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# Public Roads

## A Journal of Highway Research and Development

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**COVER:** Marine Drive in the city of Newburgh, New York, is an excellent example of a project undertaken to redevelop and revitalize a highway. As part of this project, decorative "period" lighting was installed, and all utilities were placed underground to remove the tangle of wires and poles, improving the esthetics of the highway and creating a safer environment.



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David K. Phillips, *Associate Administrator*



## IN THIS ISSUE

### Articles



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The Secretary of Transportation has determined that the publication of this periodical is necessary in the transaction of the public business required by law of this Department.

# Utility Poles— A Highway Safety Problem

by

George B. Pilkington, II

## Introduction

The utility pole accident is the most frequent and severe roadside accident involving a "man-made" object; thus, the development and use of countermeasures to reduce this threat to highway safety will be cost-effective. However, any discussion of utility pole accidents and ways of reducing them should be put into context of the larger highway safety problem and the roadside safety problem. Utility pole accidents are a subset of this latter safety problem. Their reduction, alone, may have little effect upon the larger highway safety problem, and in the current trend of annual reductions in the highway fatality rate.

## The Highway Safety Problem

The highway safety community includes the Federal Highway Administration (FHWA), State Highway Agencies, the American Association of State Highway and Transportation Officials, the National Safety Council, the Transportation Research Board, and many academic and professional organizations. The community has a long history of involvement with improving highway safety. As a result of this combined effort, a significant improvement in highway safety has been noted. For example, from 1925 through 1985, there has been a dramatic 80 percent decrease in the fatality rate on the nation's highways, as shown in figure 1. The primary reason for this trend is the highway community's progress in designing, building, maintaining, and operating a safer and more efficient highway system.


SI Conversion:
1 fatality/$10^8$ vehicle-miles = 0.62 fatalities/$10^8$vehicle-kilometres

*Figure 1.—U. S. motor vehicle traffic fatality rates, 1925–1985.*

The most significant factor in reducing the accident fatality rate was the construction of the Interstate Highway System, an intercontinental network of freeways with separated directional lanes and full control of access. Prior to the Interstate Highway System, most highways served both land-use and traffic movement. The Interstate was constructed primarily for traffic movement. Figure 2 depicts this service/movement relationship. The relationship becomes even more meaningful as the impact of access control on highways becomes more apparent. Table 1 shows the relationship of access control to accidents. A tenfold increase in the number of highway access points will more than double the accident potential, whereas a hundredfold increase in access points increases the accident potential more than twelve times. (*1*)[1] As defined in reference *1*, an access point is both an intersection and the number of roadside businesses with direct highway access. Therefore, it is not surprising that the fatality rate on both rural and urban Interstate highways is less than half that of non-Interstate facilities, as shown in figure 3.

**Table 1.—Relationship of accidents to access control (*1*)**

| Intersection per mile | (per km) | Business per mile | (per km) | Accident rate[1] | |
|---|---|---|---|---|---|
| 0.2 | (0.1) | 1.0 | (0.6) | 126 | (78) |
| 2.0 | (1.2) | 10.0 | (6.2) | 270 | (167) |
| 0.0 | (12.4) | 100.0 | (62.1) | 1718 | (1068) |

[1]Accidents per 100 million vehicle miles (Accidents/100 million vehicle kilometres)

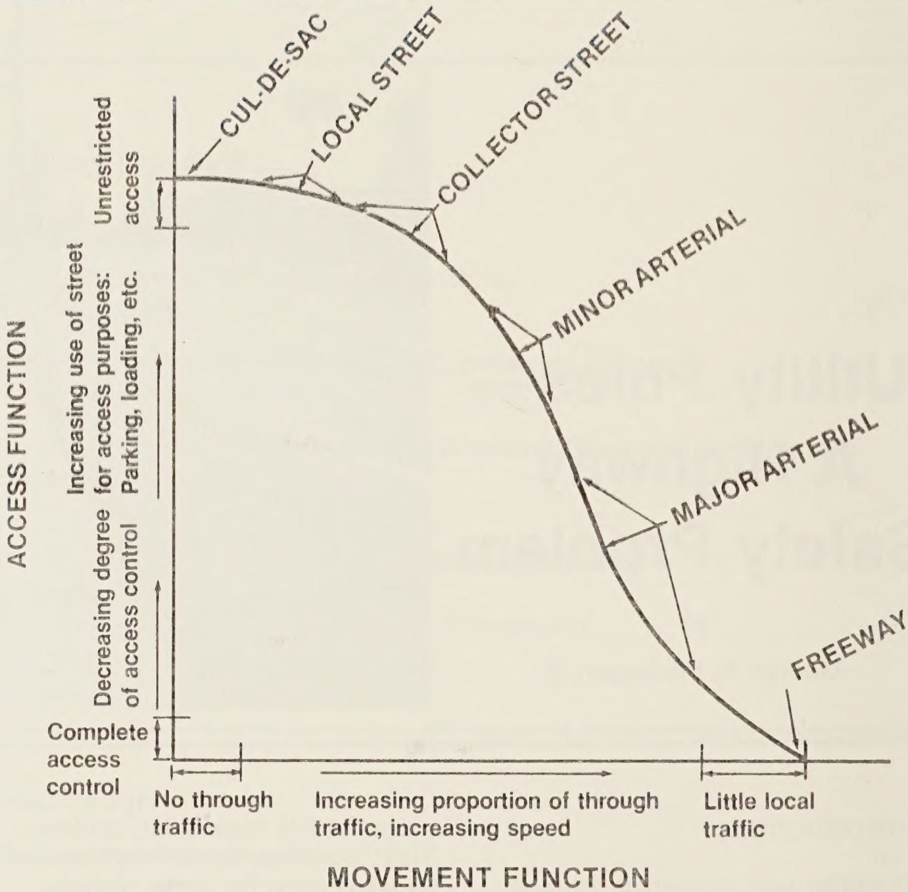
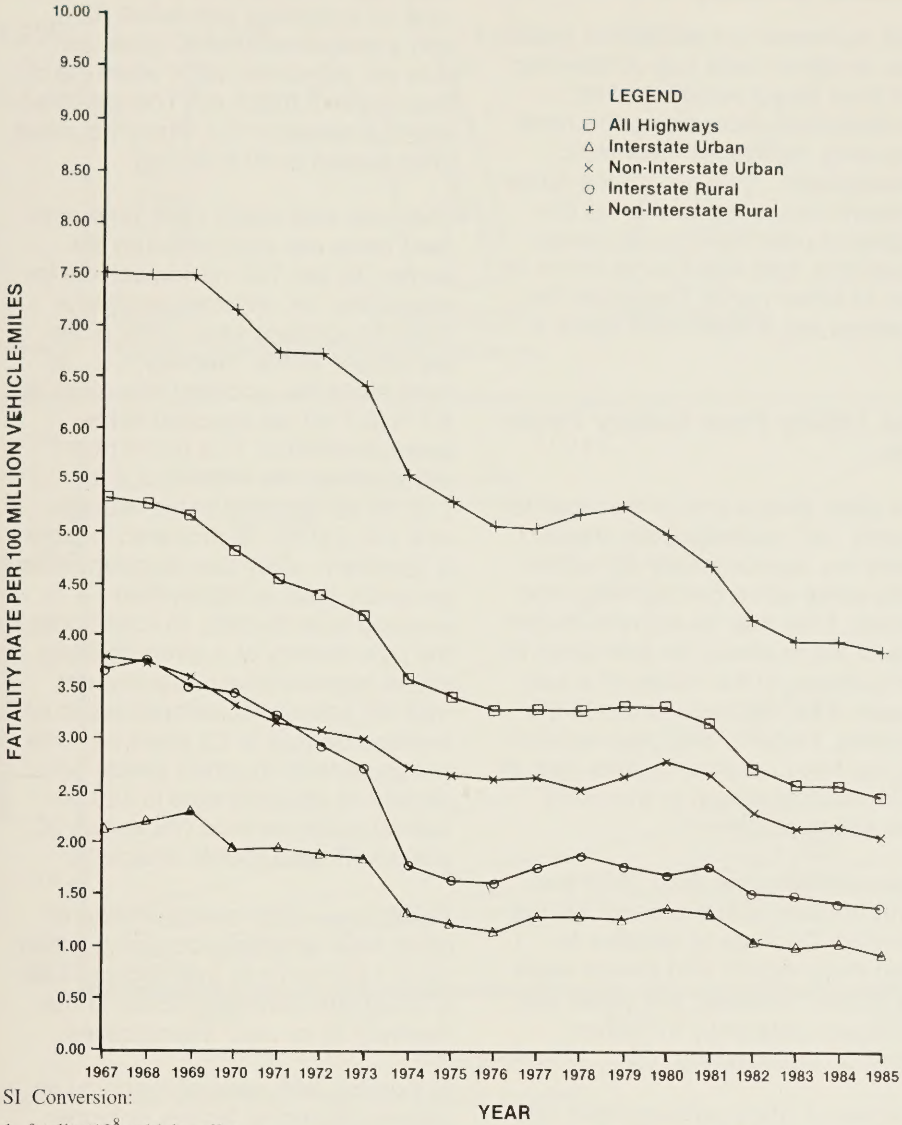



*Figure 2.—Relationship of highway access and movement.*

While the highway safety community can be proud of the continual downtrend in the highway fatality rate, more than 45,000 people still lose their lives each year in highway accidents. Even if the rate remains at its current low level, the Highway Users Federation for Safety and Mobility has predicted 85,000 fatalities annually by the year 2000. Thus, to improve highway safety, continued efforts are still required.

[1] Italic numbers in parentheses identify references on page 66.




SI Conversion:

1 fatality/$10^8$ vehicle-miles = 0.62 fatalities/$10^8$ vehicle-kilometres

*Figure 3.—U. S. Fatality rates for Interstate and other highways, 1925–1985.*

In addition to the fatality aspect, highway accidents pose a severe economic problem. In 1985, almost 7 million reported accidents resulted in 3.5 million injuries and 45,000 fatalities. The direct and indirect costs of these accidents were $48.6 billion, 10 million days of lost work, and 3.8 million days of hospitalization. This annual accident cost is approximately 65 percent of the total capital, maintenance, and administrative costs, in addition to debt retirement for the highway system administered by the States and local governments including toll facilities.

## The Roadside Safety Problem

While the Interstate system represents the model for highway design, roadside hazards on all highways remain a severe problem. Several accident studies have been performed to determine which roadside features should receive the most attention. The studies indicated that many features contribute to the roadside safety problem. The feature which receives the most attention is usually determined by the background and inclination of the person doing the study.

For example, the distribution of accidents from 7 States is shown in table 2. Conclusions drawn from these data could vary depending upon the interest of the person doing the analysis. The highway designer could conclude that improved roadside design will reduce the involvement of "embankment and other natural features" as the "bad actors." The engineer with an interest in protective structures could conclude that more protection for the permanent or necessary highway features, such as "embankments, trees, signs, and culverts," is required, or that special efforts are required to reduce the hazard of the "utility pole." The bridge engineer might conclude that the low percentage of bridge "hits" should not be ignored due to the serious impact of a bridge being out of service while an accident is removed.

Each of the conclusions, although apparently contradictory, has the common goal of improving highway safety. To improve highway safety most effectively, the consequences of each accident and situation should be examined. The following examples illustrate this point.

- On the average, a culvert has a low probability of a "hit." Culvert design to redirect or allow traversal by the run-off-the-road vehicle should appropriately receive a high priority in flash flood areas where more culverts exist.

**Table 2.—Roadside accident distribution**

| Object hit | Accident distribution percent |
|---|---|
| Embankment | 25.7 |
| Tree | 14.4 |
| UTILITY POLE | 14.4 |
| Guardrail | 10.0 |
| Fence | 7.2 |
| Sign | 6.9 |
| Mailbox | 4.6 |
| Bridge | 2.5 |
| Culvert | 2.3 |
| Other[1] | 11.8 |

[1]Coded "Other" and less than 2.0 percent

- On the other hand, a vehicle running down an embankment may suffer little damage, depending upon the steepness of the slope. This problem may appropriately receive a lower priority.

Three major influencing factors have consistently been identified in studies of roadside accidents: (1) The number, type, and offset of the fixed objects, (2) the design of the sideslope, and (3) the roadway geometry.

Each factor is discussed in detail below.

### Fixed objects

Several studies of fixed-object accidents list the type of fixed object hit. However, they rarely indicate the number of fixed objects to which the vehicle was exposed.

Fortunately, many of these studies recorded the lateral distance to the first object hit. These studies show that 80 percent of all roadside accidents occur within 20 ft (6.1 m) of the roadway. Such information has resulted in a review of the 30-ft (9.1 m) clear zone criterion. Based on one such study, New York State has recommended a "clear zone policy" based upon roadway classification and actual or projected average daily traffic (ADT). (*2*)

### Sideslope

Accident studies of roadway geometric design have shown that a run-off-the-road vehicle is more likely to be brought safely under control if the sideslope is relatively mild 3:1 or flatter. (*3*) However, recent studies have indicated that a sideslope of 4:1 may be necessary for minicars to safely traverse with a low probability of rollover.

### Roadway geometry

Both horizontal curvature and grade have an effect upon run-off-the-road and fixed object accidents, with horizontal curvature being the most frequently mentioned geometric characteristic. The run-off-the-curve accident occurs more often at the outside of a left-hand curve, as opposed to a right-hand curve or the inside of either curve. Departure frequencies are presented in figure 4. (*4*)

## The Utility Pole Safety Problem

The utility pole is one of the most frequently "hit" roadside fixed objects. There are approximately 88 million utility poles along our highways and streets. They may be located on one side of the roadway, on both sides of the roadway, in the middle of a maneuver area, and sometimes in the roadway. Recent utility pole accident studies have provided a great deal of information pertinent to the utility pole safety problem.

Approximately one third (31.7 percent) of utility pole accidents are not reported. Damage to vehicles is often insignificant, and drivers leave the scene; however, the poles are damaged sufficiently to require repair or replacement. (*5*)

The overall utility pole accident rate is only 0.2 accidents per mile per year (0.12 accidents/km/year); when the ADT, pole density, and pole offset from the roadway are considered, however, the problem takes on a different dimension. For example, figure 5 shows that the expected annual rate of utility pole accidents per mile on a highway with 5,000 ADT and a pole density of 50 poles per mile (31 poles/km) is 1.4 when the offset is only 2 ft (0.6 m). The expected rate decreases to 0.2 when the offset is increased to 30 ft (9.1 m).

The rural and urban utility pole accident rates are approximately the same; 34 per 100 million vehicle interactions, i.e., vehicles passing a pole. At accident sites, utility poles are closer to the roadway; i.e., in rural areas the accident site offset is 8.7 ft (2.7 m), as opposed to the average offset of 11.8 ft (3.6 m) In urban areas, the offset is 5.2 ft (1.6 m) as opposed to the average of 6.7 ft (2.0 m), as indicated in table 3. Similarly, utility pole accident sites generally have a higher-than-average pole density. In rural areas, the pole density at a given accident site is approximately 56 poles per mile (35 poles/km), as opposed to an average density of 22 poles per mile (14 poles/km). In urban areas, the density at accident sites is 120 versus 80 poles per mile (75 versus 50 poles/km), also shown in table 3.

There is an over-representation of utility pole accidents occurring within 50 ft (15.2 m) of an intersection. Utility poles are generally closer to the roadway at or near intersections.

In keeping with general roadside accident-influencing factors, a higher probability of a utility pole accident exists if it is located on the outside of a left-hand curve. Additionally, rural area utility pole accidents are more severe because the impact speeds are higher. In general, there is no

Table 3.—Utility pole accident site characteristics

| Area | Pole Offset: Accident site ft | (m) | Average site ft | (m) | Pole Density: Accident site ft | (m) | Average site ft | (m) |
|---|---|---|---|---|---|---|---|---|
| Rural | 8.7 | (2.7) | 11.8 | (3.6) | 56 | (35) | 22 | (14) |
| Urban | 5.2 | (1.6) | 6.7 | (2.0) | 120 | (75) | 80 | (50) |

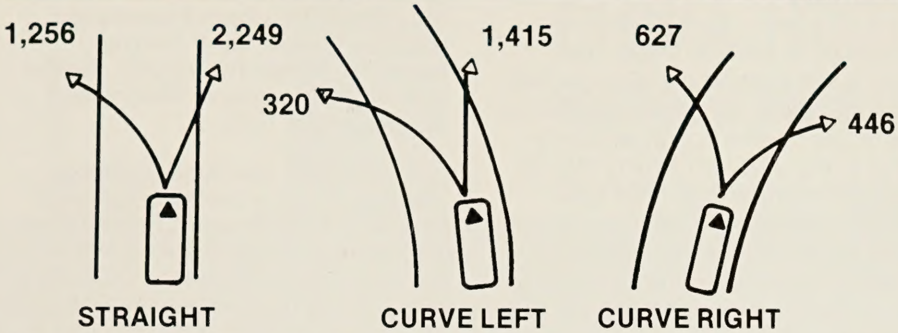


*Figure 4.—Departure frequencies by horizontal alignment.*

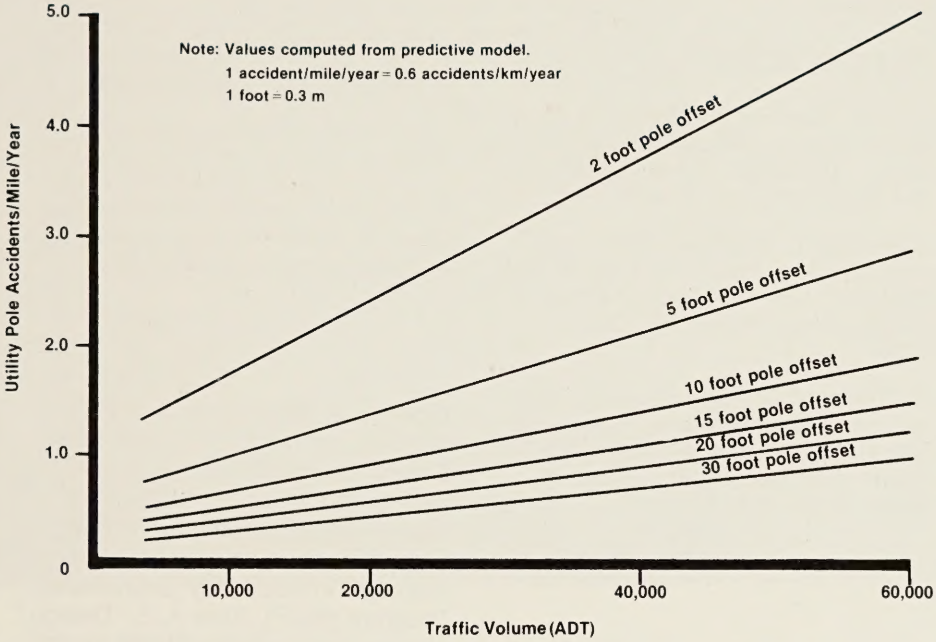


*Figure 5.—Relationship of traffic volume to utility pole accidents.*

shoulder (or only a narrow shoulder) at a utility pole accident site.

### Accident consequences

As noted earlier, reported utility pole accidents account for a small portion of all accidents. However, they are one of the most severe types of accident. A utility pole accident is six times more likely to result in a fatality and three time more likely to result in an injury than the average highway accident.

The driver is most frequently injured in a utility pole accident. A passenger in the front seat, however, is the most likely to become a fatality. Approximately 80 percent of the utility pole accidents are frontal impacts which result in injuries. However, the remaining 20 percent frequently result in a side impact fatality.

As in most highway accidents, the consequences of a utility pole accident involving a minicar are more severe than a similar accident involving its "standard-sized" counterpart.

### Countermeasures

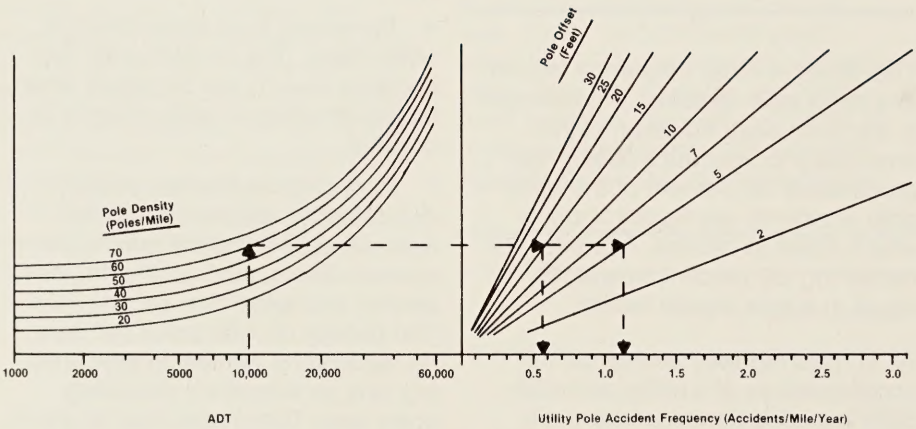
Actions taken to reduce utility pole accidents are similar to those taken to reduce most roadside accidents. Several were found to be cost-effective.

- *Burying the Utility Lines.* By burying utility lines, poles can be removed, thus completely removing the accident potential. This alternative also saves the utility company the cost of removing and replacing the pole and repairing the utility line after an accident.
- *Installing Breakaway Utility Poles.* When a pole must remain in place, it can be modified to break upon impact, thus reducing the severity of an accident. The development of breakaway devices for utility poles has been under way for several years. These are currently being installed in Kentucky and Massachusetts. (*6*) Additionally, a breakaway pole can be repaired in less time, using a smaller maintenance crew. Thus, the utility is "out of service" for a shorter period of time, and maintenance is reduced.
- *Installing Guardrails in Front of Utility Poles.* Properly placed guardrails in front of utility poles will generally reduce the severity of an accident, but will do little to reduce the number of accidents. In fact, the installation of a protective barrier may increase accidents, as the offset to the fixed object is reduced.
- *Increasing the Lateral Offset of Utility Poles.* The accident rate and accident severity will decrease when the lateral offset of utility poles is increased.
- *Reducing the Number of Utility Poles.* Utility pole density can be decreased by using the pole to carry several utilities, such as the cable, electric and telephone service lines. The density of utility poles can also be reduced by increasing pole spacing, and by selectively relocating poles away from hazardous locations.

• *Use of a Combination of Treatments to Increase the Lateral Offset and Reduce Utility Pole Density.* A nomograph (figure 6) has been developed to estimate the safety benefit of increasing the lateral offset, decreasing the pole density, or using a combination of these countermeasures.

Given this range of effective countermeasures, it is up to the individual highway agency or utility company to determine the most cost-effective treatment. This is a complex problem. However, recent FHWA research has reduced the effort required for selecting a cost-effective countermeasure for the utility pole accident. This research report, *Selection of Cost-Effective Countermeasures for Utility Pole Accidents – Users Manual,* contains the nomographs and tables which relate the ADT, roadside condition, lateral offset, and pole density when recommending cost-effective countermeasures. (*7*)

The most cost-effective measure to reduce the severity of the utility pole accident is to have the vehicle driver and passengers use their seat belts and shoulder harnesses; however, this countermeasure does nothing to reduce the number or rate of utility pole accidents.




SI Conversions:
10 poles/mile – 16 poles/km
1 ft = 0.305 m
1 accident/mile/year = 0.62 accidents/km/year

*Figure 6.—Nomographs for predicting utility pole accident frequency.*

## Summary

A number of positive steps have been taken to reduce highway, roadside, and utility pole safety problems. There has been a continual downtrend in the accident fatality rate. In addition, many efforts have been made to improve the design of the roadside and the fixed objects installed to make them more "forgiving." Effective countermeasures exist to reduce utility pole accidents, and the FHWA has provided a means to assist in selecting effective countermeasures.

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Mr. Pilkington is a member of various transportation related organizations. He currently is serving on the American Society for Testing and Materials Committee E17, "Traveled Surface Characteristics," and is chairman of Committee E43, "Metric Practice." He has represented the United States on international committees dealing with geometric design standards and low traffic roads. Mr. Pilkington has made many technical presentations before highway oriented audiences, and is the author of several technical papers.

# FHWA High Priority National Safety Research Program

by Jerry A. Reagan and Samuel C. Tignor

## Introduction

The Nationally Coordinated Program (NCP) of Highway Research, Development, and Technology (RD&T) has been established by the Federal Highway Administration (FHWA) to provide a broadly structured program for the coordination of all Federally supported research. As part of the NCP, areas of major emphasis, called High Priority National Program Areas (HPNPA's), have been identified. The development of HPNPA's allows FHWA to focus available resources on a few high payoff subjects. The objective of each HPNPA is to develop a well-defined and useable end product within approximately 3–5 years.

Work on HPNPA's is supported by research conducted by FHWA contract and demonstration (DEMO) activities staff, the National Cooperative Highway Research Program (NCHRP); the Highway Planning and Research (HP&R); Strategic Highway Research Program (SHRP) and other State and local projects.

Currently, FHWA RD&T is in progress for 14 HPNPA's in the subject areas of safety, traffic operations, pavements, and structures. The majority (six) of these HPNPA's are in the area of highway safety; these are:

1. Advance testing methods and analysis procedures,
2. Information resources,
3. Traffic barrier systems,
4. Truck highway safety,
5. Visibility of traffic control devices, and
6. Work zone traffic control.

Each of these HPNPA's has been initiated to solve problems common to many highway agencies across the country. Table 1 shows the level of activity within the individual HPNPA's. As work on these HPNPA's nears completion, new RD&T areas will be undertaken.

The remainder of this article describes the focal problem/issue of each safety HPNPA, major efforts within the research program, and expected products.

**Table 1.—HPNPA level of activity**

| HPNPA | Date | | Number of Studies | | | | | Total cost (in million dollars) |
|---|---|---|---|---|---|---|---|---|
| | Start | End | Contract | HPR | NCHRP | SHRP | DEMO | |
| 1 | 1985 | 1995 | 10 | 10 | 2 | - | - | 4.4 |
| 2 | 1989 | 1994 | 12 | 1 | 1 | - | - | 3.4 |
| 3 | 1989 | | Under development | | | | | |
| 4 | 1986 | 1993 | 10 | 7 | 2 | - | - | 4.5 |
| 5 | 1986 | 1992 | 10 | 3 | 3 | - | - | 2.5 |
| 6 | 1987 | 1991 | 9 | 11 | 1 | 1 | 1 | 3.2 |

## Advance Testing Methods and Analysis Procedures

Over the past 20 years, the number of highway fatalities has dropped from approximately 55,000 to less than 45,000 per year and the fatality rate has dropped from 4.4 fatalities per 100 million vehicle miles (MVM) driven to 2.5. However, accidents directly related to highway design continue to take their toll. Each year, approximately 12,000 people are killed in run-off-the-road single-vehicle collisions with fixed roadside objects (i.e., trees, roadside and median barriers, utility poles, crash cushions, etc.) and/or features (e.g., side slopes, drainage ditches, inlets, curbs, etc.).

Current testing procedures for assessing the effectiveness of roadside safety hardware are largely based upon intuition and experience rather than real world conditions. For example, full-scale crash testing is based upon a worst-case scenario using a tracking vehicle (i.e., one not skidding or yawing), while recent research indicates that many vehicles partially skid and yaw at impact. Also, while 25 percent of run-off-the-road fatalities are due to the car impacting sideways into a fixed roadside object or feature, current testing procedures do not address such collisions; however, increasing numbers of people are "buckling up." Although the current major measure of the potential for injury is change in velocity, it is known that the primary cause of injury in side impact collision is intrusion. Furthermore, current procedures are not consistent; they allow for different changes in velocity based upon the device or object being impacted.

In response to this situation, the goal of this HPNPA is to develop and implement testing procedures which accurately predict the probability of occupant injury and better replicate real world accident problems. Ultimately, this HPNPA will not only lower the cost of research in the roadside safety hardware area, it also will improve the quality and accuracy of this research.

This HPNPA is intimately tied to the Federal Outdoor Impact Laboratory (FOIL), a research facility designed specifically to study interactions among driver, vehicle, and roadside safety hardware. Currently, it is the only facility of its type in the United States. The FOIL is used to determine the safety performance of both new and existing roadside hardware when impacted. More importantly, it is used in research leading to new and improved testing procedures which provide a greater degree of safety on our Nation's highways.

Through a reusable surrogate vehicle (the "bogie"), the FOIL provides full-scale vehicle crash tests at moderate costs. The reusable bogie has lowered crash test costs from approximately $10,000 per test to $2,500 per test. The FOIL facilitates research in several hardware areas, including sign supports, light poles, crash cushions and roadside barriers. A "breakaway" bogie has been developed to test breakaway luminaires and sign supports. This bogie replicates the crash characteristics of the small car of the 1980's (the 1,800- lb [815 kg] vehicle), and has enabled the identification of a number of factors which significantly affect the performance of breakaway supports. Figure 1 shows the "breakaway" bogie impacting a breakaway luminaire.

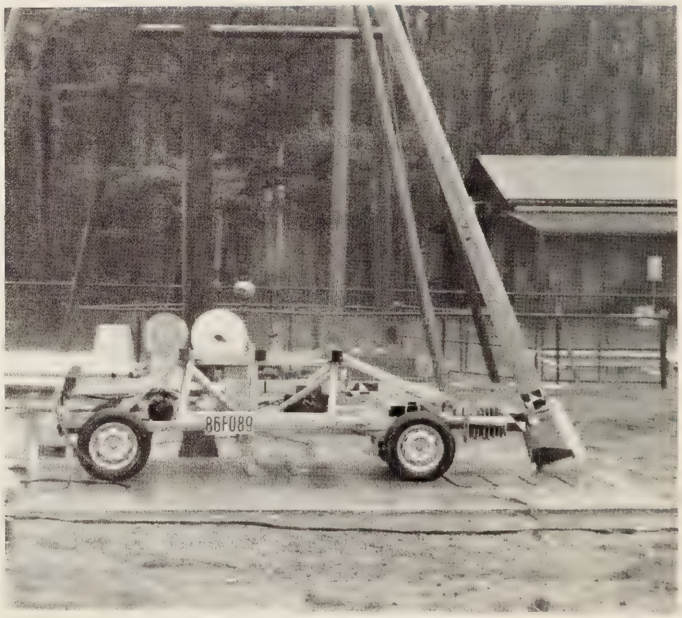


*Figure 1.—"Bogie" test vehicle during impact.*

Ongoing research efforts in this HPNPA draw on FOIL resources. These studies include the following:

- A research study is now under way to see if a reusable bogie can be applied to sign supports that bend rather than break away. The "base-bending" bogie will provide new insights into this type of test.
- A current study deals with developing a new generation data acquisition system which will collect all data (onboard vehicle, dummy, and wayside) and allow it to be entered directly into the computer without time-consuming initial preparation.
- A related study will develop standardized data collection procedures to ensure that all data is collected in the same format. This will eliminate costly repeat testing due to changes in test procedures, changes in injury prediction measures, etc.
- Another study is assessing side impacts into luminaire supports. To date, none of the test dummies have "survived" the test procedures used to study side impact. The development of mitigation measures for this type of crash may be extremely difficult.

Two NCHRP studies are related to this HPNPA. NCHRP Study 22–6 is investigating the performance, through crash testing and computer simulation, of current roadside safety hardware when impacted by a micro minisize vehicle (1,200–1,500 lb [545–680 kg]) the probable small car of the 1990's. NCHRP Study 22–7 focuses on deficiencies in existing crash test specifications and will attempt to update these specifications for the next decade.

Several future FHWA contracts will require contractors' use of the FOIL facility. This will ensure that consistent test conditions are used and will increase our understanding of what happens when a vehicle impacts a roadside device.

## Information Systems

Information about the highway and its performance is essential for determining future needs and developing sound policy. Currently, neither FHWA nor the States have economical and timely access to the data necessary to identify safety problems, assess the magnitude of new safety questions, or determine safety program effectiveness.

States and local jurisdictions spend more than a half-billion dollars annually on traffic accident reporting. (Figure 2.) However, proportionately, very little effort is devoted to using the data to analyze safety issues. This is due in part to known deficiencies in the data, existing limitations in data processing systems, and lack of statistical tools for interpreting the data. Improvements in data quality, data elements, timeliness, and reduced cost through the application of 1990 technology will benefit those at all levels who use safety data.

The objective of this HPNPA is to create an improved, broad-based, technological approach for gathering and using accident, geometric, and traffic count data for highway safety problem analysis in a timely and cost-effective manner.

A contract effort is under way to develop a prototype Highway Safety Information System (HSIS). This system will use data from several States which have developed systems capable of merging useful data from different files within the respective State. HSIS cost is relatively low because no new data will be collected. Later contract efforts will demonstrate and evaluate HSIS through its application to current issues such as the effects of increased speed limits and the introduction of large trucks. Future expansion and revision of HSIS as additional States develop improved safety information systems is possible.

*Figure 2.— More than a half-billion dollars annually is spent on traffic accident reporting.*

Research is planned to determine Federal and State safety system needs and data requirements; a study will develop requirements for uniform data definitions. These efforts are timely, because (1) they afford the opportunity to use emerging technology and (2) they consider restructuring of data collected.

Another area of research will explore the use of geographic computer reference systems for enhancing the accuracy of location information. This is the key to linking data from various files and developing strong relationships between accidents and specific highway traffic operational and physical features. The Census Bureau—in cooperation with the Coast and Geodetic Survey—has developed TIGER, which provides accurate digitized maps for the entire United States. Combined with satellite reference systems, accurate cross referencing of field location with inventory data about that location will be possible.

Other technological innovations which might improve the quality and economics of accident data collection and processing will also be examined. These innovations include digital video log storage to allow users rapid and convenient access to visual information about specific highway locations. Computerized pattern recognition might eventually permit automatic cataloging of features such as the presence of guardrail. Progress in data entry might allow police officers to enter data directly into a computer system, lessening the time lag for data availability and permitting built-in edit checks at a point when errors can be easily corrected. Some data errors may be completely eliminated if, as some computer experts predict, the keyboard is replaced with direct English-language voice communication within the next decade.

## Traffic Barrier Systems

Over the past 2 decades, most of the research in the roadside safety hardware area has been directed at solving specific operational problems. The emphasis was on what will work rather than why it works. This approach has had many successes—crash cushions, breakaway cable terminals, safety shape median barriers, etc. However, as a result of the emphasis on what will work, the current body of knowledge is based largely on limited test data, expert opinion, and observed results. This knowledge is difficult to share given its subjectivity. It is also very difficult to take this body of knowledge and apply it to other similar situations or to the future highway systems. This is unfortunate, because many changes are now occurring in the driver, vehicle, and roadway environment. It is known the vehicle fleet is changing. New materials which potentially could be used for roadside hardware are available. Drivers are getting older and more fragile, and traffic on two-lane roads is significantly increasing.

Given the limited safety resources available and the goal of lowering the existing fatality rate of 2.5 per MVM, it is imperative that research on roadside safety hardware be approached scientifically. The existing hardware is probably adequate for today, but a research program must be initiated that allows the application of objective scientific methods to the broad range of safety problems the changing future will bring.

The long-range objective is to create rational design procedures and better guidelines for the development of future roadside safety hardware. To accomplish this, a number of intermediate objectives must be met:

- Determine the real-world performance of current hardware through accident analysis.
- Determine the performance limits of various roadside safety hardware systems and components through crash testing.
- Develop improved analytical techniques for designing and evaluating roadside safety systems.
- Develop test criteria for roadside safety hardware that adequately protect vehicle occupants.
- Develop guidance for systematic design of cost-effective safety hardware.

Hopefully, through this research program, the severity of crashes like that shown in figure 3 can be reduced.

A HPNPA is now under development and peer review. Once this peer review is completed, documentation for the new HPNPA will be submitted to FHWA management for approval. The FHWA will no longer fund the design, development, and testing of specific barrier systems. Instead, the FHWA will continue to cooperate with the American Association of State Highway and Transportation Officials (AASHTO) in testing barriers designed and developed by States using HP&R funds in the pooled fund program. In the interim, a number of ongoing studies related to the development of roadside barriers will be completed soon.

- A Rural Technical Assistance Program (RTAP) study is crash-testing barriers designed for use on low-volume roadways.

- Another study has redesigned and tested the Minnesota Three-Cable Guardrail and the Modified Thrie Beam Barrier.

- Another study has reviewed the standards, plans, and experiences of several States currently using W-beam guardrail buried-in-backslopes as a terminal and successfully tested the terminal.

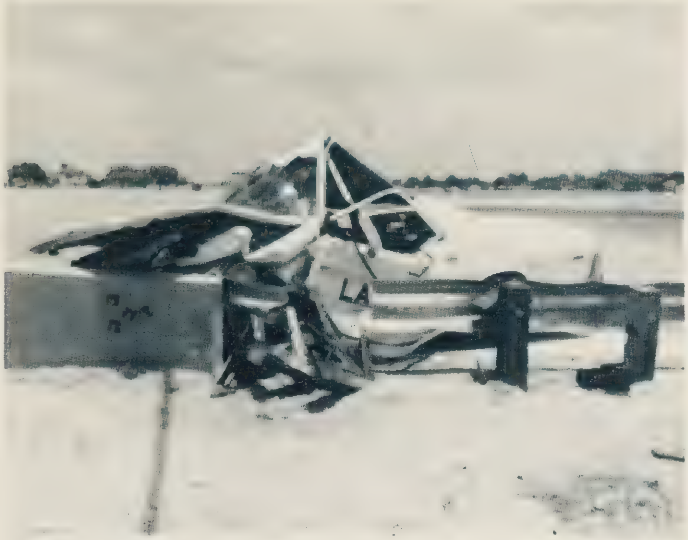

Figure 3.—Crash test of a transition section.

Figure 4.—Large truck in the traffic stream shows the relative difference in size and weight of today's trucks and automobiles.

- A self-restoring bridge (SERB) railing for new construction and deck-widening applications has been crash tested with several vehicles. Transition sections using the SERB will also be designed and tested. A pool fund study is now developing and testing bridge rails based on the proposed AASHTO bridge rail specifications.

Several of the ongoing studies relate to the new HPNPA. One study is examining traffic barriers on curves, curbs, and slopes. This study will develop guidelines for the use of guardrail on slope sections. Other studies are evaluating current computer simulation models. It is anticipated that these computer models will be increasingly used in the design and evaluation of future roadside safety hardware.

There are two related studies planned for the NCHRP program in the next fiscal year. NCHRP Project 22–7 will update the existing crash-test specifications used to test roadside safety hardware. NCHRP Project 22–8 deals with the justification of performance level warrants for barrier design. FHWA's Office of Implementation is also developing technology transfer material on bridge rails, transitions, and terminals; this includes the development of design drawings, videotapes, and pocket guides.

## Truck/Highway Safety

Although trucks are involved in a relatively small portion of the total annual number of motor vehicle accidents, because of their size and other factors, their involvement in accidents—when it occurs—is usually severe. For example, in 1984, trucks were involved in only 3.8 percent of all accidents, but in 8.9 percent of all fatal accidents, resulting in 5,600 fatalities and 171,200 injuries. Figure 4 shows the relative size of today's trucks and automobiles.

In recent years, truck size and weight limits have undergone significant changes. Twin trailer trucks with 28-ft (8.5 m) trailers and tractor semitrailers with 48-ft (14.6 m) and 53-ft (16.2 m) trailers are increasingly prevalent in the traffic stream. Many of the larger vehicles carry hazardous materials, the transport of which has become a topic of intense State and Federal interest. In fact, the Research and Special Programs Administration has initiated rulemaking on routing standards which is expected to encourage and/or require routing analyses for selected classes of hazardous materials.

Many of the present geometric design criteria and signing guidelines are based on the physical and operating characteristics of passenger cars. Past research has shown that many geometric designs (e.g., horizontal curve, interchange ramps, and speed change lanes) do not provide an adequate safety margin for current trucks. The objective of this HPNPA is to develop revised geometric design criteria and operational guidelines for safely accommodating trucks on existing and future highways.

Studies under this HPNPA deal primarily with the operational characteristics of vehicles and their effects upon highway safety. Studies that deal with the vehicles or the drivers are conducted by the FHWA Office of Motor Carriers and the National Highway Traffic Safety Administration (NHTSA). Description of the former studies follow.

- A current research study has identified 18 potential future size and weight scenarios. These scenarios are based on possible changes in gross vehicle weight, pavement loadings, bridge formulae, vehicle length, and vehicle configuration. Analytical techniques and computer tools are being used to determine safety-related maneuvering performances of vehicle designs corresponding to the selected scenarios.

- Another study is examining those highway design and operational standards which are sensitive to truck performance characteristics—braking distance, rollover, turning radius, etc. The contractor submitted the phase 1 report; this contains a review of existing data on truck characteristics that need to be considered in highway design and a sensitivity analysis of highway design and operational criteria that are affected by these truck characteristics. Phase 2 will evaluate current design criteria and will recommend new criteria based upon a cost-effectiveness analysis.

- A pooled fund study is examining the traffic operational impacts of wide trucks on narrow roadways. The operation of trucks 96 in (2.4 m) and 102 in (2.6 m) wide will be monitored for a number of geometric configurations to determine the effect of width on overall operation and safety. Data to be collected include lateral placement of trucks, encroachment on center lines and shoulders, and relative positioning of cars.

- A study has recently begun which is examining truck accidents on urban freeways. The purpose of this study is to provide local authorities with information or guidance on how to improve urban freeway safety as it relates to heavy trucks.

Additionally, there are ongoing NCHRP, Transportation Research Board (TRB), NHTSA, Office of Implementation, and Office of Motor Carriers studies that are related in varying degrees to this HPNPA. For example, NCHRP Project 3–35 will develop procedures for the design of speed change lanes. NCHRP Project 2–16 is a broad-based study on increasing the number of axles. A NHTSA study is a field evaluation of anti-locking braking systems for heavy trucks. The Office of Implementation has two ongoing studies in the area of large trucks. One is to develop a training course on the design and installation of a grade warning system for trucks; the second will develop research digests of past studies on truck climbing lanes, interchange ramp design, and the operation of large trucks on roadways with restrictive geometry. Finally, the Office of Motor Carriers has numerous studies dealing with information systems, vehicles, and drivers.

Several planned studies will essentially deal with the relationship between trucks and highway safety resulting in methods for improving the operation of large trucks on the Nation's highways in the 1993–95 time period. The final work in this HPNPA will be an extensive technology transfer activity.

## Visibility of Traffic Control Devices

Many retroreflective traffic control devices (RTCD's) have been in service for long periods of time and deteriorated to the point where drivers may not always see them and react adequately. The problem is particularly critical at night, when retroreflective devices serve as the primary cue for driver guidance and navigation. Approximately 60 percent of all vehicular deaths occur at night, but approximately 25 percent of all travel occurs during hours of darkness, therefore, nighttime accidents are overrepresented.

The *Manual on Uniform Traffic Control Devices* (MUTCD) contains standards for new signing and marking materials required or recommended for all streets and highways "open to the traveling public." The MUTCD requires that devices needed at night must be reflectorized or lighted, but does not define the retroreflectivity levels required, or provide a way to determine when a device has reached the end of its useful life. Figure 5 illustrates the type of sign deterioration which can occur. Unfortunately not all deficient signs can be spotted this easily. Often signs which appear adequate during daytime inspection do not provide sufficient retroreflectivity at night.

On April 26,1985, the FHWA published an Advanced Notice of Proposed Amendment to the MUTCD to obtain information as to whether performance standards for inservice RTCD's are needed. Subsequently, a HPNPA was established to develop the background information for the possible establishment of visibility-based performance standards for RTCD's. In addition, inventory management and field inspection techniques required to make such standards practical to implement are being considered and, if necessary, developed. Studies under this HPNPA are described below.

- A human factors contract was undertaken to determine inservice visibility requirements for all RTCD's and establish the end of life performance of retroreflective materials. Studies are now being conducted to define minimum visibility requirements of a large sample of drivers. From these studies, a series of curves relating retroreflective device performance to the proportion of the driving population served will be derived. This contract is scheduled to be completed in the summer of 1989.

- NCHRP Study 5–11 aims at determining what economic resources will be needed to bring typical inservice

*Figure 5.—A deteriorated traffic control sign.*

RTCD's above the minimum required visibility levels. This study will build on that outlined above. Study work will involve the physical inspection of all RTCD's within various geographical areas to (1) establish the current condition of RTCD's and (2) develop an economic analysis of the impacts of various alternative strategies for implementing candidate retroreflective standards.

- If inservice visibility standards are to be fully implemented, highway agencies must be given the tools to measure and manage the numerous RTCD's under their jurisdiction. Development is under way on a computerized sign management system (SMS) which will be used to predict which signs are likely to need replacement. The data base management portion of the SMS has been completed and is available for use in developing and maintaining sign inventories.[1] The feasibility of the predictive portion has been demonstrated for warning signs. A contract has been awarded to develop service life information for a wider range of conditions.

- A Small Business Innovative Research study has demonstrated the feasibility of developing a mobile laser retrorflectometer to measure inservice pavement markings. Phase 2 of this research is to develop field prototype units which will allow highway agencies to monitor the current condition of existing markings and to control the quality of newly applied markings. Arrangements will be made with three or more States to field test the prototype to survey existing markings.

- A complementary study, NCHRP Project 5–10, will determine the feasibility of a vehicle-mounted system to rapidly assess the retroreflective effectiveness of highway signs. Preliminary laboratory testing has shown the design is feasible. Authorization has been given to develop a breadboard system to demonstrate the concept in the laboratory. This breadboard study is scheduled to be completed late this year. Additional funding has been programmed by NCHRP to develop field prototype units. This would allow hands-on use of the equipment by several highway agencies and would provide feedback for commercial development of such equipment and field evaluation of rapid measurement techniques.

Current expectations are that by 1991, the research findings and economic analyses necessary for the development of draft standards (if appropriate) for a Notice of Proposed Amendments to the MUTCD will be available. Training courses will be developed to aid highway agencies in complying with these new standards should they be adopted.

## Work Zone Traffic Control

The problem of accidents and delays in highway work zones is broadbased and disproportionately affects the Interstate user. Across the Nation, fatal accidents in road construction work zones rose more than 40 percent during the first half of the 1980's. Furthermore, in 1985, work zone fatalities on the Interstate system accounted for 33 percent of all work zone fatalities, while non-work zone Interstate fatalities accounted for less than 7 percent of all total accidents. Experts expect that the death toll—now almost 700 per year—will continue to rise. In addition, as emphasis continues to shift from construction of new highways to rehabilitation of existing facilities, the number of work zones also increases.

[1] Sign Management System Update, *Public Roads*, March 1988, pp. 121–122.

*Barriers used to control traffic safety in highway construction work zones.*

This HPNPA is designed to assist the States by providing the research and training that will yield improved safety and operations in work zones. In recent years, much has been learned about how traffic can be managed in work zones to provide for both the safety of workers and of the traveling public. The problem, however, has been in nationally implementing the many good techniques and traffic control procedures found to provide for the greatest safety in work zones. This HPNPA is thus concentrating on the development of programs to disseminate, teach, and implement known-to-work technology. Projects include the following:

- A current research study involves developing guidelines for selecting the appropriate delineation device in specific work zone projects. Specifically, cost-effectiveness analysis will indicate if drums, barricades, panels, cones, or tubes should be used based on the construction type, location, and length of time the traffic control will be in operation.

- Another study aims at providing an improved Part VI, for the MUTCD, on "Traffic Control for Street and Highway Construction, Maintenance, Utility, and Emergency Operations." This part will be expanded to cover utility and emergency work zone activities plus other areas not now addressed in the manual.

- A work zone traffic control synthesis is being developed which will update the research findings associated with the use of arrow panels, barrier delineation, rumble strips, pedestrian/worker protection, and tie-down for work zone concrete barriers.

- An interactive videodisc system has been developed and is being field-tested for training personnel responsible for the management and control of traffic within work zones. This system has the capability of monitoring trainees' performance so management can determine if subjects have sufficient command and knowledge to safely perform their traffic control tasks.

- A training course, "Design and Operation of Work Zone Traffic Control," is being offered by the National Highway Institute to resident project engineers, foremen, and others responsible for installing and operating traffic control plans. This course will be presented over 40 times throughout the country over the next 2 years. A second course, "Planning and Scheduling of Work Zone Traffic Control," is being developed by the Office of Implementation for the planners and design engineers who are responsible for developing traffic control plans.

- A 2-year SHRP study is developing innovative methods to promote safe operations during short-term work zone operations. Two research phases are planned: Phase 1 is a review of known effective practices; phase 2 will test and demonstrate approaches for safely controlling traffic in and through the work area.

The final activity of this HPNPA will be to sponsor a second work zone traffic control symposium to summarize the activities of this research and implementation effort.

## Conclusion—The Significance of Safety Research

The research described above constitutes ongoing work within the six FHWA safety HPNPA's. The scope and funding of these HPNPA's do not permit all highway safety issues to be addressed: In general—in 1982, only 0.15 percent of all funds expended were allocated to highway research.

In 1982, the Transportation Research Board and FHWA initiated a study entitled "Strategic Transportation Research Study: Highways" (STRS for Highways). The study was undertaken to assess the impact of the decline in funds to build, maintain, and operate highways plus a reduction in funds available for highway research. The STRS for Highways study did not identify safety as one of its priority areas, largely because of funding problems.

Safety, however, is a critical area. It has been estimated that if the current level of 2.5 fatalities per MVM continues, 80,000 people per year will lose their lives on U. S. highways by the year 2000. A rate of 1.5 fatalities per MVM will leave the current annual loss of life at about the same level as today (46,000). This level has been recommended by the Automotive Safety Foundation and Highway Users Federation as a national highway safety goal for the year 2000.

FHWA and the National Highway Traffic Safety Administration jointly are planning a 1989 study entitled "A Strategic Research Study for Highway Safety" (STRS for Safety). This study will critically review all safety areas related to the driver, the vehicle, and the highway. The Transportation Research Board will provide the service of one or more subcontractors to provide quantitative data on critical safety issues. The goal of the STRS for Safety Study is to identify worthwhile, high payoff initiatives which should be developed through a large-scale national safety research effort over the next 5–10 years, and which will yield results and benefits well into the next century.

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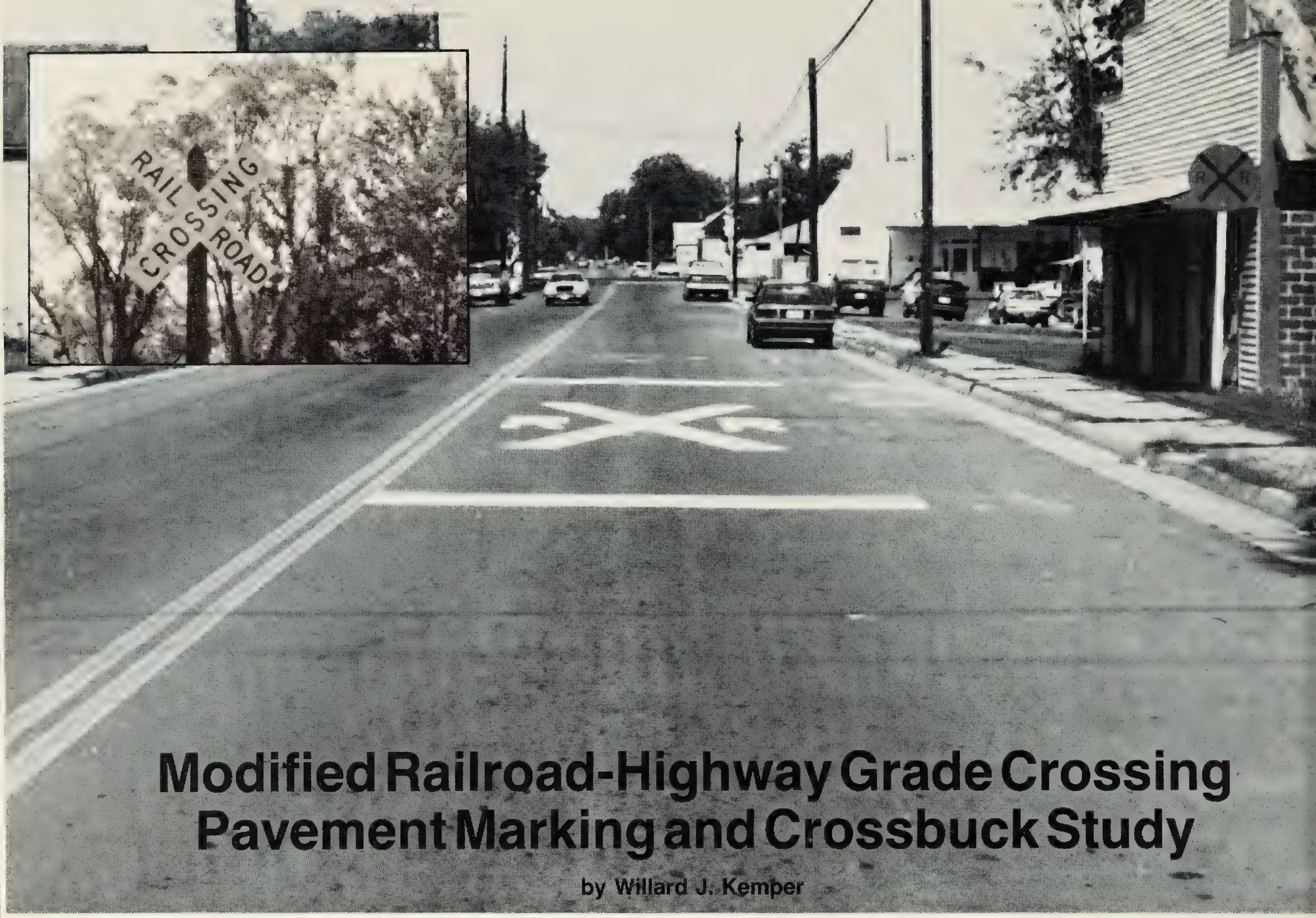



# Modified Railroad-Highway Grade Crossing Pavement Marking and Crossbuck Study

by Willard J. Kemper

## Introduction

There are more than 215,000 public railroad-highway grade crossings in the United States. While between 1977 and 1986, injuries and fatalities, respectively, have decreased from 4,455 and 846 to 2,192 and 501, many drivers are still confused as to how to proceed when approaching a railroad-highway grade crossing.

To provide motorists with information concerning a crossing, traffic control devices are placed at railroad-highway grade crossings; these can be either passive or active devices. At passive crossings—which comprise nearly 75 percent of all railroad-highway grade crossings—a crossbuck serves as a "yield sign," reminding motorists that they must yield to trains. At active crossings, drivers are warned of a train's approach by flashing lights and sometimes by automatic gates. Both passive and active control devices use advance warning signs and pavement markings to alert drivers that a crossing is ahead.

To reduce motorist confusion at crossings, modifications to two existing passive type control devices—railroad pavement markings and crossbucks—have been proposed. These changes suggest that:

- The "RR's" be eliminated from the pavement markings symbol; this would significantly reduce the cost of maintaining the symbol.

- A 2-in (50 mm) black border be added to the crossbuck symbol to improve the symbol's target value; this would increase the crossbuck's size to 52 by 13 in (1.3 x 0.3 m).

Before being installed on any road open to the public, these modifications must be incorporated into the *Manual on Uniform Traffic Control Devices* (MUTCD) through the formal rule making procedures. Figure 1 shows the current standards for pavement markings at railroad-highway grade crossings; figure 2 shows those for the railroad-highway crossing (crossbuck) sign.

To respond to requests for the MUTCD standards modifications, the Federal Highway Administration, Office of Traffic Operations commissioned the study described in this article.

## Study Approach

The study, which consisted primarily of a series of slide identifications, was conducted in an 11 by 16 ft (3.4 x 4.9 m) laboratory with walls and ceiling painted black. A rear projection Da-Lite screen measuring 59 in square was utilized. The slides were displayed using a Lafayette Model 42011-A Tachistoscope and an Eagle Eptat Model 210 Controller. The test subject sat 8 ft (2.4 m) from the screen; the projection on the screen was approximately 18 by 24 in (460 x 610 mm).

There were 40 test subjects, 20 male and 20 female, of various ages used in the study. Test subjects were asked to view 40 slides depicting a variety of highway signs and pavement markings and to indicate what each of these pictorial situations meant to them. Each slide was displayed for 7 seconds. As a "trial run," test subjects were shown three preliminary slides (two highway signs and a pavement marking) to show what they could expect during the study.

The 40 test slides were a mixture of highway signs and markings; six of them were concerned with railroad pavement X-markings and eight with crossbucks.

*Small X-marking.*

*Medium X-marking.*

*Regular X-marking.*

*Standard MUTCD pavement X-marking sizes.*

*Figure 1.—Pavement X-marking sizes.*


*Standard MUTCD crossbuck.*


*Standard crossbuck with black border.*

*Blank crossbuck with red border.*

*Blank crossbuck with black border.*

*Figure 2.—Crossbuck designs.*

The six railroad pavement X-marking slides were shown as follows:

Slide #2 – Small X-marking with no advance warning and no RR's.

Slide #13 – Regular size X-marking with no advance warning and no RR's.

Slide #19 – Medium size X-marking in a small town with no advance warning and no RR's.

Slide #27 – Same as slide #19 except a symbol Railroad Station Ahead sign.

Slide #31 – Small X-marking with an advance warning sign, but no RR's.

Slide #36 – Regular size X-marking with RR's and an advance warning sign.

Figure 1 shows the relative size of the pavement X-markings used in the study.

The eight slides depicting the crossbucks were:

Slide #4 – Close-up of a blank (no message) white crossbuck with a black border.

Slide #7 – Distant shot of a blank white crossbuck with a red border.

Slide #11 – Distant shot of a blank white crossbuck with a black border.

Slide #16 – Distant shot of a regular crossbuck.

Slide #23 – Close-up of a blank white crossbuck with a red border.

Slide #28 – Distant shot of a regular crossbuck with a black border at a crossing with flashing lights and gates.

Slide #34 – Close-up of a regular crossbuck.

Slide #39 – Close-up of a regular crossbuck with a black border.

Figure 2 shows the crossbuck designs used in the study.

Test subjects were asked to comment if they noticed anything unusual about the signs and markings during the study. Typical responses made by the subjects are shown in table 1.

After the test subjects had completed identifying and commenting on the 40 slides, each of the 14 key slides concerning the X-marking on the highway and the crossbucks was shown again for discussion and comment.

Finally, at the end of each discussion, a slide was shown of the four crossbucks used in the study (figure 3). Subjects were then asked which of the crossbucks they would most easily recognize and prefer to see at railroad-highway grade crossings.

**Table 1.—Subjects responses to pavement X-markings**

| | |
|---|---|
| 1. | Some type of crossing (11) |
| 2. | No stopping (6) |
| 3. | No parking (6) |
| 4. | Stop (2) |
| 5. | No crossing (2) |
| 6. | Pedestrian crossing (2) |
| 7. | No standing (2) |
| 8. | Don't do something (2) |
| 9. | Helicopter landing (1) |
| 10. | Keep straight ahead with caution (1) |
| 11. | Crosswalk (1) |
| 12. | Crossing - cars entering (1) |
| 13. | Prepare to stop (1) |
| 14. | No loading or unloading (1) |
| 15. | School bus stop (1) |
| 16. | Stay out of lane (1) |
| 17. | Stop for railroad crossing (1) |
| 18. | Crossroad ahead (1) |

( ) Number of subjects giving response.

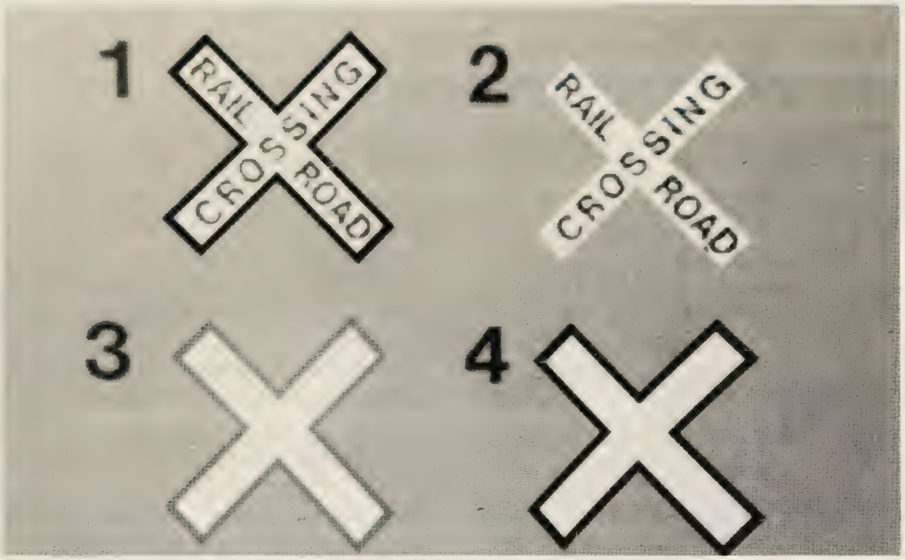


*Figure 3.—Crossbucks shown to subjects for recognition and preference.*

no significant difference at the 0.05 significance level could be found between males and females.

Overall, the first time the pavement X-marking was shown on the road with no other information (slide 2), it was recognized as an advance warning for a railroad crossing by only 10 of the 40 subjects, or 25 percent. The second and third times it was shown (slides 13 and 19)—again with no other information, but with different size X's—the recognition rose to 31 percent and 45 percent, respectively. The fourth time the marking was shown with a Railroad Station Ahead symbol sign (slide 27), there was 61 percent recognition. The fifth time the marking was shown—with the regular advance warning sign, but

## Findings

Study results are presented separately for pavement X-markings and for crossbucks in the following paragraphs.

## Pavement X-Markings

### Age comparison

Table 2 shows a percentage of X-marking recognition by age group. There were 13 subjects in the under 30 age group, 12 in the 30–40 group, and 15 in the 41 and over group. When "information statistic" at the 0.05 significance level was applied to the data, no significant difference was found over the age groups.

### Male and female comparison

There was an apparently higher percentage of recognition by males than by females (see table 3) when the X-markings, with no other information, were first shown. As additional information was given—as in slides 27, 31, and 36—the percentage of recognition was about the same. This could mean that, except for local driving, males do more of the driving, and therefore have more exposure to the markings. To further assess the table 3 results, "information statistic" was applied to the data. Overall,

**Table 2.—Pavement X-marking recognition by age**

| Age Group | Slide Number[1] 2 | 13 | 19 | 27 | 31 | 36 |
|---|---|---|---|---|---|---|
| Less than 30 | | | | | | |
| Number | 4 | 4 | 6 | 9 | 12 | 13 |
| Percent | 31 | 31 | 46 | 69 | 88[2] | 100 |
| 30 to 40 | | | | | | |
| Number | 3 | 4 | 5 | 8 | 10 | 12 |
| Percent | 25 | 29 | 38 | 63 | 83 | 96[2] |
| 41 and over | | | | | | |
| Number | 3 | 5 | 8 | 8 | 13 | 15 |
| Percent | 20 | 33 | 50 | 53 | 87[2] | 97[2] |
| Overall | | | | | | |
| Number | 10 | 13 | 19 | 25 | 35 | 40 |
| Percent | 25 | 31 | 45 | 61 | 86 | 98[2] |

[1]See description of slide numbers on page 78 .
[2]Subjects were 100 percent in identifying, but not in understanding.

**Table 3.—Pavement X-marking recognition by sex**

| Correct Recognition | Slide Number[1] 2 | 13 | 19 | 27 | 31 | 36 |
|---|---|---|---|---|---|---|
| Female | | | | | | |
| Number | 3 | 4 | 7 | 11 | 18 | 20 |
| Percent | 15 | 18 | 35 | 55 | 88[2] | 98[2] |
| Male | | | | | | |
| Number | 7 | 9 | 11 | 14 | 17 | 20 |
| Percent | 35 | 45 | 55 | 68 | 85 | 98[2] |
| Overall | | | | | | |
| Number | 10 | 13 | 18 | 25 | 35 | 39 |
| Percent | 25 | 31 | 45 | 61 | 86 | 98[2] |

[1]See description of slide numbers on page 78 .
[2]Subjects were 100 percent in identifying, but not in understanding.

without the RR's on the pavement (slide 31)—86 percent of the subjects recognized it. The final time it was shown as a regular advance warning with the RR's in the X-marking (slide 36), all but two subjects understood the message. Of these two, one subject said, "It was a railroad crossing, and the X mean't no stopping"; the other thought, "It was probably a railroad crossing," but the subject wasn't sure.

The Cochran Q Test verified that there was a significant improvement at the 0.05 significance level in subjects correctly identifying the pavement X-markings as advance warning information was provided.

### Size of X in X-marking

The size of the X within the X-marking did not seem to make any difference in subject recognition since no one commented on it. Also, recognition of the X-marking rose steadily from 25 to 45 percent with each exposure even before any additional supplemental information was given as in slides 27, 31, and 36.

## Post-Test Interview

During the post-test discussions with the test subjects, several of them suggested that the RR's could be put at the top and bottom of the X within the X-marking rather than on the sides. In this way the RR's would not wear away so quickly. This suggestion is worthy of further consideration.

## Crossbucks

As mentioned earlier, the 2-in (50 mm) border was suggested as a means of improving the target value of the crossbuck. This was accomplished by adding a 2-in (50 mm) black or red border on a 48 by 9-in (1.2 x 0.2 m) crossbuck, increasing the size to 52 by 13-in (1.3 x 0.3 m).

## Age, Male — Female Comparisons

Differences in subject response to crossbucks by age groups were assessed. As with the pavement X-markings, no significant difference at the 0.05 significance level by age was found for the subjects' understanding of the crossbuck slides.

Male and female understanding of the crossbucks is shown in table 4. When "information statistic" was applied to the data, no significant difference at the 0.05 significance level was found between male and female responses; this is the same finding as with the pavement X-markings.

In interpreting the overall table 4 data, subject recognition of the crossbucks ranged from 70 percent to nearly 100 percent depending on the different sign colors and distances used. The first time the sign was shown with a close-up of a blank black border crossbuck (slide 4), there was 81 percent understanding from the shape of the sign. The second and third times (slides 7 and 11), crossbucks were displayed with distant shots of blank red border and blank black border crossbucks: Overall recognition dropped to 76 percent and 70 percent. Some of the subjects who no longer correctly identified the crossbucks later said the red border confused them. Futhermore, since the same sign was being shown over again, they decided their initial identification must be wrong.

In the fourth presentation (slide 16), the crossbuck was too far away for the wording to be read. The only subject who did not identify it as a railroad grade crossing, was a 17-year-old male with less than 2 years' driving experience; he did, however, recognize it as a crossing of some

**Table 4.—Understanding of crossbucks by sex**

| | Slide Number[1] | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 4 | 7 | 11 | 16 | 23 | 28 | 34 | 39 |
| Male | | | | | | | | |
| Number | 18 | 15 | 15 | 19 | 17 | 20 | 20 | 20 |
| Percent | 88 | 75 | 75 | 95 | 83 | 100 | 100 | 100 |
| Female | | | | | | | | |
| Number | 15 | 16 | 13 | 20 | 16 | 19 | 19 | 19 |
| Percent | 75 | 78 | 68 | 100 | 78 | 95[2] | 95[2] | 95[2] |
| Overall | | | | | | | | |
| Number | 33 | 31 | 28 | 39 | 33 | 39 | 39 | 39 |
| Percent | 83 | 76 | 70 | 98 | 83 | 98[2] | 98[2] | 98[2] |

[1]See description of slide numbers on page 78
[2]Subjects were 100 percent in identifying, but not in understanding.

type. With slide 23, a close-up of the blank red border crossbuck, overall recognition again dropped, this time to 83 percent. The final three times the crossbuck was shown (slides 28, 34, and 39)—first an away shot of a regular crossbuck, then a close-up of a regular, then a close-up of a regular with a black border—there was nearly 100 percent identification. However, two subjects did not fully understand the meaning of the slides. One decided that stopping was required for the red border crossbuck, but was not required for the black border. The other subject identified the regular crossbuck without a border as Railroad Crossing Ahead.

## Black Border vs. Red Border

Neither the blank black nor blank red border crossbuck is currently recognized or recommended in the MUTCD. The first time the blank black border (slide 4) and the blank red border (slide 7) crossbucks were shown, 27 of the 40 subjects (67 percent) identified both correctly. Six subjects (15 percent) failed to identify one of the crossbucks and 7 subjects (18 percent) did not identify either.

The red border crossbuck seemed to pose problems for several of the test subjects. Some said they believed the red indicated stop and that the red border should not be used except when stopping is required. Three subjects said they thought the crossbuck could mean Red Cross or something medical. Others indicated that they did not like it because it was "too different." On the other hand, several subjects preferred the red because they felt it was an excellent attention getter which "stood out" much better. It is worth noting here that Canada is changing its crossbuck to the red border without wording.

## Post-Test Interview

During the post-test interview when the subjects were asked to choose the crossbucks they preferred, 36 (85 percent) chose the regular crossbuck with the black border. The three main reasons given for this choice were: (1) border stands out, (2) most clear, and (3) the most familiar printing. The remaining 15 percent chose the blank red border crossbuck because the color stands out and the crossbuck is highly visible.

## Conclusion

Although this study was limited to testing 40 subjects (all of whom were from the Washington, D. C. area), it does provide a good indication of how well drivers understand certain railroad traffic control devices. Based upon the study data analyzed regarding the pavement markings and modified crossbuck, the following conclusions can be reached:

- The pavement X-marking on the road was not well recognized, being identified by only 25 to 45 percent of the subjects when no advance warning information was given.
- The size of the pavement X-marking did not seem to make any difference in recognition, as most of the subjects did not notice the difference until it was brought to their attention.
- The crossbuck is identified mainly by its shape; up to 80 percent of the subjects recognized it without the words Railroad Crossing on it.
- The black border crossbuck was preferred by 85 percent of the subjects; none preferred the regular crossbuck in its present form.
- Some test subjects suggested using the RR's at the top and bottom of the pavement X-marking rather than on the sides to help decrease premature wear. This suggestion is worthy of further study and should be seriously considered.
- Since the black border on the crossbuck was chosen by a large percentage of the test subjects as being more visible and clearer to see, its benefits should be considered or further studied under actual field conditions.
- Since the size of the X within the X-marking did not seem to make any difference in recognition, further study of different size X's in conjunction with the RR's could be very useful.

**Willard J. Kemper** is a civil engineering technician in the Traffic Safety Research Division, Office of Safety and Traffic Operations R&D, Federal Highway Administration. He has been with FHWA since 1967 and is currently involved in NCP Program A.1, Traffic Control for Safety.

# The Marketing of New Highway Research Products—A Difficult Process

by Robert J. Betsold and Merton J. Rosenbaum

## Introduction

The marketing of new highway-related products—whether developed through Federal research activity or by the private sector—requires specific knowledge of the potential market, the product's capabilities, and the customer's needs. This article describes the programs and special efforts aimed at surmounting barriers to acceptance and implementation of new and innovative research products by the highway community which have resulted from research sponsored by the Federal Highway Administration (FHWA). Although these products are adopted via technology transfer rather than a true "sale," the marketing knowledge required is the same as for private sector developments.

## The Market

On the surface, the U.S. highway program—with annual expenditures approaching $70 billion—appears to be a ready marketplace for new technology. From a sales or technology transfer perspective, however, it is a difficult marketplace with many limiting conditions.

For example, about one-fourth of highway program expenditures are allocated to maintenance activities, and these are currently labor-intensive. In the future, however, with outputs from the Strategic Highway Research Program (SHRP) (see page 84) and the potential use of robotics, maintenance may be a major application area for innovative technologies. In addition, first costs, rather than service life costs, are often the primary basis for capital expenditures. In some cases, there are no reliable methods for determining service life. In other situations limited funds must be stretched to meet immediate needs.

The market includes 50 States and nearly 39,000 local agencies with highway or bridge responsibility. New product acceptance must be won on a State-by-State, agency-by-agency basis. Regional environmental conditions, as well as the application of local specifications and materials, cause market entry to be a time-consuming, costly, and uncertain process discouraging to many industries. Large, multi-level agencies may pass a vendor from level to level within the organization, requiring a sales effort within each office. Long delays are encountered between the planning, design, and actual construction stages of a highway project creating uncertainty as to when a product will be purchased and used. Additionally, competitive procurement rules, designed to protect the public interest, can create problems when unique or premium products are proposed.[1]

### The Product

The most serious problem faced by many new products is a lack of acceptable performance evaluation and documentation. Several years of field testing and evaluation may be necessary to win public agency acceptance. Agencies may also require their own field tests and varying degrees of formal or informal evaluation.(*1*)[2]

Accelerated testing procedures simulating inservice performance, would permit the use of performance specifications and invite new and proprietary products to compete for the highway market. Such procedures, however, have not been developed for many highway products. To be useful, such accelerated tests require national recognition to gain product acceptance. Furthermore, the performance specifications must be developed with full participation by the ultimate users—the State and local highway agencies. Accelerated tests would also allow new products to compete in life-cycle analyses.

New products, such as roadside hardware, can present logistic problems since replacement parts must be stored in accessible locations throughout a State. Maintenance forces often find it easier to work with a familiar general-use product than a new material or design configuration.

[1] A good discussion of marketing difficulties facing the private sector is contained in the July 1987 AASHTO Report "Assessment of National Programs of Highway Research," a report from the Select Committee on Research to the AASHTO Executive Committee.

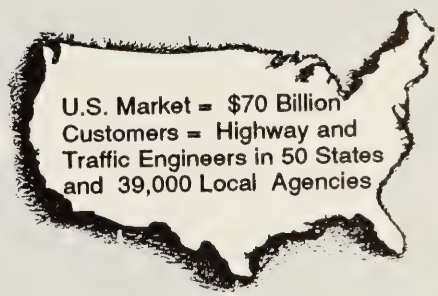
[2] Italic numbers in parentheses identify references on page 88.

## U.S. Highway Program

### Activities to Facilitate Acceptance of New Products

**Products from Research Industry**

- Experimental Projects Program
- Special Products Evaluation List
- Implementation, Field Test and Evaluation
- Regional Test Centers
- Strategic Highway Research Program




*The acceptance of new products for the highway program involves special efforts to reach the diverse customers.*

Many new or unique products are proprietary and are difficult to introduce in the public sector where, as discussed, competitive procurements and rigid specifications are applied.

## The Customer

Highway engineers are cautious and tend to be very conservative. For many new products, particularly those involving pavements and structures, the engineer cannot risk failure on the inservice highway system because of safety, liability, publicity, and political sensitivity. Thus, there is a continued reliance on traditional, well-tested designs and materials.

Highway engineers also tend to be skeptical about technologies which are outside the normal civil engineering field. The slow adoption of cathodic protection for bridge decks is a case in point.

In many public sector agencies, the rewards for innovation do not balance the risks involved. Although introduction of a successful new product is often viewed as part of the job, product failure can lead to criticism or loss of public confidence. This institutional problem increases the natural resistance to change.

## Overcoming the Barriers to Implementation

Recognizing the obstacles in the highway marketplace, FHWA is involved in numerous activities outlined below which are designed to facilitate acceptance of new products and procedures.

*Experimental Projects Program*—State highway agencies may use Federal-aid funds to incorporate appropriate experimental features—including proprietary products—into highway construction projects. States must prepare performance evaluations of these features published annually in *FHWA National Experimental Projects Tabulation.* The *Tabulation* is accessible from computer terminals.

*Special Product Evaluation List (SPEL)*—A wide range of special highway products are performance-tested through a cooperative effort of FHWA and the American Association of State Highway and Transportation Officials (AASHTO) Subcommittee on Materials. Over 6,500 evaluations conducted by 35 States and the FHWA are included in the latest edition of SPEL. A list of the agencies that conducted the tests and/or accepted the materials is also included.

*Implementation Field Test and Evaluation*—FHWA Office of Implementation is the starting point for technology transfer. In cooperation with State highway agencies, the Office of Implementation arranges for appropriate field test and evaluation of research output from the FHWA research and development program, as well as for selected products from State Highway Planning and Research Programs. States volunteer to apply the new technology—which may include prototype equipment, computer software, and design applications—within the end user's intended environment. States then prepare (and are reimbursed for) evaluation reports covering the technology's application and performance. This documentation assures the user that the technology is ready for implementation.

*Regional Test Centers*—A Pavement Marking Test Center has been established at Pennsylvania State University by FHWA as a demonstration program. This is a 2-year data collection effort on the initial cost and performance of various pavement marking materials. Life-cycle costs for various materials also can be determined. State highway agencies and material manufacturers have enthusiastically supported this demonstration. The Northeast Association of State Highway and Transportation Officials has approved a committee resolution for continuation of the test center where testing may be expanded to signing, delineators, posts, and raised pavement markers.

FHWA sponsored four workshops to encourage State cooperation to establish similar test programs in other regions. These workshops have yielded excellent results. In the southeast, the Southern Association of State Highway and Transportation Officials is initiating a cooperative test program for pavement markings and other delineation materials. Additionally, both the Mississippi Valley Conference of State Highway and Transportation Officials and the Western Association of State Highway and Transportation Officials are considering regional cooperative programs in this area.

*Strategic Highway Research Program (SHRP)*—A new 5-year highway research program was authorized by Congress to investigate areas of strategic importance to the U.S. highway system. Concrete and asphalt pavements were selected as prime targets for this research. The study design includes a concerted effort to develop performance specifications for highway materials and accelerated test capabilities to permit consideration of life-cycle costs when making highway design and procurement decisions. Industry has been involved in the study design and will play a key role in conducting the research and implementing products resulting from the program.

*Turner-Fairbank Highway Research Center (TFHRC)*—The focal point for many of the marketing activities discussed here is the FHWA Turner-Fairbank Highway Research Center located in McLean, Virginia. Additional support comes from FHWA program offices in the nearby Washington, D.C. headquarters, and the FHWA region and division offices throughout the United States.

The TFHRC staff monitors research, development, and implementation being conducted by States, universities, and private sector organizations. The TFHRC laboratories provide testing capabilities related to the evaluation and marketing of new products. Examples of ongoing tests include innovative structure design (figure 1), crash testing of highway lighting supports (figure 2), performance of hydraulic channels (figure 3), and accelerated pavement performance tests.

As a result of the recommendations of the recent American Society of Civil Engineers National Workshop on Highway Research, FHWA is considering establishment of a consolidated national data base of test and evaluation results. While this could be a valuable resource, its usefulness would depend upon the validity of the test and evaluation procedures and data from the contributing sources.

A recent study of FHWA's role in highway research and development recommended that TFHRC serve as a national test and evaluation center for selected new technologies and products.(*2*) The FHWA is studying the feasibility of expanding the TFHRC test and evaluation role.

*Figure 1.—The new TFHRC Structures Laboratory in operation.*

*(Top) Strain sensors transmit measurements to computer for recording and analysis.*
*(Center) Between floor and model structure, threaded rods provide strain.*
*(Bottom) In tunnel under lab hydraulic jacks actuate threaded rods to provide strain in model structure.*

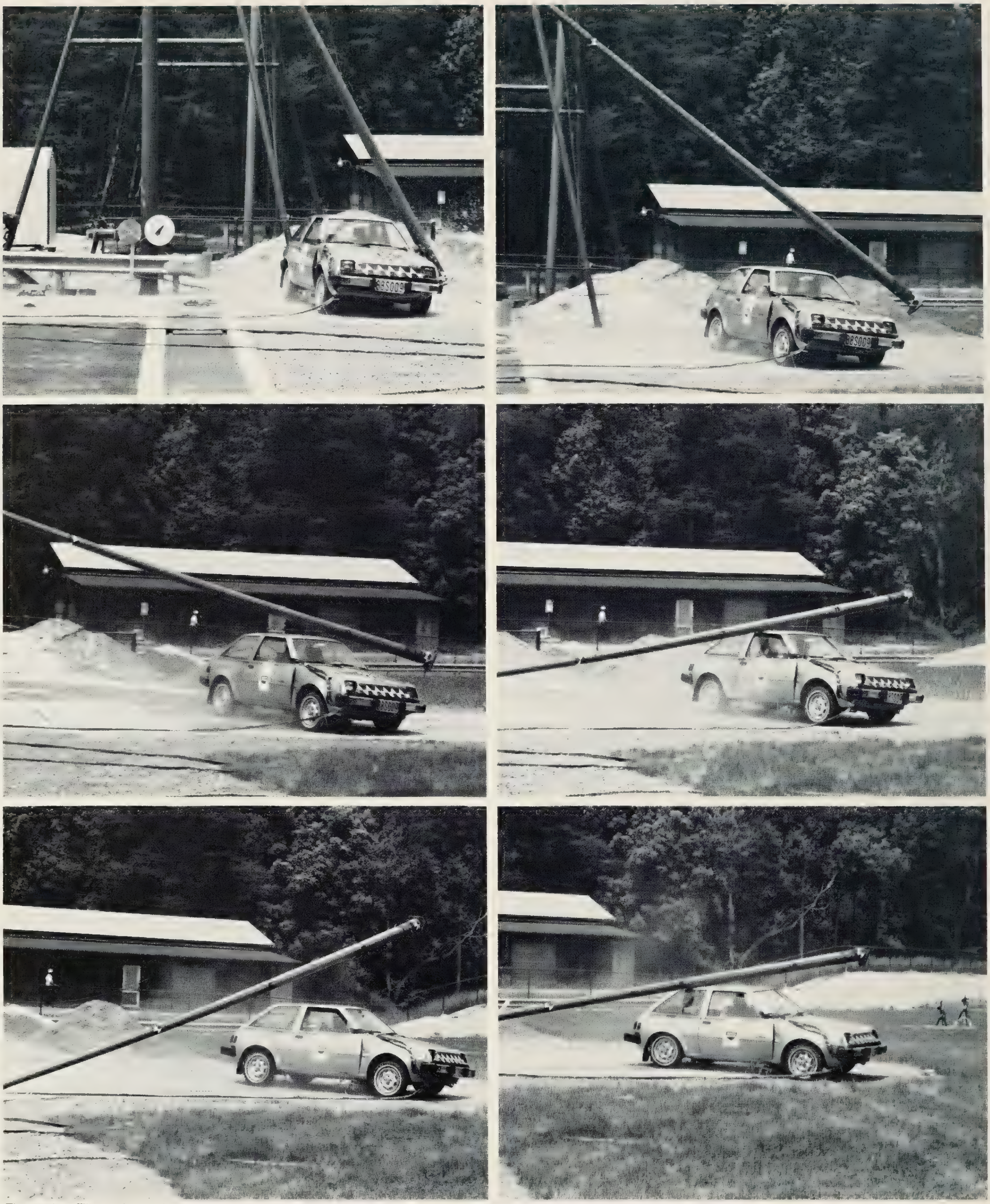
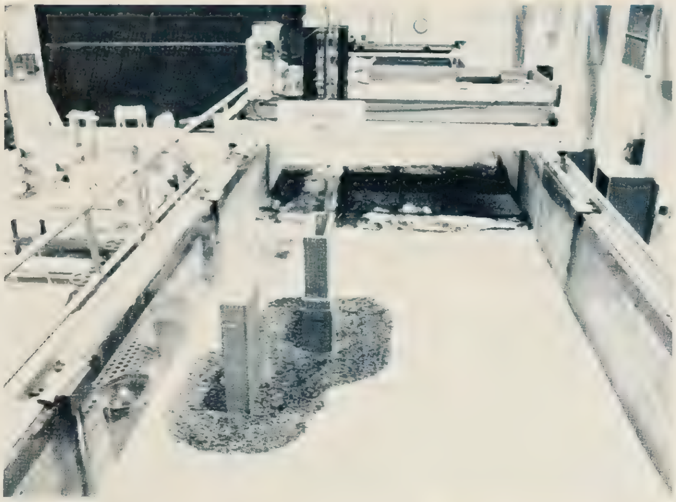


*Figure 2.—The unique side impact test capability of the TFHRC Federal Outdoor Impact Laboratory (FOIL) depicted here involves a 1,850-lb (839.1 kg) 1981 Dodge Colt and a 30-ft (9.1 m), 416-lb (188.7 kg) Slip Base Luminaire Support. (Left to Right) The luminaire support base breaks away following a 30-mi/h (48.3 km/h) impact, falls across, bounces up, and finally rests on the vehicle. This luminaire is currently approved for use on Federal-aid highways.*



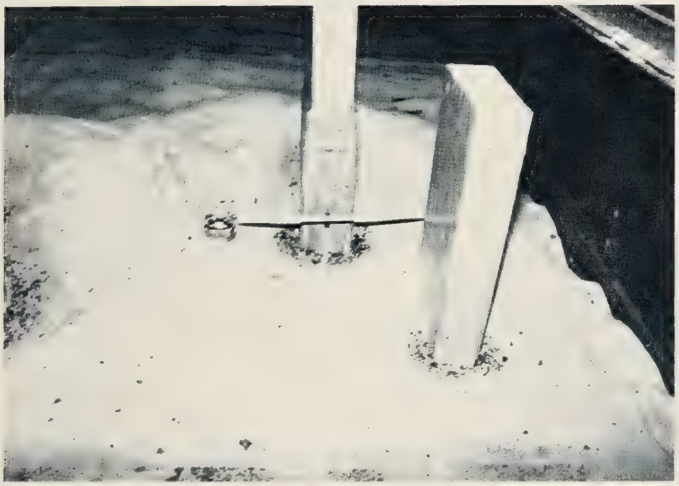


Figure 3.—The TFHRC Hydraulics Laboratory in operation. (Top) Scale model bridge piers with rip-rap mounted in flume for scour tests. (Center) Water flowing at scale speed causes scour around pier bases. (Bottom) Results of base scour being measured for analysis.

Two recent examples of TFHRC laboratory activity were reported in the June 1988 issue of *Public Roads*. One of these activities is the Accelerated Loading Facility (ALF). This outdoor machine can subject pavements to repeated truck wheel loading. In a few months' time, it can provide the effects of many years of actual pavement wear. ALF can also be moved to other locations. Additionally, FHWA is considering obtaining additional ALF's for use by States under a National pool fund HP&R study. Pavement testing will then be conducted under various regional and related environmental conditions.(*3*)

The second activity discussed was the large Structures Laboratory at TFHRC. In this laboratory, a 0.4-scale model of a two-span continuous highway bridge was erected. (See figure 1.) Together, FHWA and the American Iron and Steel Institute (AISI) are conducting an evaluation of this unique structural design. This evaluation, and related research activities, will help develop design methods for applying the autostress concept to plate girder bridges, and incorporating these concepts into AASHTO bridge specifications.(*4*)

A new Photometric and Vision Laboratory, is currently being considered. This laboratory will provide the capability to calibrate and test equipment used to measure retroreflectivity of traffic control devices, and allow testing of new retroreflective materials. It could also serve as an important resource for the marking and delineation test centers under development in the AASHTO regions as previously discussed.

Future *Public Roads* articles will feature TFHRC and other sectors of FHWA activity related to the evaluation and marketing of research products, as well as relevant laboratory and field research findings.

## REFERENCES

(*1*) John E. Burke, "New Product Evaluation Procedures," NCHRP Report 90, *Synthesis of Highway Practice, National Research Council,* Washington, DC, June 1982.

(*2*) Gary Byrd, "Innovations in Transportation—The Research, Development, and Technology Transfer Program of the Federal Highway Administration," Washington, DC, July 1987.

(*3*) R. Bonaquist, C. Churilla, and D. Freund, "Effect of Load, Tire Pressure, and Tire Type on Flexible Pavement Response," *Public Roads*, vol. 52, No. 1, June 1988, pp. 1–7.

(*4*) L. Cayes, "Structural Modeling for Autostress Design by Loading Through a Precast Deck," *Public Roads,* vol. 52, No. 1, June 1988, pp. 8–12.

**Robert J. Betsold** is Director of the Office of Safety and Traffic Operations Research and Development, FHWA. His previous assignments in FHWA have included Director, Office of Implementation; Deputy Director, Office of Environment and Design, Region 5, Chicago, Illinois; and Engineer-Manager for the Chicago Crosstown Expressway. Before joining FHWA in 1964, Mr. Betsold served as an urban transportation planning consultant, as an instructor in civil engineering at the University of Massachusetts, and as an officer in the U.S. Army Corps of Engineers.

**Merton J. Rosenbaum** is a highway research engineer in the Traffic Safety Research Division, Office of Safety and Traffic Operations Research and Development, FHWA. He is involved in research to improve traffic safety and capacity on rural and urban highways. Before joining FHWA in 1961, Mr. Rosenbaum worked for 15 years with the Virginia Department of Highways and Transportation in highway location and design, traffic and planning, and computer applications.

# Recent Research Reports You Should Know About

The following are brief descriptions of selected reports recently published by the Federal Highway Adiministration, Offices of Research, Development, and Technology (RD&T). The Office of Engineering and Highway Operations Research and Development (R&D) includes the Structures Division, Pavements Division, and Materials Division. The Office of Safety and Traffic Operations R&D includes the Traffic Systems Division, Safety Design Division, and Traffic Safety Research Division. All reports are available from the National Technical Information Service (NTIS). In some cases limited copies of reports are available from the RD&T Report Center.

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

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

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

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

## Calibration of Weigh-In-Motion (WIM) Systems, Vol. I, Summary and Recommendations, Publication No. FHWA–RD–88–120, and Vol. II, Final Report, Publication No. FHWA–RD–88–129

**by Traffic Systems Division**

WIM systems are becoming increasingly popular with States as a means of automatically monitoring heavy truck weights. For accurate measurements, a section of smooth pavement is required prior to the WIM system.

Sections of smooth pavement lengths can be shorter for the approach to the WIM scales than are generally being used at the present time. This results in a substantial savings in construction costs for future WIM sites.

Volume I of this report series documents a study to determine the length and smoothness of an approach section to achieve specific levels of WIM measurement accuracy based on data collected at three WIM field installations. Since the largest proportion of the vehicle fleet consists of the 3S–2 truck (5 axle) configuration and the testing focused on this type, recommendations are based primarily on this vehicle configuration.

An empiricle relationship has been developed to predict axle and gross weighing error as a function of pavement roughness. A procedure also was developed to calculate pavement smoothness requirements for WIM installations to achieve the specified accuracy levels.

Volume II documents the methodology, developments, and findings of the study and serves as an informational document.

These reports may only be purchased from the NTIS: (Vol. I. PB No. 89–115968, Price code: A05; Vol. II, PB No. 89–115976, Price code: A14).

## Self-Restoring Median Barriers and Bridge Railings, Vol. I, Research Report, Report No. FHWA/RD–87/002

**by Safety Design Division**

This report describes the design and development of the self-restoring (SERB) bridge rail and the SERB median barrier. The SERB bridge rail has successfully passed full-scale tests with 1,800-lb (0.82 Mg) cars and 5,400-lb (2.45 Mg) pickup trucks. The SERB median barrier has successfully passed tests with vehicles ranging from 1,800-lb (0.82 Mg) cars to 40,000-lb (18.14 Mg) intercity buses.

Due to its low weight (50 lb/lin ft [75 kg/m]), the SERB median barrier is particularly well suited for bridge upgrading projects where a heavy median barrier would reduce the live load rating of the bridge. The barrier is expected to require little if any maintenance. Both soil-mounted and deck structure-mounted post systems passed the full-scale tests.

This report should be of interest to engineers concerned with roadside safety hardware.

Limited copies of the report are available from the RD&T Report Center.

## Assessment of Changeable Message Sign Technology, Report No. FHWA/RD–87/025

**by Traffic Systems Division**

This report reviews the operational experience of the three principal types of Changeable Message Signs (CMS) used on freeways and Interstate highways in the continental United States. The three types examined were the lightbulb matrix, rotating drum, and disc matrix. These types have experienced only minor technical improvements since their introduction in the 1970's. Part 1 of the report describes each type, lists operational experience, and reports on new CMS technology. Part 2 reports on the radically new 3-dimensional imaging medium called holography. A survey of manufacturers of holographic materials was conducted to access the potential use of holography to present more effective sign messages to motorists. Fourteen responses from manufacturers are summarized and recommendations made for further work on this new sign technology.


This report may only be purchased from the NTIS: (PB No. 87–154431/AS, Price code: A02).

## Methodology for Road Roughness Profiling and Rut Depth Measurement, Report No. FHWA/RD–87/042

**by Pavements Division**

This report describes the development of the PRORUT system, a system for simultaneous profiling of the two-wheel tracks and for measuring the average rut depth. Integration of these measurements resulted in a relatively simple system, using three height sensors and a personal computer for controlling the operation and processing the data. Reliability of system performance is maintained through calibration, controlled by the on board computer.

Two companion reports are: PRORUT Users Manual, (FHWA/RD–87/043) and Reference Manual, (FHWA/RD–87/044) providing instructions for operating the system and details of the hardware and software design.

A limited number of copies are available by writing to Dr. Rudolph Hegmon, Federal Highway Administration, Pavements Division, (HNR-20), 6300 Georgetown Pike, McLean, Virginia 22101–2296. When this supply is exhausted, the three volumes may be purchased from the NTIS: (Final Report, PB No. 88–241559, Price code: A04; Users Manual, PB 88-238779, Price code: A04; and Reference Manual, PB 88–232582/AS, Price code: A14).

## Preferred Drying Methods of Calcium Magnesium Acetate Solutions, Report No. FHWA/RD–87/045

**by Materials Division**

Sodium Chloride is currently used to remove ice from roads. While inexpensive, sodium chloride is corrosive and contaminates ground water and streams. The Department of Transportation, under the sponsorship of the Federal Highway Administration, began a search for a sodium chloride substitute. Calcium magnesium acetate (CMA) was identified as an environmentally safe deicer.

The study examines the best ways to prepare dry CMA from CMA solutions, determine the ice melting ability of CMA made by the best process, and recommends an optimum process for producing solid CMA from CMA solutions.

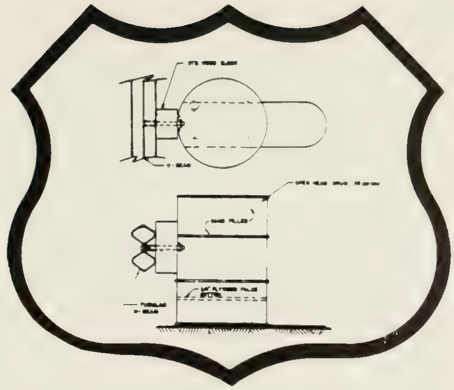
This report may only be purchased from the NTIS: (PB No. 87–191722/AS, Price code: A04).

## Impact Attenuators - A Current Engineering Evaluation, Final Report, No. FHWA/RD–86/054 and Executive Summary, Report No. FHWA/RD–86/055

**by Safety Design Division**

This final report describes the impact performance of inertial barrels and GREAT impact attenuator systems using full-scale crash testing with small and large test vehicles. Results of the program showed small-car performance to be generally acceptable when using NCHRP 230 and dummy analysis procedures. The large car produced higher decelerations and in some cases the values exceeded the limits specified. The manufacturer has corrected this problem.

(These reports, which were previously announced in the June 1988 issue of *Public Roads*, describe tests conducted several years ago. The reader should note that the problem identified in that notice with the large-car test was resolved by the manufacturer soon after these tests were conducted. FHWA recognizes the impact attenuator in question as an acceptable safety hardware device for use on Federal-aid projects.)



## Barriers in Construction Zones, Vol. I, Summary Report, Report No. FHWA/RD–86/092; Vol. II, Appendix A, Report No. FHWA/RD–86/093; Vol. III, Appendixes B, C, D, E, and F, Report No. FHWA/RD–86/094; Vol. IV, The Response of Atypical Vehicles During Collisions with Concrete Median Barriers, Report No. FHWA/RD–86/095

**by Safety Design Division**

These reports address the design and performance of longitudinal barriers for construction zones. The strengths of various connections for portable concrete median barriers (PCB) are analyzed and theoretical treatments of behavior of the PCB during a collision are presented. These analyses along with cost data and crash test information are used to develop a barrier performance rating and selection system. Reports on crash tests with various types and sizes of vehicles on a nondeflecting PCB are presented.

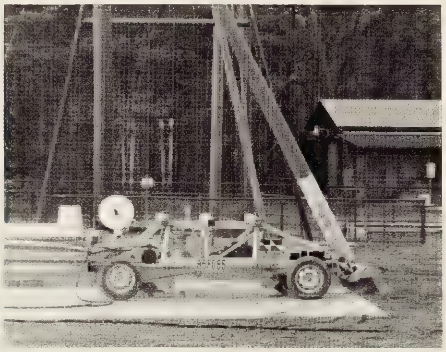
The reports may only be purchased from the NTIS: (Vol. I, PB No. 86–173994/AS, Price code: A07; Vol. II, PB No. 86–174000/AS, Price code: A09; Vol. III, PB No. 86–174018/AS, Price code: A12; Vol. IV, PB No. 86–174026/AS, Price code: A09).

### Laboratory Procedures to Determine the Breakaway Behavior of Luminaire Supports in Minisized Vehicle Collisions, Vol. I, Executive Summary, Report No. FHWA/RD–86/105; Vol. II, Technical Report, Report No. FHWA/RD–86/106; Vol. III, FOIL Operation and Safety Plan, Report No. FHWA/RD–86/107

**by Safety Design Division**

The Federal Outdoor Impact Laboratory (FOIL) was designed and constructed under this study. The FOIL is a research and learning center for highway engineers, scientists, and others working on roadside safety research to study the interaction between driver, vehicle, and roadside safety hardware. Singular features of the FOIL include the first side impact test capability (for the testing of roadside safety hardware) in the United States and the "breakaway" bogie vehicle, the first in a series of reusable test vehicles under development by FHWA R&D. The study also developed operational procedures for the safe and efficient execution of impact tests involving automobiles crashing into such roadside hardware.

The first series of tests conducted under this study explored the behavior of the minisized 1,800-lb (818 kg) vehicles impacting breakaway luminaire supports under frontal and side impact conditions. The second series of tests used the FOIL bogie vehicle and automobiles to validate bogie simulation of a minisized vehicle. The third series of tests demonstrated the performance of the bogie vehicle. The fourth series investigated the influence of the point of application of the impact force on breakaway performance, and the last series was side impact tests to determine vehicle side impact characteristics and to explore the performance of existing breakaway hardware in a side impact mode.



These reports may only be purchased from the NTIS: (Vol. I, PB No. 87–204368/AS, Price code: A04; Vol. II, PB No. 87–204376/AS, Price code: A13; Vol. III, PB No. 87–204384/AS, Price code: A11).

### Cost-Effective Bridge Maintenance Strategies, Vol. I, Executive Summary, Report No. FHWA/RD–86/109; Vol. II, Guidelines and Recommendations, Report No. FHWA/RD–86/110

**by Pavements Division**

These reports provide guidelines and recommendations on developing a systematic approach for managers of bridge maintenance. Volume II also includes a summary synthesis on the state of the practice of bridge maintenance programs in the United States.

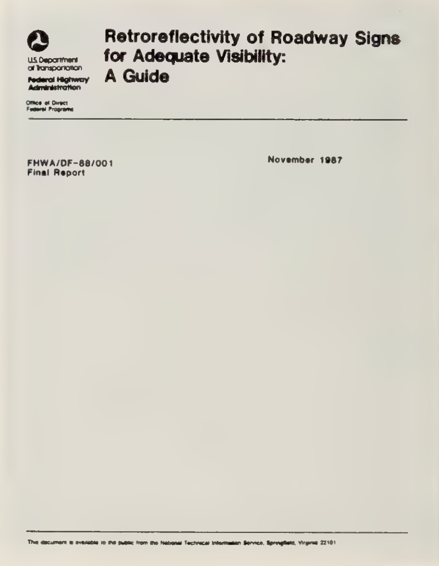
Elements of cost-effective bridge maintenance strategies are defined, and guidelines to assist bridge maintenance managers are presented.

These reports may only be purchased from the NTIS: (Vol. I, PB No. 87–155016/AS, Price code: A02; Vol. II, PB No. 87–155024/AS, Price code: A10).

### Retroreflectivity of Roadway Signs for Adequate Visibility: A Guide, Publication No. FHWA/DF–88/001

**by Traffic Safety Research Division**

The Guide serves as an introduction to retroreflectivity as it relates to roadway signs. The specifications and test procedures contained in the *Standard Specifications for Construction of Roads and Bridges on Federal Highway Project (FP–85)*[1] are reviewed and explained. Other topics discussed include retroreflective material selection and sign fabrication, inspection, and maintenance. The Guide should be of value to anyone involved in the selection, installation, inspection, and maintenance of retroreflective sheeting material for use on permanent and construction roadway signs.


U.S. Department of Transportation
Federal Highway Administration
Office of Direct Federal Programs

Retroreflectivity of Roadway Signs for Adequate Visibility: A Guide

FHWA/DF-88/001
Final Report

November 1987

This Guide may only be purchased from the NTIS: (PB No. 88–214614/AS, Price code: A04).

[1] FP–85 is very similar in its requirements to AASHTO Specification M–268 and to those of most States.

# New Research in Progress

The following new research studies reported by FHWA's Office of Research, Development, and Technology are sponsored in whole or in part with Federal highway funds. For further details on a particular study, please note the kind of study at the end of each description and contact the following: Staff and administrative contract research—*Public Roads* magazine; Highway Planning and Research (HP&R)—Performing State highway or transportation department; National Cooperative Highway Research Program (NCHRP)—Program Director, National Cooperative Highway Research Program, Transportation Research Board, 2101 Constitution Avenue, NW, Washington, DC 20418.

## NCP Category A—Highway Safety

### NCP Program A.5: Design

Title: Modernization of Virginia's Wet Accident Reduction Program (NCP No. 4A5G0272)

**Objective:** Identify aggregates with respect to their unique polishing characteristics and the skid resistant characteristics of Virginia's pavement surface mixes. Develop methods for determining the cost-effectiveness of countermeasures and develop a skid accident reduction program manual.
**Performing Organization:** Virginia Transportation Research Council, Charlottesville, VA 22903
**Funding Agency:** Virginia Department of Highways and Transportation
**Expected Completion Date:** May 1991
**Estimated Cost:** $212,500 (HP&R)

## NCP Category B—Traffic Operations

### NCP Program B.1: Traffic Management Systems

Title: Arterial Control and Integration. (NCP No. 4B1E1032)

**Objective:** Evaluate traffic responsive control strategies having application to arterial signal systems. Visit three sites where such strategies are undergoing field testing and evaluation. Evaluate strategies for coordinating arterial and freeway control.
**Performing Organization:** University of Washington, Olympia, WA 98501
**Funding Agency:** Washington State Department of Transportation
**Expected Completion Date:** June 1990
**Estimated Cost:** $94,000 (HP&R)

#### NCP Program B.2: Traffic Analysis and Operational Design Aids

**Title: Development and Application of Procedures for Design of Freeway Weaving Sections—Phase I. (NCP No. 4B2C2042)**
**Objective:** Analyze data previously collected by video at eight California sites for operation of weaving sections near or at capacity conditions, capacity versus weaving section configuration, performance measurements, validation of the procedure, and integration with Caltrans procedures.
**Performing Organization:** University of California (Berkeley), Berkeley, CA 94720
**Funding Agency:** California Department of Transportation
**Expected Completion Date:** December 1990
**Estimated Cost:** $100,000 (HP&R)

### NCP Category C—Pavements

#### NCP Program C.1: Evaluation of Rigid Pavements

**Title: Pavement Subbases. (NCP No. 4C1B1262)**
**Objective:** Define and quantify pavement subbase properties necessary for optimum performance. The study will investigate certain parameters known to affect the function of the subbase such as saturated hydraulic conductivity, coefficient of volumetric compressibility, frequency of applied load, and the effective overburden pressure which are used in the computer pumping model, ILLIPUMP. The results will be used to develop an improved set of design procedures for subbases. Investigate both stabilized and unstabilized materials including open-graded materials.
**Performing Organization:** University of Illinois, Urbana, IL 61801
**Funding Agency:** Illinois Department of Transportation
**Expected Completion Date:** August 1990
**Estimated Cost:** $116,000 (HP&R)

**Title: Reliability of AASHTO Design Equations for Predicting Performance of Flexible and Rigid Pavements. (NCP No. 4C1B1263)**
**Objective:** Conduct a research study for the State of Ohio to verify the accuracy of the AASHTO design equations in predicting the performance of flexible and rigid pavements, and revise the AASHTO components to reflect chance variation in the design-performance process for flexible and rigid pavements. Determine the overall standard deviation and calculate the design reliability factors for different reliability levels applicable to Ohio flexible and rigid pavements.
**Performing Organization:** Ohio Department of Transportation, Columbus, OH 43215
**Expected Completion Date:** July 1993
**Estimated Cost:** $604,100 (HP&R)

**Title: Pavement Drainage and Pavement Shoulder Joint Evaluation and Rehabilitation. (NCP No. 4C1B2042)**
**Objective:** Address subdrainage requirements for both new and retrofitted systems including literature survey and purchase of a borescope; evaluate the need, types, and procedures for site testing and evaluation; survey existing subdrainage systems; develop analysis procedures and criteria; test subdrainage components; provide test criteria and prepare final report.
**Performing Organization:** Purdue University, Indiana Joint Research Program, West Lafayette, IN 47906
**Funding Agency:** Indiana Department of Highways
**Expected Completion Date:** January 1992
**Estimated Cost:** $193,290 (HP&R)

### NCP Program C.2: Evaluation of Flexible Pavements

**Title: Performance of New Rut-Resistant Asphalt Concrete Overlay. (NCP No. 4C2A2403)**
**Objective:** Evaluate the effectiveness of a new rut-resistant asphalt mixture used as an overlay on a portland cement concrete pavement. Build four experimental projects and evaluate their performance for 5 years.
**Performing Organization:** Wisconsin Department of Transportation, Madison, WI 53707
**Expected Completion Date:** May 1994
**Estimated Cost:** $165,900 (HP&R)

### NCP Program C.3: Field and Laboratory Testing

**Title: Evaluation of Instruments and Devices Intended for the Measurement of Transverse Highway Profiles. (NCP No. 4C3A1432)**
**Objective:** Evaluate equipment for transverse highway profiling and recommend the most appropriate equipment for network and project level testing.
**Performing Organization:** Connecticut Department of Transportation, Wethersfield, CT 06109
**Expected Completion Date:** June 1989
**Estimated Cost:** $90,400 (HP&R)

## NCP Category D—Structures

### NCP Program D.1: Design

**Title: Whittier Narrows Earthquake Freeway Bridges: Performance, Analysis, and Repair. (NCP No. 4D1A2142)**
**Objective:** A number of freeway bridges suffered structural damage in the October 1,1987 Whittier Narrows earthquake. In most cases, the damage was minor and easily repairable. However, the I–605/I–5 separator, a major nine-span bridge carrying eight lanes of I–605 traffic over the I–5 San Diego-Los Angeles freeway, was severely damaged. Shear failures in columns very nearly caused the collapse of two spans onto I–5 at a time when morning commuter traffic was at its heaviest. The action of earthquake restrainer cables apparently contributed to the survival of the bridge.

It is now recognized that a large number of freeway bridges constructed in the 1950's and 1960's in California and elsewhere have inadequate seismic resistance. Column retrofit programs are currently being implemented in a limited program on selected vulnerable bridges. This research will refine skills in assessing vulnerability and the seismic resistance of bridges supported on columns.
**Performing Organization:** University of California (San Diego), La Jolla, CA 92093
**Funding Agency:** California Department of Transportation
**Expected Completion Date:** May 1990
**Estimated Cost:** $135,000 (HP&R)

**Title: Bridges Constructed from Flatbed Railroad Cars. (NCP No. 4D1C1032)**
**Objective:** Investigate the use of salvageable flatbed railroad cars as highway bridges on low-volume roads. Information gathered will provide technical data required in establishing load ratings and load carrying capacities for the railroad car bridges.
**Performing Organization:** Arkansas State University, Little Rock, AR 72467
**Funding Agency:** Arkansas State Highway and Transportation Department
**Expected Completion Date:** August 1990
**Estimated Cost:** $99,970 (HP&R)

**Title: Evaluation of Weldments Incorporating Backing Materials. (NCP No. 5D1B3012)**
**Objective:** Develop a better understanding of the performance characteristics of fused steel bars and alternative weld backing materials, and determine their potential benefits and limitations.
**Performing Organization:** National Academy of Sciences, Washington, DC 20418
**Expected Completion Date:** May 1991
**Estimated Cost:** $260,000 (NCHRP)

**Title: Development of Comprehensive Bridge Specifications and Commentary. (NCP No. 5D1A4052)**
**Objective:** Develop new AASHTO specifications for bridge design technology and design practice based on load and resistance factor design concepts. The areas to be studied include general design features and provisions; loads; analysis and evaluation of superstructures; deck systems; concrete structures; timber structures; joints, bearings, and accessories; foundations, substructures, and retaining walls; soil-structure interaction systems; moveable bridges; and code calibration.
**Performing Organization:** Modjeski and Masters, Inc., Harrisburg, PA 17105
**Expected Completion Date:** January 1992
**Estimated Cost:** $600,000 (NCHRP)

### NCP Program D.2: Management

**Title: Bridge Information System. (NCP No. 4D2D1102)**
**Objective:** Develop and implement a bridge information system combining up-to-date pictorial records with existing textural and numeric data in an easy to use desktop delivery system.
**Performing Organization:** Connecticut Department of Transportation, Wethersfield, CT 06109
**Expected Completion Date:** June 1990
**Estimated Cost:** $247,000 (HP&R)

### NCP Program D.3: Hydraulics

**Title: Evaluation of Bridge Scour Data at Selected Sites in Ohio. (NCP No. 4D3C1502)**
**Objective:** Collect reliable and sufficient data during flood events to determine whether local scour, constriction scour, and general scour, are occurring at 20 selected sites. Compare and evaluate published local scour-prediction equations with observed data. Compare local scour data collected using geophysical techniques with local scour data defined by physical measurements.
**Performing Organization:** U. S. Geological Survey, Ohio District Office, Columbus, OH 43212
**Funding Agency:** Ohio Department of Transportation
**Expected Completion Date:** July 1996
**Estimated Cost:** $651,000 (HP&R)

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**Title: Repair and Protection Alternatives for Coastal Highways Vulnerable to Storm Damage, Shoreline Erosion, and Sea Level Rise. (NCP No. 4D3B2932)**
**Objective:** Develop a decision model to facilitate the systematic evaluation of various alternatives for protecting or relocating sections of a coastal highway vulnerable to storm damage, shoreline erosion, and sea level rise.
**Performing Organization:** North Carolina State University, Raleigh, NC 27695
**Funding Agency:** North Carolina Department of Transportation
**Expected Completion Date:** July 1990
**Estimated Cost:** $149,375 (HP&R)

**Title: Performance Evaluation of Multi-Cell Culverts. (NCP No. 4D3B2942)**
**Objective:** Develop practical procedures for hydraulic analysis and design of multi-cell culverts through field surveys and laboratory model studies.
**Performing Organization:** University of Akron, Akron, OH 44325
**Funding Agency:** Ohio Department of Transportation
**Expected Completion Date:** July 1991
**Estimated Cost:** $267,000 (HP&R)

## NCP Category E—Materials and Operations

### NCP Program E.2: Cement and Concrete

**Title: Design and Construction of an Environmentally Controlled Test Facility for Portland Cement Concrete. (NCP No. 4E2A1123)**
**Objective:** Develop a portland cement concrete test facility capable of investigating the properties and problems of a full-size pavement slab. This facility will be environmentally controlled and will include the subgrade and base course as well as the slab.
**Performing Organization:** University of Texas, Austin, TX 78712
**Funding Agency:** Texas State Department of Highways and Public Transportation
**Estimated Completion Date:** December 1990
**Estimated Cost:** $265,000 (HP&R)

### NCP Program E.3: Geotechnology

**Title: Miniature Electric Cone Penetrometer. (NCP No. 4E3B0492)**
**Objective:** Conduct an in situ testing program to study the applicability of miniature electric cone penetrometers for highway design and construction control. Design and fabricate a jacking system based on a selected commercial miniature cone.
**Performing Organization:** Louisiana State University, Baton Rouge, LA 70803
**Funding Agency:** Louisiana Department of Transportation and Development
**Expected Completion Date:** June 1990
**Estimated Cost:** $120,300 (HP&R)

**Title: Stability of Sound Walls on Mechanically Stabilized Earth Walls. (NCP No. 4E3B0512)**
**Objective:** Compare the earthquake performance of a model 12-ft high sound wall atop a mechanically stabilized earth structure to the performance of a sound wall atop a conventional concrete retaining wall.
**Performing Organization:** California Department of Transportation, Sacramento, CA 95807
**Expected Completion Date:** June 1990
**Estimated Cost:** $124,000 (HP&R)

### NCP Program E.4: Paints and Coatings for Highways

**Title: Feasibility of Applying Cathodic Protection to Underground Culverts. (NCP No. 4E4A0202)**
**Objective:** Determine if cathodic protection of culverts is economically feasible. Evaluate both sacrificial anodes and impressed current systems for application both on the soil and waterside.
**Performing Organization:** University of Southwestern Louisiana, Lafayette, LA 70504
**Funding Agency:** Louisiana Department of Transportation and Development
**Expected Completion Date:** July 1993
**Estimated Cost:** $176,900 (HP&R)

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