIS. (PB No. 93-123560/AS, price code: A10.)

Investigation of the Tire/Pavement Interaction Mechanism: Phase III Final Report, Volume I: Tire/Pavement Contact Force Modeling; Volume II: Dynamic Response Modeling of the Inflated Tire Structure; Volume III: Modeling Tire Acoustic Response

by Materials Division

The interaction mechanism of heavy vehicle tires with road surface pavement is developed as a force, excitation, response problem. Results are presented in three volumes that report tire/pavement contact pressures, structural vibration response, and surface vibration acoustic modeling methods respectively. The results of each report provide detailed information that may be utilized for tire/pavement evaluation by the methods developed in the subsequent reports.

In volume I, an efficient algorithm is derived and validated for the evaluation of road surface contact pressure, contact length, depth of tire penetration, and deformed tire geometry.

In volume II, a three-dimensional, orthotropic, nonlinear dynamic finite element shell model is developed for evaluation of the damped vibration response of the tire.

In volume III, the parameters of importance for numerical analysis of the acoustic radiation from a vibrating tire surface are defined. A finite element formulation is developed, treating the medium as a stationary compressible fluid.

Limited copies of these reports are available from the R&T Report Center.

Study Designs for Passing Sight Distance Requirements, Publication No. FHWA-RD-91-078

by Information & Behavioral Systems Division

This report documents the results of an examination of the passing sight distance standards in *A Policy on Geometric Design of Highways and Streets*, published by the American Association of State Highway and Transportation Officials (AASHTO), and the current sight distance requirements for marking passing and no-passing zones cited in the *Manual on Uniform Traffic Control Devices (MUTCD)*. Relevant findings in the available literature are summarized. The current AASHTO design standards and MUTCD marking standards related to passing sight distance on two-lane highways are described. Issues related to the current standards and practices are identified and discussed. This includes the results of a meeting of knowledgeable authorities. Finally, three experimental plans that address three selected, critical issues are presented. These include: (1) an accident-based analysis of current practices, (2) a field-based observational study of passing behavior to determine the adequacy of the current standards, and (3) a field-based observational study of passing behavior to determine if the minimum passing zone length of 400 ft (122 m) implied in the MUTCD is inadequate and to determine what the minimum passing zone length should be. These three plans may serve as a basis for future research.

This publication may be purchased from the NTIS. (PB No. 92-205525/AS, price code: A08.)

A Systemwide Methodology for Evaluating Highway Safety Studies, Publication No. FHWA-RD-92-049

by Information & Behavioral Systems Division

This study developed a new, better procedure for assessing widespread geographic effects resulting from the use of safety treatments. Most currently used statistical methods for countermeasure evaluation assess the spot or local changes that result from the new treatment. The effects of the treatment on the entire system or nearby contiguous links are seldom evaluated. The new approach is ideal for applications where large quantities of data reside in a PC computer format. Incorporated in the methodology are known procedures for determining if regression-to-the-mean (RTM) problems exist and how those problems can be minimized when they are present. A previous research study developed a computer program—Bayesian Estimation of Accidents in Transportation Studies (BEATS)—that identifies and corrects regression-to-the-mean bias in highway safety studies.

Step-by-step guidelines were developed on how to plan and use new procedures to evaluate highway safety studies. The guidelines describe what are adequate sample sizes, how to identify RTM problems, and how computerized data analysis procedures can be used.

This publication may be purchased from the NTIS. (PB No. 93-127504/AS, price code: A06.)

The following are brief descriptions of selected items that have been completed recently by State and Federal highway units in cooperation with the Office of Technology Applications and the Office of Research and Development, Federal Highway Administration. Some items by others are included when they are of special interest to highway agencies. All publications are available from the National Technical Information Service (NTIS). In some cases, limited copies of publications are available from the R&T Report Center.

When ordering from the NTIS, include the PB number (or publication number) and the publication title. Address requests to:

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5285 Port Royal Road
Springfield, Virginia 22161

Requests for items available from the R&T Report Center should be addressed to:

Federal Highway Administration
R&T Report Center, HRD-11
6300 Georgetown Pike
McLean, Virginia 22101-2296
Telephone: (703) 285-2144

Sign Fabrication, Installation, and Maintenance—Innovative Practices, Publication No. FHWA-SA-91-033

by Office of Technology Applications

Many State and local agencies have developed innovative procedures and devices to facilitate highway sign fabrication, installation, and maintenance. This handbook describes several of these innovations.

A literature review and nationwide search was made to gather information on innovations. The innovations that were received ranged from very simple, but effective tools, to more elaborate sign trucks. Innovations were developed from new uses for existing equipment and modifications to existing equipment or procedures to provide a more efficient use for it. A total of 27 innovations are described in this report. The information is provided in a concise format and includes a description, procedure for the product's use, the benefits attained, and a person to contact for further information.

This publication may be purchased from the NTIS. (PB No. 92-239136/AS, price code: A04.)

Work Zone Traffic Control Information Catalog, Publication No. FHWA-SA-92-037

by Office of Technology Applications

Through the years, the Federal Highway Administration and other organizations have published material that provides information and guidance on work zone traffic control. This catalog provides a listing of selected standards and guides; handbooks and manuals; training courses, video and slide-tape presentations; implementation packages; technology-sharing reports; and research reports and technical papers on the subject. For each entry, the catalog lists the title, a description, the author, any cost or ordering information, and the source from which the material may be obtained.

Limited copies of this publication are available from the R&T Report Center.

Local Technical Assistance Program Accomplishments and Successes, Publication No. FHWA-SA-93-017

by Office of Technology Applications

This publication was originally issued by the Local Technical Assistance Program (LTAP) Clearinghouse under the sponsorship of the FHWA. The publication includes highlights from each of the LTAP Technology Transfer Centers across the country. It lists projects and training sponsored by the centers during 1991 and provides information on the location and telephone numbers for the centers.

Limited copies of this publication are available from the R&T Report Center.

Federal Highway Administration Technology Applications Program—January 1993, Publication No. FHWA-SA-93-016

by Office of Technology Applications

This publication is issued biannually by the FHWA to provide updated information on the agency's

Technology Applications Program. It focuses on the four categories that, for the most part, make up the strategies employed in the program: demonstration projects, application projects, test and evaluation projects, and special projects. Technical activities are assigned to one of the categories depending on the stage the technology is in, and, after development, what technology transfer or marketing approach would be most useful in reaching the intended users.

Each project writeup in this publication includes its project number; its title; description and status sections; and the name, organization code, and telephone number for the project manager and, where appropriate, for a project coordinator. The description section includes information about the reasons for initiating the project and the background and processes related to the individual project. The status section includes a discussion of the current and some of the past activities of the project.

Limited copies of this publication are available from the R&T Report Center.

Report on the 1992 U.S. Tour of European Concrete Highway, Publication No. FHWA-SA-93-012

by Office of Technology Applications

In spring 1992, a 21-member group consisting of representatives from the Federal Highway Administration, the American Association of State Highway and Transportation Officials, State highway agencies, the American Concrete Pavement Association, the Strategic Highway Research Program, the Transportation Research Board, the Portland Cement Association, and The Road Information Program. This discusses the 14-day tour through France, Austria, Germany, Netherlands, Belgium, Spain, Portugal, Italy, and Switzerland and details the findings of the participants in the examination of these countries' concrete pavements and related technology.

Limited copies of this publication are available from the R&T Report Center.

Local Low-Volume Roads and Streets, Publication No. FHWA-SA-93-006

by Office of Technology Applications

This publication was prepared under the direction of the American Society of Civil Engineers Highway Division. In addition, the Federal Highway Administration and the U.S. Department of Agriculture Forest Service participated in the development of the publication. It serves as a reference for local agencies with basic information concerning local low-volume roads and streets (LLVRS). Although much of the information contained is applicable to all roads and street activities, emphasis has been placed on LLVRS. The publication will be particularly beneficial to individuals with limited technical expertise and no formal training or experience.

Limited copies of this publication are available from the R&T Report Center.

Field Trials of Low-Cost Bridge Weigh-In-Motion, Publication No. FHWA-SA-92-014

by Office of Technology Applications

This publication presents an evaluation of a low-cost bridge Weigh-In-Motion system developed under the National Cooperative Highway Research Program (NCHRP) Project 3-36. Two States that used a bridge WIM system provided independent input to the evaluation. Recommendations for further system enhancements and use of the bridge WIM system are also presented.

Limited copies of this publication are available from the R&T Report Center.

Summary Report on Selected Bridge Railings, Publication No. FHWA-SA-91-049

by Office of Technology Applications

This report summarizes the development, testing, and field experience for three bridge designs: the F-shape concrete bridge railing, the vertical wall bridge railing, and the Illinois 2399-1 steel tube bridge railing. Descriptions of these appurtenances and an explanation of the design principles is included along with estimates of the construction costs.

Limited copies of this publication are available from the R&T Report Center.

Summary Report on Selected Guardrails, Publication No. FHWA-SA-91-050

by Office of Technology Applications

This report summarizes the crash test results as well as the construction, maintenance, and accident experience observed for three types of guardrails: the modified South Dakota 3-cable guardrail, the modified Minnesota 3-cable guardrail, and the modified three-beam guardrail. Where it was available, construction, cost, and accident data is presented from States that have used these systems.

Limited copies of this publication are available from the R&T Report Center.

Summary Report on Aesthetic Bridge Rails and Guardrails, Publication No. FHWA-SA-91-051

by Office of Technology Applications

Providing safe roadside barrier hardware on scenic roadways and parkways is as important as safety on more typical roads. Recently a number of guardrails and bridge railings have been developed for these types of scenic roads. This report summarizes the development, testing, and field experience for three aesthetic bridge railing designs and three guardrail designs: the glue-laminated wood bridge railing, the Federal Lands Highway modified Kansas corral bridge railing, the stone masonry bridge rail, the steel-backed timber guardrail, the stone masonry guardrail, and the pre-cast simulated stone guardwall. This report describes the history of each barrier system and summarizes the crash tests. The features and components of each system are discussed, and drawings are presented.

Limited copies of this publication are available from the R&T Report Center.

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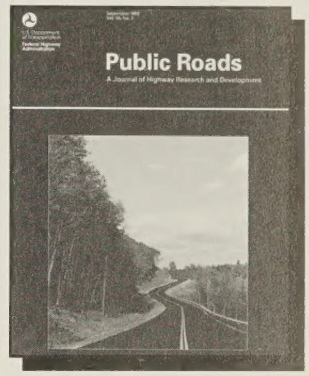

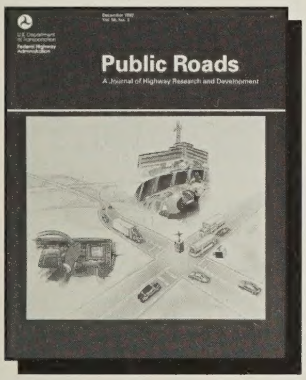

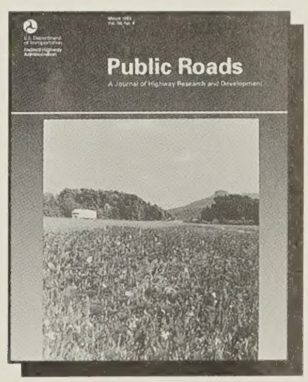

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