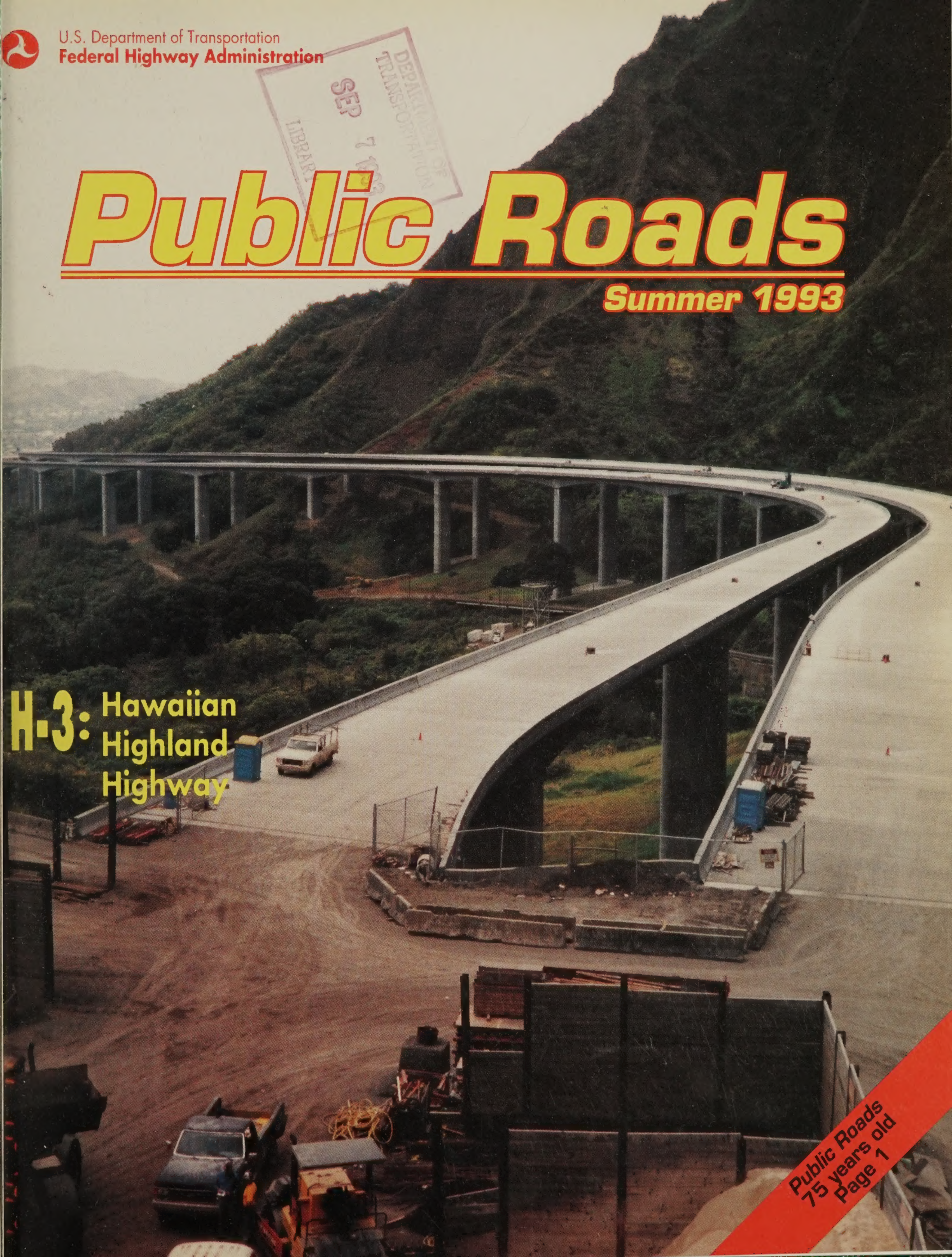
U.S. Department of Transportation
Federal Highway Administration

Public Roads

Summer 1993



H-3: Hawaiian Highland Highway

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Public Roads

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Cover:
The Windward Viaduct is a spectacular 1.6-kilometer (one-mile) section of the H-3 highway, "island interstate" on Oahu. The viaduct is supported by 23 sets of piers, which vary from 3.7 to 48.8 meters (12 to 160 feet) in height.

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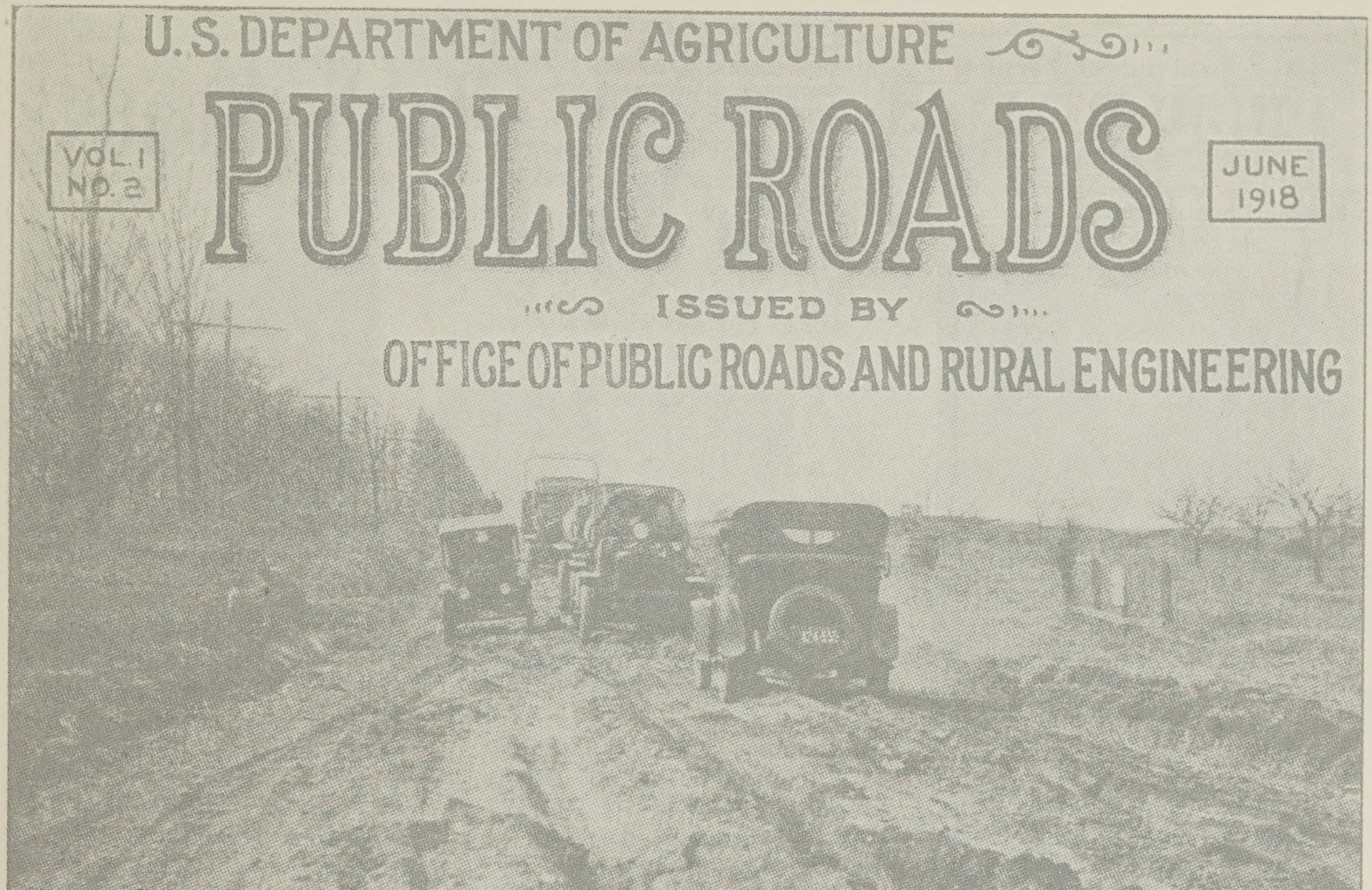


75 YEARS OLD AND GOING STRONG

by Robert V. Bryant

Wow!

Public Roads has just turned 75.

Its longevity is a testament to its importance to the community of highway engineers and other transportation professionals. But in some ways, this issue of the magazine marks a rebirth.

For almost its entire 75 years, *Public Roads* has been exclusively an in-house research journal for engineers, scientists, and economists, fulfilling part of its original mission to publish "the results of researches, experiments and studies of those connected with (the forerunner of the Federal Highway Administration), and of highway officials of the various States." (*1*)

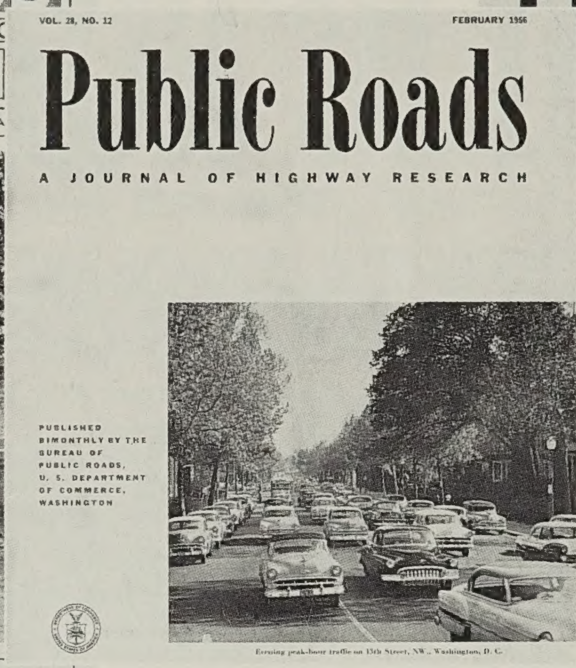
Now, however, to meet the changing and expanding needs of FHWA and true to the "what goes around, comes around" axiom, *Public Roads* is becoming more relevant for the future by picking up part of its past—the other part of its original mission which was to be a forum for the discussion of current problems including "the dissemination of such information as the officials of the various States may desire to spread for the benefit of their contemporaries." (*1*)

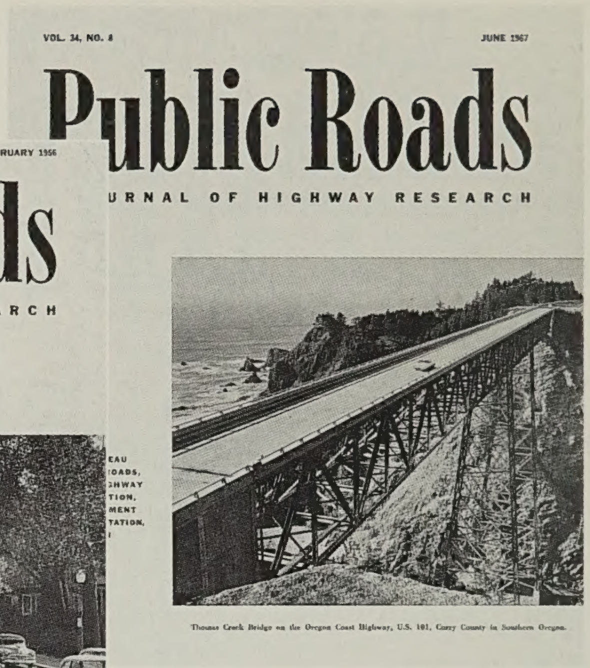
The most apparent aspect of the magazine's evolution is the new design unveiled in this issue. Some specific design changes include use of full color in some internal sections of the magazine, more photographs and color photographs, and a more lively layout. The idea is to communicate through a balance of text and visual elements and through a balance of substantive feature articles and technical articles. But this is much more than a facelift for a 75-year old; the magazine is developing a "new attitude."

With the emphasis on intermodalism—highways as a part of a comprehensive transportation system that includes all modes of transportation in efforts to meet increasingly complex social needs—*Public Roads* is broadening its scope and audience. In addition to articles about advances in research and technology, *Public Roads* must address critical national transportation issues and subjects of interest to highway industry professionals. While *Public Roads* remains a predominately research-oriented publication, *Public Roads* is now the magazine of the entire FHWA and has dropped its subtitle—A Journal of Highway Research and Development.

In this new format, *Public Roads* fills a void in the transportation community not occupied by academic journals, trade publications, or association magazines. The expanded audience includes technical personnel interested in the latest highway research and technology; international, national, state, and local transportation officials; and others interested in the highway indus-

Over the years *Public Roads* has been a part of the Department of Agriculture, Department of Commerce, and Department of Transportation.





try. The magazine has a limited free mailing list to universities and government officials. It is anticipated that subscriptions will increase with the expansion of the scope and audience.

A major part of the new scope is the transition to a transportation system that is more fully integrated to meet the more complex needs of society. This transitioning transportation system has three operational requirements. Highways must be integrated into a complete transportation network that includes railways, airports, waterways, etc. Social factors such as environmental quality and traffic congestion must be taken into account in new projects. FHWA must work much more closely with state and local governments to plan the overall impact of new highway projects.

The magazine will also emphasize the commitment of FHWA to continue to be a world leader in promoting highway research and technology transfer.

Being involved at the cutting edge of new technology and new developments is old business for *Public Roads*. *Public Roads* was the original publisher of many landmark papers in highway research. A paper published in the May 1929 issue, "Interrelationship of Load, Road and Subgrade" by C. Hogentogler and C. Terzaghi, "laid the foundations of subgrade soil classification and marked a turning point in studies of subgrade soils." (*2*) During the 1920s, 30s, and 40s, highway researchers were constantly making new discoveries and inventing new instruments to measure what had never been measured before. Information about many of these new instruments—for example, the Goldbeck Pressure Cell for measuring pressures under pavement, the electric eye and road tube traffic counters, the Benkelman Beam for measuring minute deflections in pavements under load—"first reached the scientific world through the pages of *Public Roads*." (*2*)

The following account of the history of *Public Roads*, which made its debut in May 1918, is taken from *America's Highways 1776-1976: A History of the Federal-aid Program*.

"(*Public Roads*) provided the State highway officials with a welcome forum for the discussion of current problems. The first issue brought the industry up-to-date by summarizing motor vehicle licensing laws and fees for registration and operators' licenses. This wartime issue also urged highway builders to conserve scarce fuel by proper attention to the firing of boilers and the careful use of steam in road machines and in quarrying. An entire issue (June 1918) was devoted to the catastrophic road breakups caused by heavy trucking during the 1918 spring thaw. The May 1919 issue dealt with the social and economic benefits of using convict labor on the public roads. When the Government distributed the huge surpluses of military equipment to the States, *Public Roads* ran articles on how to take care of the equipment and convert it to civilian highway use.

"*Public Roads* published the resolutions adopted by the American Association of State Highway Officials (AASHO) at its annual meetings of December 1918, 1919, and 1920, and also the papers read at those conventions. In effect, its was the official journal of AASHO until that organization launched its own publication, *American Highways*, in 1922.

"Within a year of its first issue, *Public Roads* was an important voice of the young highway industry, with a long waiting list of would-be-subscribers. In fiscal year 1920, the authorized monthly circulation was raised to 4,500 copies, but hundreds of requests for the magazine had to be refused.

Budgetary cuts reduced the circulation to 4,000 copies per month for fiscal year 1921, and, without explanation, publication was suspended altogether after the December 1921 issue. The suspension drew an immediate protest from the American Road Builders' Association, AASHO, and other organizations interested in roads and also '... many expressions of regret not only from its engineer subscribers, but also from the non-technical administrative heads of county highway activities to whom it had been helpful. Not the least gratifying of such expressions were those which came entirely without solicitation from the editors of other technical engineering journals.' (*3*)

"*Public Roads* resumed publication in March 1924, with the return of better times. However, the magazine was no longer a forum for the administrative and technical problems of the States, this function having been assumed by *American Highways* after *Public Roads* ceased publication. Instead, the new *Public Roads* was exclusively a house research journal....

"Publication has continued without interruption from March 1924 down to the present, although the frequency of issues has varied widely. Through the years, *Public Roads* again expanded to include articles on highway research and development from sources outside of the Bureau of Public Roads. Throughout its long history, *Public Roads* has maintained a high standard of scientific accuracy and literary clarity and, taken as a whole, is a remarkable chronology of the development of highway engineering and economics in the motor age." (*2*)

Public Roads has been redesigned and rejuvenated to become a magazine more in tune with a new era and the needs of FHWA—the *Public Roads* of the 21st century. So, this birthday is a celebration of the strength of tradition and the dynamics of changing times.

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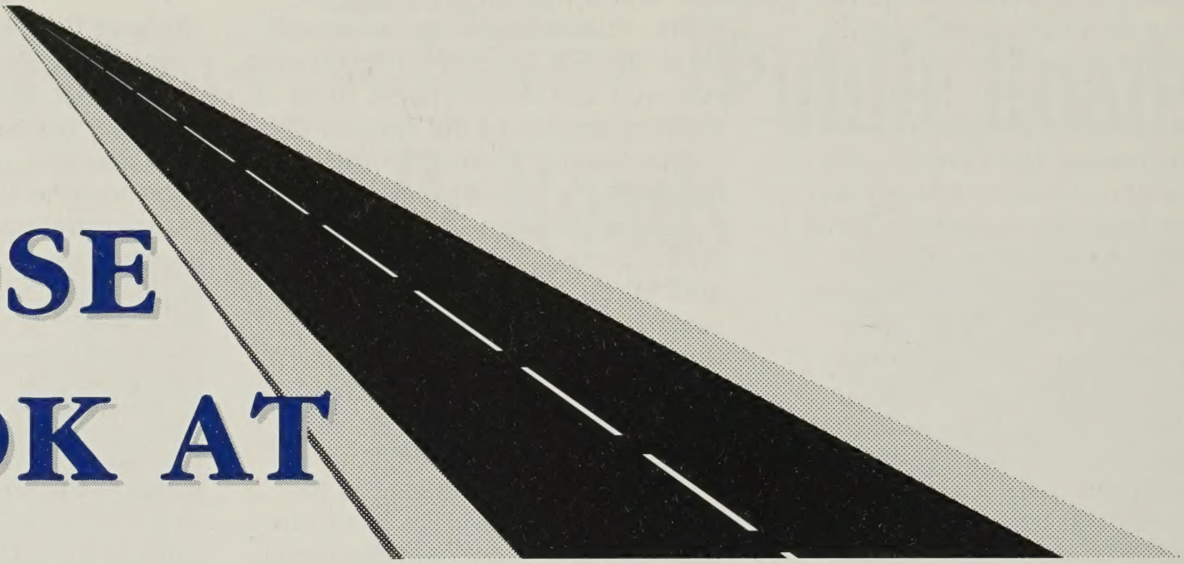
Robert V. Bryant has been the editor of *Public Roads* since September 1992. He works for Walcoff and Associates as the project manager of an editorial support team in the Federal Highway Administration's Office of Research and Development Operations and Support. For the preceding 22 years, he was an U.S. Army infantry and public affairs officer. His last military assignments were at the Pentagon as acting chief of Army Command (internal) Information and as editor-in-chief of *Soldiers*, the Army's official magazine.

The past issues of *Public Roads* are a chronicle of highway research.

A CLOSE LOOK AT ROAD SURFACES



by Rudolph R. Hegmon

Introduction

To most people, including the majority of readers of *Public Roads*, road surfaces are just gray areas stretching for miles and miles. Road surfaces are expected to provide safe driving conditions in dry and wet weather, provide a smooth and quiet ride all the time, minimize splash and spray during rain, provide good visibility under adverse conditions, and have a long service life.

A close look at the surface reveals many features including texture, which is needed to provide skid resistance, reduce splash and spray in heavy rain, and reduce headlight glare in night driving. But texture may increase noise and reduce the life of both pavement and tire. Further, as roads age and deteriorate from the effect of heavy truck traffic and weather, signs of distress appear. Road roughness is one sign of distress and is detrimental to both pavement life and ride quality. This article discusses only road roughness, how roughness is measured, and the effect of roughness on the highway user and on pavement life.

Effects of Roughness

Roughness causes a number of problems to the highway user, including poor ride quality, unsafe driving conditions, excitation of truck dynamics leading to further pavement deterioration, and damage to vehicles and cargo. The vast majority of highway users is most sensitive to ride quality; therefore, ride quality is the primary criterion in setting pavement rehabilitation priorities. Since it is not possible to build perfectly smooth pavements, paving specifications usually prescribe the maximum acceptable roughness.

Measuring Ride Quality

Two basic approaches to measuring ride quality are currently used. One measures the effect of roughness on ride quality through rating panels or equipment correlated with rating panels. The second approach, called profiling, describes pavement surfaces independent of the measuring equipment.

Ride quality can be determined by pavement serviceability ratings (PSRs) given by panels of drivers and passengers who ride over sections of highways in passenger cars. The PSRs range from zero to five; five represents a perfectly smooth ride. Because of the expense, rating panels are usually limited to a relatively small number—generally about 10 to 20 people. To ensure rating accuracy, the panels are instructed in advance about what to rate and what to ignore. Studies have explored issues of panel rating reliability and accuracy across panels and states, for various pavements, and over time. In one study, a small but significant difference was found between the ratings of two panels from different states in the rating of 31 pavements. (*1*) In another study, no significant differences were found in two ratings conducted five years apart. (*2*) A relatively simple way to estimate ride quality by objective means is to measure the dynamic response of a passenger car as it is driven over a pavement. The Federal Highway Administration's predecessor, the Bureau of Public Roads, developed a single wheel trailer—the roughometer—to perform this measurement. Commercial ride meters, installed in passenger cars or trailers, were later introduced. (*3*) Most Response Type Road Roughness Measuring (RTRRM) systems measure the accumulated suspension deflections over the length of the test sections. The results are expressed as the ratio between suspension deflections in meters (or in inches) and the length of the test section in kilometers (or miles). This roughness index of m/km or in/mi has been in use for many years. The International Roughness Index (IRI), now in commom use, has the same units of measure. The standard IRI is derived from a computer simulation using a set of standard suspension parameters and a recorded road profile to drive the simulation. (*4*) The Pavement Serviceability Index (PSI) computed from the m/km statistics is an estimate of PSR, the panel rating. A statistical relationship and IRI has been developed under a current study. *(5)*

PSR = 5/exp(C*IRI).

The value of C is 0.226 for flexible pavements and 0.286 for rigid and composite pavements. IRI is in m/km. If the IRI is given in in/mi, it must be divided by 62.6 to convert it to m/km.

Profiling Road Surfaces

Road-surface profiling is another means of measuring road roughness. Road-surface profiles present a "profile," or picture, of the road described in terms of wavelengths and amplitudes.

The road surface profile is measured by road-profiling systems, or profilers for short. Attempts to measure the pavement profile go back to the 1920s. These early profilers, however, lacked an independent reference, and the measurements were therefore affected by the geometry of the profiler.

In 1964, General Motors built a profiler using accelerometers to establish an inertial reference. *(6)* The inertial reference is used to correct for the bounce of the survey vehicle. This makes it possible to measure true pavement profiles over a wide range of roughness wavelengths. The recorded profile is independent of the type of survey vehicle and of the profiling speed. This system is commercially available under the trade name "Profilometer."

Between 1974 and 1987, FHWA built two prototypes of profiling equipment, combining longitudinal and transverse profiling. The first, named SIRST (System for Inventorying Road Surface Topography), used 12 infrared sensors to cover the full lane width. *(7)* It was too costly to be promoted for wide use. The second profiler, named PRORUT (Profile and Rut Depth Measuring System), uses only three sensors. *(8)* Two sensors measure the profile in each of the wheel tracks; the third sensor measures an average rut depth. PRORUT was evaluated and used successfully by a number of state highway agencies. *(9)* The cost for building a similar system was estimated to be between $100,000 and $150,000. A new, upgraded PRORUT is now being built in the Pavement Performance Laboratory at the Turner-Fairbank Highway Research Center in McLean, VA. It is similar in layout to the first PRORUT, but uses state-of-the-art data aquisition and computer equipment.

The major cost items of profiling systems are the optical non-contact sensors used for measuring the vertical distance to the pavement. A profiler using ultrasonic instead of optical sensors was built by South Dakota. The cost of such sensors is about 1/20 or less of the cost of optical sensors, enabling South Dakota to build a profiler for less than $50,000. *(10)* This substitution of sensors reduces the vertical resolution and limits the number of samples per unit length. However, for many applications the performance with ultrasonic sensors is adequate. South Dakota offered assistance to any state interested in building a South Dakota-type profiler.

Currently, there are about 40 South Dakota-type systems in operation. Because of the wide interest and in order to promote use of profiling instead of response-type measurements, the Road Profiler Users Group was formed in 1989 and has met annually. *(11)* The 1993 meeting is scheduled to be held in Pennsylvania. For more information, contact Gaylord Cumberledge at (717) 787-1199.

FHWA has initiated a pooled fund study entitled "Interpretation of Road Roughness Profiles." The objective is to develop relationships between longitudinal pavement profiles and ride quality, pavement performance, dynamic loads, highway safety, and vehicle and cargo wear. This study is expected to show that different ranges of the pavement profile (different wavelengths) are associated with the various effects outlined in the objective. As an example, it was found in a recent study that panel ratings of ride quality in passenger cars correlate best with an pavement index computed from wavelengths between 0.5 and 2.5 m (1.6 and 8 ft) corresponding to vibration frequencies of 10 to 50 Hz at a speed of 85 km/h (about 53 mi/h). *(1)*

The pooled fund study is coordinated by the University of Michigan Transportation Research Institute. UMTRI is responsible for developing the test program and developing the relationships mentioned above. Some of these relationships will be empirical, while others will have to be developed from computer simulations, using profile data as one of the inputs. A combination of these two, empirical and simulation, will probably yield the best relationships.

The participating state highway agencies agreed to conduct tests and provide the data and related information to UMTRI. Most states are known to operate South Dakota-type profilers with limited resolution and sampling rates. These limitations may affect some of the planned analyses. Some profilers with better resolution, including FHWA's PRORUT, will be available for this study when more detailed profiles are needed.

A real road-surface profile contains many wavelengths and amplitudes. The larger amplitudes are generally associated with longer wavelengths. Figure 1 shows a record of a typical bituminous road surface over a distance of 100 m (330 ft). The maximum

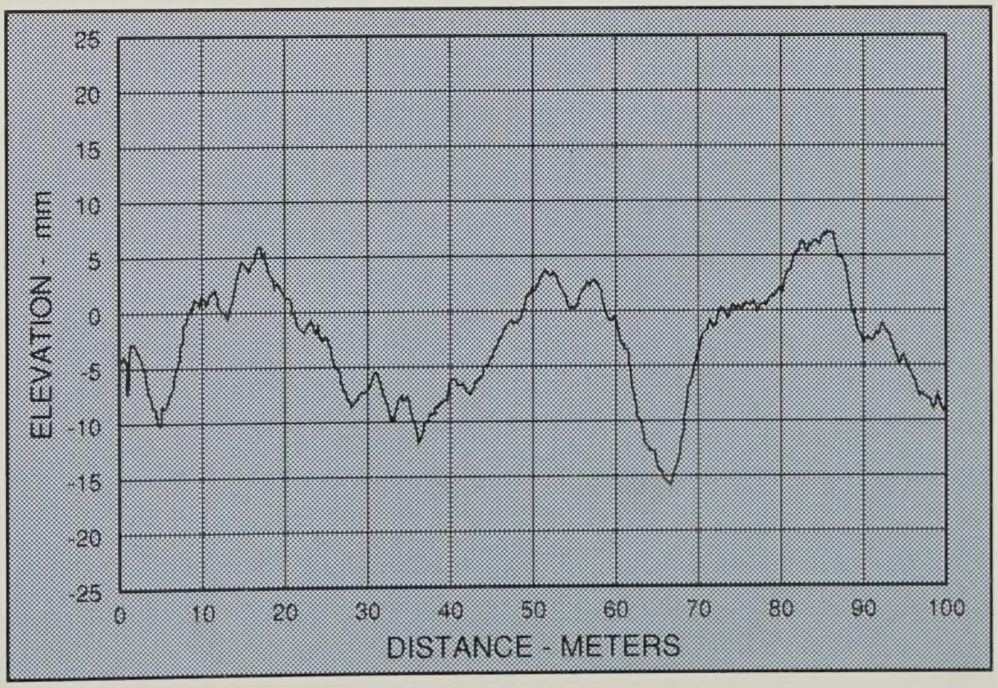


Figure 1—Typical road surface profile.

amplitudes here are about 50 mm (2 in). When the long waves are removed by filtering down to 10 m (33 ft), the same surface looks quite different, and the maximum amplitudes are now about half. (See Figure 2.)

Another way of presenting the road profile is by the so-called spectrum. (See Figure 3.) The horizontal axis shows cycles per unit distance (cycles/m or cycles/ft) which is the inverse of wavelength L. The amplitudes corresponding to each wavelength are plotted on the vertical axis and are seen to decrease with decreasing wavelength (increasing spacial frequencies).

Ride quality, however, is better discussed in terms of frequency of vibration because humans are more sensitive to some frequencies than to others. Frequency is obtained by dividing the speed of travel by the wavelength, giving lower frequencies for longer wavelengths. Car suspensions are tuned to reduce the vibration amplitudes at the frequencies to which humans are most sensitive. The two curves are similar but are from two different roads. The distribution of wavelengths is about the same, but the amplitudes of one road are greater than for the other one. Ride quality gets worse as the amplitudes increase.

Truck suspensions are designed to support heavy loads and are much stiffer than passenger car suspensions. This is a compromise between the desire to provide good ride quality to truck drivers and carrying full loads without excessive suspension deflection. This results in larger dynamic forces damaging the pavement, the truck, and the cargo. Dynamic forces also lead to momentary reductions of the wheel to pavement contact force, which can lead to reduced traction and loss of control.

At this time, the principal use of the profile is to compute and report IRI values to the Highway Performance Monitoring System. This system is the responsibility of the Office of Highway Information Management. The IRI and other information are compiled in an annual report on the state of the highway system. Before the widespread changeover to profiling, the IRI was derived from response-type measurements. The IRI computed from profiles is more reliable and will lead to an overall improved performance measurement.

Some profilers can measure rutting of flexible pavement and faulting of rigid pavements. Ruts are depressions in the transverse pavement profile. Some measuring systems record transverse profiles. A profiler with the two sensors in the rutted wheel tracks and one or more additional sensors can measure rut depth directly. The precision needed for rut depth measurement is not as high as for profiling, so ultrasonic sensors are adequate.

Faults can be measured at travel speeds from profile records, provided the profiler is capable of a high sampling rate. Figure 4 shows a profile recorded by PRORUT at a rate of 10 samples per 0.3 m (10/ft). Faulting is clear from this record, and the fault steps are about 10 mm (3/8 in).

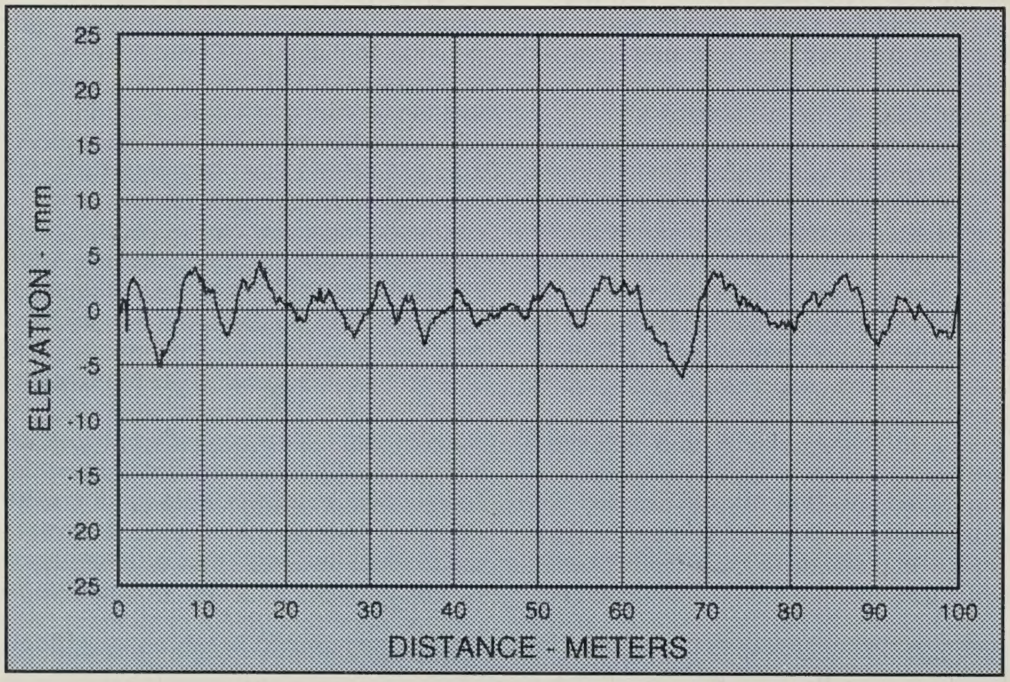


Figure 2—Same surface as in Figure 1 with long waves filtered out.

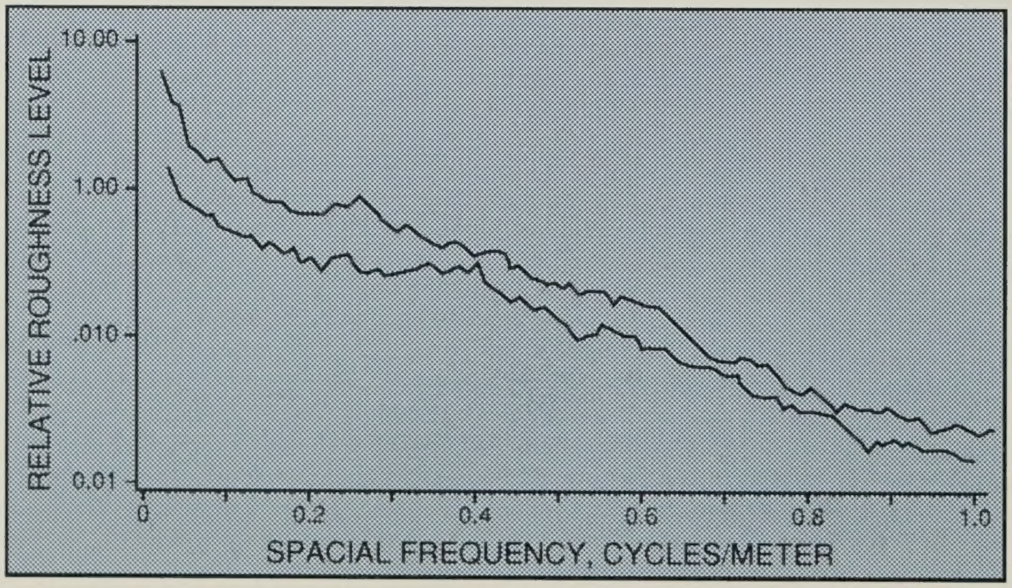


Figure 3—Profile spectrum of two different road surfaces. Upper line is rougher surface.

Summary

The pavement surface shows many features. Although some are needed for good performance, most develop from exposure to traffic and the elements and are manifestations of distress. Pavement distress affects the highway user in many ways. Ride quality is the most obvious and is a primary factor in pavement management decisions. The highway engineer needs reliable tools to determine the condition of the highway system. Early detection of distress can help to take preventive actions instead of more expensive repairs later on. Profiling systems are very effective in measuring road roughness at travel speeds, and if properly equipped can also measure rut depth and faulting.

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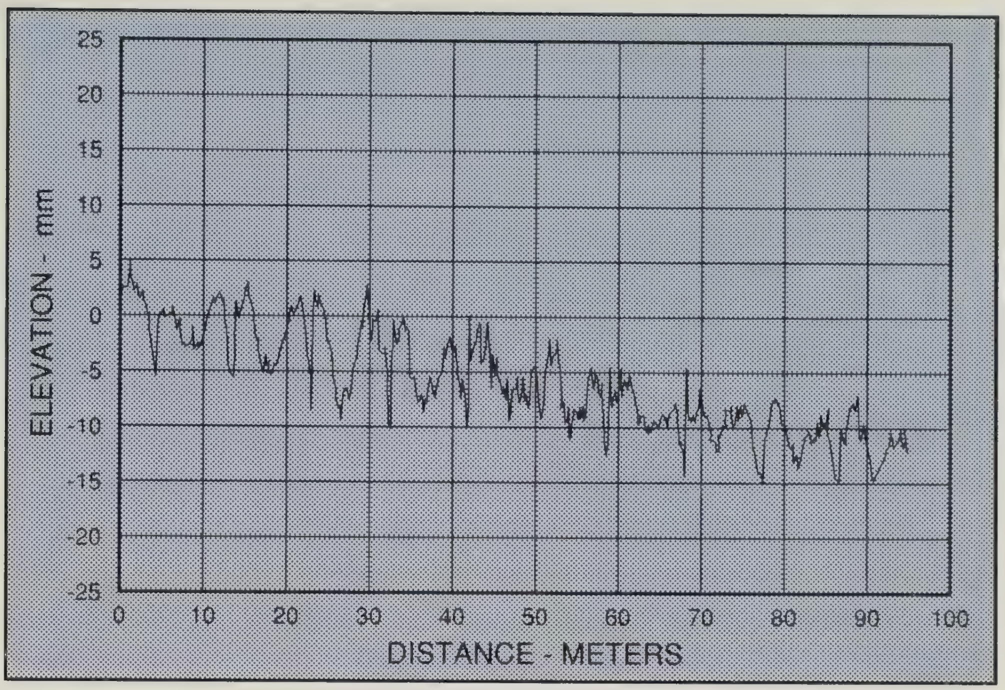

Figure 4—Profile of rigid (portland cement) pavement, showing faulting at joints.

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Rudolph R. Hegmon is a mechanical engineer in the Pavement Division of the Office of Engineering and Highway Operations at the Federal Highway Administration's Turner-Fairbank Highway Research Center. He has worked for FHWA in the areas of traffic safety and truck ride quality since 1973. Dr. Hegmon currently is working on the development of instrumentation for the measurement of pavement performance. His research responsibilities include pavement-vehicle interactions and their effect on traffic safety, dynamic axle loads, and ride quality. He manages the Pavement Performance Laboratory at TFHRC.

Description of the new PRORUT

The new PRORUT is housed in a minivan. The principal components and features are:

- Three laser height sensors which are mounted to a transverse beam below the vehicle body. Two sensors are aligned with the wheel tracks 1.8 m (6 ft) apart. The third sensor is mounted along the vehicle center line.
  Make and model: SELCOM Optocator Type 2008.
  Vertical resolution: 0.25 mm (0.01 in).
  Standoff distance: 390 mm (15.5 in).
  Linear range: 128 mm (5 in).
- Laser control unit, mounted in rear of van.
  Make and model: SELCOM Rack with power supply, three receiver averaging boards.
- Power requirements: 1110 VAC, 50-60 Hz.
  Output: Digital and analog.
  Sampling rate: Up to 16,000 Hz.
- Accelerometers, mounted on left and right height sensors.
  Make and model: Schaevitz LSB, +/- 2g.
- Computer, mounted on stand and accessible to operator and driver.
  Make and model: DOLCH Portable 486/33 VGA Color Monitor.
  Data acquisition board, installed in computer: Data Translation DT 2801A.
- Power supply: 110 V, 1200 Watt.
  Make and model: Heart Interface HF 12-1200U.
- PRORUT sample spacing: 10 mm or larger (up to 30 samples/ft).
- Test speed: 25 to 100 km/h (15 to 60 mi/h).
- Outputs: Raw and processed data, graphical and numerical, choice of filters.
- Statistics: IRI for each wheel track at selected section lengths and average of both wheel tracks. Average rut depth for section length.

HIGHWAY, BRIDGE, AND TRANSIT CONDITIONS AND PERFORMANCE: 1993

This article was adapted from and summarizes the 1993 Highway, Bridge and Transit Conditions and Performance (C&P) Report. The C&P Report is a biennial report that provides Congress and other decision makers with an ongoing appraisal of the current condition and performance of the U.S. highway system.

Our nation's productivity and international competitiveness depends on fast and reliable transportation. As we move toward the 21st century, the status of our highways, bridges, and transit is of paramount importance to the vitality of our economy.

Americans travel roads and highways more often than any other mode of transportation. Highways provide the United States with an efficient network for moving people and goods. More than 90 percent of all travelers and 75 percent of the value of all goods and services are conveyed on highways. Growth in productivity in virtually every sector of the nation's economy depends upon adequate transportation.

The *C&P Report* covers all of the nation's roads and bridges, including all public-use highway and bridge infrastructure and all privately owned toll facilities. Among other subjects, the report provides assessments of system characteristics, trends, highway investment, and investment levels needed to meet future demands.

The information for the report was compiled at the end of 1991 by the states and reported to the Federal Highway Administration (FHWA) in summer of 1992. FHWA assembled and analyzed the information and prepared the report. The report was presented to Congress on January 15, 1993.

Prior to this *C&P Report*, highway/bridge analyses and transit analyses were submitted as separate reports. Because of the complementary nature of these modes of transportation, discussions of highways and transit have been merged. Future reports will build upon this merger, with common data systems and analytical procedures developed to support more rigorous and consistent multimodal analyses of investment options.

This *C&P Report* includes, for the first time, information on environmental impacts. This reflects the need for surface transportation to meet environmental goals and standards as well as mobility goals and standards.

Future travel forecasts used to estimate investment requirements were developed by the states. All investment estimates are for the period January 1, 1992, through December 31, 2011, and are expressed in 1991 dollars.

The National Highway System

The Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 established a new National Highway System (NHS), consisting of approximately 155,000 miles (249,440 kilometers) of highways. This designation can vary by 15 percent in either direction. Although the states will designate the majority of NHS, the interstate system (45,300 mi or 72,900 km), the Strategic Highway Corridor Network (STRAHNET)(15,000 mi or 24,140 km), major STRAHNET connectors (2,200 mi or 3,540 km), and ISTEA-specified high-priority corridors (4,500 mi or 7,240 km) must be included. NHS highways—together with all other arterials, rural major collectors, and urban collectors—will be eligible for federal aid.

Designation of the flexible mileage portion of the NHS will be carried out by the states in cooperation with metropolitan planning organizations and the Department of Transportation; this designation will be submitted to Congress by December 18, 1993. As a prelude to NHS designation, states are reclassifying their roads and streets to establish an updated principal arterial system.

NHS will be the major focus of federal highway investments for the future. The system is expected to carry the bulk of interstate and interregional travel and commerce. The benefits of making these investments are manifold, including: economic growth; national security; intermodal connectivity; system connectivity; safety; the ability to accommodate expanded trade between Canada, Mexico, and the United States; and the ability to sustain a growing tourism industry. Future editions of the C&P Report will include NHS statistics and investment analyses.

Overall Status

System Characteristics

- Total public road mileage reached almost 3.9 million miles in 1991—an increase of almost 13,000 miles over 1989.
- Total highway travel reached almost 2.2 trillion vehicle miles in 1991—a total increase of 3 percent over 1989.
- Transit passenger miles traveled increased by 8 percent from 1980 and 1990.

Highway and Transit Finance

- In 1991, disbursements for highway programs by all levels of government totaled $78.3 billion, with $3.8 billion spent on debt retirement and $74.5 billion on current operations. This expenditure for current operations equates to 3.4 cents per mile of travel—a decline in spending of more than 50 percent in constant dollars since 1960. In nominal dollars, however, 1991 spending for current operations increased more than $7 billion over 1989.
- In 1991, $36.1 billion was spent on highway and bridge capital improvements, compared to $33.1 billion in 1989; $38.3 billion was spent for noncapital purposes. The federal share of capital investment was 41 percent in 1991, down from a high of 56 percent in 1980.
- In 1990, the cost to operate mass transit service in the United States was approximately $14.7 billion; capital expenditures accounted for $4.3 billion, for a total of $19 billion. In 1990, fares and other revenue collected from direct transit customers covered about 43 percent of operating costs with state and local subsidies covering 52 percent and federal subsidy covering 6 percent. The federal share of total reported capital activity declined from 78 percent in 1980 to 60 percent in 1990.

System Condition and Performance

- Pavement condition improved throughout the 1980s and continues to do so into the 1990s. However, approximately 234,500 miles of arterials and collectors remain rated as in "poor" or "mediocre" condition.
- Highway performance declined throughout the 1980s, especially in the larger urbanized areas although most recently, performance has stabilized. This is a direct result of the temporary hiatus in urban travel as a result of the economic slowdown over 1989-1990. More than half of the urban peak hour congestion occurs in the 33 urbanized areas larger than 1 million population. Of urban interstate highways, 70 percent experienced peak hour congestion in 1991.
- In 1992, about 118,500 of the nation's 575,000 bridges were rated as structurally deficient.
- The fatalities on the nation's highways continue to decrease, dropping from 2.6 fatalities per 100 million vehicle miles of travel in 1983 to a low of 1.9 in 1991. However, the total economic cost to the nation of motor vehicle crashes in 1990 was more than $137 billion.

Highway, Bridge, and Transit Investment Requirements

- The cost to immediately eliminate all existing backlog highway deficiencies on arterials and collectors on December 31, 1991, is approximately $212 billion, $7 billion more than the backlog in 1989.
- The cost to eliminate all backlog bridge deficiencies is approximately $78 billion, a $13 billion reduction since 1989, reflecting increased bridge rehabilitation and replacement activity and modifications to the procedures used to rate bridge conditions.
- The cost to eliminate the 1992 backlog of bus and rail transit deficiencies, including equipment and facilities, is estimated at $18 billion.
- The total annual cost to eliminate highway and bridge backlog deficiencies and to meet additional highway and bridge infrastructure requirements for developing urban and suburban areas is $67.1 billion through 2011.
- The total annual cost to maintain overall 1991 highway and bridge conditions and performance is $51.6 billion through 2011.
- The cost to systematically improve transit condition and performance—by eliminating the backlog of bus and rail deficiencies, maintaining current market share, and adding additional service to accommodate anticipated urban demand not included in either the highway cost to maintain or improve assessments—is $6.6 billion annually through 2011.
- The cost to maintain transit condition and performance, including the cost to meet new statutory obligations to serve disabled Americans and improve vehicular emissions, is estimated at $3.9 billion annually through 2011.

The percentage of peak hour travel that occurred under congested or severely congested conditions in 1991 exceeded 70 percent on urban interstate highways and 61 percent on other urban freeways and expressways.

System Conditions and Performance

Highway operating characteristics

Continuing growth in travel is causing increasing highway congestion, particularly in urbanized areas. The percentage of peak hour travel on urban interstate highways that occurred under congested or severely congested conditions exceeded 70 percent in 1991, up from 55 percent in 1983. Urban interstate peak hour congestion has grown at an average annual rate of 3 percent since 1983.

The percentage of congested peak hour travel on other freeways and expressways (OF&E) in urban areas increased from 49 percent in 1983 to more than 61 percent in 1991. Urban peak hour congestion on OF&E has grown at an average annual rate of 2.8 percent since 1983.

For urban interstate peak hour travel, more than 55 percent of the congested travel and more than 73 percent of the highly congested travel occurs in the most populous 33 urbanized areas. Approximately 37 percent of the mileage, almost 41 percent of the lane-miles, and more than 53 percent of the travel on non-local urban roads occurs in these 33 areas. However, more than 65 percent of the overall peak hour congested urban travel is in these same areas.

Highway physical characteristics

Table 1 compares pavement condition, based on the pavement ser-

Table 1.— Estimated highway mileage by pavement condition, functional system, and year

Functional System	Year	Poor	Mediocre	Fair	Good	Unpaved	Total
Rural Interstate	1983	13.3	13.8	14.3	58.6	0.0	100
	1985	10.8	14.1	15.4	59.7	0.0	100
	1987	11.6	15.5	14.4	58.4	0.0	100
	1989	9.1	15.4	17.4	58.4	0.0	100
	1991	7.6	15.6	15.9	60.8	0.0	100
Urban Interstate	1983	16.8	16.1	13.7	53.4	0.0	100
	1985	11.1	19.5	13.5	56.0	0.0	100
	1987	11.1	18.5	15.0	55.4	0.0	100
	1989	9.6	16.1	16.7	57.6	0.0	100
	1991	7.7	15.6	16.6	60.1	0.0	100
Rural Other Arterials	1983	11.1	11.8	35.3	41.8	0.1	100
	1985	8.3	10.0	36.7	44.9	0.1	100
	1987	6.6	11.0	37.3	45.0	0.1	100
	1989	4.8	9.9	37.4	47.8	0.0	100
	1991	3.9	8.0	38.3	49.8	0.0	100
Urban Other Arterials	1983	10.0	13.6	34.1	41.7	0.6	100
	1985	9.0	13.9	34.7	42.0	0.5	100
	1987	8.7	14.0	35.2	41.7	0.4	100
	1989	7.7	13.4	36.5	42.1	0.3	100
	1991	6.8	13.2	36.0	43.6	0.4	100
Rural Collectors	1983	15.0	12.1	25.5	24.7	22.8	100
	1985	12.8	13.4	27.2	24.2	22.3	100
	1987	12.0	13.0	26.9	26.5	21.7	100
	1989	10.5	12.7	27.9	28.6	20.3	100
	1991	8.2	12.0	29.8	30.1	19.9	100
Urban Collectors	1983	14.9	15.5	34.2	33.3	2.0	100
	1985	13.1	17.4	35.3	32.5	1.7	100
	1987	13.6	17.4	36.6	31.1	1.3	100
	1989	17.6	16.5	33.3	31.3	1.4	100
	1991	11.3	17.4	36.0	34.2	1.1	100

Substantial resurfacing and rehabilitation programs will be required to maintain pavement structure in an acceptable condition.

viceability rating system, by functional system over time. Between 1983 and 1991, the percentage of pavements in poor condition (those needing improvement now) decreased or maintained a stable condition for all functional systems, rural and urban. The total mileage in the mediocre pavement category (those needing improvements in the near future, generally within the next five years) has become relatively stable. For the interstate functional systems, the mileage in the mediocre category is within 2 percent of the value for 1983. For other arterial systems, the percentage of miles in the mediocre category ranges from a low of 7.3 for rural other principal arterials to a high of 14.7 for urban minor arterials.

The pavement rated as fair will likely need improvement in the five- to 10-year range, and pavement in good condition will not likely need improvement for 10 to 15 years or more.

The mileage in poor condition in most states has declined over the past few years. This represents a real accomplishment in addressing the worst pavement needs. However, because of traffic loads and the environment, pavements will continue to deteriorate, and substantial resurfacing and rehabilitation programs will be required to maintain pavement structure in an acceptable condition.

Bridges

The percentage of interstate, arterial, and collector bridges classified as structurally deficient increased from 1984 to 1992—rising from 13.2 to 14.3 percent. Generally, the higher functional systems have fewer deficient bridges than lower systems. However, the proportion of interstate bridges classified as structurally deficient increased from 5.1 percent in 1984 to 6.8 percent in 1992. This is indicative both of the heavy use of the interstate system and the fact that many of these bridges are nearing the point when rehabilitation will be required.

Most bridges that are *structurally* deficient are not in danger of collapse, but they are likely to be load-posted so that heavier trucks will be required to take an alternative, longer route. *Functionally* deficient bridges are those that do not have adequate lane widths, shoulder widths, or vertical clearances to serve traffic demand or whose waterway may allow occasional flooding of the roadway.

The major increase in functionally deficient bridges between 1988 and 1990—especially on the interstate system—resulted from changes in the *Recording and Coding Guide for the Structure Inventory and*

Building new highways and bridges today requires techniques which limit environmental damage.

Appraisal of the Nation's Bridges. More specific criteria are used to assess condition and identify deficient bridges. In 1992, 25.3 percent of the interstate bridges were classified as being deficient, compared to 13.1 in 1984.

Highway safety

Fatality rates decreased from 1983 to 1991 for both rural and urban interstate, other arterials, and collectors. Rates ranged from a high of 3.27 per 100 million vehicle miles traveled on rural collectors to a low of 0.67 on urban interstate highways. The fatality rates on the interstate highways—the system with the lowest accident rate—decreased from 1.50 in 1983 to 1.25 in 1991 in rural areas and from 1.01 to 0.67 in urban areas. Overall fatality rates are 2.76 for rural highways and 1.32 for urban highways, with an overall average of 1.91.

Although fatality rates decreased to a historic low in 1991, the National Highway Traffic Safety Administration estimated that the total economic cost to the nation of motor vehicle crashes in 1990 was more than $137 billion.

Environmental conditions and performance

The environmental consequences of transportation arise from both construction and use. Indices of performance pose both conceptual and practical challenges. However, an initial set of categories were identified: air quality, water quality, wetlands, energy, noise, land and open space, threatened and endangered species, and community impacts.

Progress is being made in each of these categories. As an example, there was significant progress in reducing the overall levels of the major transportation-related air pollutants over the last decade. According to the Environmental Protection Agency's *National Air Quality and Emissions Trends Report* in 1990, pollution from carbon monoxide, lead, nitrogen monoxide, and smog were all reduced along the nation's highways from 1981 to 1990 despite a 39-percent increase in vehicle miles traveled. Emissions of carbon monoxide were down by 39 percent, of lead by 85 percent, of nitrogen dioxide by 6 percent, and of smog (hydrocarbons) by 12 percent.

Transit service quality

The perception of quality among customers and potential customers is an important determinant of transit use and is often more important than the cost of the fare. According to National Personal Transportation Survey (NPTS) data, the majority of transit users spend very little time waiting for service. Approximately 47 percent of transit trips involve one or more transfers. In addition, approximately 17 percent of transit trips involve a transfer from a private vehicle—e.g., park and ride situations. According to NPTS 1990 data, over 40 percent of all transit commuters reported trip times of 10 minutes or less; nearly 87 percent of transit riders arrive at work in less than half an hour.

Bus and paratransit condition

The Federal Transit Administration has established minimum requirements for the period of time an asset must remain in mass transit service before it will be considered eligible for replacement. If it were possible for transit agencies to replace vehicles on this schedule, the average age of each type of vehicle would be one-half the useful life guideline. In reality, however, the average fleet age for all classes of buses and paratransit vehicles is greater than the optimum guideline. As a result, there is a backlog of overage vehicles of each type in need of replacement.

Since 1990, the total fleet size has not changed noticeably, but the average age of the vehicles has increased.

Rail conditions

Detailed information is available on the condition of the nation's rail system from the Rail Modernization Study published in 1987. Specific definitions were developed for each of five condition levels—excellent, good, fair, poor, and bad. The key condition level is good, which is

Approximately 42 percent of the highway backlog is pavement cost.

defined as "good working order and requiring only nominal or infrequent minor repairs."

Maintenance yards and facilities are in the most need of improvement because only 17 percent of the yards and 28 percent of the facilities were rated as being in good or better condition. Also in need of substantial improvement are elevated rapid rail structures (with only 19 percent in good or better condition), stations (29 percent), and bridges (32 percent). Substations are in the best overall shape; 66 percent is in good or better condition. Commuter rail vehicles are also generally well off; 49 percent of locomotives and 55 percent of unpowered cars are in good or better condition.

Highway, Bridge, and Transit Investment Requirements, 1992-2011

The following provides estimates for total capital investments required by all units of government to achieve specified levels of overall system condition and performance for all highways, bridges, and transit systems for the period 1992-2011. Future travel forecasts used to estimate investment requirements were developed by the states. All investment estimates included in this article are for the period January 1, 1992, through December 31, 2011, and are expressed in 1991 dollars.

Investment requirements are presented in Table 2 as two scenarios:

- Cost to improve overall conditions and performance.
- Cost to maintain current overall conditions and performance.

The remaining 58 percent of highway backlog is the cost of adding capacity, including building more lanes, to restore system performance to minimum capacity performance standards.

Highway and bridge requirements

Estimates of highway and bridge investment requirements were prepared based on sophisticated engineering-based models—i.e., the Highway Performance Monitoring System (HPMS) Analytical Process and the Bridge Needs and Investment Process (BNIP). The highway and bridge estimating procedures received input from HPMS and National Bridge Inventory (NBI) data bases.

HPMS contains information about physical conditions and use for more than 100,000 non-local highway sections. The HPMS analytical procedure uses this data to simulate highway investment decisions and predict system performance.

NBI contains detailed information about all highway bridges in the country. Using this data, BNIP compares bridge conditions to a prescribed set of minimum bridge condition standards. Deficiencies are noted, and the appropriate improvement is simulated.

HPMS data suggests that highway travel will increase at an average annual rate of about 2.5 percent through 2011. That is slightly below the average 3-percent increases for the past decade.

The "backlog" of highway and bridge deficiencies is the cost of bringing the current system up to minimum standards from its existing conditions and performance status. As of December 31, 1991, the cost of eliminating the backlog of highway deficiencies was estimated at $212 billion for all existing arterials and collectors. This amount is $7 billion more than the comparable figure from 1989; the increase is attributed to deterioration in overall average system performance.

Approximately 42 percent of the highway backlog is pavement cost; the remaining 58 percent is the cost of adding capacity to restore system performance to minimum capacity performance standards. The urban backlog is twice as high as rural backlog, reflecting the capacity defi-

Table 2.—Investment scenarios

	Description	
Scenario	**Highway and Bridges**	**Transit**
Cost-to-improve conditions and performance	Goal: • Eliminate backlog and accruing performance and conditions deficiencies. • Ensure that by the year 2011 no highway or bridge will be in poor condition.	Goal: • Eliminate backlog of transit equipment and facility deficiencies. • Increase rate of ridership growth and increase market share.
Cost-to-maintain conditions and perfomance	Goal: • Maintain overall condition and performance through 2011, except in the largest cities, where performance can be expected to decline due to inadequate capacity.	Goal: • Maintain current levels of service. • Maintain current growth trends in transit patronage.

ciencies in the larger urban areas. Backlog deficiencies are fairly evenly distributed among the functional highway systems.

As of December 31, 1991, backlog requirements on the nation's highway bridges were $78 billion. The cost to eliminate the backlog of bridge deficiencies could increase to as much as $112 billion, depending on the number of years required to meet that objective, because of the deferred capital cost of bridge repair. The bridge backlog estimates have decreased significantly from the $91 billion estimate in 1989 because of bridge improvements and revisions in the rating criteria.

The average annual cost through 2011 to repair all backlog deficiencies and keep all highways above the specific minimum condition and performance level standards through 2011 is $59.1 billion. This figure includes an estimated $4.8 billion in annual capital savings from the coordinated traffic management program. The average annual investment required to repair, replace, or widen all backlog and accruing bridge deficiencies on all highway bridges through 2011 is $8.2 billion.

The "cost-to-improve" scenario would result in modest improvements in overall pavement conditions on the higher functional systems. It would increase the average pavement condition to approximately a 3.5 pavement serviceability rating. Consequently, pavements would have, on average, between 8 and 12 years of remaining design life.

System performance on rural and many urban highways would improve under this scenario, supporting at least a minimum level of service during the daily peak period of demand. The scenario would eliminate most highly congested conditions and improve performance on high-volume highways soon to be congested.

Under this scenario, conditions and performance would be superior to today's but substantially below the design and performance standards expected of new, or nearly new, roads. No section of road would be in poor condition.

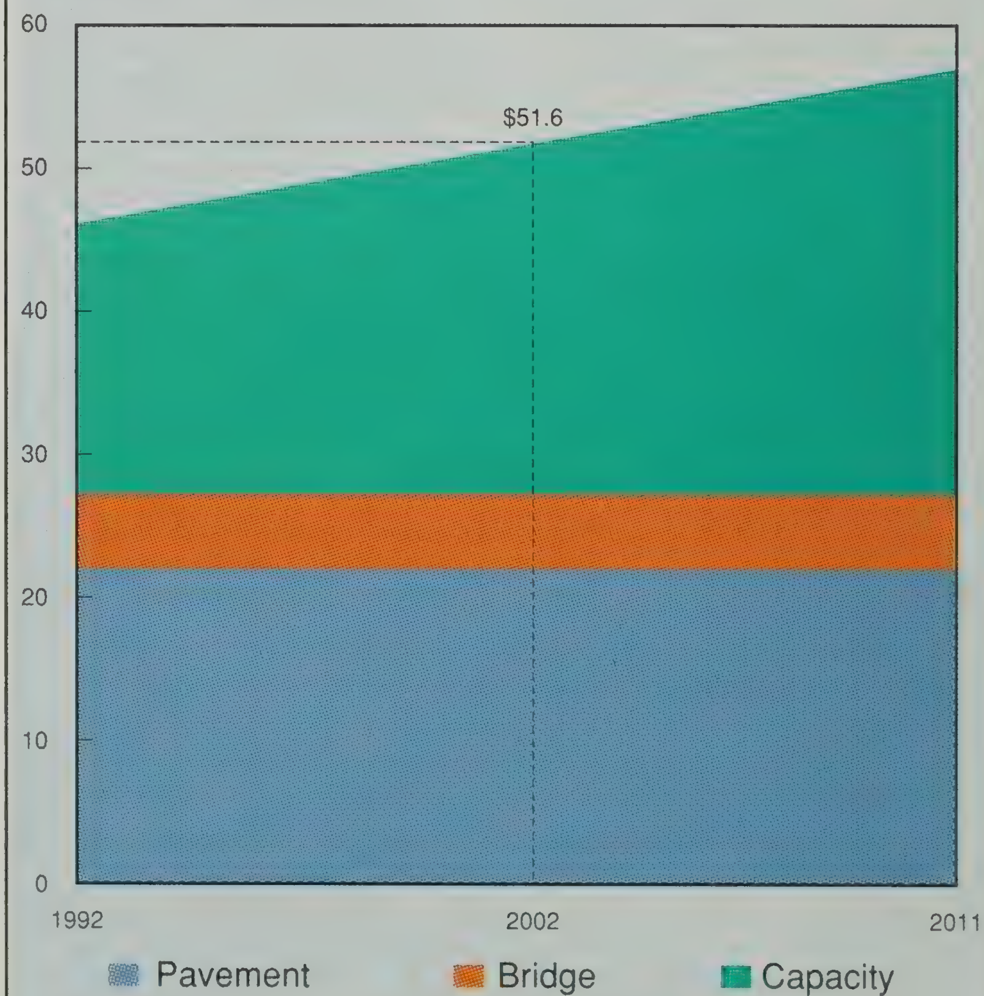
The magnitude of new capacity required to improve conditions to or above the minimum condition standard for performance is unlikely to occur, given the extensive right-of-way acquisition, social dislocation, air quality, and noise effects that would result from such an effort.

Table 3.— Investment requirements for highways and bridges vs. related capital outlay, 1991-2011 (projecting 2.5% growth rate in vehicle miles traveled (all estimates expressed in billions of 1991 dollars and do not reflect inflation)

Functional System	Annualized Cost To Improve			Annualized Cost To Maintain			1991 Related Capital Outlay
	System Preservation	Capacity	Total	System Preservation	Capacity	Total	
Rural							
Interstate	2.4	1.8	4.2	2.0	1.7	3.7	2.5
Other Principal Arterial	2.5	1.7	4.3	1.9	1.1	3.0	3.6
Minor Arterial	2.9	1.3	4.2	2.2	1.0	3.2	2.1
Major Collector	5.3	0.7	6.0	4.2	0.7	4.9	2.3
Minor Collector	3.4	0.1	3.5	2.0	0.1	2.1	0.8
Local	0.7	-	0.7	0.5	-	0.5	[2]
Subtotal Rural	17.2	5.6	22.9	12.8	4.6	17.4	11.3
Urban							
Interstate	4.9	5.3	10.1	4.1	4.4	8.5	4.7
Other Freeway and Expressway	1.9	2.6	4.5	1.5	1.9	3.4	2.4
Other Principal Arterial	4.8	7.3	12.1	3.7	4.3	8.1	4.8
Minor Arterial	3.5	5.3	8.7	2.8	3.6	6.4	2.2
Collector	2.6	2.4	5.0	2.1	1.8	3.8	1.0
Local	0.2	3.8	4.0	0.1	3.8	3.9	[2]
Subtotal Urban	17.9	26.5	44.4	14.3	19.9	34.2	15.1
Total	35.1	25.0	60.0	27.1	24.5	51.6	32.1
1992 Estimate (1)	35.1	25.0	60.0	27.1	19.1	46.2	
2011 Projected (1)	35.1	40.2	75.2	27.1	30.7	57.8	

1 See Table 4.
2 Data is not available to disaggregate "local" capital outlay by urban and rural categories; therefore, the total 1991 related capital outlay included spending while rural and urban subtotals do not include this spending. Local spending in 1991 was $5.7 billion.

Table 4.— Annual cost to maintain scenario for 1991 highway and bridge condition and performance.



Capacity improvements include additional lanes on existing facilities plus additional infrastructure to support anticipated suburban growth.

Table 5.—Summary of annualized transit investment requirements, 1992-2011 (All estimates are expressed in billions of 1991 dollars and do not reflect inflation)

Scenario	Explanation	...Annual Cost
Improve conditions and performance	• Eliminate backlog. • Increase transit market share by 25% over 20 years. • Service expansion to meet 10% of 34,000 lane-miles of highways not built. • Improve stations to current standards. • Include ADA* requirements.	$6.6
Maintain conditions and performance	• Include ADA* requirements. • $3.1 billion/year to maintain transit conditions. • $0.8 billion/year to maintain trends in patronage.	$3.9

*Americans with Disabilities Act

The average annua! cost to maintain existing highways through 2011 is estimated at $46.4 billion. This figure includes savings from the coordinated traffic management program.

The average annual cost to maintain overall bridge conditions as they were reported on June 30, 1992, is estimated at $5.2 billion annually through 2011. This investment level would maintain the current total number and distribution of structurally deficient and functionally obsolete bridges.

Under this scenario, the backlog would remain essentially unchanged over the 20-year analysis period. Conditions described earlier would be maintained except in the larger urbanized areas, where further deterioration can be expected because of the capacity constraints imposed in the analysis.

Table 3 summarizes annual investment requirements to meet each scenario target for all urban and rural areas. The table shows total 20-year investment requirements categorized as pavement and capacity improvements, with annualized totals. The annualized total is the 20-year total divided equally. Under the cost-to-improve scenario, two-thirds of total investment would occur in urban areas; capacity improvements would account for about half of total investment.

Table 3 compares highway and bridge capital requirements for 1992-2011 with actual 1991 capital expenditures by state and local governments. The cost-to-improve scenario would require a total annual investment in highway infrastructure of $67.3 billion—more than twice what was spent in 1991 for corresponding capital improvements. Increasing investment in infrastructure from its 1991 level of $32.1 billion to $67.3 billion would require spending an additional 1.6 cents per mile of travel. The "cost-to-maintain" scenario would require an additional 0.9 cents per mile of travel. Total spending capital for highways and bridges would need to increase by $35.2 billion annually in 1991 dollars to improve 1991 overall conditions and performance. If funded by motor fuel taxes, this increase in spending would require a fuel tax increase of approximately 27 cents per gallon. To provide the $19.5 billion required to maintain 1991 conditions, a fuel tax increase of 15 cents per gallon would be required.

Table 4 graphically illustrates the investment stream on a year-to-year basis for the cost-to-maintain scenario. Pavement and bridge requirements are essentially the same annually over the 20-year period, reflecting the continuing nature of system condition maintenance. The "ramping" of total investment requirements to meet existing and anticipated growth in travel is illustrated by the increasing capacity requirements shown. All values are in 1991 dollars and do not reflect any inflation in highway construction costs over the period.

Transit requirements

The transit backlog includes the estimated costs of replacing all bus and rail transit equipment that has exceeded its usable design life. Eliminating the backlog would bring the average fleet age down to the minimum useful life standards and bring rail equipment and facilities to good condition. The total transit backlog is estimated at $17.6 billion or $0.9 billion per year if eliminated over the 20-year period.

The cost-to-improve scenario is estimated at $131.8 billion for the period 1992-2011. This cost would require an annual investment of $6.6 billion, assuming that the backlog would be eliminated over 20 years.

At this investment level, transit services will increase over a 20-year period to about 283 million revenue vehicle hours per year, thereby providing capacity to accommodate about 64 billion passenger miles per year, compared with 38 billion passenger miles today. In addition, the backlog of deferred rail and bus modernization and rehabilitation needs would be eliminated, restoring those systems to good condition and bringing them up to modern transit standards.

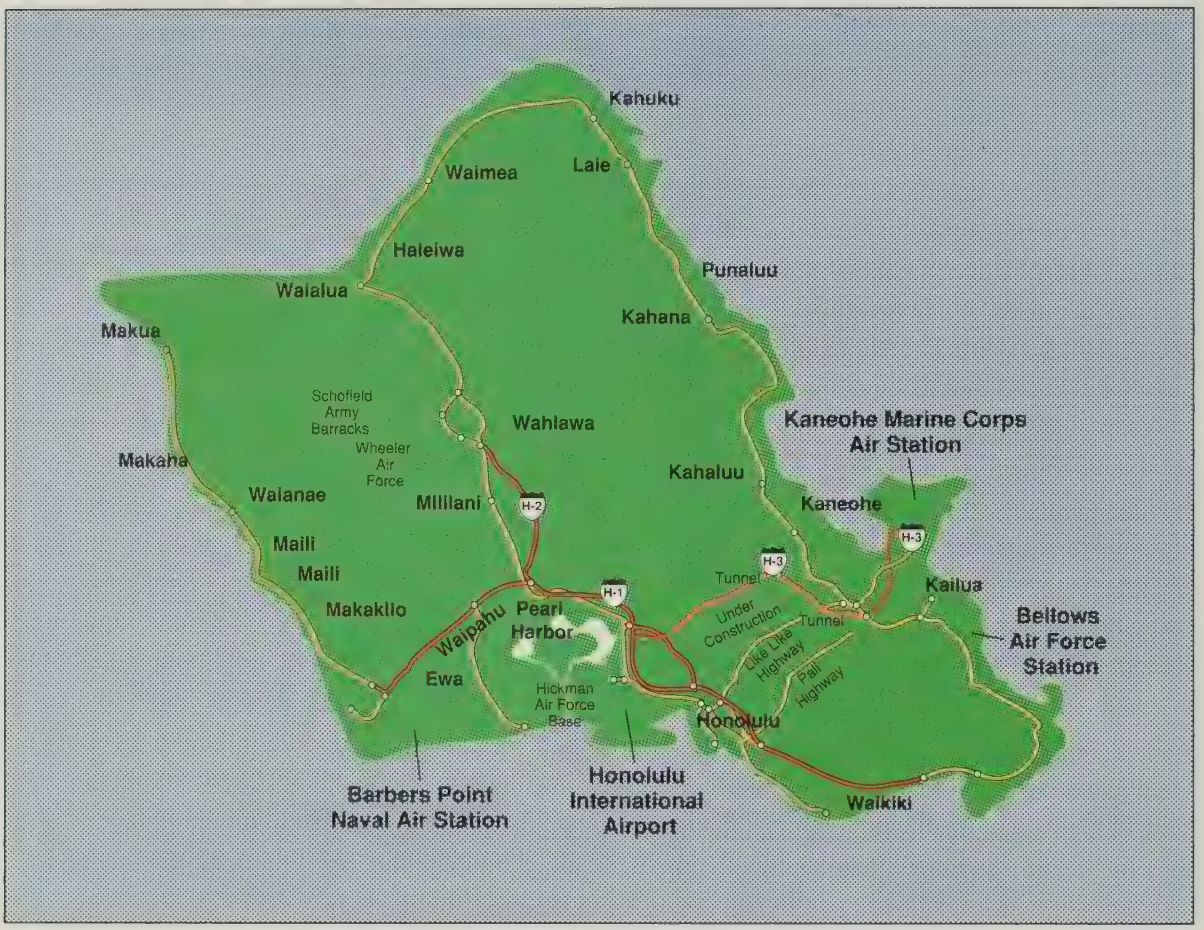
The cost-to-maintain scenario is estimated at $77.8 billion through 2011 or $3.9 billion per year. This figure is the investment needed to maintain current levels of service. At this level of investment, facilities and equipment would be maintained in their current state of repair. The estimate also includes the additional investment level needed to extend coverage and improve service levels to maintain current trends in growth in transit patronage. It includes low capital demand management as well as new starts at historical levels.

At this level of investment, the amount of transit service provided would increase at a rate of 0.8 percent per year, consistent with the increase in transit patronage over the last 10 years. In 20 years, this would result in an increase in capacity of 17 percent, raising the total amount of transit service from the present 169 million revenue vehicle hours to about 198 million revenue vehicle hours. This increase in capacity could accommodate an increase in passenger miles from the present 38 billion to about 44 billion.

Under this scenario, transit vehicles would be replaced at about the current rate, which is slightly slower than optimal. Existing rail systems would be maintained in the current conditions with no major improvements. Investments on existing rail systems would occur at the rate needed to ensure that equipment and facilities are replaced as they wear out. New rail systems would be constructed at a rate sufficient to accommodate the present rate of transit patronage growth. Table 5 summarizes 1992-2011 transit investment requirements.

H-3: THE ISLAND INTERSTATE

by Craig Sanders



H-3 will provide much needed relief to the other two trans-Koolau routes—the Likelike and Pali highways—which have long been operating at capacity during the morning and evening rush hours. When H-3 is opened, it is predicted that one-third of the present traffic crossing the mountains will use H-3, one-third will use the Likelike Highway, and one-third the Pali Highway.

H-3 is the biggest construction and the largest public works project ever undertaken by the state of Hawaii. This immense goal, consisting of 20 separate contracts, includes both leeward and windward viaducts joined by a 5,000-foot trans-Koolau tunnel, bridges, interchanges, access roads, and more. The planning and construction of H-3 has been costly, lengthy, and anything but easy. At times it seemed that there was no end to the environmental, archaeological, legal, and engineering challenges.

To those on the mainland United States, visions of Hawaii usually bring thoughts of relaxing on a white, sandy beach during the long, warm, tropical days, sipping on a fruity drink while an exhilarating equatorial breeze gently whisks away the stress and worries common to everyday life.

While these peaceful images of Hawaii may hold true for the two-week tourist, we who live in and around the city of Honolulu on the island of Oahu, which houses 80 percent of Hawaii's residents, must deal with the big city problems of population and traffic congestion. In the last 20 years, the population has increased 44 percent while the number of motor vehicles on the highway has risen 111 percent. Interstate route H-3 is part of the Hawaii Department of Transportation's (HDOT) integrated long range transportation plan to accommodate the island's growing population.

How can any highway on an island be designated as an interstate? In 1959, after Hawaii became a state, Congress felt both Alaska and Hawaii needed to be included in the interstate highway system, granting the new state of Hawaii 50 miles of this high-speed, limited access freeway for the highly populated island of Oahu. So, by nature of its designation and funding, we have an interstate system in Hawaii separated from the next nearest state by a 2000-mile stretch of the Pacific Ocean.

The 52-mile-long interstate system was planned to solve Oahu's projected traffic demands and connect the island's major military centers. This network consists of three freeways: H-1, H-2 and H-3.

H-1, 27 miles long and now complete, connects the Hawaii National Guard at Fort Ruger to the Barbers Point Naval Air Station and runs through the middle of Honolulu. H-2, also complete and only eight miles long, joins Pearl Harbor Naval Base and Hickam Air Force Base to Wheeler Air Force Base. H-2 also serves as a partial connection from H-1 to the North Shore of the island. The 15-mile-long H-3 will connect the Kaneohe Marine Corps Air Station to the Pearl Harbor defense bases, passing through the Koolau Mountains to join the windward towns of Kailua and Kaneohe to the leeward cities of Pearl City and Honolulu.

Construction on the Kaneohe interchange which is one of 20 contracts for the H-3 project. The shear windward side of the Koolau Mountains is in the background.

Top. A view of the windward city of Kailua. The Windward Viaducts are visible on the right. The antennae from the Coast Guard Omega Station can be seen in the upper right.

Right. The Coast Guard Omega Station located on the windward side of the Koolaus near the mouth of the Trans-Koolau Tunnels. This station causes large, insulated objects nearby to become charged, posing the threat of shocks to workers and users of H-3. Several countermeasures have been taken to eliminate this problem.

However, it has been an invaluable learning experience for HDOT.

Although the planning for H-3 began much earlier, the passage of the National Environmental Policy Act of 1970 required the state to file its first Environmental Impact Statement (EIS). The law demands the study, documentation, and possible mitigation measures of significant impacts on the environment caused by any projects using federal funds. At the time, the concept of putting environmental concerns ahead of engineering issues was rarely considered on most projects.

HDOT conducted specialized studies for different areas of concern, including archaeology, plants and animals, and air and noise quality. To validate these studies, experts in each of the involved fields—botany; zoology; archaeology; Hawaiian culture; and water, air, and noise quality—were hired.

When all the environmental questions had been answered and the studies completed, the results were compiled into a huge, several-volume EIS document. These findings were discussed with the public, evaluated by the state and federal governments, and finally incorporated into the planning and design of the H-3 project. Although much time and money was spent on the preparation of the EIS, HDOT had its first experience with the new law and had planned and designed a project with the environment as a prime consideration.

An often overlooked benefit of the H-3 project is the wealth of archaeological knowledge uncovered. The proposed H-3 corridors routed the freeway through undeveloped lands on the island. Recognizing the possibility of unearthing artifacts of the ancient Hawaiians, HDOT hired archaeological experts from the Bishop Museum in Hawaii to find, survey, and study archaeological sites. After the important areas were identified, H-3's alignment was designed to avoid any adverse impacts.

A section of the Moanalua Valley, once considered a possible corridor for H-3, was even placed on the National Register of Historic Places. A Bishop Museum archaeologist declared that the H-3 process saved these priceless sites from private development. The examination of the sites is ongoing, and much more is expected to be learned about the early Hawaiians.

The Coast Guard Omega Station (OMSTA) presented a unique challenge. The station, located on the windward side near the mouth of the Trans-Koolau Tunnels, is part of an eight-station, worldwide network which allows any aircraft or ship to determine its location to within a mile. OMSTA causes large insulated objects near the station to become energized, providing a small shock to anyone coming in contact with these items. HDOT was concerned that "surprise shocks" to workers on H-3 might result in a fall or other accident. In some cases, workers in sensitive areas were required to wear gloves or rubber boots. To prevent any effect on H-3 travelers, a device known as a Faraday Shield was installed over a short section of the highway near the mouth of the tunnels to reduce the electric field. The shield consists of six three-eighth-inch-diameter wires on each side of the road spaced one vertical meter apart and eight three-eighth-inch-diameter wires overhead. A wire mesh is incorporated into the pavement below to complete the shield.

Hoomaluhia Park on the windward (east) side of the Koolau Mountains was developed in conjunction with the H-3 alignment. The Department of Parks and HDOT worked together to produce a park which would be partially bordered by H-3. However, a legal challenge stemming from this shared border delayed the construction of the freeway for more than two years.

A small group of opponents to the highway saw the shared border as an opportunity to use the park and the Section 4f of the U.S. Department of Transportation Act to stop the construction of H-3. Section 4f protects some public lands and historic sites. On August 21, 1984, the Ninth Circuit Court of Appeals determined that there had been "constructive" taking of park land, effectively stopping all construction activity on H-3. Although no park land was actually taken, the more abstract "constructive" possesion of the park land was defined as the overall reduction in environmental quality to the park as a result of the 1.7-mile border with H-3. State attorneys appealed this ruling but were unsuccessful in overturning the injunction.

Finally, it was decided to pursue an exemption to Section 4f by presenting the case to the U.S. Congress. After a constant bombardment of phone calls, letters, petitions, and meetings with subcommittee members in support of H-3, Congress approved and President Reagan signed an exemption into law in October 1986. Then, after more than two years of delay, the U.S. District Court dismissed all injunctions against the construction of H-3.

The new animal quarantine station.

With the lifting of the injunction, construction began on the five-mile, $8.5-million North Halawa Valley access road. Many obstacles had to be overcome to build this road. For example, everyday, surveyors had to be airlifted deep into the beautiful but rugged North Halawa Valley to set the road alignment, gather topographical information, and build a landing pad for their return ride in the evening.

At the completion of the access road in 1989, work began to relocate Hawaii's unique animal quarantine station and to construct a short "cut and cover" tunnel, viaducts, and the trans-Koolau tunnels. Unfortunately, the best alignment of H-3 routed it through the middle of the state's animal quarantine station. This was the only facility capable of holding animals in accordance with the state law requiring a 120-day quarantine of all potential carriers of rabies imported into Hawaii. The station was relocated using federal funds allowed for "functional replacement," meaning that the relocated facilities could be designed and built to current codes but could only perform the same functions as the existing facilities. The new AQS was completed in 1991 for $20 million.

Hospital Rock Tunnel is a 690-foot "cut and cover" with separate inbound and outbound tunnels. A cut and cover tunnel is cut completely away to daylight, the tunnel constructed, and the cover backfilled around the concrete tunnel section. These tunnels cost nearly $18 million.

The Hospital Rock "cut and cover" tunnels.

The real showcases of H-3 are the North Halawa and Windward Viaducts and the connecting mile-long Trans-Koolau Tunnel.

H-3 passes through the majestic Koolau Mountains via the mile-long Trans-Koolau twin tunnels. The construction of the tunnels involves six different contracts, including ones for an exploratory tunnel, ventilation, control and support systems, finishing, and tunneling. All contracts are expected to be completed by December 1994.

When the North Halawa Valley was opened up by the newly built access road in January 1989, the boring of an 14-foot-wide exploratory

Top. The twin Windward Viaducts looking away from the tunnels.
Center. The portal buildings on the windward side.
Bottom. The outbound, windward side portal structure.

tunnel began through the Koolau Mountains. An exploratory tunnel is used by engineers to provide geological information and assist in the design of the main tunnel. Although this exploratory tunnel, finished in March 1990, cost $12 million, it has been proven that an exploratory tunnel saves money in the long run by reducing the expense of the main tunnel.

The actual tunneling work for the main tunnels was split between two contracts—one beginning on the leeward or North Halawa side and one starting from the windward or Haiku side. A joint venture of contractors, called H-3 Tunnelers, began tunneling from the Halawa side in January 1991 for a contract price of $89 million. Another joint venture, named Trans-Koolau, began tunneling from the Haiku side in October 1990 for a price tag of $108 million. The tunnelers used the "drill and blast" method of tunnel excavation, following with shotcreting and rock bolting for temporary support. A soft ground type called sapprolite was encountered for the first 300 feet into the Halawa side of the tunnels. The rest of the tunneling was done in good rock. Although the H-3 tunnels are above the groundwater table, rain water filters through the porous rock and poses the problem of nuisance drips. To alleviate this problem, a waterproof membrane seals the shotcrete to a 14-inch-thick concrete lining, which is being constructed using a 50-foot-long moving form.

The tunnel section is horseshoe shaped with an invert width of 48 feet for two lanes of traffic and an excavated height of 38 feet. The profile has a maximum grade of six percent; the Haiku and a Halawa portal elevations are 840 and 1,305 feet above sea level, respectively. The rock cover above the tunnel ranges from 600 to 1,385 feet. The top of the Koolau Range reaches an elevation of 3,760 feet. Included in the design of the tunnel are 10 horseshoe-shaped cross-passages, which are excavated 10 feet wide by 24 feet high and are from 115 to 226 feet in length.

There are two portal structures on each side of the mountain—one for the inbound and one for the outbound lanes. These are four-level concrete buildings designed to house the ventilation and control systems, including electrical switchgear for power, transformers,

The control building and outbound portal on the North Halawa or leeward side of the Trans-Koolau Tunnels.

communications equipment, lighting, air supply and exhaust fans, water supply for fire protection, service and emergency vehicles, and more.

The control building, separate from the portal structures, is located at the Halawa mouth of the tunnels. It is the "brain" of the H-3 tunnel operations, housing the computer equipment, variable message sign controls, emergency generator, closed circuit television equipment, fire and intrusion alarms, carbon monoxide monitoring system, and AM/FM rebroadcast system.

The ventilation for the tunnels is accomplished by a false, flat concrete ceiling which runs for the entire length of the tunnels. The area between the arch of the tunnel and the false ceiling is separated into two sections by a concrete divider, with one compartment used for inhaling exhaust air and one compartment used for distributing fresh air. Large fans either draw or blow air the into the separated compartments.

The Windward Viaducts are spectacular, one-mile-long twin structures connecting the Haiku side of the Trans-Koolau Tunnels to the cut and cover Hospital Rock Tunnel. Through a contractor-submitted Value Engineering Contract Proposal (VECP), the design of these structures was changed from segmentally constructed, cast-in-place to segmentally constructed, precast, prestressed boxgirder viaducts. This request also included a change from precast driven to drilled shaft piles. After those critical design issues were resolved, the VECP was accepted by the state. This resulted in a savings of $2.2 million split equally by the state and the contractor for this $136 million contract.

The viaducts have 23 sets of piers, each supported by six three-foot-diameter drilled shaft piles 40 to 140 feet long. The piers vary from 12 to 160 feet in height and have a double box cross section with walls 18 inches thick. These massive piers measure 22 feet long by 14 feet wide and are topped by pier tables. The superstructures are made up of the precast, single box girder sections with 24 to 30 segments per span. The segment depths vary from eight feet at midspan to 16 feet at the piers giving the superstructures an arched span appearance.

The construction of the superstructure for each viaduct involved the use of a specially designed, twin, self-launching, steel erection truss system. This system physically picks up the precast girder segment and helps set it into place in the viaduct, allowing the then in-place section to be prestressed with steel tendons. This 384-foot-long truss enabled the construction of the inbound and outbound structures simultaneously.

A precasting yard was constructed near the job site to produce the precast segments. The yard produced an average of four segments per day, manufacturing a total of 1,338 for the viaducts.

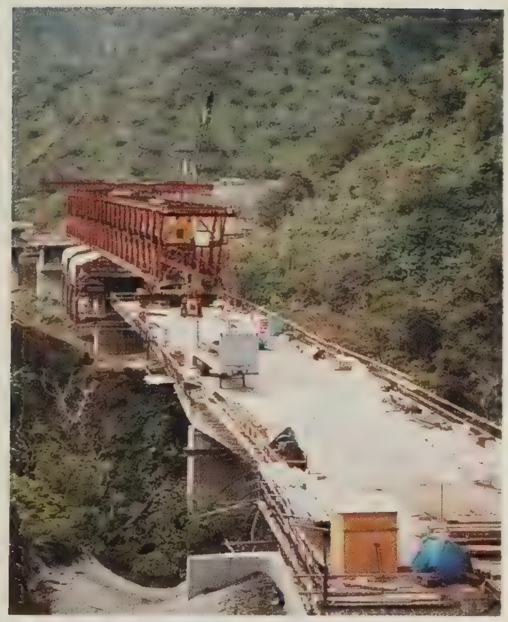
Although the construction of the twin structures is now substantially complete, delamination problems with the three-inch deck overlay are expected to delay its finishing until the end of 1993.

The twin, mile-long North Halawa Valley inbound and outbound viaducts on the Halawa side of the tunnels will also be impressive structures. Although there was the option to build precast superstructures like the Windward Viaducts, the contractor for these viaducts chose to build cast-in-place, prestressed, segmental superstructures as originally designed for a bid price of $141 million.

The superstructures are supported by 17 outbound and 19 inbound double celled box piers, whose heights range from 27 to 105 feet. The piers' crosssection measures 23 feet long by 10 feet wide with 18-inch-thick walls and is supported underneath by five to nine five-foot-diameter drilled shaft piles, 35 to 65 feet in length. The cast-in-place superstructure segments range in height from 18 feet at the pier to eight feet at the midspan with a wall thickness of eight to 27 inches and a bottom width of 23 feet. The concrete overlayed decks vary from 41 to 53 feet in width.

Three specially designed, steel cantilevered trusses are being used to construct the superstructures. One truss began construction at one end of the viaducts, and the other two started from the opposite end. The contractor has been averaging a segment turnaround time of 14 hours.

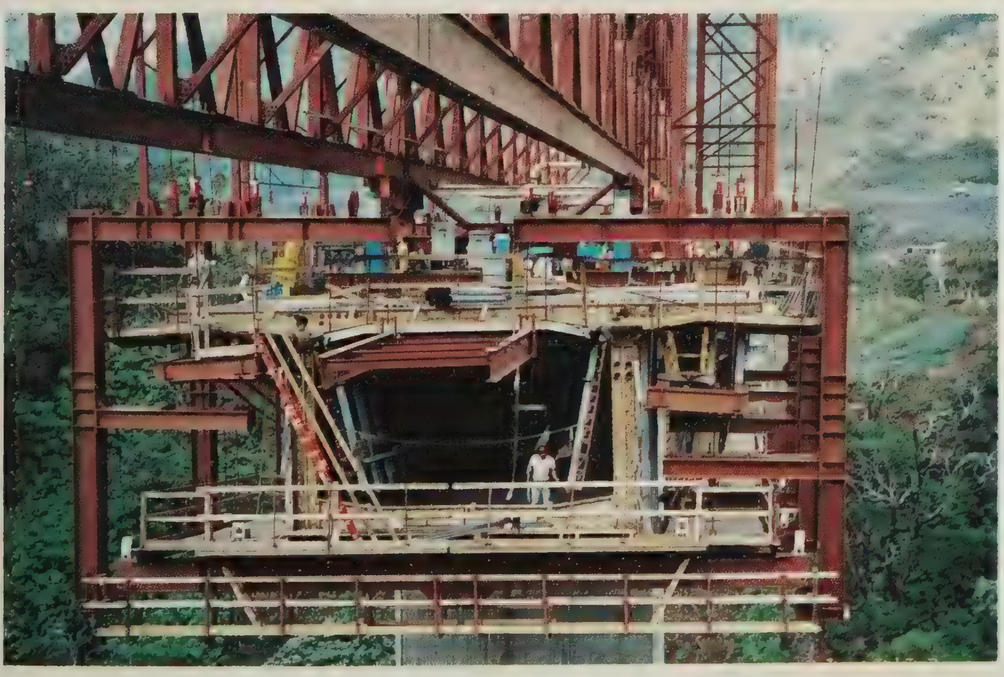
Construction of the North Halawa Valley Viaducts piers and stream bank protection.



Unusually large boulders encountered during the boring for the drilled shaft piles have added another $6 million to the cost of the project. Although the contract specified two- to three-foot boulders were likely to be encountered during the drilling, the contractor had to deal with boulders the size of automobiles.

The North Halawa Valley Viaducts are expected to be completed by December 1994.

H-3 required a great deal of time, money, and political support, but the highland highway is almost a reality. The freeway, envisioned more then 30 years ago, will soon be in service to ease the trans-Koolau traffic crunch. Total cost of this extraordinary project, which should be completed by 1996, is expected to come close to $1 billion dollars. Hawaii may never again have the opportunity to "experience" a project of this magnitude and complexity.



Top. A view of the steel cantilevered truss used to construct the North Halawa Valley Viaducts.

Center. Pier 17 outbound, the first segment of the North Halawa Valley Viaducts, and the steel cantilevered truss use for the construction of the cast-in-place, segmental superstructure.

Bottom. An up-close look at pier 17 outbound and the truss.

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Craig Sanders is in the FHWA's Highway Engineer Training Program (HETP), currently assigned to the small and busy Hawaii division office. The Hawaii division office is responsible for the islands of O'ahu, Kaua'i, Maui, Molokai and Hawaii in the state of Hawaii as well as the territories of Guam, the Northern Marianas, and American Samoa. Sanders is in the final year-long phase of his training, working six months in the division office and six months on the massive H-3 construction project. He hopes to receive permanent placement in a direct Federal Lands office upon graduation from HETP in December 1993.

All Alliance in New Mexico Brings High-Tech to Transportation

A New Approach To Public-Private Cooperation In Transportation Research

by Daniel S. Metzger

Alliance For Transportation Research (ATR)

As a result of the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) and the enlightened vision of planners in the Department of Transportation (DOT), transportation research has a bright future. With the completion of the Eisenhower National Interstate Highway System comes the challenge of maintaining this remarkable infrastructure and using it in the safest and most economically beneficial manner. ATR brings to the transportation community new capabilities for research and development (R&D) and mechanisms for rapidly integrating the results of research into the transportation market place.

ATR

Alliance for Transportation Research

This is the ATR logo.

ATR Composition and Organization

ATR is a partnership formed in October 1991 among New Mexico's major educational institutions: the University of New Mexico and New Mexico State University; two Department of Energy (DOE) national laboratories: Los Alamos National Laboratory and Sandia National Laboratories; and the New Mexico State Highway and Transportation Department (NMSHTD). These partners realize that external interactions are important to energize the enterprise. The president, David Albright, and his administrative staff are sponsored by the NMSHTD. Each of the participating national laboratories sponsors a vice president. Functionally, the staff reports to an executive committee that comprises high-level representation from each of the partners.

ATR is fortunate to have the active participation of advisors from both the Federal Highway Administration (FHWA) and DOE. In addition, an Industrial Advisory Board represents the active and growing interests of the private sector, and the National and International Research Council helps ATR keep in touch with global research activities in transportation.

ATR is unique in its approach of bringing together public and private knowledge and capabilities to address problems of national interest. Fundamental to the effectiveness of ATR has been its priority to find ways to contribute significantly rather than to first institutionalize an organization.

An aerial view of Los Alamos looking west.

ATR Vision and Mission

Simply stated, the vision of ATR is to apply the enviable intellectual and physical resources available in New Mexico to important transportation issues. The governor and the department secretary have empowered the NMSHTD, in conjunction with industry and the other partners, to use the entire state highway system, which spans several climatic zones, as a test bed for research objectives. This collection of resources is proving attractive, both to the industrial participants and to the potential sponsors. Industrial participation is essential to the success of this cooperative research.

The primary work of ATR is to identify worthy, fundable research projects; to match the skills of the partners with the necessary tasks; and to disseminate the results.

National laboratories pursue technology transfer activities with the clear intent of providing the benefits from federal research to boost U.S. industrial competitiveness. Technology transfer became a mission of the national laboratories with the enactment of the National Competitiveness Technology Transfer Act of 1989, which is consistent with the Stevenson-Wydler Act of 1980. These acts establish the primary technology transfer mechanism, the Cooperative Research and Development Agreement (CRADA), and these agreements protect intellectual property for the industrial participants so they can profitably take the research results to market.

Summary of ATR Achievements

In its first year, ATR has stimulated the interest of the national laboratories in important transportation issues. The centerpiece of participation by the national laboratories has been their capabilities in enterprise and engineering modeling. Enterprise modeling is systems oriented and involves energy, environmental, and economic simulations based on a collection of validated models. Engineering models use the vast computing power of the laboratories to compute the properties of complicated physical systems under realistic conditions. These modeling and simulation capabilities allow planners to realistically investigate the consequences of decisions without expensive physical implementation. In addition, the laboratories have demonstrated interest in applying their resources in sensors, data processing, and data fusion to the crucial issues concerning the reliable acquisition of information from the roadway.

ATR has also attracted the attention of industry. Currently, about a dozen agreements exist, or are pending, between ATR and the industrial firms, both large and small, who see a commercial advantage in such a partnership. Among the companies represented in such agreements are JHK Associates, Barton-Aschmann, Hughes, Rockwell, Santa Fe Industries, General Atomic, IRD, and IBM. Some of these companies have set up offices in New Mexico to associate themselves more closely with the available resources.

ATR has illuminated the need for a proactive position regarding transportation and air quality. In Barcelona—during the Olympic Games—and in Mexico City, ATR partners demonstrated that the means exist to physically characterize air pollution in urban areas and to examine feasible remedial measures. This demonstration has led to an ATR proposal for a National Center for Transportation and Air Quality.

To link more effectively with the transportation research community, ATR has also reached out to other organizations. A program for research associates allows specific complementary capabilities to join with ATR in seeking solutions to transportation problems. ATR recently established associate relationships with Princeton University, Georgia Institute of Technology, the University of Florida, the University of Minnesota, and the New Mexico Institute of Mining and Technology. In addition, ATR has established an agreement with the FHWA's Turner-Fairbank Highway Research Center (TFHRC) to exchange staff for specific, mutually beneficial purposes. At this writing, three one-week exchanges have taken place.

Los Alamos National Laboratory and the University of California

We focus on Los Alamos as a specific member of ATR to illustrate, in somewhat more depth, the contribution such an institution can make to transportation research.

The Los Alamos National Laboratory is operated for DOE by the University of California (UC), which actually employs the staff of the laboratory. This relationship has existed since the Manhattan Project, which began in 1943 to construct the first atomic bomb. Since then, the laboratory has adopted a broad charter to address problems important to national security, which includes economic competitiveness and the effective use of energy. As a Federally Funded Research & Development Center (FFRDC), Los Alamos is prohibited from competing with industry and, therefore, from bidding on procurements, unless specifically invited to do so by the sponsor. Oversight of the laboratory is in the hands of DOE, and scientific and technical excellence are assured through the relationship with UC.

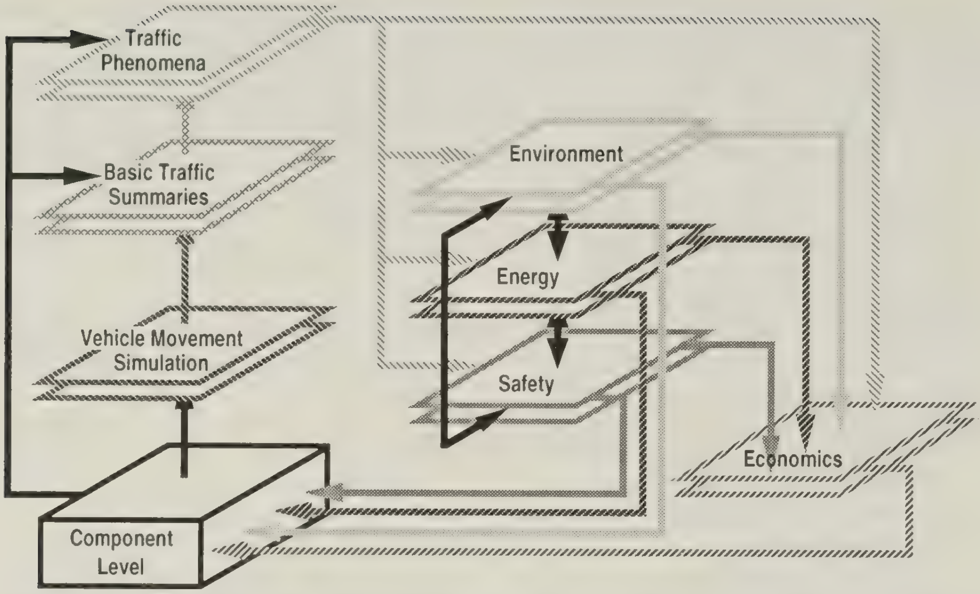
Specific Projects

In the following paragraphs, we briefly review some ongoing projects of interest to FHWA. These reviews are presented as progress statements because, in most cases, the funding has only recently been secured.

Policy and planning

Public policy is based on planning to achieve benefits demanded by the public. Decision-oriented planning provides planners with the information they need to make effective decisions. *(1)* An important and imperfect part of the decision-making process is the assessment of consequences of decisions. Transportation is a complicated system that involves both the details of individual behavior and the macroscopic properties of the economy, the environment, and public safety. Using its modeling and simulation capabilities, Los Alamos has embarked on an ambitious project to simulate the transportation system and subsystems and to use these simulations to examine the consequences of decisions faced by local, regional, and national planners. Such decisions may involve factors such as land use, vehicle or roadway component technologies, restrictions on traffic, or alternative fuels. The goal of the project is to produce a TRansportation ANalysis SIMulation System (TRANSIMS) that will advance the state of the art in simulation technology to the benefit of the transportation policy, planning, and engineering communities.

The approach to the problem is to integrate the process of transportation system design and analysis by developing an integrated suite of models and simulations. We intend to develop techniques that produce multi- and intermodal trip routing plans for individual loads with travel requirements. These "load-oriented" techniques will be developed to interface with emerging activity-based travel demand analytic methods. The trip routing plans will be coupled with a detailed microsimulation of the vehicles attempting to execute their plans



High-level architecture of the Transportation Analysis and System (TRANSIMS) being developed at Los Alamos. Fundamental data, vehicle characteristics, and trip sets are contained at the component level. Information is generated at other levels according to the problem being investigated.

in a particular geographic area. The data output from the vehicle micro-simulations include the vehicle-byvehicle movement dynamics, the vehicle mechanical state, and the control logic state, both in space and in time. These low-level data can be used, for example, to produce accurate pollution load terms for predicting air quality, to indicate the severity of an accident in terms of momentum differences, and to obtain other forms of "higher-level" information. Large urban regions represent the geographical scale for which the TRANSIMS simulation capability eventually will be applicable.

TRANSIMS is an ambitious project that will take years to complete and will require the cooperative efforts of modelers both inside and outside the transportation community. For the first year's effort, we have begun to design and demonstrate proof of principle of the essential TRANSIMS elements. We are developing prototype route planning and microsimulation software, and we are assessing scaling issues in the TRANSIMS approach.

Neural network computational techniques applied to traffic monitoring and automatic vehicle classification

Los Alamos is executing a proof-of-principle demonstration of the value of neural network computational techniques to the application of traffic volume and classification monitoring. Artificial neural networks are a relatively new computational approach—motivated by biologic neurological systems—that uses networks of identical processing elements for learning inductively from data base examples. Such networks are effective in performing tasks such as signal processing; pattern recognition; feature extraction and classification; and the modeling, prediction, and control of complex, nonlinear systems. *(2)* These networks function in a manner similar to that of a conventional clustering algorithm, but with detailed architectural implementation and training algorithm differences that are motivated by current neural-network computational techniques. *(3)*

The goal in monitoring traffic is to determine the volume and the types of vehicles that are using existing streets and roadways. *(4)* Such data are valuable for managing and controlling traffic and for planning the maintenance and design of the highway infrastructure. Accomplishing this goal will require that many low-cost monitoring stations be instrumented for continuous, reliable data collection and reporting.

Included among the widely used traffic monitoring sensors are piezoelectric strip detectors and magnetic inductive-loop detectors. A typical traffic monitoring station includes an array of such detectors, configured in sets (such as piezo-loop-piezo or loop-piezo-loop) that are deployed in one or several highway lanes. The process of converting the electrical signals from detector arrays into vehicle classification data is difficult and is subject to the following potential errors:

- Nonreproducible sensor signals that depend on such uncontrolled factors as vehicle and sensor construction, and vehicle, sensor, installation, and environmental conditions.
- Intermittent or continuous sensor or electronic failures.
- Traffic flow anomalies, such as lane-positioning, vehicle transitions, or highly variable speeds.

This project was conceived to address the several operational difficulties that lead to unreliable data and to provide:

- Increased volume and classification accuracy.
- Automatic screening and rejection of anomalies.
- Self-calibration and drift compensation within a designated range.
- Self-detection and diagnosis of sensor and recording-system faults.

A scientist doing transportation analysis with a developing version of the TRANSIMS framework.

• Automatic attention notification.

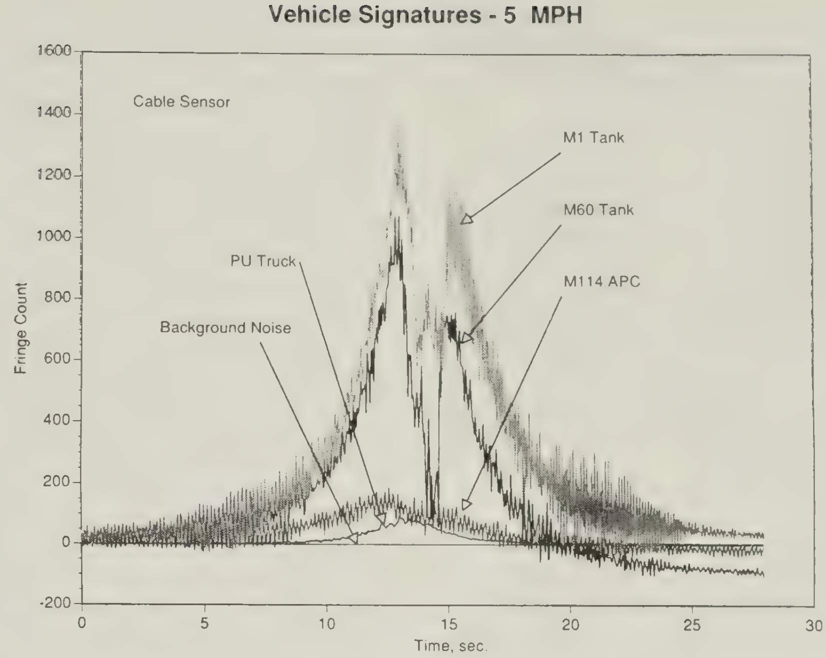
If these objectives can be met, a substantial improvement in traffic monitoring will be possible.

Los Alamos is designing and fielding experimental sensor test sites, examining typical conventional sensor signals, and instrumenting traffic monitoring test sites. Our initial test site, located near Los Alamos on state Route 4, was designed and constructed with redundant arrays of conventional sensors. The NMSHTD installed the sensors for this site and will install other developmental sensors in the future.

An approach to weigh-in-motion

Because of the severe damage caused to public roads by overweight trucks, federal, state, and local government agencies are concerned with overweight vehicle violations. The preferred method for measuring the weight of a vehicle is to measure it at highway speeds. (This method is most desirable because it places a very low compliance burden on legal truck traffic.) Weigh-in-motion instruments typically require extensive roadway modifications and, thus, tend to be very expensive. During the late 1980s, Los Alamos scientists, working on the instrumentation to verify compliance with arms reduction treaties, used fiber optics interferometry to develop weigh-in-motion sensors that do not require any roadway modifications because they are installed at the side of the road. These sensors are potentially much less expensive than current commercial sensors.

As a moving vehicle drives over the surface of a road, the pavement and the ground beneath it deform slightly, depending, primarily, on the weight of the vehicle. Then, as the vehicle moves on, the deformed pavement and the ground return to their original shapes. Because these deformations have both vertical and lateral components, sensors buried at the side of the road can make weigh-in-motion measurements based on the lateral deformations. Although imperceptible to the human eye and to most instrumentation, these deformations are large relative to the wavelength of light. Thus, fiber-optic sensors and optical interferometry, which measure displacements with resolutions in wavelengths of light, enable such roadside measurements.



Data from fiber-optic sensor tests on various military vehicles at White Sands Missile Range. The apparent noise on the heavier treaded vehicles is actually the signatures of the individual treads. The fringe counts on the ordinate of the plot are the signal amplitudes given by the optical interferometer and indicate the large dynamic range of the system.

ATR sensor test site #1 where sensors and power were installed by the New Mexico State Highway and Transportation Department.

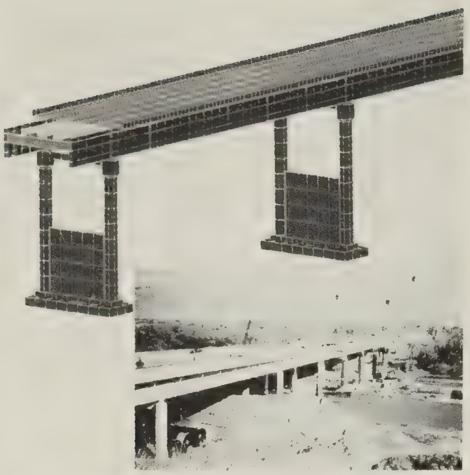
During the 1980s, the laboratory was faced with the problem of identifying various types of armored vehicles (tanks, etc.) moving in a stream of other vehicles. The idea was to install the fiber-optic sensors and optical interferometric instrumentation in the former Warsaw Pact countries to count the armored vehicles as they moved in and out of the depots and maintenance facilities. These counts were to be used to verify compliance with the treaties that had been negotiated with the former Soviet Union. The instrumentation was required to identify armored vehicles by weight as they moved in streams of regular traffic, to avoid any interference with the traffic flow, and to operate unattended. The roadside installation satisfied all of these requirements.

In 1991, Los Alamos tested the instrumentation on various military vehicles at White Sands Missile Range. Under Los Alamos supervision, the NMSHTD installed similar sensors near a busy intersection in Albuquerque as part of a traffic and air quality study.

A fiber-optic sensor being emplaced at a busy intersection in Albuquerque.

Nondestructive evaluation of bridges

Because of traffic safety considerations, the Rio Grande bridges on Interstate 40 in Albuquerque are being replaced with wider, prestressed concrete girder bridges. The 30-year-old existing bridges are fracture-critical, two-girder steel designs, typical of many two-girder designs built in the 1960s and 1970s. The fracture-critical classification indicates a lack of redundancy in the structural design and means that the failure of either of the primary plate girders would result in a catastrophic failure of the bridge. The existing spans are scheduled to be razed in



Finite element mesh for computing dynamic characteristics of the I-40 bridges being razed in Albuquerque.

the summer of 1993. But before these structures are demolished, New Mexico State University and Los Alamos National Laboratory researchers will apply various state-of-the-art nondestructive test methods to one of the structures as various levels of damage are introduced into the plate girders. This planned destruction will advance the state of the art in nondestructive evaluation (NDE) techniques.

In support of this research effort, Los Alamos will develop detailed numerical models of the bridge and correlate the numerically predicted responses of the bridge with the observed physical responses. The advanced computing facility at Los Alamos will be instrumental in developing these models and analyses.

The numerical models will be used to determine the static and dynamic structural properties of the bridge. Los Alamos will use the results from the preliminary experiments conducted on the bridge to verify the numerical models. The predicted responses will be correlated with the measured results from the actual structure. We anticipate that the numerical models will have to be refined after we measure the experimental responses of the bridge. When benchmarked, these computer models will be used to benchmark other, simpler microcomputer-based numerical models, and the benefits of this research will be readily available to others in the NDE community.

Throughout the research effort, the computer models will be used to determine location of the instrumentation, required sensitivity, and the safety implications of introducing damage into the structure.

LIDAR, a powerful tool for air quality measurements

Recent measurements and demonstrations by Los Alamos National Laboratory, in collaboration with a variety of other organizations, have shown LIDAR to be a powerful tool for measuring air quality associated with vehicle emissions. Experimental campaigns conducted in Mexico City, Mexico; Barcelona, Spain; and Albuquerque have located sources of pollution, tracked the movement of aerosols, and located mixing layer boundaries as a function of time and traffic conditions.

LIDAR is an acronym for LIght Detection And Ranging (or laser radar). When a short pulse of laser light is emitted through the atmosphere, the light interacts with aerosol molecules and is then scattered back to the receiving telescope and detectors, which are usually located with the transmitting laser. The distance

LIDAR laser beam reaching out over a region of Mexico City to document air pollution sources.

from the LIDAR unit can be determined by timing the pulse return. The elevation and azimuth directions of the unit determine the location of the scattering aerosol particles.

Different types of LIDAR systems are used for different purposes. The simple scattering systems (usually in the infrared) that observe light scattered back to the detector at the same wavelength (or color) as the laser will locate the aerosols, but they will not identify the species of the molecules doing the scattering. These systems have a longer range than the others because their infrared wavelengths of light are transmitted through the atmosphere with a minimum of absorption.

Two other types of LIDAR systems use Raman scattering and fluorescence to identify the species of molecules being located. These systems, which often use ultraviolet lasers, have shorter ranges because of atmospheric absorption and, often, can detect very low concentrations of fluorescent chemicals. In some cases, less than two parts per million have been observed.

The most versatile type of LIDAR system is the DIAL, or DIfferential Absorption Lidar system. This system uses two different wavelengths of laser light, one of which is tunable. The fixed wavelength is chosen so that there is very little atmospheric absorption; the tunable wavelength varies across the absorption bands of the molecules being measured. Thus, the DIAL system can identify most molecules. The wavelength requirements, however, make this system more complicated and more expensive than the others.

Several of the simple scattering LIDAR systems Los Alamos has are mobile or portable. One is the size of a large footlocker and weighs about 150 pounds, and some others are mounted in mobile vans. These systems have been used in various cities to locate sources of pollution aerosols and to track the movement of the aerosol clouds. Original data are color coded to show the variable intensities of aerosol concentration. Other data have been taken to measure the location of the mixing layer boundaries. These boundaries show where the more polluted near-surface air is trapped. The correlation of these data with data on traffic movement and traffic congestion levels could provide substantive information on pollution levels and sources and on possible corrective measures.

Locker-sized LIDAR equipment used in the Barcelona air quality measurements.

Los Alamos is developing smaller versions of these systems, as well as other environmental monitoring techniques.

Conclusion

ATR is rapidly organizing state, national, and private resources to address important transportation research issues. The national laboratories' contributions in this effort eliminate much of the risk associated with applying this new technology. Our goal is to assist DOT with improvements in environment, efficiency, and safety through the development and application of new technologies.

The following Los Alamos scientists contributed to this article: Chris Barrett, TRANSIMS; William Mead, automatic vehicle classification; Thomas Kuckerts, weigh-in-motion; Charles Farrar, NDE; and Dennis Gill, LIDAR.

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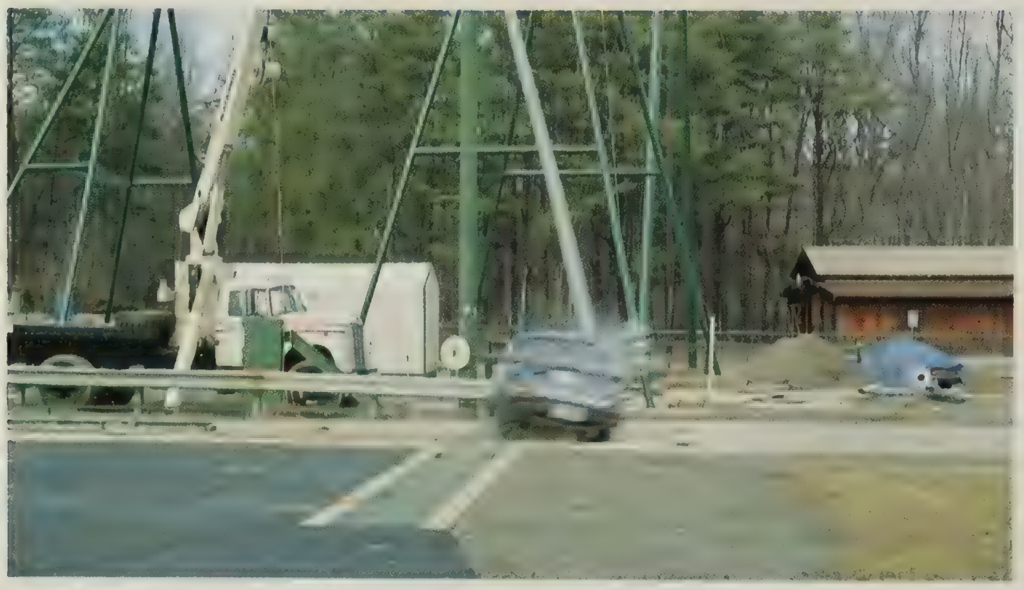
A tree-lined street is beautiful, but the trees can be roadside hazards.

The Highway Perspective of Side Impacts

by Jerry A. Reagan



At the Federal Outdoor Impact Laboratory, a car is crashed into a guardrail terminal as part of a series of tests on side impacts.

This paper incorporates opening remarks presented at the Society for Automotive Engineers International Congress and Exposition held in Detroit, Michigan, on March 1-5, 1993. The author was a cochairperson on a session on side-impact collisions.

The National Highway Traffic Safety Administration (NHTSA) seeks to improve highway safety by improving the crashworthiness of motor vehicles. In recent years NHTSA and the automobile industry have been involved in studying side-impact issues. These studies have focused on vehicle-to-vehicle side impacts and the injuries associated with such collisions.

The Federal Highway Administration (FHWA) seeks to improve highway safety through the design, construction, and maintenance of safer highways. For the past decade, FHWA has been studying the side impact issues from a roadside safety hardware perspective. We are currently focused on side impacts into narrow objects such as trees, utility poles, sign and light supports, and guardrail terminals.

While there has been some exchange of ideas within the agencies at the working level, both agencies and the automobile industry have largely pursued their respective interests independently. Efforts to work together have been hampered because of the limited information available on side-impacts into narrow objects, the lack of a common scientific basis for sharing information, and a lack of understanding of highway design practices. To overcome these problems, FHWA, through the Federal Outdoor Impact Laboratory (FOIL), conducted a series of side impact tests into narrow objects. The results of these tests are available in four reports. *(1,2,3,4)* The data provide valuable information on side impacts into narrow objects, including the performance of small cars when impacting existing roadside safety hardware. The number of fatalities and the severity of injuries mandate that the agencies and industry work closely together to design automobile and roadside safety hardware as a system.

A quick glance at some statistical data will show that each agency's perspective is important. Data on fatalities are from the Fatal Accident Reporting System (FARS) and all other data are from the National Accident Sampling System (NASS) Continuous Sampling System (CSS). There are also some differences in the way FARS and NASS data are coded. For example, the NASS CSS does not contain most harmful event data. However, the general trends are accurate.

Table 1 shows the seriousness of fixed-object and overturn-most-harmful events. *(5)* Both fixed object and overturn (as well as pedestrian/cyclists) account for a greater percentage of total fatalities than they do of total injuries. Fixed objects account for 21 percent of all fatalities and 15 percent of all injuries. Overturns account for 15 percent of all fatalities and 6 percent of all injuries. By comparison vehicle-to-vehicle collisions account for a smaller percent of total fatalities (40 percent) than they do of total injuries (51 percent).

Table 2 lists all of the fatalities of Table 1 in which the first harmful

Table 1.—Fatalities and injuries by most harmful event (1985) *(5)*

Most Harmful Event	FARS *(Fatalities)*		NASS *(Injuries)*	
	Frequency	Percent	Frequency	Percent
Vehicle-to-Vehicle	17,495	40	1,721,000	51
Fixed Object	9,239	21	503,000	15
Pedestrian/Cyclist	7,481	17	114,000	3
Overturn	6,698	15	186,000	6
Other/Unknown	2,912	7	839,000	25
Total	43,825	100	3,363,000	100

Table 2.—Roadside fatalities—most harmful events when first harmful event is outside the shoulder (1985) *(5)*

Harmful Event	Most Harmful Event	Percent
Fixed Object	8,107	56
Overturn	4,820	33
Other/Unknown	1,508	11
Total	14,435	100

Table 3.—Occupants involved in single or multiple vehicle accidents where the most harmful event was a fixed roadside object by region of impact *(2)*

Most Harmful Event	1980-1985 FARS		1982-1985 NASS	
	Frequency	Percent	Frequency	Percent
Front	5,701	65	603,000	66
Side	2,241	25	226,000	25
Rear	168	2	27,000	3
Other	685	8	58,000	6
Total	8,795	100	914,000	100

Side impact into a utility pole was part of the FOIL testing.

event is outside the highway shoulder. *(5)* This is the roadside safety problem. Note that 72 percent of all overturns (4,820 out of 6,698) occur on the roadside. Fixed-object collisions constitute 56 percent of the roadside fatalities. This paper does not discuss overturns (rollovers), but they too are a serious problem both for NHTSA (crashworthiness) and FHWA (design).

Roadside hazard, fixed-object collisions can be further broken down by the region of impact where the vehicle struck the fixed object. Table 3 shows that in both the FARS and the NASS data, the roadside-hazard, fixed-object, side-impact category represents 25 percent of the total fixed-object roadside safety problem.

The roadside hazard, fixed-object, side-impact problem is broken down by vehicle type in Table 4. Table 5 shows that most passenger car crashes involve narrow objects such as trees, utility poles, sign and light supports, and guardrail terminals.

In summary, approximately 160,000 people are involved in accidents where the side of the passenger car impacts a fixed roadside object such as a tree, utility pole, light support, etc. More than 1,600 occupants—about one in 100—are killed. The annual cost to society is $3 billion each year.

Given the magnitude of the problem, serious thought must be given to reducing this tragedy. NHTSA, FHWA, and the automobile industry must recognize that the vehicle and the roadway cannot be treated separately. The crashworthiness of cars and the design of roadside safety hardware represents a system.

Treatment of the vehicle and the roadway as a system means that many of the concepts that have been used in the past must be re-examined. It may be that the current notions favoring redirection when cars impact guardrails and roadside safety hardware that breaks away on impact need to be re-examined. It may also mean that the current dynamic side-impact test standard, Federal Motor Safety Standard (FMVSS) 214, should include a car-to-fixed object test as well as the current car-to-car test.

Additional work on side impacts into fixed objects is planned by FHWA. It is anticipated that much of the work will be coordinated with NHTSA with three ideas in mind. First, FHWA, NHTSA, and the automobile industry need to agree on a standard set of analytic tools so that data can be shared and understood. Secondly, there needs to be a standard vehicle adopted by FHWA, NHTSA, and the automobile industry that can be used for the design of roadside appurtenances under side-impact conditions. Such a vehicle should represent the best thinking on how future vehicles will be constructed. Third, the design of roadside safety appurtenances may require changes in both existing hardware and automobile side structure.

It is anticipated that this additional work will build on two joint FHWA/NHTSA initiatives that are now underway. FHWA/NHTSA have signed an interagency agreement with the Department of Energy to have the Lawrence Livermore National Laboratory (LLNL) adapt the non-linear finite element code DYNA3D to simulate crash impacts. LLNL are developers of the DYNA3D code. In addition, FHWA and NHTSA are jointly funding the National Crash Analysis Center (NCAC) located on the George Washington University Virginia Campus. The NCAC maintains all FHWA and NHTSA crash films and uses these films for crash analyses, including side impacts. Finally, the side-impact crash tests supporting this program will be conducted at FOIL. FOIL is located at the Turner-Fairbank Highway Research Center in McLean, Virginia, and has a unique capability to conduct side-impact tests into narrow objects.

Table 4.—Occupants involved in single-vehicle, fixed-object, side-impacts by vehicle type *(2)*

Most Harmful Event	1980-1985 FARS		1982-1985 NASS	
	Frequency	Percent	Frequency	Percent
Passenger	1,647	79	168,000	79
Utility	262	12	26,000	12
Motorcycle	151	8	4,700	2
Other	36	1	13,000	7
Total	2,096	100	211,700	100

Table 5.—Type of fixed object struck in single passenger vehicle, side-impact, fixed object accidents *(5)*

Object Struck	1980-1985 FARS		1982-1985 NASS	
	Frequency	Percent	Frequency	Percent
Narrow	1,314	80	100,000	59
Broad	189	11	30,000	18
Other	144	9	38,000	23
Total	1,647	100	168,000	100

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"Along the Road" is a hodgepodge of items of general interest to the highway community. But this is more than a miscellaneous section ; "Along the Road" 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.

The New Public Roads

If you are a regular reader of *Public Roads*, you have already noticed that something is very different about the look of this issue. The magazine is looking forward to better serving you in the future, and one way to do that is to recapture an important element from its past. We want *Public Roads* to once again be a forum for the discussion of current problems. We solicit your comments and your input. We recognize that there is a great deal of important and innovative highway-related work being done throughout the United States. Let us hear from you. Let us know what topics you would like covered in the magazine. "Instructions to Authors" on the inside back cover provides our address and telephone number as well as information about writing for *Public Roads*. However, there are two caveats: We will focus on subjects relevant to the mission and work of the Federal Highway Administration, and research and technology will remain our foundation.

New FHWA Leaders Take Charge

On May 28, Rodney E. Slater was confirmed by the U.S. Senate to become the administrator of the Federal Highway Administration. Slater's formal swearing-in ceremony was conducted on June 16. Slater was formerly the chairman of the Arkansas State Highway Commission and a member of the American Association of State Highway and Transportation Officials' Executive Committee of Commissions and Boards. He was awarded the 1990 Arkansas Transit Association's "Arkansas Public Transportation Advocate Award" for his efforts as a staunch advocate for greater investment in transportation to stimulate the economy. Earlier in his career, Slater served as an assistant attorney general for Arkansas and was a key member of the governor's staff, serving as executive assistant for economic and community programs. He graduated from the University of Arkansas School of Law in 1980.

Slater also served on the Arkansas Sesquicentennial Commission and as liaison with the Martin Luther King Jr. Federal Holiday Commission. He is secretary-treasurer of the Arkansas Bar Association. In December 1989, he was named an "Arkansas Hero" in the *Arkansas Times* magazine for his work to improve conditions in the Delta. He was also honored by the Arkansas Jaycees as one of the "Ten Outstanding Young Arkansans" in March 1990.

Jane F. Garvey has been selected by Secretary of Transportation Federico Peña to serve as deputy administrator of FHWA. From 1991 to her selection as deputy administrator, Garvey was director of aviation at Logan International Airport in Boston, directing airport management and capital planning. In 1988, after serving five years as the associate commissioner, she became commissioner of the Massachusetts Department of Public Works, the agency responsible for construction and maintenance of the statewide network of highways, bridges, and roadside areas. As the commissioner, she was responsible for developing innovative public and private financing and new environmental programs for the agency, and she oversaw all aspects of Boston's $5 billion Central Artery/Tunnel project.

Rodney E. Slater is the new FHWA Administrator.

Colorado Orders Drivers to "Move It"

On May 6, Colorado Governor Romer signed into law a congestion/incident management-related bill that requires drivers to move their vehicles from an accident scene if the accident occurs on "the traveled portion, median, or ramp of a divided highway." The "move it" bill, patterned after similar laws in Florida and Texas, does not apply if a vehicle is too badly damaged to be driven or if either driver is under the influence of alcohol or drugs.

Howard Transportation Information Center Dedicated

Dedication ceremonies were held for the James and Marlene Howard Transportation Information Center at Monmouth College in New Jersey on May 7. The center, which was funded last year with a $2,242,000 grant under the Intermodal Surface Transportation Efficiency Act, is known on campus as Howard Hall, and it is the new home of the School of Information Sciences and Technology. The school is designed to foster research in computer science, electronic engineering, software engineering, and communications technology and to provide links for technology transfers between academic institutions and industry.

I-80/National Commercial Vehicle Program Meeting Held in Kansas City

FHWA Region 7 hosted an I-80/National Commercial Vehicle Program meeting in Kansas City on May 5 and 6. Approximately 53 representatives from state agencies, motor carrier industry, and FHWA attended. The purpose of the meeting was to present the concepts of the National Commercial Vehicle Program and how the I-80 states could participate. The Iowa Department of Transportation agreed to take the lead in forming a coalition of I-80 states to participate in the program and in organizing a meeting in October to further develop the coalition structure and a commercial vehicle operations business plan.

The services of the National Commercial Vehicle Program include one-stop shopping; preclearing trucks for credentials, size and weight, and safety; reporting/audit trail; fleet management; international cross-border; and hazardous materials incident response.

States Await Guidance on Converting Highway Signs to Metric Units

The Omnibus Trade and Competitiveness Act required federal government agencies to use the metric system in procurements, grants, and other business-related activities, except to the extent that such use is impractical or would likely cause significant inefficiencies. Several states have requested specific direction on how to proceed with their planned metric signing projects and with routine sign refurbishment projects. To assist in finding answers to some sign format questions, FHWA has recently approved Manual on Uniform Traffic Control Devices—Section 1A-6—experimentation in Florida and Kentucky.

Meeting on Environmental Analysis in Transportation Set for July

The annual meeting of Transportation Research Board Committee A1F02 is being held this year in Seattle, Washington, hosted by the Washington State Department of Transportation. The meeting will be held July 20-23, 1993, at The Westin Hotel in downtown Seattle. The goal of this national meeting of transportation environmental officials is to provide a forum to discuss research and practices that will improve the management of environmental process and policy in transportation design. Attendees from across the United States and Canada are expected.

This year's program includes presentations on the implementation in the state of Washington of ISTEA, Clean Air Act amendments, and the state's Growth Management Act; wetland banking; and public involvement using interactive computer imaging. There will also be a tour of one of the last completed stretches of I-90, addressing mitigation for historic structures and other environmental impacts.

Florida Enforces Seat Belt Law

In April, the Florida Highway Patrol (FHP) began a stepped-up effort to enforce Florida's safety belt law. The objective is to increase safety belt use in Florida from 58 percent to 70 percent. During the first week of a three-week intensive, statewide campaign, FHP issued 7,886 warnings and 1,577 citations for safety belt violations. Additionally, 250 warnings and 107 tickets were issued for failing to use child car seats. FHP's new director, Col. Ronald Grimming, patterned this effort after a successful campaign in Illinois, where he was formerly the deputy director of the state police.

Second U.S./Japan Workshop Promotes Cooperation

The second U.S./Japan Workshop on Advanced Technology for Highway Engineering was held in Japan on April 20-23. Representatives of FHWA's Intelligent Vehicle-Highway Systems Division participated. The workshop was part of an agreement between the United States and Japan on "Cooperation in Research and Development in Science and Technology." A specific agreement was signed in May 1992 by the U.S. Department of Transportation and the Japanese Ministry of Construction to promote, encourage, and advance highway transportation through research, development, and cooperation. The first workshop was conducted from Nov. 30 to Dec. 2, 1992.

New Jersey Initiates Innovative CMAQ Project

In cooperation with the Northeast States Ozone Transport Commission, the New Jersey Department of Transportation in a joint effort with the state environmental agency, has launched a comprehensive communications effort to educate the public on the impact of motor vehicle emissions on air quality and on ways to reduce these emissions. The 16-month campaign has four themes: cars pollute, drive clean, go with cleaner cars and fuel, and tune up to clean up. These themes will be introduced one at a time at four-month intervals. Communication materials for each theme will be marketed to appropriate audiences. Federal Congestion Mitigation and Air Quality Improvement Program funding in the amount of $250,000 has been approved for this effort, and the Division Office Planning Unit has also initiated an overture to have the Technology Transfer Center assist in this project through its newsletter to local governments.

Kentucky Motorists Face Triple Jeopardy

On May 26, Kentucky kicked off a new statewide highway safety program called "Triple Jeopardy." If a motorist is stopped for speeding, drunk driving, or not wearing a seat belt, the motorist will be checked for all three violations. The program is patterned after a program developed by the Knoxville (Tenn.) Police Department.

Louisiana I-310 Project Wins Award

The recently opened I-310 section constructed by T.L. James & Company Inc. was recently awarded the prestigious 1992 Build America Award in the Highway Division category. This award recognizes excellence in the construction industry. The almost two-mile section of I-310 consisted of twin bridges built through environmentally sensitive, protected wetlands. There were no alternative corridors. The structures were built using "end-on" construction techniques with each section being built from the previous section from the top down. This difficult and unique project was completed well ahead of schedule enabling the complete I-310 corridor to be opened on May 7.

Star (*) DUI Program Works in Colorado

The Colorado Department of Transportation reports that more than 1,200 suspected drunk drivers were reported to law enforcement agencies by Colorado motorists in the first three months of 1993. More than one-fourth of the reports were made from cellular telephones using the "* DUI" number.

North Carolina Selects Route for I-73

On May 11, North Carolina officials announced the selection of the route of I-73 through the state. I-73, a new north-south interstate highway between Charleston, S.C., and Detroit, Mich., was included in the Intermodal Surface Transportation Efficiency Act of 1991.

I-73 will enter North Carolina on I-77 at the Virginia state line in Surry County. It will use I-77 to the U.S. 52 Connector north of Pine Ridge and then use U.S. 52 through Stokes and Forsyth counties to U.S. 311 in Winston-Salem. From there, the highway will use U.S. 311 through Guilford and Randolph counties to U.S. 220 north of Asheboro. From there, the interstate will use U.S. 220 through Randolph, Montgomery, and Richmond counties to U.S. 1 in Rockingham and then exit the state on U.S. 1 at the South Carolina state line.

Except for the I-77 segment in Surry County, none of the highways to be used for I-73 are built to interstate standards. Although those are scheduled in the N.C. Department of Transportation's Transportation Improvement Program to be upgraded to multilane highways, additional funds will be required to bring them to interstate standards. Existing state and federal funds will be used since no additional funding for I-73 in North Carolina was designated in the federal legislation.

Asphalt Binder Equipment Circulates Through RMUPG

The Federal Highway Administration is continuing to monitor and support the education and training of state department of transportation personnel in the use of the new Strategic Highway Research Program (SHRP) asphalt binder equipment. The equipment and tests developed by SHRP are expected to replace the older, less accurate, and less scientific asphalt binder tests for classifying asphalt cements. Currently, one trailer containing the binder equipment is being circulated through the states in the Rocky Mountain User-Producer Group, which generally corresponds to FHWA Region 8. On May 28, the trailer was moved from Wyoming to North Dakota, where it will remain for six weeks. The trailer has already visited Colorado, New Mexico, and Utah; after North Dakota, the trailer will visit Montana, Idaho, and the Canadian province of Alberta before the equipment is returned to the Central Federal Lands Office in Denver.

Incident Management Conferences Held Across the Country

On May 14, National Incident Management Coalition sponsored a conference in New Orleans with about 220 participants representing state and local agencies that operate roadways, causeways, bridges, ferries, and transit facilities and services. This was the 11th major conference on incident management conducted over the past 18 months as part of a series jointly funded by the Federal Highway Administration and others to promote better handling of freeway accidents and other incidents. As a result of these conferences, some measures have already been taken to prevent and clear incidents and to assure traffic movement. At least five more conferences are planned; they will be held in Milwaukee, St. Louis, Princeton, Las Vegas, and Phoenix.

University Transportation Centers Program Expands

Three new University Transportation Centers have been established since the passage of the Intermodal Surface Transportation Efficiency Act of 1991; this brings the total number of centers in the program to 13. In addition, the Federal Highway Administration has revised the roles of its headquarters and field offices in interacting technically with the centers. The three new centers are:

National Center for Transportation and Industrial Productivity
Center for Transportation Studies and Research
New Jersey Institute of Technology
Newark, N.J. 07102
Contact: Louis J. Pignataro, (201) 596-3355

National Center for Transportation Management, Research, and Development
School of Graduate Studies
Morgan State University
Baltimore, Md. 21239
Contact: Frank E. Enty, (410) 319-3666

Mack-Blackwell National Rural Transportation Study Center
4190 Bell Engineering Center
University of Arkansas
Fayetteville, Ark. 72701
Contact: E. Walter LeFevre, (501) 575-7957

Additionally, the program has established the University Transportation Centers Clearinghouse under the direction of Ann Marie Quinn. The clearinghouse's address is The Pennsylvania State University, Research Office Building, University Park, Pa. 16802-4710. The telephone number is (814) 863-3614.

Within FHWA, field offices have been given the lead in technical interaction on highway-related activities at the centers. This interaction will be similar to that of SP&R activities at state highway agencies. The field offices will also assist the Research and Special Programs Administration (RSPA) in the annual onsite evaluation of the centers. The National Highway Institute (NHI) at FHWA headquarters will provide a focal point at the national level. NHI will work with RSPA and the Federal Transit Administration on national policy and administrative matters.

Highway Construction Costs Increase

The Federal Highway Administration announced in February that highway construction costs for the fourth quarter of 1992 increased 7.1 percent. The fourth quarter results raised the FHWA composite bid price index for highway construction costs to 107 percent of the 1987 base index for which 1987 average costs equal 100 percent.

Increases in the unit prices for portland cement concrete, bituminous concrete, structural steel, and structural concrete resulted in the overall increase in the index for the fourth quarter. There were decreases in the unit prices for excavation and reinforcing steel.

The three-quarter moving composite price index, which is obtained by combining data for the last three quarters of 1992, increased 1.6 percent from the previous three-quarter average.

Trends in highway construction costs are measured by an index of average contract prices compiled from reports of state highway contract awards for federal-aid contracts greater than $500,000. During the transition after the enactment of the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA), the index reflects federal-aid contracts on National Highway System projects and pre-ISTEA federal-aid contracts exclusive of secondary and off-system projects.

Requirements for State and Metropolitan Transportation Plans Proposed

In March, the Department of Transportation issued proposals to foster greater cooperation among states and metropolitan areas in developing transportation plans and programs for enhancing mobility, reducing traffic congestion, and encouraging the use of mass transit.

The department's Notices of Proposed Rulemaking (NPRM) carry out provisions of the Intermodal Surface Transportation Act of 1991 that call for a continuous, comprehensive, and coordinated transportation planning process in each state and metropolitan area. Public comments on the NPRM were due 60 days after the publication in the *Federal Register*.

The proposed rules stress comprehensive transportation plans which focus on developing seamless connections among transportation modes and which consider more than one mode to serve transportation needs within a given area. Among the subjects that states and metropolitan areas will consider as part of the planning process are:

- The social, economic, energy, and environmental effects of transportation decisions.
- Ways to preserve existing transportation facilities and make them more efficient.
- Ways to reduce and prevent traffic congestion, including reducing single-occupant motor vehicle travel.
- Ways to expand and enhance mass transit services and encourage their use.
- Methods of enhancing efficient movement of freight.
- The effect of transportation decisions on land use and development.
- Use of innovative financing methods, such as congestion pricing.
- Preservation of the rights-of-way for future transportation projects.
- Incorporation of bicycle facilities and pedestrian walkways where appropriate.
- Access to international border crossings, ports, airports, intermodal facilities, and parks and other recreational areas.
- Development of financial plans that demonstrate whether the costs of proposed transportation investments are consistent with expected revenues.

A long-range planning horizon of at least 20 years would be required for state and metropolitan plans.

DOT and DOD Jointly Review GPS

The Department of Transportation and the Department of Defense announced on May 27 that the two departments will conduct a joint review to determine how to get maximum use of the DOD's Global Positioning System (GPS) to satisfy both military and civilian needs.

GPS is a space-based positioning and navigational system that uses a network of Navstar satellites to provide very precise three-dimensional position and velocity information. While the system is designed primarily to meet military requirements, the federal government wants to ensure the maximum civilian use consistent with national security needs. These civil uses are expected to grow and generate benefits such as increased transportation safety and efficiency and economic growth.

Actual and projected uses of GPS include the precise monitoring of transit buses, information enabling city drivers with special receivers to avoid congested routes in peak hours, highly accurate navigation for civil aviation, harbor entrance and coastal navigation uses for ships, and the tracking of land vehicles.

The task force will be jointly chaired by Joseph F. Canny, deputy assistant secretary of transportation for policy and international affairs, and Richard G. Howe, DOD's director for theater and tactical C3—command, control, and communications. It will operate under the auspices of the DOT Navigation Council and the DOD Positioning/Navigation Executive Committee. The task force is expected to complete its work by the end of 1993 and make a report to the two secretaries.

Neglecting Infrastructure Can Kill

Neglecting the nation's roads, bridges, power distribution systems, water supplies, and waste water facilities could kill more Americans than all past 20th century wars, says civil engineer Dr. Robert L. Lytton, head of the Center for Infrastructure Engineering in the Texas Engineering Experiment Station (TEES)—a member of The Texas A&M University System.

A regimented program is needed to repair and preserve the trillions of dollars invested in our national infrastructure, according to Lytton. Neglecting our deteriorating infrastructure will mean dangerous bridges, hazardous roads, risky water supplies, and unreliable electrical and gas distribution systems.

"The physical elements needed to support civilized living—elements that make it possible for large numbers to live together in cities—are taken for granted. We all would be nomads without our infrastructure," Lytton said. "I don't want to be an alarmist, but there is a great deal riding on maintaining the infrastructure."

The center is an interdisciplinary group of researchers studying infrastructure problems including converting military technology to civilian uses. The center studies the public and private works that support habitation and the transportation and occupational needs of urban society.

The cost of restoring our infrastructure will dwarf the defense budget. "Right now, the country has a 'panic management' repair policy that is extremely expensive," said Lytton; however, careful management, the latest research, and the right timing could slash the cost of infrastructure repairs by up to 60 percent.

—Texas Engineering Experiment Station

Hanging Lake Tunnel in Colorado's Glenwood Canyon

Glenwood Canyon Tunnel Project Wins ACEC Award

Parsons Brinkerhoff Quade & Douglas Inc. of San Jose, Calif., won a Grand Award in the American Consulting Engineers Council's 27th annual Engineering Excellence Awards competition for the design and construction of the Hanging Lake Tunnel, part of Colorado's enormous Glenwood Canyon Project.

The tunnel was conceived to meet the multiple demands of transportation, environment, and access to one of Colorado's most popular scenic tourist areas. The tunnel causes no disruption to the hundreds of wildlife species present in Glenwood Canyon and the Colorado River. In addition, it does not intrude upon its pristine surroundings and is virtually undetectable from the opposite side of the river.

The entire 12-mile segment of I-70 through the Glenwood Canyon was described by former FHWA Administrator Thomas Larson as "a world class piece of environmentally sensitive engineering" and "a scenic byway that is one of the wonders of the interstate system." With the completion of the Glenwood Canyon segment in October 1992, the entire 2,175-mile length of I-70 from Baltimore, Md., to Cove Fort, Utah, is now open.

—American Consulting Engineers Council

Structural Engineers Form New National Council

Twenty state and regional structural engineer associations recently formed the National Council of Structural Engineer's Associations to reduce the difficulty in working across state lines. At a March 27 organizational meeting in Denver, officers were elected and bylaws were adopted. Committees were immediately formed to address state-to-state variations in registration and licensing requirements, project peer review and special inspection requirements, standards of practice, and coordination of state legislative efforts. The new group intends to provide a forum to establish a national consensus on multistate issues. The national office for the council is located at 1015 15th Street N.W., Washington, D.C. 20005. The telephone and fax numbers are (202) 347-7474 and (202) 898-0068 respectively.

—National Council of Structural Engineer's Associations

California Transportation and Environmental Agencies Sign Pact

A landmark agreement signed by the California Department of Transportation (Caltrans) and the Department of Fish and Game regarding the use of asphalt on state highways will protect the environment while speeding the delivery of needed public works improvements.

The memorandum of understanding, signed by Caltrans Chief Engineer Richard P. Weaver and Fish and Game Chief Deputy Director John Sullivan, establishes a framework to address environmental and transportation concerns.

The agreement spells out guidelines for using asphalt chunks, pieces, and grindings in road embankments and shoulder backing along state highways. In addition, a joint committee of the two departments has been created to review future technical and policy issues involving transportation projects that could affect the state's rivers and streams.

"With this agreement," said Weaver, "we now have a vehicle in place to make sure all the various concerns of both departments are aired and resolved in a manner that protects the environment while allowing critical transportation improvements to be completed on schedule and within budget."

—California Department of Transportation

Access Management Conference Scheduled in August

The first national conference on access management for streets and highways will be conducted on August 2, 3, and 4 in Vail, Colorado. Access management is the strict control of the location, design, and operation of all driveways and public street connections onto the highway. Access management calls for a significant improvement in access design and spacing standards in recognition that the lack of access control is the largest single cumulative design element reducing roadway safety and capacity. Usually in excess of 50 percent of all traffic accidents are access related, and access control can increase capacity by 25 to 35 percent.

The conference, which is jointly sponsored by the Federal Highway Administration, Transportation Research Board, and Colorado Department of Transportation, will feature more than 30 presentations on subjects such as current issues in access management, legal issues, establishing a program, corridor specific plans, spacing issues, turning movement design and restrictions, local government approach, and project implementation.

For more information, contact either:

- Jim Scott
  TRB, National Research Council
  2101 Constitution Ave. N.W.
  Washington, D.C. 20418
  Telephone: (202) 334-2968
- Philip Demosthenes
  Colorado DOT
  4201 East Arkansas Ave., Rm. 291
  Denver, Colo. 80222
  Telephone: (303) 757-9844
  Fax: (303) 757-9820

Pan American Highway Meeting Set for September in Chile

The Pan American Highway Institute and the Catholic University of Chile invite highway authorities and experts in highway and transportation activities to participate in the Second PIH Technology Transfer Centers Annual Meeting in Santiago, Chile, on September 21-25. The objective of the meeting is to share new technologies, experiences, and information to contribute to an efficient and effective technology transfer for better highway systems. At the meeting, there will be simultaneous translations in Spanish and English.

PIH was founded in 1986 to act as a network of road and transportation organizations for transferring both innovative and traditional highway technology. Presently, the network has 30 technology transfer centers in 13 countries.

For more information, contact Dr. Carlos Videla C., Director centro IPC No. 8—Chile, Escuela de Ingeniería, Pontificia Universidad Católica de Chile, Vicuña Mackenna 4860, Macul, Casilla 306, Santiago, Chile. His telephone numbers are (56-2) 5522375 or 5522372 Extensions 4245 or 4573. The fax numbers are (56-2) 5524054 or 5531000.

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: Highway Safety Design Practices and Criteria

Title: Computer Simulation Using DYNA3D

Objective: The objectives of this study are: (1) to perform computer simulations of vehicle crashes into fixed roadside objects, with emphasis on side impact, using the non-linear finite element (FE) code package INGRID/DYNA3D/TAURUS; (2) to provide training and assistance on the use of the FE code package INGRID/DYNA3D/TAURUS and associated computing hardware; and (3) to assess and provide recommendations to FHWA/HSR-20 regarding division computer simulation goals, objectives, actions, and contractor/subcontractor computer simulation related actions and deliverables.
Performing Organization: Momentum Engineering
Sponsoring Organization: FHWA
Expected Completion Date: August 1993
Estimated Cost: $24,997

NCP Category D—Structures

D.1: Bridge Design

Title: Innovative Bridge Designs Using Enhanced Performance Steel

Objective: This research is being conducted to develop innovative bridge designs to take advantage of the new high performance steel and concrete that will soon be available. These materials cannot be effectively used in present day designs. These new materials have the potential to make significant improvements in cost and service life of highway bridge structures.
Performing Organization: Modjeski and Masters, Inc.
Sponsoring Organization: FHWA
Expected Completion Date: March 1995
Estimated Cost: $600,000

NCP Category E—Materials and Operations

E.6: Snow and Ice Control

Title: Calcium Magnesium Acetate (CMA) At Lower Production Cost

Objective: To develop a cost-effective method that can be commercialized by industry to produce CMA from biomass.
Performing Organization: Engineering Resources, Inc.
Sponsoring Organization: FHWA
Expected Completion Date: May 1994
Estimated Cost: $271,616

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

Development Of An Upgrading Plan For Highway Safety Simulation Models, Volume I: Final Report, Publication No. FHWA-RD-92-077

by Design Concepts Research Division

A study was performed to develop a long-range upgrading plan for FHWA's crash simulation activity. The four major work items consisted of the following:

(a) A review was made of available general purpose finite element programs which were considered to be possibly able to simulate vehicle/barrier crash events. One of the programs was recommended to be the subject of a preliminary study designed to examine the feasibility of using this class of programs to simulate the crash problems of interest to the FHWA.

(b) A review was conducted of various existing FHWA computer programs for the analysis of vehicle impact and vehicle handling problems.

(c) An outline was developed for the structure of a Roadside Safety Analysis System (RSAS) which would essentially be a repository of vehicle crash and handling programs and associated data. Also, a user interface was designed for this system to provide a common interaction vehicle with which to allow convenient access to the simulation program and to control the generation, manipulation and review of associated input/output files and data base information.

(d) A long-range plan for the further development and maintenance of crash simulation software for the

FHWA and the development and support of an RSAS was outlined.

This is volume I of a two-volume set. The other volume is FHWA-RD-92-078, Volume II: Executive Summary.

This publication may be purchased from the NTIS. (PB No. 93-167575, price code: A06.)

Proceedings of the Bridge Scour Symposium, Publication No. FHWA-RD-90-035

by Bridge Scour Symposium co-chairmen

These proceedings contain all 21 papers and seven summaries of discussions on research needs presented at the Bridge Scour Symposium held at the Turner-Fairbank Highway Research Center of the FHWA on October 17 to 19, 1989. The symposium consisted of six sessions on various aspects of this critical problem: scour prediction, scour monitoring, scour modeling, scour protection, special problems, knowledge gaps, and research needs.

This publication may be purchased from the NTIS. (PB No. 93-167369, price code: A17.)

Environmentally Acceptable Materials for the Corrosion Protection of Steel Bridges: Task C, Laboratory Evaluation, Publication No. FHWA-RD-91-060

by Materials Division

The recently promulgated environmental regulations concerning volatile organic compounds (VOCs) and certain hazardous heavy metals have had a large impact on the bridge painting industry. As a response to these regulations, many of the major coating manufacturers have begun to offer "environmentally acceptable" alternative coating systems to replace those traditionally used on bridge structures. In the interest of determining the relative corrosion control performance of these newly available coating systems, the FHWA contracted for a seven-year study.

As a precursor to long-term, natural exposure testing of various environmentally acceptable coating systems, a battery of accelerated laboratory screening tests were performed. These tests included 13 high solids or waterborne, conventionally applied coatings; 14 powder coating or metallized coatings; and seven high VOC control coatings. These systems were tested in a cyclic salt fog/natural marine exposure, a cyclic brine immersion/natural marine exposure. Adhesion and water penetration tests were also performed on each system. The results of these various test were used to develop a matrix of test coatings to be used in the follow-on, long-term natural exposure testing.

In the accelerated laboratory screening tests, several of the low VOC coating systems performed as well or better than the high VOC controls. In general, the low VOC zinc-based systems (both inorganic and organic zinc) and the epoxymastic-type systems performed the best in the accelerated tests. These types of systems were included in the long-term exposure test matrix.

This publication may be purchased from the NTIS. (PB No. 93-175099, price code: A06.)

Stability of Rock Riprap for Protection at the Toe of Abutments located at the Floodplain, Publication No. FHWA-RD-91-057

by Structures Division

This report presents the results of a research conducted in a hydraulic flume to determine the stability of rock riprap protecting abutments located on flood plains. The observed vulnerable zone for rock riprap failure is presented for two abutment types: vertical wall and spill-through (H:V = 2:1).

Equations and velocity multipliers to assist an engineer in determining the stable rock riprap size are presented in this report for the two abutment types. Conditions found to influence the stability of rock riprap are also presented.

The results obtained in this research report have been published in FHWA Publication HEC No. 18, "Evaluating Scour at Bridges," dated February 1991.

This publication may be purchased from the NTIS. (PB No. 93-174639, price code: A06.)

The Simulation of Vehicle Dynamic Effects On Road Pavements, Publication No. FHWA-RD-92-108

by Pavements Division

The effect of traffic loads on pavement performance is a fundamental concern of highway engineering. The mechanisms by which moving loads interact with pavements take on an added significance today, with the growing concern to preserve our nation's infrastructure.

This research develops a methodology to investigate the accelerating process by which variations in pavement condition and vehicle loads reinforce each other through time and that leads to significant pavement deterioration.

Heavy truck dynamic modeling fundamentals were developed and used to simulate a broad variety of truck configurations and suspension types. In addition, pavement models for both flexible and rigid pavements were described and used in connection with the truck dynamic models to parametrically study the interaction between vehicle suspensions, highway roughness, and pavement primary and ultimate response.

These parametric studies show that consideration of dynamic loading is necessary and that there is considerable variation of dynamic loads produced by alternative tandem axle configurations.

This publication may be purchased from the NTIS. (PB No. 93-175396, price code: A13.)

Cost-Effective Geometric Improvements for Safety Upgrading of Horizontal Curves, Publication No. FHWA-RD-92-021

by Design Concepts Research Division

The purpose of this study was to determine the horizontal curve features that affect safety and traffic operations and to quantify the effects on accidents of various curve-related improvements. The primary data base developed and analyzed consisted of 10,900 horizontal curves in Washington state. Three existing federal data bases on curves were also analyzed. These data bases included the cross-section data base of nearly 5,000 mi (8,050 km) of roadway from seven states, a surrogate data base of vehicle operations on 78 curves in New

York state, and 3,277 curve segments from four states.

Based on statistical analyses and model development, variables found to have a significant effect on accidents include degree of curve, roadway width, curve length, average daily traffic, presence of a spiral, superelevation, and roadside condition. Curve flattening is expected to reduce accidents by up to 80 percent, depending on the amount of flattening. Widening lanes or shoulders on curves can reduce curve accidents by as much as 33 percent, while adding spiral transitions on curves was associated with a 5-percent accident reduction. Improving deficient superelevation can reduce accidents by 10 percent or more, while the effects of specific roadside improvements were also quantified. An economic analysis was conducted to determine when curve flattening and/or widening are cost-effective.

An informational guide entitled "Safety Improvements on Horizontal Curves for Two-Lane Roads" (FHWA-RD-90-074) was developed in conjunction with this report to give specific guidance for the design of new curves and for upgrading existing curves.

This publication may be purchased from the NTIS. (PB No. 93-160679, price code: A11.)

Research and Development Achievements Report—1992, Publication No. FHWA-RD-93-019

by the Office of Research and Development Operations and Support

This report is the 16th in a series of annual achievements reports of the FHWA's Office of the Associate Administrator for Research and Development. The report covers the period from October 1991 to September 1992. It includes information about R&D mission, organization, budget, staff, and facilities; efforts to foster innovation and collaborate with other U.S. agencies and international organizations; research highlights; and National Highway Institute activities.

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

Nationally Coordinated Program of Highway Research, Development, and Technology: Annual Progress Report Fiscal Year 1992, Publication No. FHWA-RD-92-094

by the Office of Research and Development Operations and Support

This progress report gives an overview of research being conducted under the Nationally Coordinated Program of Highway Research, Development, and Technology (RD&T) from October 1, 1991, through September 30, 1992. The NCP is organized into categories, programs, and projects; the NCP categories covered in this 1992 report are: A. Highway Safety, B. Traffic Operations/Intelligent Vehicle-Highway Systems, C. Pavements, D. Structures, E. Materials and Operations, F. Policy, G. Motor Carrier Transportation, J. Planning, K. Environment, and L. Right of Way. New to the NCP this year is the Office of Advanced Research, which will plan, administer, and conduct research and innovative adaption for emerging and advanced technologies that have potential for long-range applications in the highway program. The report highlights the high priority areas to show the research emphasis areas of the NCP.

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

TECHNOLOGY APPLICATIONS

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:

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

Soil and Base Stabilization and Associated Drainage Considerations—Volume I, Pavement Design and Construction Considerations, Publication No. FHWA-SA-93-004; and Volume II, Mixture Design Considerations, Publication No. FHWA-SA-93-005

by Office of Technology Applications

This report consists of two volumes: Volume I, Pavement Design and Construction Considerations, and Volume II, Mixture Design Considerations. These two volumes represent the revisions to the original manuals prepared in 1979. These manuals include new information and procedures incorporated into the pavement field since that time. A significant portion of the information prepared for the original manuals has been retained. The primary purpose of these manuals is to provide background information for those engineers responsible for using soil stabilization as an integral part of a pavement structure. Information is included to assist the engineer in evaluating the drainage problems of a pavement structure. Sufficient information is included to allow the pavement design engineer to determine layer thicknesses of stabilized layers for a pavement using the 1989 American Association of State Highway and Transportation Officials Guide procedures. Material properties are presented with the use of this design procedure, which the materials engineer will find useful in selecting the type and amount of a stabilizer to use with specific soil types. Construction details are presented with elements of quality control and specifications. The manuals are presented to allow an engineer to recommend where, when, and how soil stabilization should be used and to assist the engineer in evaluating problems which may occur on current stabilization projects.

This volume presents the specific details of laboratory testing for the different stabilizer additives. Typical properties are given and the test procedures to select optimum amounts are presented. These chapters provide the engineer with detailed information required from the laboratory to ensure the necessary material properties are obtained in the paving project. Volume I presents the details of drainage and pavement design and construction considerations for stabilization of pavement materials.

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

Moving America Through Innovative Technology, Publication No. FHWA-SA-92-038

by Office of Technology Applications

This brochure briefly describes the FHWA Technology Applications Program, providing information on the elements within the program and some examples of technology applications in action. The brochure also includes a telephone directory of FHWA field offices, through which readers may follow up on technology applications activities.

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

State and Local Highway Training and Technology Resources—January 1993, Publication No. FHWA-SA-93-023

by the Office of Technology Applications

Originally published by the Local Technical Assistance Program Clearinghouse managed by the American Public Works Association, this publication lists technology assistance products useful to the state and local highway community. Included in the publication are entries about videotapes, slide packages, publications, training packages, and other material. In general, this material originated in the technology transfer centers nationwide. The source for the products is cited in each entry.

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

Guidelines for Design, Specification, and Contracting of Geosynthetic Mechanically Stabilized Earth Slopes on Firm Foundations, Publication No. FHWA-SA-93-025

by the Office of Technology Applications

This report provides comprehensive guidelines for design, specification, and contracting of mechanically stabilized earth slopes. These guidelines were developed for use by transportation agencies. Both a material specification and a systems specification approach are addressed. A material specification approach is suited for in-house design by an agency, and the systems specification approach is suited to a "line and grade" process, similar to that widely used with MSE wall structures.

Slopes on firm foundations are specifically addressed, and embankments over soft soils are not covered. Use of geosynthetic reinforcement is included in this document, with geogrids and geotextiles specifically addressed. These guidelines are primarily based upon existing FHWA reports on soil reinforcement. Specific reports and guidelines are cited in the text and listed as references.

This document was prepared under the sole sponsorship of the Geotextile Division of the Industrial Fabrics Association International (IAFI) for presentation to FHWA. FHWA published this document in partnership with IAFI.

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

Background

As you can tell from this issue—the debut of the new *Public Roads*—this magazine is evolving from a technical journal to a first-rate, color magazine. See the story on page 1 for an explanation of the *Public Roads* evolution.

Public Roads is soliciting articles and input in the form of feature articles, technical articles, information for the "Along the Road" department, reader feedback, and suggestions concerning story ideas to be developed. Feature articles should deal with surface transportation issues and topics in the following general categories: significant technological advancements and innovations, important activities and achievements, specific program areas, and general interest subjects. An example of feature article format is the story on page 16, "H-3: The Island Interstate." Technical articles should describe technical issues/developments or new research that makes a significant contribution to the body of knowledge. Examples of technical article formats are the stories about the New Mexico Alliance for Transportation and side impacts on pages 22 and 28, respectively.

All Alliance in New Mexico Brings High-Tech to Transportation

A New Approach To Public-Private Cooperation In Transportation Research

by Daniel S. Metzger

Alliance For Transportation Research (ATR)

As a result of the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) and the enlightened vision of planners in the Department of Transportation (DOT), transportation research has a bright future. With

Alliance for Transportation Research

This is the ATR logo

the completion of the Eisen-hower National Interstate Highway System comes the challenge of maintaining this remarkable infrastructure and using it in the safest and most economically beneficial manner. ATR brings to the transportation community new capabilities for research and development (R&D) and mechanisms for rapidly integrating the results of research into the transportation market place.

ATR Composition and Organization

ATR is a partnership formed in October 1991 among New Mexico's major educational institutions: the University of New Mexico and New Mexico State University; two Department of Energy (DOE) national laboratories: Los Alamos National Laboratory and Sandia National Labor-atories; and the New Mexico State Highway and Transportation Department (NMSHTD). These partners realize that external interactions are important to energize the enterprise. The President, David Albright, and his administrative staff are sponsored by the NMSHTD. Each of the participating national laboratories sponsors a vice president. Function-ally, the staff reports to an executive committee that comprises high-level representation from each of the partners.

ATR is fortunate to have the active participation of advisors from both the Federal Highway Administration (FHWA) and DOE. In addition, an Industrial Advisory Board represents the active and growing interests of the private sector, and the National and International Research Council helps ATR keep in touch with global research activities in transportation.

ATR is unique in its approach of bringing together public and private knowledge and capabilities to address problems of national interest. Fundamental to the effectiveness of ATR has been its priority to find ways to contribute significantly rather than to first institutionalize an organization.

An aerial view of Los Alamos looking west

Page 22 PUBLIC ROADS • SUMMER • 1993

Before you spend a great deal of time developing and writing an article, call or write the editor to discuss the concept and scope of the article. You can call editor Bob Bryant at (703) 285-2443 or managing editor Anne Barsanti at (703) 285-2102. The address is provided below.

The new *Public Roads* attempts to communicate through a balance of text and visual elements—photographs, charts, graphs, and other illustrations. An appropriate number of high quality photographs and/or illustrations with proper captions is an indispensable part of an article. Lack of photographs or other visual elements in sufficient quantity or quality may be rationale for rejecting an article.

All manuscripts submitted for publication in *Public Roads* are reviewed by experts in the professional field to determine the suitability of the article for the magazine. Authors are notified of acceptance or rejection.

Authors should review this and future issues of the new *Public Roads* for style and use of illustrations and references. *Public Roads* follows the *Associated Press Stylebook and Libel Manual* with a few minor exceptions.

Manuscript Elements A complete manuscript consists of: title page, text, references (if appropriate), author(s) biography, and supporting visual elements. Only complete manuscripts will be considered for publication.

Manuscript Specifications

Provide a hard copy and a copy on 3.5-inch computer disk using WordPerfect.

Type the manuscript using double-line spacing with at least 25-mm (1-in) margins on 216- by 279-mm (8.5- by 11-in) paper. Excluding visual elements, one magazine page equals about three pages of manuscript.

Measurements should be expressed in metric units followed immediately, when appropriate, by English units in parentheses. For figures and tables, the English equivalent units are placed in the legend.

If the article has been previously published or presented publicly, provide the following information on the title page: the publication or forum in which the information has been presented, the audience (approximate circulation/size and general make-up), and the date of publication/presentation.

Follow the appropriate feature or technical format as explained in background information above.

Number each page in the lower right corner.

Avoid trademarks and brand names in the text unless it is directly related to the object of the article. The magazine neither endorses nor wants to appear to be endorsing specific products or manufacturers.

Provide a list of all photographs, tables, figures, and other illustrations with a complete caption for each.

Cite all tables and figures in the text in the same sequence as the tables and figures appear. Do not substantially repeat in the text information that is clearly represented in the table or figure. Place all references and footnotes at the end of the sentence after the final punctuation.

Follow the reference format used on page 30 of this issue.

Submit a brief biography of the author(s) with the manuscript. Include the author's present position and responsibilities and previous positions relevant to the subject of the article.

Submission

Submit the complete manuscript/illustration package to:

Editor, *Public Roads*, HRD-10
Turner-Fairbank Highway Research Center
6300 Georgetown Pike
McLean, Va. 22101-2296
U.S.A.

Manuscripts submitted by authors employed by federal, state, or local governmental agencies must include a letter of transmittal from the author's supervisor, endorsing the publication of the article.

Manuscripts by authors within the Department of Transportation must be endorsed by the applicable office director.

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SECOND CLASS MAIL
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in this issue