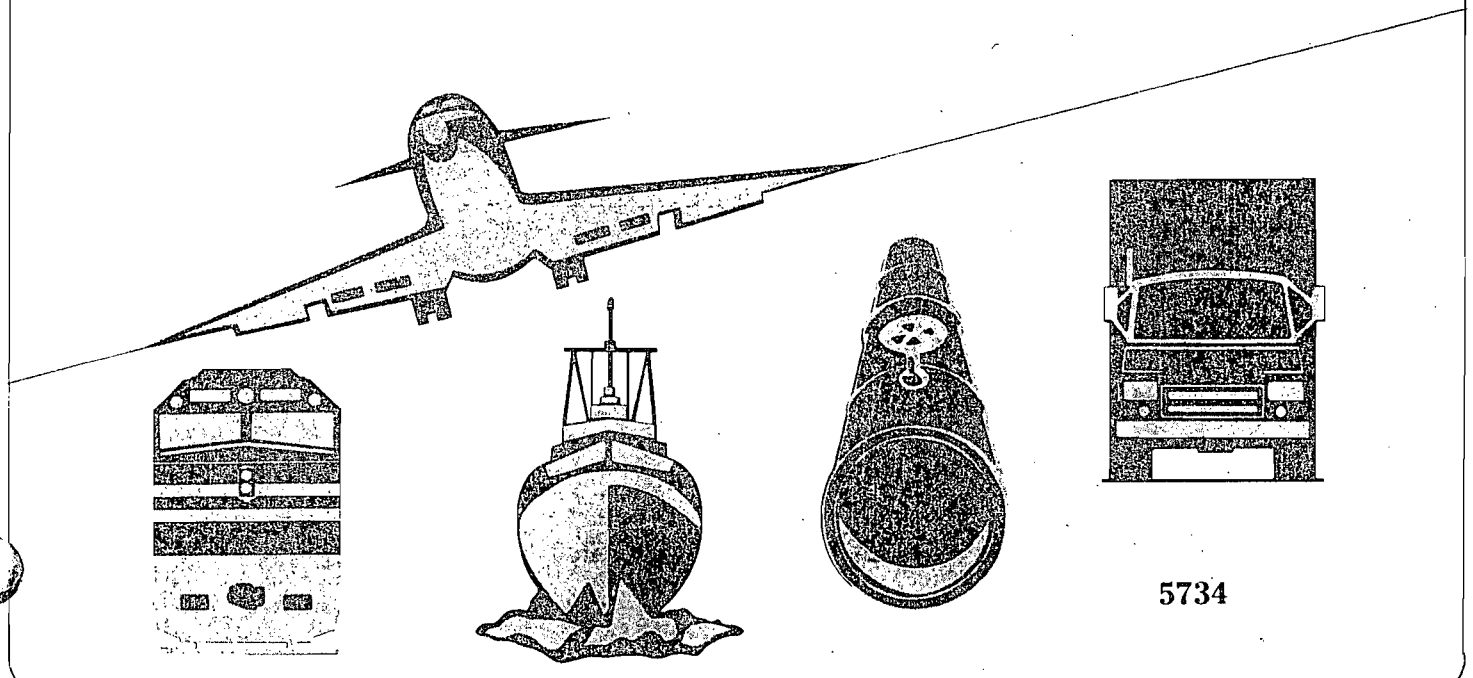
PB92-917005
NTSB/SS-92/02

NATIONAL TRANSPORTATION SAFETY BOARD

WASHINGTON, D.C. 20594

SAFETY STUDY

HIGHWAY WORK ZONE SAFETY



5734

Abstract: This study addresses the adequacy of traffic safety in work zones. The specific safety issues discussed in this study are: the usefulness of work zone accident data; the hazards of two-lane, two-way operations without positive separation of traffic on a normally divided highway; the use of truck-mounted attenuators in moving/maintenance operations and at long-term construction sites; the placement of flaggers; the need to identify design changes in work zones that will aid drivers with degraded sensory perceptions resulting from aging, inattentiveness, or impairment; the lack of compliance with existing guidelines for work zone traffic control devices and procedures; and the need for a national work zone safety program. Recommendations concerning these issues were made to the National Highway Traffic Safety Administration, the Federal Highway Administration, and the American Association of State Highway and Transportation Officials.

The National Transportation Safety Board is an independent Federal agency dedicated to promoting aviation, railroad, highway, marine, pipeline, and hazardous materials safety. Established in 1967, the agency is mandated by Congress through the Independent Safety Board Act of 1974 to investigate transportation accidents, determine the probable causes of the accidents, issue safety recommendations, study transportation safety issues, and evaluate the safety effectiveness of government agencies involved in transportation. The Safety Board makes public its actions and decisions through accident reports, safety studies, special investigation reports, safety recommendations, and statistical reviews.

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HIGHWAY WORK ZONE SAFETY

Adopted: May 12, 1992
Notation 5734

CONTENTS

EXECUTIVE SUMMARY

The number of fatalities that occurred in highway work zones increased from 489 in 1982 to 780 in 1988. Concurrently, total spending on highway construction increased from about $32 billion to about $52 billion. The Nation's interstate system, for the most part, has been completed. As the infrastructure ages, the number of maintenance and construction zones to repair and to replace sections of the network can be expected to increase. Further, growth in traffic volume has required that roadway capacities be increased to provide a more desirable level of service to motorists; thus construction for this reason can also be expected to increase. The available data indicated that unless additional efforts were made to reduce work zone accidents, the number of fatalities would continue to increase. Because of these factors, the National Transportation Safety Board became increasingly concerned about the adequacy of traffic safety in work zones and initiated a study in 1988 concerning work zone related accidents. More than 40 accidents were investigated during the next 2 years, and previous work zone accidents investigated by the Safety Board were reviewed.

In July 1990, as the review of the accident cases neared completion, the Safety Board conducted a major investigation of a work zone accident near Sutton, West Virginia. Eight persons were killed in the accident, and five vehicles were either destroyed or severely damaged. In its statement of probable cause, the Safety Board determined that contributing to the cause of the accident was the less than optimal work zone control devices and procedures used at the site. The accident underscored the Safety Board's concern regarding safety in work zones, and several safety recommendations were issued to the West Virginia Department of Transportation and the Federal Highway Administration to improve work zone safety.

Additional investigations of work zone accidents were conducted in 1990 and 1991, as they occurred. A review of these accidents and the Sutton, West Virginia, accident raised additional work zone safety issues that are discussed in this study.

The safety issues discussed in this study are:

- the usefulness of work zone accident data;
- the hazards of two-lane, two-way operations without positive separation of traffic on a normally divided highway;
- the use of truck-mounted attenuators in moving maintenance operations and at long-term construction sites;
- the placement of flaggers;
- the need to identify design changes in work zones that will aid drivers with degraded sensory perceptions resulting from aging, inattentiveness, or impairment;

- the lack of compliance with existing guidelines for work zone traffic control devices and procedures;

- the need for a national work zone safety program;

As a result of this study, safety recommendations were issued to the National Highway Traffic Safety Administration, the Federal Highway Administration, and the American Association of State Highway and Transportation Officials.

INTRODUCTION

The number of fatalities that occurred in highway work zones increased from 489 in 1982 to 780 in 1988. Concurrently, total spending on highway construction increased from about $32 billion to $52 billion.[1] The Nation's interstate system, for the most part, has been completed.[2] As the infrastructure ages, the number of maintenance and construction zones to repair and to replace sections of the network can be expected to increase. Further, growth in traffic volume has required that roadway capacities be increased to provide a more desirable level of service to motorists; thus construction for this reason can also be expected to increase. The available data indicated that unless additional efforts were made to reduce work zone accidents, the number of fatalities would continue to increase. Because of these factors, the National Transportation Safety Board became increasingly concerned about the adequacy of traffic safety in work zones and initiated a study in 1988 concerning work zone related accidents. More than 40 accidents were investigated during the next 2 years, and previous work zone related accidents investigated by the Safety Board were reviewed.

In July 1990, as the review of the accident cases neared completion, the Safety Board conducted a major investigation of a work zone accident near Sutton, West Virginia. In that accident, which occurred on July 26, 1990, a truck transporting eight automobiles entered a highway work zone on northbound Interstate Highway 79 and struck the rear of a utility trailer being towed by a Dodge Aspen. The Aspen then struck the rear of a Plymouth Colt, and the truck and the two automobiles traveled into the closed right lane and collided with three West Virginia Department of Transportation (WVDOT) maintenance vehicles.

Fire ensued, and the eight occupants in the Aspen and the Colt died. The Aspen, Colt, truck, and two of the three WVDOT vehicles were either destroyed or severely damaged. The truckdriver and one firefighter sustained minor injuries.

In its statement of probable cause, the Safety Board determined that contributing to the cause of the accident was the less-than-optimal work zone control devices and procedures used by the West Virginia Department of Transportation. This accident underscored the Safety Board's concern regarding safety in work zones, and several safety recommendations were

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[1] These figures are based on information from The Road Information Program, "1991 State Highway Funding Methods." May 1991. [Actual dollar figures for the respective years were used.]

[2] According to figures provided in December 1991 by the U.S. Department of Transportation (DOT), of the 42,795 miles in the interstate system, 42,545 miles, or 99.4 percent, are open to traffic. Of the 250 miles not open to traffic, 228 miles are currently under construction and 22 miles are in the design phase.

issued to the WVDOT and the Federal Highway Administration (FHWA) to improve work zone safety. These safety recommendations will be discussed in more detail later in the report.

Additional investigations of work zone related accidents were conducted in 1990 and 1991, as they occurred. A review of these accidents and the Sutton, West Virginia, accident raised additional work zone safety issues that are discussed in this study. This study does not attempt to discuss every issue raised in the accident investigations or all issues that may be pertinent to work zone safety, but rather to address certain recurring work zone safety issues, related deficiencies in current standards and guidelines, and the adequacy of monitoring and enforcing safety practices in highway work zones. Further, because of proposed changes to the section of the Federal Manual on Uniform Traffic Control Devices that relates to work zones, the study concentrates on those accidents that, in the Safety Board's view, illustrate deficiencies in the proposed changes. Eighteen accidents investigated between 1988 and 1991 are highlighted in this study. An additional 8 to 10 accidents that the Safety Board investigated mirror, to a large extent, the 18 accidents discussed. The remaining accidents involved a variety of individual issues that could not be adequately addressed in this study. In preparing the study, the Safety Board considered including a discussion on devices such as portable radio transmissions, citizen band broadcasts, and radar. However, the accident data indicated that a discussion of these devices was not appropriate in this study.

The first chapter briefly discusses accident data as provided by the National Highway Traffic Safety Administration's Fatal Accident Reporting System. The next three chapters of the study address, respectively: (1) two-lane, two-way operations on a normally divided highway, (2) the use of truck-mounted attenuators in moving/maintenance operations and at long-term construction sites, and (3) placement of flaggers. Each of these three chapters begins with a description of the work zones and accidents, followed by a discussion of the issues and the corrective actions needed. The fifth chapter describes several human performance related accidents that reinforce the need for the research called for in the safety recommendations issued in conjunction with the Sutton, West Virginia, accident report. Efforts to date to implement these human performance related safety recommendations are outlined. The sixth chapter highlights two problem areas of noncompliance with existing guidelines and the need for FHWA field personnel to monitor and observe problems at work zone sites. The final chapter highlights work zone safety programs developed by various States. For example, the "Give 'Em a Brake" program, implemented initially by the State of California, and similar safety programs emphasize work zone hazards for both motorists and workers. Accidents investigated in conjunction with this study suggest that further efforts are needed in this area, particularly at the national level, to achieve a unified program that addresses education and enforcement.

DATA COLLECTION

The Fatal Accident Reporting System (FARS), a database on fatal highway accidents maintained by the National Highway Traffic Safety Administration (NHTSA), U.S. Department of Transportation (DOT), provides data on fatal accidents and injuries in work zones. The accidents are separated into construction, maintenance, utility, and unknown work zones. The FARS definitions for work zones follow:

> Construction indicates that the accident occurred in the vicinity of highway construction activity or within an area marked by signs, barricades, or other highway construction zone. Highway construction includes construction of appurtenances such as guardrails or ditches, surveying activity, installation of utilities within the right-of-way, etc.
>
> Maintenance indicates that the accident occurred in the vicinity of highway maintenance activity or within an area marked by signs, barricades, or other devices as a highway maintenance zone. Highway maintenance includes pavement marking, painting guardrail, cleaning ditches, mowing grass, etc.
>
> Utility indicates that the accident occurred in the vicinity of utility work such as electrical work within the right-of-way. The work must have been performed by the utility company.
>
> Work Zone, Type Unknown is used when there is insufficient information to distinguish between construction, maintenance and utility.

Fatal accidents by type of work zone for the most recent 4-year period for which data are available are shown in table 1. The data illustrate that

Table 1.--Fatal accidents by type of highway work zone for the last 4 years

Year	Construction	Maintenance	Utility	Unknown	Total
1987	464	70	12	50	596
1988	549	64	13	57	683
1989	540	69	7	75	691
1990	556	56	9	60	681
Total	2,109	259	41	242	2,651

Source: Fatal Accident Reporting System

most fatal accidents occur in construction work zones. For example, in 1990, 81.6 percent of the fatal accidents that occurred in work zones occurred in construction work zones (see figure 1). The FARS data also indicate that a large percentage of fatal accidents in work zones occurs on the interstate. For example, in 1990, 29 percent of the fatal accidents in work zones occurred on the interstate (see figure 2).[3]

Concern has been expressed in the industry about the accuracy of work zone related data. With respect to fatalities, FARS does not, for example, distinguish between persons driving highway maintenance vehicles within work zones and other drivers who crash in work zones while traversing the work zone site. A 1991 study[4] by the National Institute for Occupational Safety and Health recommended that data collection be adjusted to enable this distinction, primarily because countermeasures for these two types of crashes are different. The Safety Board concurs and believes that the NHTSA should revise the reporting of fatalities to make this distinction.

A 1987 study[5] by the American Association of State Highway and Transportation Officials (AASHTO) recommended that "All States should assure their accident data systems are capable of providing sufficient information to monitor the accident experience of work zones within their State."

Work zone fatalities by States as reported by FARS for 1990[6] are illustrated in figure 3.[7] Because of the concern expressed in the above referenced studies, Safety Board staff selectively reviewed State data and

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[3] The interstate represents only 1.1 percent of the total mileage of roads in the United States. However, 21.9 percent of the annual miles traveled is on the interstate system.

[4] Landen, Deborah; Kisner, S. 1991. Occupational fatalities in highway work zones: fatal accident reporting system, 1987-1988. Washington, D.C. National Institute for Occupational Safety and Health, Division of Safety Research.

[5] American Association of State Highway and Transportation Officials--Standing Committee on Highway Traffic Safety. 1987. Summary report on work zone accidents. Washington, D.C. April.

[6] Work zone fatalities for 1990 represented about 1.76 percent of all highway fatalities.

[7] Each year since 1982, Texas has reported a high number of fatal accidents in work zones. The placement of the construction data element at the top of the accident report form may account, in part, for this high reporting. Other factors could include the police officers' sensitivity to the question on the report form. Other States, for example, require the work zone to be a factor in the accident before the work zone data element is indicated on the form.

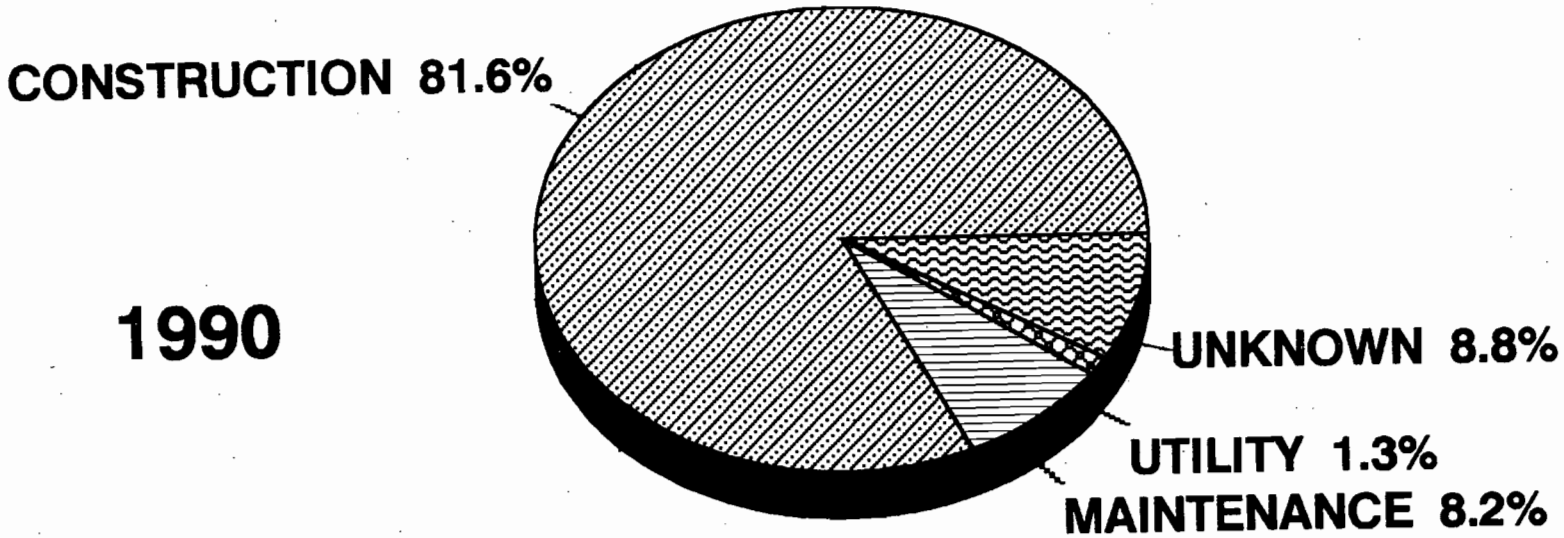

Figure 1.--1990 data on fatal accidents by type of work zone

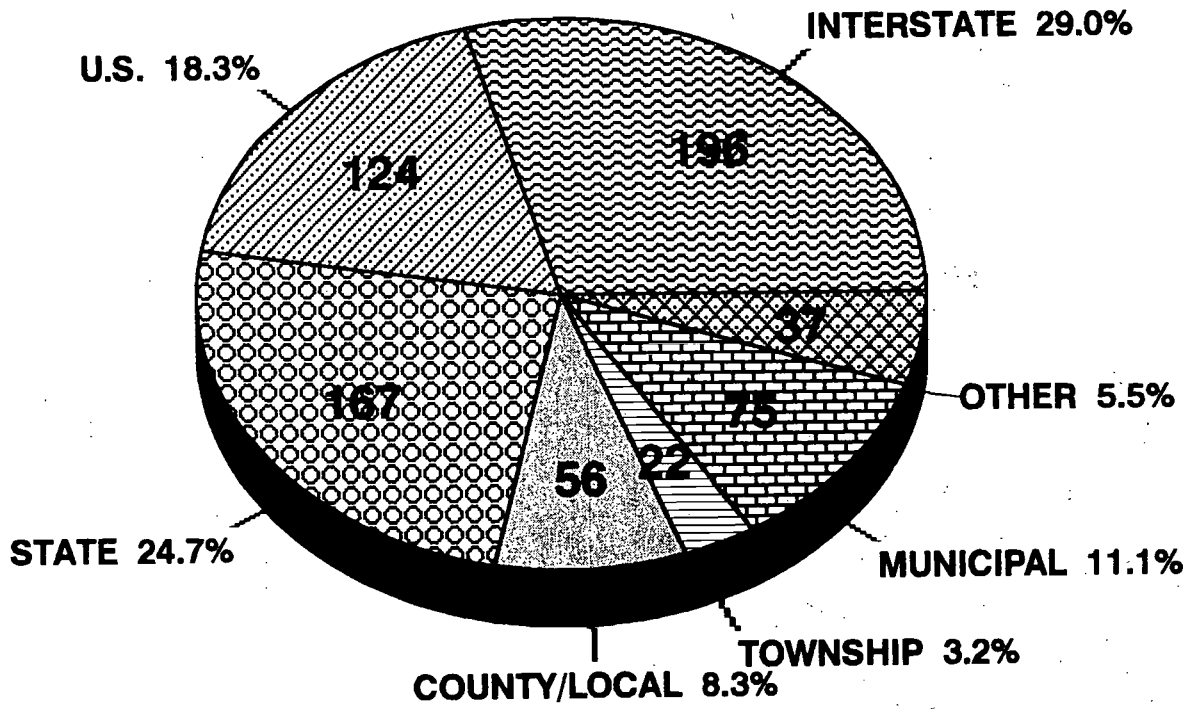

Figure 2.--1990 data on fatal accidents in work zones by route

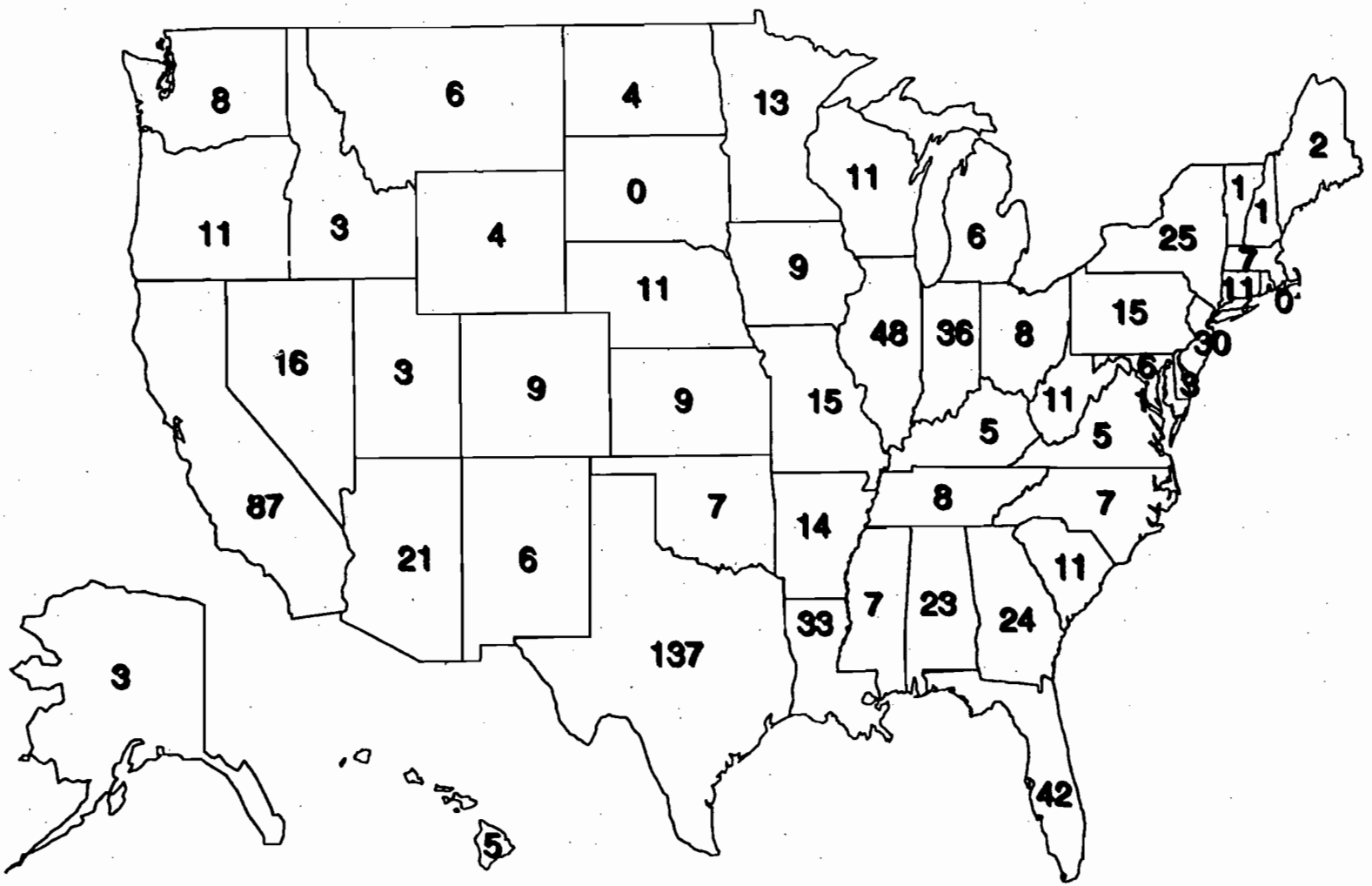

Figure 3.--1990 data on work zone fatalities by State

the report forms[8] used by States to determine how States document or code accidents that occur in work zones. The review revealed some discrepancies between State data and FARS data. For example, in 1989, the State of North Carolina reported that 16 fatalities occurred in work zones, but the FARS data indicated that 3 fatalities occurred in work zones in the State. For the same year, the State of Minnesota reported that 11 fatalities occurred in work zones, compared to 16 fatalities according to FARS data. In 1990, the FARS data indicated that 11 fatalities occurred in work zones in the State of West Virginia, while the State reported 14 fatalities.

NHTSA staff involved with the FARS data indicated that some differences in the number of fatalities reported by FARS and the States may exist because only fatalities that occur within 30 days after the accident are included in the FARS data. However, NHTSA staff also acknowledged that the discrepancies could very likely be caused by the various ways States document and code work zone related accidents. On some State forms, there are no categories to document accidents occurring in work zones. In preparing the FARS data, NHTSA's analysts in these States would have to interpret the narrative of the accident found on the State form to determine if the accident was work zone related. Figure 4 illustrates the various ways in which States document work zone accidents, as compared to the FARS data form.

Section 402 of the Intermodal Surface Transportation Efficiency Act of 1991[9] provides for:

> ...annual reports to the Secretary [of the DOT] on the efforts being made by the States in reducing deaths and injuries occurring at highway construction sites and the effectiveness and results of such efforts. The Secretary shall establish minimum reporting criteria for the program. Such criteria shall include, but not be limited to, criteria on deaths and injuries resulting from police pursuits, school bus accidents, and speeding, on traffic-related deaths and injuries at highway construction sites and on the configuration of commercial motor vehicles involved in motor vehicle accidents.

The above legislation provides an excellent opportunity to achieve uniformity in the documentation of work zone related accidents. The Safety Board has been informed by NHTSA officials, however, that some States are streamlining their accident report forms to reduce the time required to fill out the form because of budgetary constraints. Such action, in the Safety

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[8] Every other year, NHTSA publishes the "State Accident Report Forms Catalogue," the purpose of which is to provide a comparative accident data reference document for use by the States, NHTSA regional offices, other Federal agencies, and private organizations. NHTSA acknowledges that it hopes that States will ultimately collect uniform accident data.

[9] Legislation signed by the President on December 18, 1991, that provides authorizations for highways, highway safety, and mass transportation for the next 6 years.

77 **CONSTRUCTION/MAINTENANCE ZONE**

0—None
1—Construction
2—Maintenance
3—Utility
4—Work Zone, Type Unknown

FARS

9. ROAD DEFECTS
1. Loose material on surface
2. Holes, deep ruts
3. Low shoulders
4. Soft shoulders
5. Other defects
6. Under construction with defects
7. No defects
8. Under construction no defects

North Carolina

ROADWAY DEFECTS

6

1. NO DEFECTS
2. HOLES, RUTS, BUMPS
3. SOFT OR LOW SHOULDER
4. UNDER REPAIR
5. LOOSE MATERIAL
6. RESTRICTED WIDTH
7. SLICK PAVEMENT
8. ROADWAY OBSTRUCTED
9. OTHER DEFECTS

Virginia

Y N Construction Zone
Y N Investigated at Scene

Michigan

ROAD WORK
(Check one)

1 ☐ Construction zone
2 ☐ Maintenance activity
3 ☐ Not applicable

Nebraska

10. ROAD CONSTRUCTION/MAINTENANCE/UTILITY WORK PRESENT?
1. Yes 2. No

Indiana

10 ROADWAY DEFECTS

1 - Shoulder Low
2 - Shoulder Soft
3 - Holes, Bumps, etc.
4 - Loose Material
5 - Repair Work Barricaded
6 - Repair Work not Barricaded
7 - No Defects
8 - Other _____

Illinois

34. CONSTRUCTION ZONE _____

0 – NOT APPLICABLE
1 – CONST – SHORT TERM
2 – CONST – LONG TERM
4 – MAINT – SHORT TERM
5 – MAINT – LONG TERM
7 – UTILITY MAINTENANCE

Pennsylvania

Figure 4.--FARS and State forms for collecting data on work zone accidents

Board's view, appears contrary to the intent of Section 402. Moreover, the Safety Board believes that there is a need for more reliable data on work zone accidents and that the NHTSA and the FHWA should review all State forms and select the data elements that comprehensively document work zone accidents. The States should be encouraged to incorporate these data elements into the States' accident report forms.

During the course of this study, the Safety Board attempted to document exposure data with respect to work zones to compare accident rates in work zones with accident rates on roads not under construction. No such data exist. The only measure of the amount of work zone activity is the number of dollars spent for construction. Various studies in the past have cited the lack of exposure data for work zone accidents. One of the recommendations of the previously cited 1987 AASHTO study was that "the Committee [AASHTO Standing Committee on Highway Traffic Safety] should work with states to provide some measures of exposure for work zone accidents...." A 1990 study prepared by the Minnesota Department of Transportation cited "the need for a measure of exposure...."[10] FHWA officials indicated to the Safety Board that collection of work zone exposure data, which would be a relatively expensive project, has been proposed but never approved for funding within FHWA.

The Safety Board acknowledges that exposure data for some moving maintenance activities, such as painting or mowing, would be difficult to document because of the short-term duration of the activities. However, the Safety Board believes that exposure data for long-term construction sites on the interstate system, for example, should be documented, particularly in view of the large percentage of construction work zone accidents that occur on the interstate system. The 1990 FARS data indicated that over 80 percent of the fatal accidents in work zones occur in construction work zones (and only 20 percent in the other categories of work zones), and that almost 30 percent of the fatal accidents in work zones occur on the interstate system. Given the expected increase of construction and maintenance on the interstate system, the Safety Board urges the FHWA to develop a program to collect exposure data for construction zones on the interstate system. Such data would enable the FHWA and State transportation officials to measure more precisely the effects of work zones on accident rates and the treatments needed to reduce accident rates.

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[10] Minnesota Department of Transportation, Standards Unit, Office of Traffic Engineering. 1990. Work zone accident analysis for calendar year 1989. November.

TWO-LANE, TWO-WAY OPERATIONS

Need for Positive Separation of Traffic

In October 1990, construction work began on a 10-mile section of Interstate 20 about 20 miles east of Birmingham, Alabama. The construction included the replacement of a bridge and a lane widening project. To perform the work, a two-lane, two-way operation (TLTWO)[11] was set up, which required lane reductions and a median crossover to the eastbound lanes. The speed limit approaching the work zone was 65 mph; the speed limit was reduced to 45 mph just within the work zone and prior to the lane reduction. The warning signs approaching the work zone from both directions were appropriately placed in conformance with existing guidelines. The lane closure was delineated with white and orange reflectorized barrels on the right side and a yellow edge line on the left.

The crossover surface was asphalt. The crossover was delineated with orange and white reflectorized barrels on the right and a yellow 4-inch-high asphalt island on the left. Reflectorized orange and white 12-inch-high rubber posts were mounted in the center of the asphalt island every 10 feet. The distance from the beginning of the crossover to the end of the work zone was about 1,000 feet. The temporary raised asphalt island functioned as a lane divider throughout the two-lane two-way operation (see figure 5).

On April 27, 1991, a 1985 Chevrolet S-10 pickup truck was traveling eastbound in the construction zone, and a 1986 Nissan Pulsar was traveling westbound. The driver of the Nissan lost control of the vehicle, and it traveled across the raised asphalt island into the eastbound lane where it collided with the eastbound pickup. According to the police report, the pickup truck was estimated to be traveling at 45 mph at the time of the collision and the Nissan at 60 mph. Both drivers and a passenger died in the accident. The accident occurred during daylight hours. At the time of the accident, the sky was cloudy and the pavement was wet. According to the police report, alcohol was not a factor for either driver. Fatigue was listed as unknown.

About 7 p.m. on May 3, 1991, a westbound Honda passenger car, occupied by its driver and a passenger, entered the same construction zone. An eastbound Mazda passenger car, occupied by its driver and a passenger, also entered the construction zone at the opposite end traveling at an estimated speed of 45 mph. A witness, who was traveling eastbound behind the Mazda, observed the Honda traveling at an estimated 60 mph. As the Honda entered the transition to the one-lane westbound roadway, it crossed over the 4-inch-high asphalt island and collided head on with the Mazda. After impact, the

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[11] Typically, the type of operation implemented during construction work when an interstate highway is switched from a four-lane, divided operation to a two-lane, two-way operation.

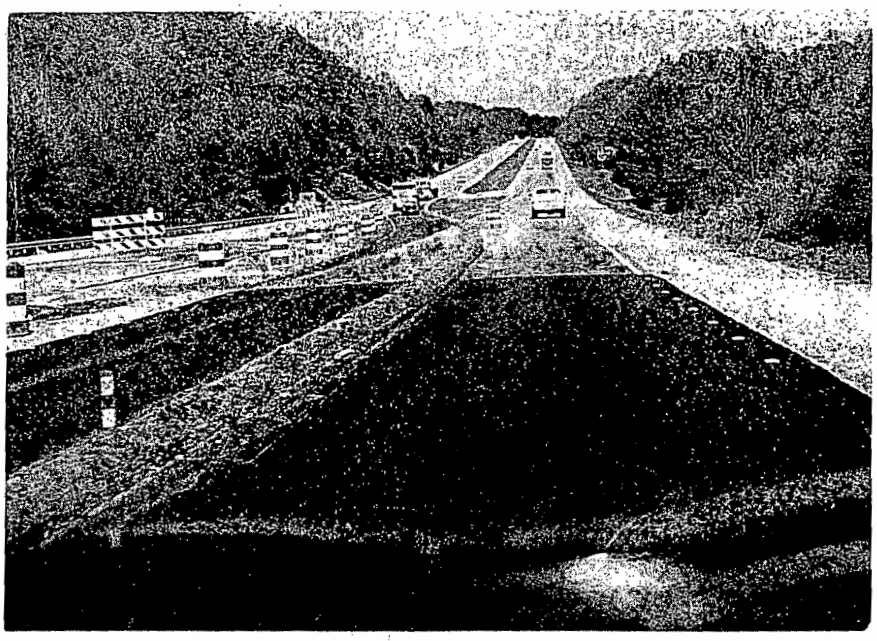

Figure 5.--Two-lane, two-way operation near Birmingham, Alabama, October 1990

Honda and the Mazda rotated off the right edge of the travelway, and the Honda erupted in flames. The driver and passenger of the Honda were fatally injured, and the driver and passenger of the Mazda were seriously injured. Both vehicles were destroyed by the collision and subsequent fire (see figure 6). The accident occurred during daylight on a wet road; the sky was overcast.

This construction zone was in place from October 1990 through May 1991. As part of its investigation of the accident that occurred on May 3, 1991, Safety Board staff reviewed computer records to determine the number of accidents in this area during the time the construction zone was in place. The review revealed at least five additional accidents in which vehicles crossed the median (island) in this area.

On March 5, 1991, an eastbound 1986 Dodge Ram van crossed the median and struck a 1985 Cadillac Cimmaron head on. Police reports indicate that the van was traveling at an "unsafe" speed, estimated at 60 mph. The accident resulted in one fatality and four injuries. At the time of the accident, the pavement was dry. According to the records reviewed, alcohol and drugs were not factors in the accident.

On December 22, 1990, a 1983 Buick traveling westbound at an estimated speed of 50 mph crossed the median during rain and struck an eastbound 1988 Ford Escort in the side. There were no injuries. According to police reports, the driver of the Buick "had used alcohol." At the time of the accident, the pavement was wet.

On February 15, 1991, a westbound 1983 Toyota Corolla lost control on ice, slid at an angle across the median, and struck the middle of the left side of an eastbound 1987 Pontiac. There were no injuries. The speed of both vehicles was estimated at 45 mph. According to the report, alcohol and drugs were not factors in the accident.

On April 13, 1991, a westbound 1979 Lincoln Continental lost control during rain, crossed the median, and was hit in the right rear side by a 1979 Datsun pickup. Both vehicles were estimated to be traveling at 45 mph at the time of the accident. Both drivers were injured. Neither alcohol nor drugs were considered factors in the accident.

The warning signs in place at this construction zone generally were in compliance with the State manual and with the Federal Manual on Uniform Traffic Control Devices (MUTCD).[12] Notwithstanding the compliance with the manuals, six accidents occurred on this busy section of I-20 (the average daily traffic count was 38,000 vehicles) in about 6 months, illustrating the hazard in conducting two-lane, two-way operations on the interstate system without positive separation of traffic. The State Highway Engineering Office

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[12] See appendix A for a brief description and history of the Manual on Uniform Traffic Control Devices. Some provisions of the manual are mandatory, others are advisory, and yet others are permissive (see specifically section 1A-5).

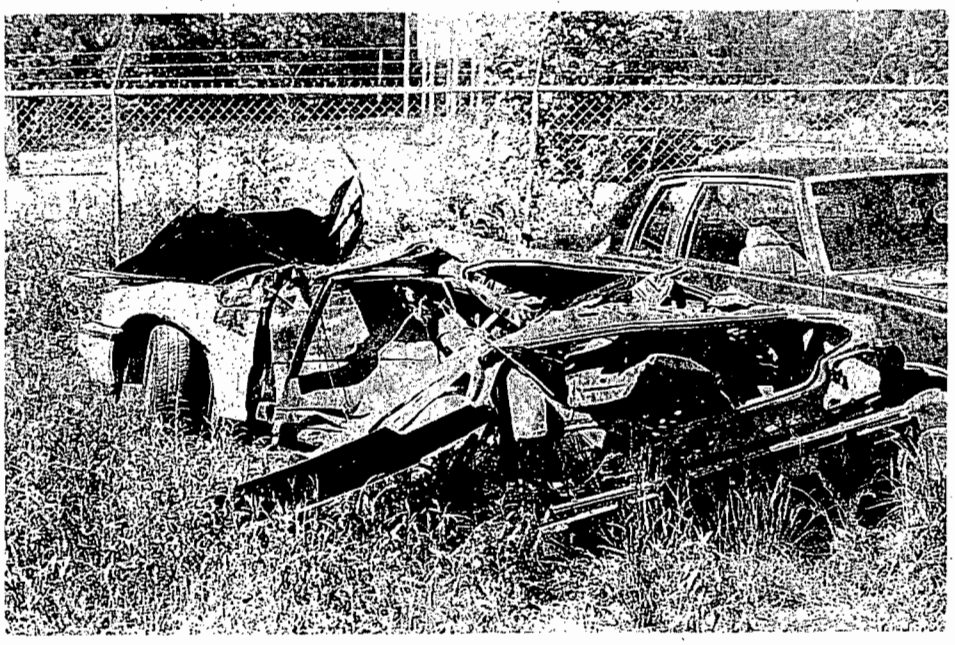

Figure 6.--Vehicle damage, Birmingham, Alabama, May 1991

reported that it conducted a review of the work zone after the accident that occurred on April 13, 1991, but no changes to the work zone were contemplated. Two days after the accident, which occurred on May 3, 1991, a positive barrier was erected between the eastbound and westbound lanes through May 1991 (see figure 7).[13] Also as a result of the accidents, the State police conducted a speed enforcement campaign between May 5 and May 25; 59 speeding citations and 2 warnings were issued. The fact that the earlier accidents did not alert officials to the problem of head-on collisions and prompt corrective action sooner raises concerns that will be addressed later in the study about the monitoring of work zone sites.

The Safety Board has addressed the issue of TLTWOs in the past. For more than a decade, the Safety Board has expressed concern about the lack of positive separation of opposing traffic in work zones.

On August 22, 1979, a westbound tractor-semitrailer sideswiped an eastbound tractor-semitrailer and then struck an eastbound motor home on a two-lane, undivided roadway in a 9-mile-long construction zone on I-80 about 30 miles northwest of Laramie, Wyoming. The driver and codriver of the westbound tractor-semitrailer were killed. Six of the seven persons in the motor home were ejected and killed; one person was partially ejected and seriously injured. Based on its investigation, the Safety Board concluded that the westbound truck struck the eastbound truck and the motor home at speeds of 68 mph and 58 mph, respectively.

Alcohol and drugs were not a factor in the accident. However, based on the investigation, the Board determined that the driver of the westbound vehicle was fatigued as a result of the length of time on duty, changing tires, unloading cargo, and prolonged driving before the accident.

In its report of that accident investigation, the Safety Board concluded that "the accident history at this location indicates that accident rates, especially fatal accident rates, increase significantly when an interstate highway is switched from a four-lane, divided operation to a two-lane, two-way operation during construction work." The Board's report expressed concern about the FHWA's efforts at the time to address two-lane, two-way operations on high-speed, high-volume highways.

Federal Actions, Policies, and Standards

On September 17, 1979, 3 1/2 weeks after the Laramie accident, the FHWA issued an emergency final rule (FHWA Docket No. 79-31) entitled "Traffic Safety in Highway and Street Work Zones; Separation of Opposing Traffic." The emergency final rule would have amended 23 CFR 630 and was to have been effective immediately. The summary of the emergency final rule and the specific amendment follow:

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[13] For the purposes of this study, positive barrier or positive separation of traffic refers to the use of concrete barriers to separate traffic, notably the New Jersey type barrier.

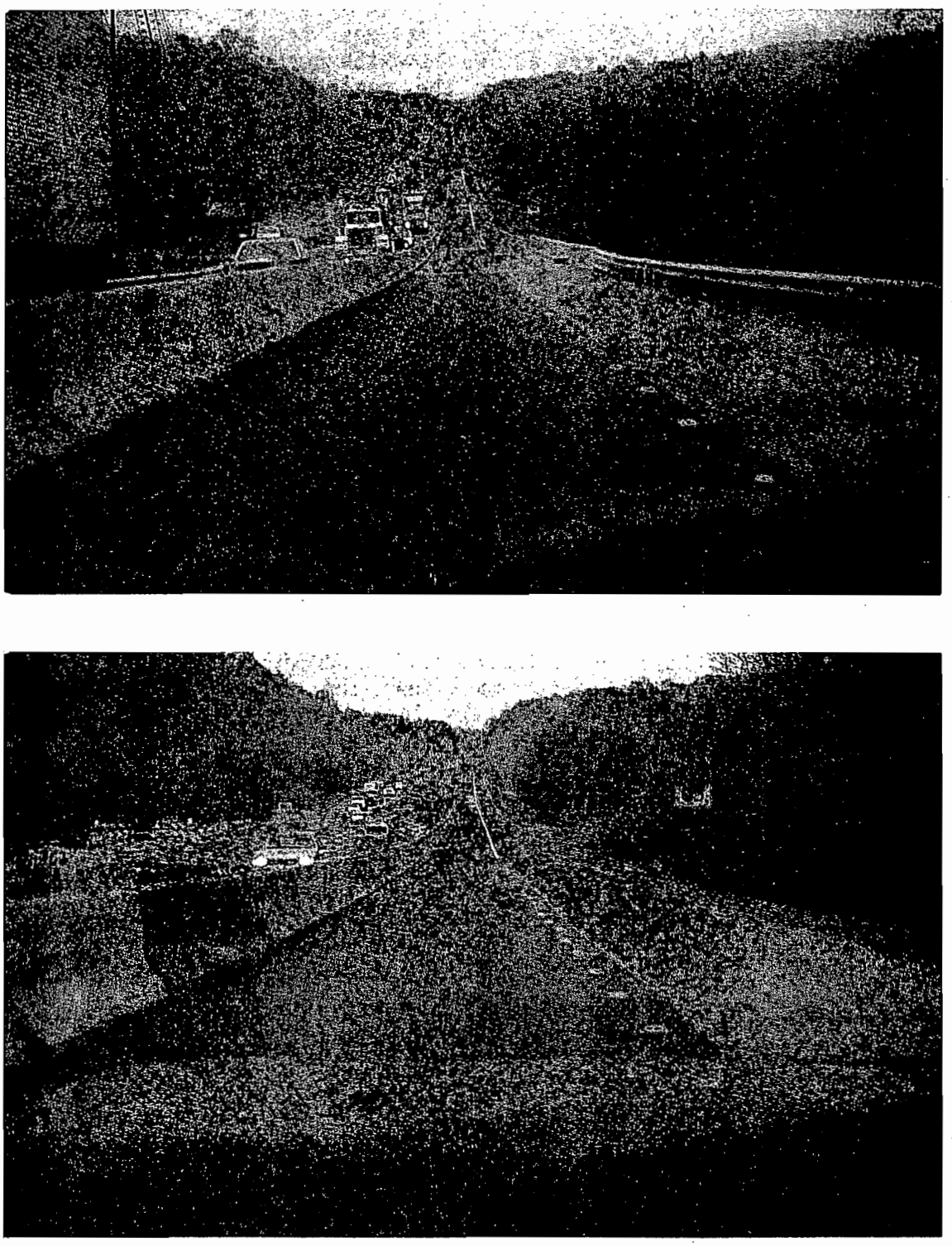

Figure 7.--Positive separation of two-lane, two-way operation, Birmingham Alabama, May 1991

SUMMARY: The Federal Highway Administration (FHWA) has determined that an alarming number of fatal traffic accidents is occurring where two-way traffic is maintained on one roadway of a normally divided highway. This rule amends existing procedures to require more stringent control measures to reduce the incidence of such accidents on highway construction projects funded by FHWA.

* * * * *

(5) The TCP [traffic control plan] shall include provisions for the separation of opposing traffic whenever two-way traffic must be maintained on one roadway of a normally divided highway. Two-way operation on one roadway of a normally divided highway shall be permitted only when other methods of traffic control are determined infeasible [emphasis added].

* * * * *

(i) Where two-way traffic must be maintained on one roadway of a normally divided highway, opposing traffic shall be separated with positive barriers (concrete safety-shaped or approved alternate) or with drums, cones, or vertical panels throughout the length of two-way operation, except for transition zones, where positive barriers shall be used. Where terminal sections of temporary positive barriers are not tied to an existing structure, the barriers shall be flared or fitted with impact attenuation devices. The use of striping and complementary signing, by themselves, is prohibited.

(ii) An exception to the provisions of paragraph (a)(5)(i) of this section may be granted only when it has been demonstrated that the use of positive barriers or delineation and channelization devices is not feasible or practical. An exception shall not be granted where drivers entering the two-way operation cannot see the transition back to a one-way operation. Each exception granted by FHWA will require the written approval of the FHWA Division Administrator.

The Safety Board concurred in the intent of the FHWA's rulemaking at the time it was issued. The Board also stated, however, that the constraints as outlined in the rulemaking should apply to work on all Federal-aid roads, not just to construction projects funded by the FHWA (Safety Recommendation H-80-9).

In response to the FHWA's emergency final rule, some State transportation agencies began to modify their traffic control plans to emphasize the use of single-lane closures, rather than TLTWOs, because of the prohibitive cost of positive barriers. Recognizing the States' concern, the

FHWA on October 16, 1980, published a notice of proposed rulemaking (NPRM) to amend the emergency final rule. The NPRM was intended to give flexibility to allow the use of separation devices other than positive barriers throughout the TLTWO, including transitions, when conditions such as time and length of exposure, type of traffic, and the type of facility warranted.

About 9 months later, on July 22, 1981, about 5:50 a.m., a 1978 van occupied by seven persons was traveling eastbound on the Ohio Turnpike in a construction zone near Cleveland, Ohio, where two-way traffic was operating in the eastbound lanes. The posted speed for the construction zone was 50 mph. Shortly after the van, which was traveling about 55 mph, entered the construction zone, it drifted into the westbound lane and forced an oncoming westbound car off the roadway onto the median shoulder. The van continued about 400 feet in the opposing traffic lane and collided nearly head on with a GMC tractor-semitrailer traveling westbound at an estimated speed of 45 mph. The van driver and five passengers in the van were killed, and one passenger was seriously injured. The driver of the tractor-semitrailer received minor injuries.

The investigating officer of the Ohio State Highway Patrol said that the weather was clear and dry and that the ambient light did not require the use of headlights. Traffic control devices in place at the construction zone were determined to be in compliance with the MUTCD. A toxicological analysis of the van driver's blood was negative for alcohol. Also, the Safety Board concluded, in its report of the accident, that there was no evidence to suggest that the van driver was either fatigued or incapacitated before straying into the opposing traffic lane.

The Safety Board determined that the probable cause of the accident was the failure of the van driver to maintain his vehicle within the proper traffic lane. Contributing to the cause of the accident was the lack of positive separation of opposing traffic in the construction work zone. As a result of its investigation of the Cleveland accident, the Safety Board, on March 30, 1982, urged the FHWA to "promptly adopt the final rule changing the Manual on Uniform Traffic Control Devices (MUTCD) to incorporate the provisions of the "Emergency Final Rule, 23 CFR 630.101" (Safety Recommendation H-82-8). The Safety Board continued to believe that two-way operations on one roadway of a normally divided highway should be permitted only when other methods were determined to be infeasible.

On May 20, 1982 (less than 2 months after the Safety Board issued Safety Recommendation H-82-8), the FHWA published a final rule that, in essence, weakened the emergency rule that was published 3 years earlier. The final rule permits TLTWOs only after other available methods of traffic control have been carefully considered. The emergency rule permitted TLTWOs only when other methods of traffic control were determined to be infeasible. The FHWA stated in the rulemaking that as a result of experience with the use of separation devices in TLTWOs, the FHWA had determined that there may be instances in which a properly separated TLTWO could be preferable to other feasible types of traffic control in work zones. As stated in the Federal Register at the time the final rule was published, "The FHWA has decided not to stipulate further traffic control design requirements in this

situation.... This will allow greater flexibility to develop traffic control detail tailored to the particular circumstances on each project. This amendment is intended to place the primary responsibility for determining the appropriate traffic control details for each project on the State and local highway agencies." The final rule reads:

> (5)(i) Two-lane, two-way operation on one roadway of a normally divided highway (TLTWO) shall be used only after careful consideration of other available methods of traffic control. Where the TLTWO is used, the TCP shall include provisions for the separation of opposing traffic except:
>
> (a) Where the TLTWO is located on an urban street or arterial where operating speeds are low;
>
> (b) Where drivers entering the TLTWO can see the transition back to normal one-way operation on each roadway; or
>
> (c) Where FHWA approves nonuse of separation devices based on unusual circumstances.
>
> (ii) Center line striping, raised pavement markers, and complementary signing, either alone or in combination, are not considered acceptable for separation purposes.

The final rule was incorporated into the Federal-aid program manual on July 1, 1982.[14] The FHWA indicated to the Safety Board in 1983 that as an alternative approach to H-80-9 and H-82-8 (discussed above), it would consider revising the MUTCD to incorporate the language of the final rule; however, such action was never taken. The FHWA did include a discussion of TLTWOs in the Traffic Control Devices Handbook (TCDH).[15] The handbook states:

> The two-lane, two-way on one roadway of a normally divided highway is a typical application that requires special consideration in the planning, design, and construction phases. As unique operational problems (typically serious head-on collisions) can arise with the TLTWO, this typical application will be discussed with a greater level of detail than other typical applications.

The section that discusses "selection of separation devices" states:

> The portable concrete barrier is often the most costly but provides the greatest protection from potential head-on collisions. This is the preferred treatment for many TLTWO applications.... Roadway

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[14] A manual used by Federal and State highway transportation officials that contains all regulatory material and orders, policies, procedures, and instructional memoranda issued by the FHWA.

[15] The Traffic Control Devices Handbook was first published by the FHWA in 1983 to augment the MUTCD. The handbook does not establish policies or standards; rather it offers guidelines for implementing the standards and applications contained in the MUTCD.

> drainage and snow and ice removal must be considered when either the portable barrier or raised island are used....Drums, barricades, vertical panels, tubular markers, and cones will require varying degrees of maintenance. Sometimes these devices are hit so frequently that the cost of repositioning and replacing them with new devices makes them more expensive than the portable concrete barrier. The repositioning or replacement of impacted devices will entail a certain amount of risk for workers involved.

Because the introduction to the Traffic Control Devices Handbook contains the statement, "...the Handbook does not establish Federal Highway Administration (FHWA) policies or standards," the Safety Board believed that the FHWA was not adequately emphasizing the problem by only dicussing it in the TCDH and not incorporating a policy statement in the MUTCD. Consequently, the Safety Board placed Safety Recommendations H-80-9 and H-82-8 in a "Closed--Unacceptable Action" status in January 1985.

On January 10, 1992, the FHWA published an advance notice of proposed rulemaking in the Federal Register regarding proposed amendments to Part VI of the MUTCD. Part VI addresses traffic controls for street and highway construction, maintenance, utility, and emergency operations. These proposed revisions to the MUTCD contain a discussion of TLTWOs. The first paragraph in the proposed revisions mirrors the opening paragraph found in the Traffic Control Devices Handbook. The wording of the remaining three paragraphs in the proposed revisions duplicates the original wording of the emergency final rule issued in 1979. Although the proposed revisions to the MUTCD suggest a stronger position on this issue by the FHWA, comparable to the position taken in 1979, the Safety Board remains concerned that TLTWOs can still be implemented on the interstate system without positive separation of opposing traffic.

State Practices

Through its accident investigation experience and data collection activities, the Safety Board is aware that not all States use positive separation of opposing traffic when TLTWOs are implemented on the interstate system. For example, asphalt medians are used to divide TLTWOs in Michigan, Louisiana, and North Carolina; tubes are used in Louisiana and Kentucky; and cones are used in Kentucky and Florida. Further, a 1990 study noted that North Carolina, Florida, Ohio, and Pennsylvania have used a 12- to 18-inch-wide by 4-inch-high asphalt median with reflectorized yellow paint and orange tubes with reflectorized white collars spaced at 50-foot intervals as a divider for TLTWOs when the average daily traffic (ADT) count is less than 30,000.[16] The study also noted that "The medians are generally not recommended...where the traffic volume is high, for example, where the ADT

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[16] Cottrell, B. H., Jr. 1990. Temporary asphalt medians for two-lane, two-way operation. Transportation Research Record No. 1258.

is greater than 50,000." The Roadside Design Guide[17] discusses the use of a temporary raised island and cautions, "Presently, since there is limited operational experience with the temporary raised island [4-inch-high asphalt median], there is not a consensus on the traffic and geometric conditions that warrant its use. Until there is more operational experience with the device, it should only be used on roadways with speeds of 45 mph or less except when recommended by an engineering study."

The Safety Board continues to believe that operating speeds and conditions on the interstate system warrant in most cases positive separation of traffic. In addition to the accidents discussed above, the Safety Board has investigated several other accidents that emphasize the need for positive separation in TLTWOs.

A TLTWO with a median crossover had been set up on I-40 in Old Fort, North Carolina, because of a 3-mile-long construction zone in the area. Eastbound and westbound traffic were separated by an 18-inch-wide by 4-inch-high temporary asphalt median (see figure 8). On March 16, 1990, a westbound Pontiac went out of control and crossed the temporary median during heavy rain. The rear of the Pontiac was struck by an eastbound 1987 GMC tractor/twin trailer combination unit (see figure 9). The unbelted driver of the Pontiac was ejected and killed; the truckdriver was not injured. The estimated speed at impact was 50 mph for both vehicles. The posted speed limit was 55 mph. There was no evidence of physical impairment or fatigue of the truckdriver at the time of the accident, and he was in compliance with the hours of service regulations. There was also no evidence of any physical impairment of the Pontiac driver at the time of the accident.

The Board's investigation of this accident revealed that two previous accidents in which vehicles crossed the median had occurred in this work zone on July 3 and August 27, 1989. In both accidents, vehicles crossed the median and collided with other vehicles traveling in the opposite direction. One person was killed and five persons were injured as a result of the two previous accidents.

About 6:15 p.m. on July 17, 1989, a Nissan pickup truck was traveling south in the right lane of I-25 about 15 miles south of Buffalo, Wyoming. The southbound lanes had been converted to two-way traffic because of the resurfacing of a 5-mile segment of the right northbound lane. The pickup had traveled about 2.3 miles into the construction zone and about 990 feet through a 1-degree, 1,358-foot-long curve when it struck a plastic barrel used to separate the opposing lanes of traffic. The pickup crossed the double yellow center line and struck a northbound 1983 Buick. The restrained 67-year-old driver of the Buick was killed, and the restrained 65-year-old driver of the pickup was seriously injured. Both vehicles were estimated to

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[17] The Roadside Design Guide, developed by the AASHTO Task Force for Roadside Safety, presents a synthesis of current information and operating practices related to roadside safety. The document is a guide; it is not a standard or a design policy. It is intended for use as a resource document from which individual highway agencies can develop standards and policies.

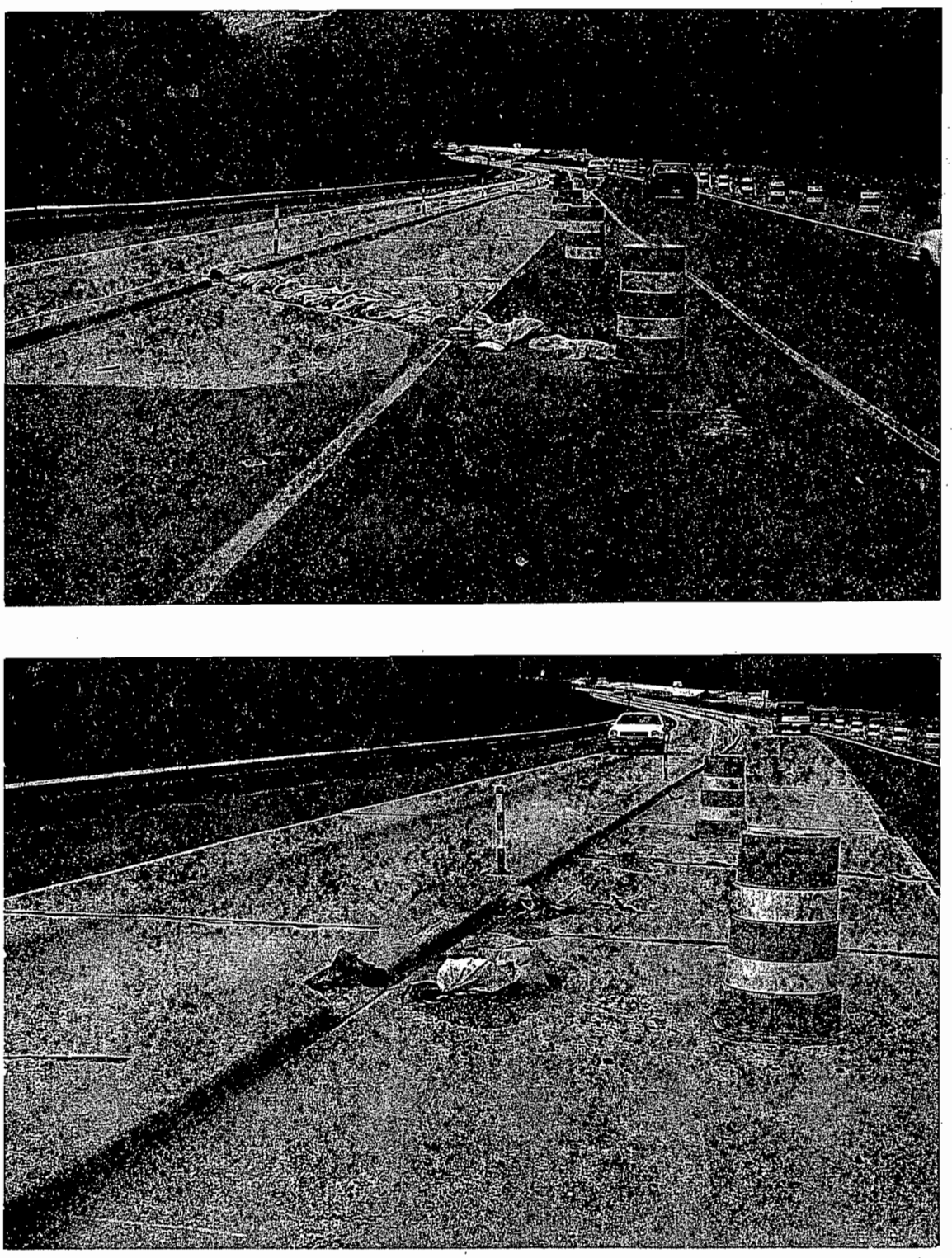
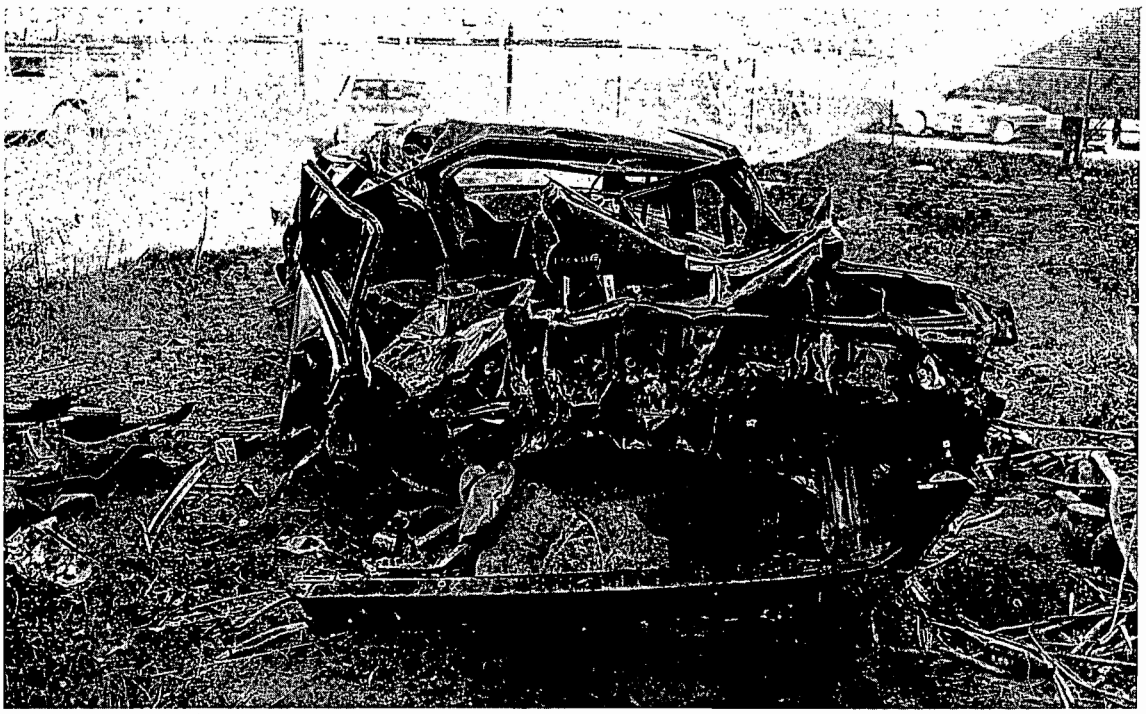


Figure 8.--Two-lane, two-way operation near Old Fort, North Carolina, March 1990



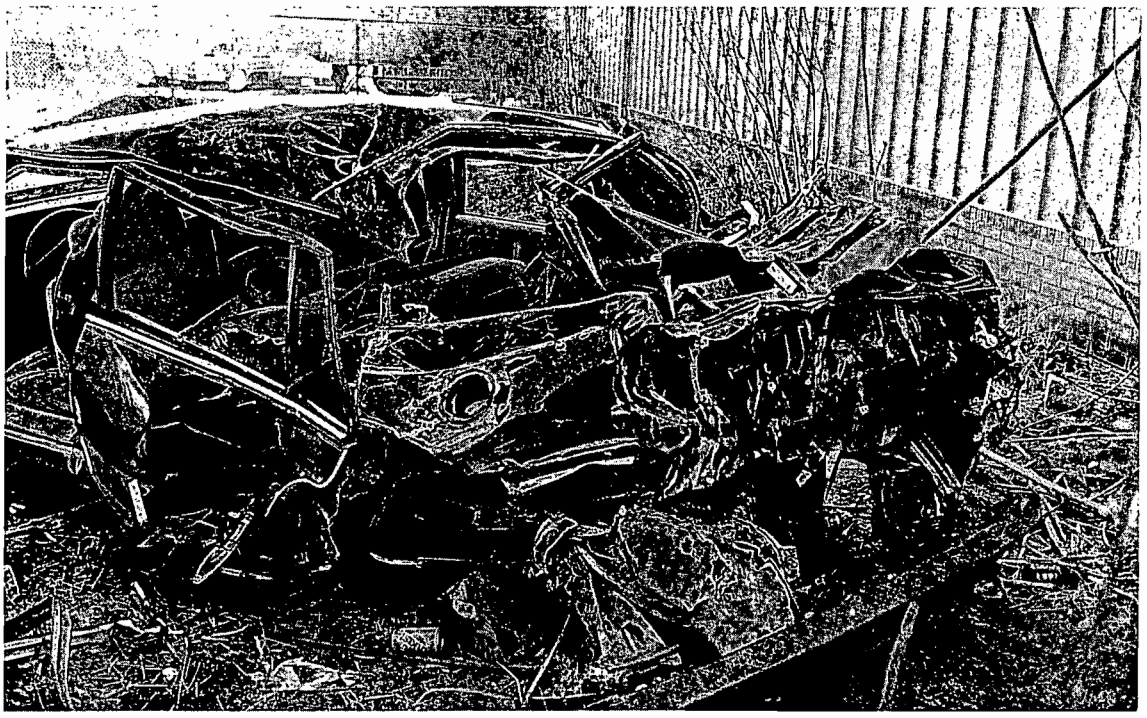


Figure 9.--Vehicle damage, Old Fort, North Carolina, March 1990

be traveling at the posted speed limit of 55 mph at impact. Both vehicles were extensively damaged (see figure 10). Postaccident toxicological tests were not performed.

With posted speed limits of 55 mph and 65 mph on the interstate system and with traffic often exceeding those limits, it may be unreasonable to expect to achieve speed reductions to 45 mph or below in work zones. In fact, the MUTCD states that "traffic movement should be inhibited as little as practicable" and that "reduced speed zoning should be avoided as much as practicable." Given these conditions, the Safety Board strongly believes that if TLTWOs are implemented on a normally divided highway, positive separation of opposing traffic must be achieved. The use of cones, drums, tubes, or temporary asphalt medians will not achieve the desired separation. The MUTCD and the Traffic Control Devices Handbook should be revised accordingly. The Safety Board acknowledges that on some stretches of the interstate the ADT may be extremely low and that, consequently, the ADT may be a factor that needs to be considered in requiring positive separation. Other factors may also need to be considered, such as the percentage of large commercial vehicles.

The Safety Board is aware that State transportation officials and highway contractors have expressed concern about operational problems associated with the use of portable concrete median barriers, including movement, storage, and placement of the barriers. In the past, moving the New Jersey type concrete barriers has been costly and time-consuming. However, current technology has reduced some of the time associated with moving and placing the concrete type barriers. An example is the movable concrete barrier system, which was described in a paper by a highway engineer at the FHWA.[18]

> The system consists of a series of hinged 1-meter concrete barriers (similar to the New Jersey barrier) that are transferred and placed at a lateral distance from 4 to 18 feet by a Transport and Transfer Vehicle (TTV). The barriers have a "T" shaped top to allow rollers on the TTV to lift them. The 1,400-pound barriers can be hinged together at any desired length. The continuous barrier permits the S-shaped roller system on the bottom portion of the TTV to move the barrier to the desired lateral distance.

Because current technology has reduced some of the time associated with moving and placing the concrete type barriers and because stockpiling of these devices has reduced some of the costs, requiring positive separation of traffic on the interstate system should not present, as extensively, the operational and expense problems encountered in the past.

Although the prevailing view is to minimize speed reductions through work zones on the interstate to prevent speed differentials, the Safety Board

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[18] Oliver, Morris B. 1990. Overview of a movable concrete barrier system. Washington, D.C. Federal Highway Administration, Office of Traffic Operations. April 30.

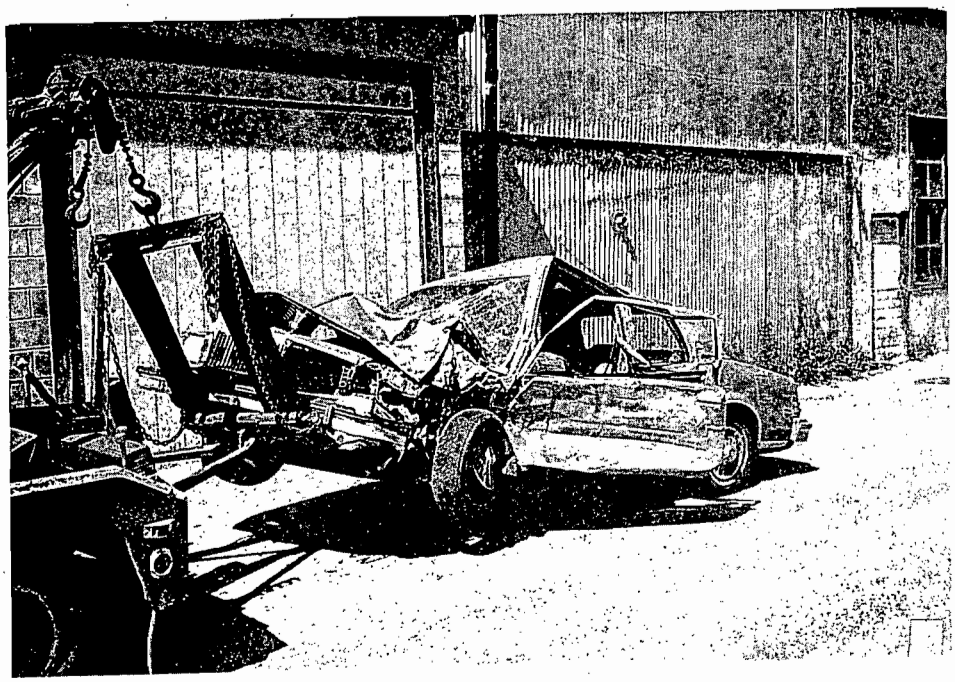

Figure 10.--Vehicle damage, Buffalo, Wyoming, July 1989

has some concern that the currently used positive barriers are not designed to provide the level of protection needed for large commercial vehicles traveling through work zones at speeds as high as 55 mph and 65 mph. The concrete barrier in some cases would probably have limited effect in preventing accidents of commercial vehicles at these speeds. Consequently, the FHWA should determine if a combination of efforts, such as speed reductions coupled with onsite enforcement and positive barriers, may be needed at work zones when commercial vehicles are a relatively large percentage of the ADT.

TRUCK-MOUNTED ATTENUATORS

Use and Effectiveness of TMAs

About 9 a.m. on September 26, 1989, four State of Illinois Department of Transportation maintenance trucks began a pavement striping operation, traveling north in the right northbound lane of I-39 near Ogle County, Illinois, at a speed estimated by one of the truckdrivers to be 20 mph. The operation included the painting of the right edgeline and the dashed white line separating the two northbound lanes. The paint striping machine was being pulled by the lead truck. All four trucks involved in the operation were equipped with illuminated, directional arrow boards (pointing to the left), revolving yellow lights, and flashing running lights, all of which were operating. The first three trucks were also each equipped with two rear facing orange signs which read "Pass With Care" and a left arrow, and "Wet Paint" with a left arrow. The last truck, a 1987 Ford 8000, was equipped with a truck-mounted attenuator (TMA), which is a type of crash cushion mounted typically on the rear of a State transportation vehicle. No advance signs warning of the painting operation ahead were posted on the 10-foot-wide shoulder, nor were they required to be. Although the MUTCD recommends that other traffic control devices should be used in conjunction with the advanced warning arrow panel, they are not required.[19]

About 10:50 a.m., a 1986 Mack tractor, traveling in the right northbound lane and pulling a 1970 Heil dry bulk trailer loaded with dry concrete (78,000 pounds), overtook the painting operation on a straight section of roadway and struck the rear of the TMA-equipped Ford 8000 truck at a speed estimated by the driver of the Mack truck to be 55 to 60 mph. Another truckdriver following the Mack truck indicated that the driver of the Mack truck may have been traveling at 65 mph. The Mack truck crushed and overrode the TMA on the rear of the Ford truck and pushed the Ford truck across the left northbound lane and into the median of I-39 (see figure 11). From the point of impact, the vehicles traveled a distance of about 700 feet to their final resting positions.

The driver of the Mack combination unit stated that he saw the flashing yellow lights on the State trucks about 1/2 mile ahead of him on the roadway, but did not realize the trucks were traveling at such a slow rate of speed. He further stated, "I never saw the last truck." He also indicated that he was eating a sandwich at the time of impact. His logbook indicated that he was within the hours of service regulations.

Most likely because the TMA absorbed a substantial amount of the impact forces, the driver of the Mack combination vehicle was not injured. The driver of the Ford truck received minor injuries (cervical neck strain, scalp abrasion, abrasion/contusion on his right calf) and was treated and released from a local hospital.

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[19] See appendix A, section 1A-5, for the MUTCD definitions of "shall," "should," and "may" with respect to use of traffic control devices.

Figure 11.--Vehicle damage, Ogle County, Illinois, September 1989

On the morning of March 19, 1989, the California Department of Transportation was conducting a trash removal/sweeping operation on I-5, in Downey, California. The highway in this area was four lanes in each direction separated by a W-beam guardrail. The median and right shoulder on the northbound lanes were both 10 feet wide. The vehicles involved in the trash removal/sweeping operation included (from front to rear) a trash truck, two dump trucks, two sweepers, and two shadow trucks.[20] Both shadow trucks were equipped with TMAs on the rear, flashing arrow board signs, and a white and black warning sign that read "Sweeper Ahead." There were no signs posted in advance of the vehicles to warn of the sweeping operation ahead, nor did the MUTCD require that signs be posted.

About 6:30 a.m., while the sweeping operation was being conducted in the lane adjacent to the median, traveling at a speed estimated by the driver of the last truck in the operation to be 3 mph, a Dodge Omni traveling north on I-5 ran into the TMA on the rear of the last truck in the sweeping operation. According to the driver of the Omni, he had been traveling about 55 mph before applying his brakes, but was unable to stop before impacting the TMA.

The driver related that he was returning home from work, having just completed the night shift. He stated that he did not recall seeing the flashing arrow sign on the Caltrans truck until it was too late to avoid the collision. He further stated, however, that he did not think he had fallen asleep. At the time of the accident, it was daylight, the weather was clear, and the road surface was dry. In the area of the accident, the road was straight. According to the police report, the driver had not been drinking.

The Dodge Omni sustained crush damage across the front to a maximum depth of 2 feet (see figure 12). The TMA sustained severe crush damage; there was no damage to the shadow truck. Based on the damage to the TMA, the estimated speed of the car at the time it struck the TMA was between 30 and 40 mph.

Neither the driver of the Dodge Omni nor the driver of the shadow truck was injured as a result of the accident. Both drivers were restrained with lap/shoulder belts. Although the Safety Board has some concerns that advance warning signs were not being used in the above two examples of slow moving maintenance operations and believes that the lack of severe injuries can be attributed, in part, to the fact that occupant restraints were used in one case, the benefits of using truck mounted attenuators in slow moving, maintenance operations are apparent.

A TMA, as defined by a 1988 FHWA report, is "a compact crash cushion which is attached to the rear of a shadow truck and is intended to reduce the

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[20] A shadow truck is typically the last vehicle in a moving work zone procession that provides protection for workers.

Figure 12.--Vehicle damage, Downey, California, March 1989

accelerations felt by occupants in a vehicle striking a shadow truck."[21] Th TMA is an offshoot of the impact attenuators or crash cushions that were developed in the 1960s. During that time, State highway agencies became increasingly aware of the large number of fixed roadside hazards that were contributing to fatalities and injuries. Rather than remove or relocate all roadside hazards, highway personnel began using impact attenuators and crash cushions to mitigate the result of fixed object impacts. Success with these designs stimulated interest in developing mobile systems that could be attached to work vehicles. The first TMA was built in 1972 and consisted of 55-gallon steel drums welded together and mounted on a trailer axle.[22] Since this first TMA, several TMA systems have been designed and refined.

Safety Board staff discussions with personnel of State departments of transportation and a review of available data indicate that the purchase and use of TMAs have increased substantially over the last couple of years. Before then, several factors contributed to the reluctance of industry to use TMAs, including inadequate tilt capabilities and mounting procedures of first-generation TMAs, high initial purchase, maintenance and replacement costs of early designs, and the lack of trucks that could be dedicated to TMA usage. However, as stated by one of the manufacturers of TMAs, new models "allow easy reuse of undamaged cartridge section[s] after partial impact by replacing only [the] damaged modular section." Further, available hardware now allows TMAs to be used on trucks engaged in operations such as salt spreading--an operation that was not feasible with earlier designs of TMAs. Manufacturers of TMAs also now provide training sessions on installation, use, and maintenance of TMAs.

As a result of the improvements in the TMAs, their use has increased nationwide. California, for example, currently has more than 600 TMAs in use on State department of transportation vehicles. In early 1990, the Pennsylvania Department of Transportation purchased 256 TMAs to improve the safety of its trucks used as shadow vehicles. The New York Department of Transportation currently has about 215 TMAs for use on its own maintenance vehicles. The Safety Board has also learned that when some State departments of transportation contract a job with a private company, the awarding of the contract is often contingent on the company's use of TMAs.

One currently available TMA is made of energy absorbing hex-foam cells encased in a fiberglass shell. The crash cushion (see figure 13) is 84 inches long, 26 inches high, and 95 inches wide, and weighs about 1,200 pounds. The Hex-Foam TMA was designed to meet the criteria for crash testing

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[21] Buth, C.E.; Olson, R.M.; Morgan, J.R.; and others. 1988. Truck-mounted Attenuators. FHWA-TS-88-018. Washington, D.C.

[22] Marquis, E.L.; Hirsch, T.J. 1972. Texas Crash Cushion Trailer to Protect Highway Maintenance Vehicles. Research Report 146-6. Texas Transportation Institute.

as recommended by the National Cooperative Highway Research Program[23] Report 230. Report 230 recommends that three tests be conducted: (1) the rear center of the cushion is impacted at 0^{o} angle by a 4,500-pound passenger car traveling at 45 mph; (2) the rear center of the cushion is impacted at a 0^{o} angle by a 1,800-pound car traveling at 45 mph; and (3) the cushion is impacted at a 10^{o} to 15^{o} angle at a point about 3 feet from the rear center of the cushion by a 4,500-pound car traveling at 45 mph.[24]

Figure 13.--Truck-mounted attenuator courtesy of Energy Absorption System, Inc.

The angle or offset at which a TMA is struck may affect the effectiveness of the TMA to mitigate injuries. One example follows:

On May 17, 1989, the Texas Department of Highways and Public Transportation was painting pavement stripes on I-20 eastbound near

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[23] In 1962, the highway administrators of the American Association of State Highway and Transportation Officials (AASHTO) initiated an objective national highway research program. The program is developed on the basis of research needs identified by chief administrators of the highway and transportation departments and by committees of AASHTO. At the request of AASHTO, the Transportation Research Board of the National Research Council administers the research program.

[24] The safety performance of the cushion is judged on three factors: structural adequacy, occupant risk, and vehicle trajectory after collision.

Sweetwater, Texas. About 3:05 p.m., maintenance personnel positioned a 1985 GMC 7000 truck astraddle the right edgeline about 1/2 mile west of the area being painted. The truck was equipped with a Hex-Foam TMA on the rear and a flashing arrow board mounted about 6 feet above the ground.

The Texas Manual on Uniform Traffic Control Devices (MUTCD)[25] states that vehicles equipped with arrow board panels may provide a taper by having the rear vehicle in the convoy straddle the right edgeline. Shortly after the truck equipped with the TMA was positioned astraddle the right edgeline, a 1989 Ford F250 pickup truck, traveling about 65-67 mph in the right eastbound lane, skidded 10 feet and then impacted the left side of the TMA. The pickup truck then struck the left side of the GMC truck. The TMA was crushed about 12 to 18 inches along the entire 7-foot-long left side, and the metal backup plate was pushed inward about 2 feet. There was about 12 inches of contact damage along the right side of the pickup truck, and the hood, door, and roof were crushed into the passenger's seating area.

The passenger of the pickup truck, who was restrained with a lap/shoulder belt, was killed. The driver of the pickup truck, who was also restrained, received moderate injuries. Most likely because of the angle at which the TMA was impacted, the effectiveness of the TMA to mitigate injuries was substantially reduced.

The manufacturer of the Hex-Foam TMA warns TMA users in its training session not to position a truck with a TMA halfway on the roadway or straddling a lane. Positioning a truck with a TMA partially in one lane, according to the manufacturer, increases the chances of a vehicle impacting only part of the crash cushion. Further, a representative of the company that manufactures the Hex-Foam TMA stated that his company believes that additional testing is warranted to address severe offset impacts that can occur on the highway, particularly the interstate system. According to the representative, "We have formally proposed [a] fourth crash test to the NCHRP [National Cooperative Highway Research Program] Report 230 rewrite panel. The impact should be 0^0 on the nose, with a 2.5-foot offset. Any offset beyond this creates occupant risk 'G' levels that exceed current guidelines. We are not sure current TMA models can pass this severe of an offset impact, but we feel the issue must be addressed." FHWA officials have proposed revisions to Report 230 that would encourage optional testing of TMAs at 62 mph and at an offset impact.

The Safety Board encourages additional testing, including impacts at various angles and offsets. The Safety Board has learned that manufacturers of TMAs are conducting research to determine if TMAs can be improved to withstand impact forces in excess of 45 mph. TMAs currently are not designed for crashes in which the speed differential exceeds 45 mph. The above accidents illustrate that moving work/maintenance zones are often performed on divided highways where the speed limit is not reduced from the normal posted speed limit of 55 or 65 mph, and because of the relatively low speeds

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[25] States typically develop their own MUTCDs, modeled after the Federal manual.

at which the moving/maintenance operations are performed, major speed differentials are created.

While encouraging additional testing and research of TMAs, the Safety Board also believes that an analysis of the effects of using TMAs in high-speed environments should be conducted. Problems may be introduced that could result in a degradation of safety to motorists and drivers of TMA-equipped vehicles. A trade-off analysis of the benefits and shortcomings of using TMAs in high-speed environments (in excess of 45 mph) is necessary. The FHWA is the appropriate agency to conduct or sponsor, in conjunction with industry, the research and analysis.

Guidance on the Applicable Uses of TMAs

The statement by the manufacturer of the Hex-Foam TMA--that it warns users of TMAs not to position a truck with a TMA astraddle or partially in a lane--raises additional concerns regarding the adequacy of guidance currently available on the applicable uses of TMAs. Although the manufacturer's statement may be sound advice, there appears to be little additional information to support or refute such a position, despite the ever increasing use of these devices by State departments of transportation in the last few years.

Both the current guidelines in the MUTCD (last revised in 1988) and the proposed revisions to the MUTCD, as outlined in the advance notice of proposed rulemaking in the Federal Register on January 10, 1992, provide very limited information on the applicable uses of TMAs. The Traffic Control Devices Handbook, for example, simply states that "crash cushions can be attached to the shadow vehicle [in a moving operation] to protect motorists and workers from a collision."

Because of the limited guidance available on the use of TMAs, researchers at the University of Tennessee Transportation Center in 1989 conducted extensive interviews with highway agency personnel from five States involved in maintenance and construction work zone activity. The interviews were to be the basis for developing a set of guidelines on the use of TMAs. The results of the interviews indicated that the most common application of TMAs was for protection of workers and motorists in moving work zones. Those interviewed, however, voiced strong support for more frequent use of TMAs on barrier vehicles in stationary operations. Based on the information gathered, the researchers developed suggested priorities for the application of TMAs (see table 2).

In their conclusions, however, the researchers cautioned:

> Two limitations on the significance and suggested use of the guidelines are acknowledged by the research team. First, the project was not a research project spelled with a capital "R." Such an effort would have involved the collection and analysis of data which are not readily available, at a cost measured in $100,000s (well beyond the budget of this project) over a period of

time measured in years. Second, the guidelines in the present format are most appropriately used as a policy formulation and budgeting tool. Further refinement and simplification will be required.

Table 2.--Suggested priorities for the application of TMAs

Closure/Exposure Condition	Ranking*			
		Non-Freeway with Speed Limit		
	Freeway	≥50 mph	40-45 mph	≤35 mph
No Formal Lane Closure				
Shadow Vehicle for Operation Involving Exposed Personnel	A	A	A	A
Shadow Vehicle for Operation Not Involving Exposed Personnel	E	E	E	E
No Formal Shoulder Closure				
Shadow Vehicle for Operation Involving Exposed Personnel	B	B	C	C
Shadow Vehicle for Operation Not Involving Exposed Personnel	E	E	E	E
Formal Lane Closure				
Barrier Vehicle for Operation Involving Exposed Personnel	B	B	C	D
Barrier Vehicle for Condition Involving Significant Hazard	E	E	E	E
Formal Shoulder Closure				
Barrier Vehicle for Operation Involving Exposed Personnel	C	C	D	D
Barrier Vehicle for Condition Involving Significant Hazard	E	E	E	E

*The ranking letter indicates the priority assigned to the use of a shadow/barrier vehicle. The use of shadow/barrier vehicles:

- A is very highly recommended.
- B is highly recommended.
- C is recommended.
- D is desirable.
- E may be justified on the basis of special conditions encountered on an individual project when an evaluation of the circumstances indicates that an impact with a shadow/barrier vehicle is likely to result in less serious damage and/or injury than would impact with a working vehicle or the hazard.

The Safety Board's investigations of work zone accidents over the last several years revealed that the severity of several accidents could have been substantially reduced had TMAs been used on barrier vehicles at stationary work zone sites.

In June 1988, pavement work was being performed in the left lane of southbound I-57 near Effingham, Illinois. In advance of the construction work zone were posted a "Road Construction 1 Mile Ahead" sign, a "Left Lane Closed 1/2 Mile" sign, and lane reductions signs with attached 45-mph advisory signs. The left lane reduction taper was effected by using orange traffic cones 25 feet apart beginning at the left edgeline and running south to the center line between the right and left lanes, a distance of about 62 feet. The cones continued south spaced at 50-foot intervals along the center line for a distance of 800 feet throughout the work zone. Other warning signs included a "Flagman Ahead" sign, located about 100 feet south of the beginning of the taper; a flashing arrow board located about 226 feet inside the taper; "Workers Ahead" signs with flashing strobe lights; and regulatory "45 mph" signs stating "45 mph speed limit is in effect when the lights are flashing," located about 410 feet inside the taper. Because the field supervisor for the work zone did not have batteries for the strobe lights on June 15, the "Workers Ahead" signs were not activated and the speed reduction was not in effect that day.

A flagger was located about 1,286 feet into the zone about 100 feet ahead of a pavement grinding machine that was working in the left lane near the center line and extending across the center line about 14 inches. The flagger's duties were to monitor southbound traffic in the right lane and to watch the grinding machine. As the grinding machine approached her location, she would remain at least two cones ahead of the machine and move the cones outward from the center line into the right lane. The Illinois Department of Transportation Flagger's Handbook advises that flaggers be located 200 to 300 feet in front of the operation.

About 8:35 a.m., on June 15, 1988, a 1984 Freightliner truck tractor pulling a van semitrailer was traveling at an estimated speed of 55 to 70 mph in the right lane approaching the construction zone. According to witness statements, about 1,076 feet into the work zone, the driver applied the brakes in emergency and the unit veered to the left straddling the center line with its left side tires. The truck then skidded about 330 feet before colliding with the left front of the pavement grinder. The combination unit veered to the right, traveled about 134 feet in a jackknifed configuration, and then came to rest on the west side of I-57 engulfed in flames. The pavement grinder was rotated 228^{0} counterclockwise and pushed rearward about 28 feet. The truck driver and codriver were fatally injured as a result of the collision and postcollision fire. The operator of the pavement grinder was fatally injured as a result of the collision. The semi-combination was destroyed by the collision and fire, and the pavement grinder was substantially damaged.

In June 1989, a contractor hired by the Illinois Department of Transportation was installing raised reflective pavement markers on I-94, a six-lane divided highway, in Chicago, Illinois. A 4.8-mile section of the

right northbound lane was closed for installation of these markers. Four crewmembers, working as two-member teams, were installing markers near the 111 Street exit ramp on the morning of June 24, 1989. One member of the team would install the markers while the other member monitored traffic.

About 8:24 a.m., a 1979 Cadillac traveling north on I-94 entered the construction zone. The vehicle had traveled about 3 miles into the contruction zone when it suddenly veered to the right and entered the closed lane. The Cadillac struck three reflectorized drums and one barricade before striking three of the construction workers. Two workers were killed and one was injured. The driver of the Cadillac stated that he had fallen asleep.

The Safety Board believes that had TMAs been in use on barrier vehicles immediately behind the workers in both of the above accidents, far more protection would have been provided to the workers, and the accidents might not have resulted in fatalities. A vehicle equipped with a TMA could easily have been positioned in front of the grinding machine in the Effingham accident, and in front of the workers in the Chicago accident.

Notwithstanding the work by the University of Tennessee Transportation System Center, the Safety Board is concerned that the use of TMAs in various work zone environments has not been sufficiently addressed in the guidance and reference materials routinely used by state and local transportation officials. According to the FHWA, because a TMA is not a traffic control device, the MUTCD and the Traffic Control Devices Handbook are not the appropriate manuals in which to discuss the applicable uses of TMAs. According to FHWA and AASHTO officials, the Roadside Design Guide would be the appropriate document in which to incorporate guidance on the applicable uses of TMAs in short-term moving/maintenance operations and long-term stationary construction sites. Although the Safety Board recognizes that additional tests and research are needed to determine the effectivness of TMAs when impacted at an angle or offset and when used in situations where the speed differential exceeds 45 mph, the Board believes that sufficient information is currently available to provide some guidance on the various applications of TMAs. Accordingly, the Safety Board urges AASHTO to incorporate such guidance into the Roadside Design Guide. The Safety Board also believes that even though the TMA is not considered a traffic control device and, consequently, the applicable uses of TMAs would not be appropriate in the MUTCD, a reference to the Roadside Design Guide concerning the uses of TMAs would be appropriate in the MUTCD and the Traffic Control Devices Handbook.

One figure in the proposed revisions to the MUTCD illustrates trucks equipped with TMAs, one of which is straddling the pavement edgeline, as optional in a mobile operation on a multilane road (see appendix B). Because the effects of impacting TMAs at various angles and offsets are currently being researched and given the warning of one manufacturer not to position a truck with a TMA astraddle or partially in a lane, the Safety Board believes that the FHWA should revise the figure in the proposed revisions to the MUTCD to eliminate the depiction of vehicles equipped with TMAs positioned astraddle pavement edgelines.

Operation of Vehicles With a TMA

Also of concern to the Safety Board is that drivers of vehicles equipped with TMAs may not be provided adequate protection in terms of restraints and headrests. In the moving maintenance operation of the State of Illinois Department of Transportation during September 1989, discussed at the beginning of this chapter, the driver of the vehicle that struck the TMA was not injured. However, the driver of the State department of transportation vehicle that was equipped with a TMA did receive minor injuries, including cervical neck strain, scalp abrasion, and abrasion/contusion on his right calf. The investigation of the accident revealed that the State vehicle was not equipped with a headrest and that the seatbelt was being worn loosely at the time of the accident. The Safety Board believes that because of the likelihood of rear-end collisions, vehicles equipped with truck-mounted attenuators need to be equipped with lap/shoulder restraints and headrests to provide drivers the maximum protection possible.

In a manual developed by one manufacturer of TMAs, safety instructions address the use of seatbelts and headrests for the occupants of trucks equipped with a TMA (see appendix C). The Safety Board is aware that some State highway departments recognize the need to provide protection to the drivers of trucks with TMAs. California, for example, installs headrests and lap/shoulder restraints on vehicles equipped with TMAs. The Safety Board is concerned, however, that recognition of the need to provide the driver with adequate protection to mitigate injuries may not be widespread, as the above accident suggests. The FHWA and AASHTO should encourage State highway departments to incorporate these safety features into the specifications for the purchase of new vehicles and to retrofit existing vehicles.

FLAGGING

The issue of flagging at work zone sites was most recently addressed by the Safety Board in its report of the Sutton, West Virginia, accident.[26] The flagger at the accident site was positioned 200 to 210 feet ahead of the area where the work was being performed. The MUTCD states, "Flagger stations shall be located far enough in advance of the work site so that approaching traffic will have sufficient distance to reduce speed before entering the project. This distance is related to approach speed and physical conditions at the site; however, 200 to 300 feet is desirable." In addition, the West Virginia Department of Transportation (WVDOT) manual on "Traffic Control for Street and Highway Construction and Maintenance Operations" recommends that the flagger station should be in advance of the work site so that the "approaching traffic will have sufficient distance to reduce speed before entering the project...500 feet is desirable." The placement of the flagger complied with MUTCD guidelines, but not with the WVDOT manual. As previously noted, the FHWA is revising Part VI of the MUTCD, which includes flagger placement. Consequently, as a result of its investigation of the Sutton accident, the Safety Board recommended that the FHWA:

H-91-30

> Revise Section 6F-5 of the Manual on Uniform Traffic Control Devices to establish recommended distances for posting flaggers at work zones based on the legal speed limit approaching the zone.

The FHWA did not concur with the Board's Safety Recommendation H-91-30. In its letter of September 20, 1991, the FHWA stated that "the recommended distances for posting flaggers at work zones are adequately covered in the MUTCD and that these distances exceed the stopping sight distances for the range of legal speed limits which are encountered at work sites." The FHWA also referred to the MUTCD provision regarding placement of an "Advance Flagger Sign" at a distance of 500 feet in advance of the flagger placement point.

The Safety Board did not agree with FHWA's position and in a letter dated January 22, 1992, stated:

> ...the provisions of Section 6F-5 of the MUTCD should be revised by either deleting the sentence concerning "desirable" distance from the MUTCD or including in the MUTCD a detailed matrix table based on various speeds and stopping distances. Because of the institution of high speed limits (65 mph) on certain highways, such a revision will enhance motorist safety....

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[26] "Multiple Vehicle Collision and Fire in a Work Zone on Interstate Highway 79 Near Sutton, West Virginia, July 26, 1990" (NTSB/HAR-91/01).

The Safety Board urged the FHWA to reconsider its position and classified Safety Recommendation H-91-30 as "Open--Acceptable Response," pending FHWA's further review of the Board's comments.

The American Traffic Safety Services Association (ATSSA)[27] also provides guidance on flagging procedures, citing other factors that should be taken into consideration when determining the location of flaggers. The ATSSA's Flagging Handbook states, "Generally flagger stations should be located about 200 feet and not less than 100 feet in advance of the work site. Factors such as visibility, speed and volume of traffic, condition of the road, and work being done should be considered in determining your location." The handbook further states, "Certain situations may require that advance flaggers also be used where there is limited sight distance to the work area, or when traffic volume is such that the distance between the first vehicle in the line and the last vehicle in line is great."

The Safety Board's investigation of accidents in conjunction with this safety study revealed several instances in which the placement of the flagger appeared inadequate given the various conditions at the work site. In the accident that occurred near Effingham, Illinois, on June 15, 1988, (previously discussed in the chapter "Truck Mounted Attenuators"), the flagger was located about 100 feet beyond the pavement grinder to move cones as the pavement grinder continued down the interstate highway, rather than the distance of 200 to 300 feet in front of the operation as recommended by the MUTCD and the Flagger's Handbook of the Illinois Department of Transportation.

The accident near Effingham, Illinois, also highlights the issue addressed in the report of the Sutton, West Virginia, accident: that flaggers should be in a position to warn workers of approaching danger, such as out-of-control vehicles. The farther a flagger is placed ahead of the actual work area, the more difficult it becomes to warn workers in the zone of an erratic vehicle's approach. As a result, the Safety Board urged the FHWA to "add a section to the MUTCD encouraging or requiring the use of audible warning devices, such as horns, by work zone flaggers to alert highway workers of the approach of an erratic vehicle" (Safety Recommendation H-91-31). The FHWA responded positively stating that it would consider adding information to the new Part VI of the MUTCD regarding the intent of the Board's safety recommendation. As a result, Safety Recommendation H-91-31 is currently being held in an "Open--Acceptable Response" status.

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[27] The American Traffic Safety Services Association (ATSSA) is a nonprofit association organized for the purpose of promoting the best interests of the companies that supply traffic control and safety devices and materials and services to governmental agencies and private industry by providing educational programs, data collection, marketing information, and a means for the exchange of information. ATSSA's primary goal is to improve the safety of the motorist, pedestrian, and worker through the use of more effective traffic control devices and procedures.

About 1:30 p.m. on September 19, 1989, a 1987 Toyota pickup truck and a 1984 GMC utility pickup truck were northbound on State Route 22 near New Lebanon, New York. The vehicles were traveling through a maintenance work zone during rain. The speed limit was 55 mph. The Toyota driver was stopping for a flagger standing in the roadway when the GMC driver approached from the rear, applied brakes, slid on the wet pavement, and crashed into the rear of the Toyota. Neither driver was seriously injured.

In the area of the accident, State Route 22 goes through mountainous terrain with many curves and grades. There was a 0.3-mile tangent followed by a hillcrest and a curve about 150 feet before the accident location. The flagger would have been visible to approaching traffic for only about 150 feet. A "One Lane Ahead" sign and a "Flagman Ahead" sign were located on the shoulder of State Route 22 about 4 miles and 3 miles, respectively, before the flagger's location.

On April 17, 1989, the New York State Department of Transportation began a moving road patching operation on State Route 3 near Harrietstown, New York. The westbound lane was closed for the repair work, and the eastbound lane was controlled by two flaggers. About 2.5 miles west of this location, a "Work Area" sign and a "Flagman Ahead" sign were placed on the shoulder of the roadway. The area is rural and the terrain is mountainous. The eastbound lane descended an 11-percent grade for about 590 feet approaching the work area.

About 1:40 p.m., a GMC flatbed truck was eastbound on Route 3. The posted speed limit was 55 mph. As the truck crested a hill, a flagger was waving an eastbound 1989 Mazda to stop. As the Mazda was slowing to a stop, the GMC truck, which was braking, swerved to the left, began to overturn, and struck the Mazda in the rear. The Mazda was pushed forward and to the right 62 feet into a cable guardrail on the shoulder. The restrained truckdriver and the restrained front occupants of the Mazda were not injured; the unrestrained occupant in the rear seat of the Mazda suffered moderate injuries.

After cresting the hill, the truckdriver had a view of the flagger for about 450 feet. With a posted speed limit of 55 mph on a descending grade, the distance was insufficient to enable the driver to react, reduce speed, and stop short of the traffic ahead. Given the topography of the area, the flagger should have been located at the crest of the hill or an additional flagger should have been placed at that location.

Although the ATSSA's guidance on the placement of flaggers cites more factors than that provided by the FHWA, the above two accidents illustrate that further guidance is needed on the placement of flaggers at work zone sites. Because these accidents suggest that factors in addition to the legal speed limit approaching the work zone should be considered in establishing recommended distances for posting flaggers at work zones, Safety Recommendation H-91-30 is being placed in a "Closed--Unacceptable Action/Superseded" status. A new recommendation is being issued to the FHWA to revise the MUTCD to provide more detailed information on such factors as posted speed limits, actual vehicle speeds, commercial vehicle deceleration

rates, road conditions, and topography in determining the placement of flaggers at work zone sites. Because of current technology, the need for the flagger to warn workers vocally of impending danger is no longer a factor that has to be considered in determining the location of flaggers.

HUMAN PERFORMANCE FACTORS

The Safety Board's concern about human performance, including inattention from fatigue and alcohol impairment, in all modes of transportation is well documented. Based on its experience in accident investigations, the Safety Board in 1989 called for an aggressive Federal program to address the problems of fatigue and sleep issues in transportation safety. The Safety Board stated that such a program should include a coordinated research effort, an extensive educational effort directed toward all segments of the transportation industry, and a systematic review and improvement of regulations governing hours of service across all transportation modes.[28]

In calling for a Federal program, the Safety Board stated in its recommendation letter to the Secretary of the U.S. Department of Transportation that, "some of the clearest instances of fatigue-related problems are seen in the Safety Board's investigations of major highway accidents. As a result of its investigation and analysis of 182 fatal-to-the-driver heavy truck accidents that occurred in eight States between October 1, 1987, and September 30, 1988, the Safety Board concluded that the most frequently cited cause of or factor in these accidents was truckdriver fatigue."

As a follow-on to the Board's investigation of the fatal-to-the-driver heavy truck accidents, the Board is currently studying the role of fatigue in commercial truck driver accidents. Factors that are believed to increase the likelihood of driver fatigue will be examined. Those factors include work/rest cycles, sleep patterns and sleep environment, nutrition, physical fitness and health, and requirements to load and unload truck cargo.

The Safety Board has issued several highway-related safety recommendations about fatigue, work duty time and its limitations, and recordkeeping. Recommendations included asking the Office of Motor Carriers (OMC) to issue "On Guard Notices"[29] warning drivers of the problems of fatigue, and recommending that the OMC find methods and means to prevent dozing at the wheel by drivers of carriers in interstate commerce. The Safety Board has stated that there are serious deficiencies in the industry's understanding and application of knowledge about sleep, circadian factors, and fatigue as they affect driver performance on the Nation's highways.

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[28] See appendix D for the text and status of Safety Recommendations I-89-1 through -3 issued to the Secretary of the U.S. Department of Transportation on May 12, 1989.

[29] "On Guard Notices" are informational bulletins prepared and distributed by the Office of Motor Carriers of the Federal Highway Administration. The bulletins alert drivers to potential problems in the highway environment.

A highway work zone presents a unique challenge to an inattentive or otherwise impaired driver. The Safety Board concluded in its report of the Sutton, West Virginia, work zone related accident discussed previously, that fatigue-induced inattention, exacerbated by an inadequate and unbalanced diet the day of the accident, caused the truckdriver to fail to heed warning signs and to slow the truck in time to avoid the collision.

The Safety Board further stated in its report of that accident:

> The traffic control devices in the work zone at the accident site were in substantial compliance with the MUTCD and West Virginia guidelines. The Safety Board believes that these guidelines, concerning signing and other work zone safety features, provide more than adequate advance warning for a vigilant driver, but may be inadequate for an inattentive or otherwise impaired driver.

As a result of its investigation of the Sutton accident, the Safety Board issued the following safety recommendations to the Federal Highway Administration:[30]

H-91-27

Conduct research to determine: (a) what characteristics of work zone traffic advisories work best to counter driver inattention, and (b) how to provide more readily understandable displays of critical information. Use the results of this research to design better and more meaningful work zone traffic advisories.

H-91-28

Encourage the use of work zone safety devices and procedures, such as "rumble strips," that alert the various senses.

H-91-29

Encourage the use of the "design driver" concept, which assumes that some drivers are impaired or inattentive, in designing work zone safety features and signing.

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[30] See appendix E for the Safety Board's January 22, 1992, letter to the FHWA regarding the status of the safety recommendations issued in conjunction with the Board's investigation of the Sutton, West Virginia, accident.

Several accidents investigated by the Safety Board as part of this safety study support the subject of the above recommendations.[31] Examples follow.

Accidents Involving Fatigue

About 4:30 p.m. on November 3, 1989, a 1988 Lincoln sedan with two occupants was stopped in the open left lane of two westbound lanes as a result of traffic congestion in a work zone on I-90, near Blooming Grove, Wisconsin. A 1986 Mercury Lynx 4-door sedan with three occupants was stopped behind the Lincoln. A 1979 Freightliner tractor, pulling a trailer loaded with 25,557 pounds of paper cups, approached the stopped vehicles from behind, jackknifed, and then struck the Mercury. As a result of the impact, the Mercury rotated 180° and then struck the Lincoln. The truckdriver and the occupants of the Lincoln were not injured. The occupants of the Mercury received serious injuries. (See figure 14 for damage to Mercury.)

The construction zone was 3 miles long and involved the resurfacing of the westbound lanes. The construction zone was set up in July 1989, and work was expected to continue through November 1989. Signs indicating construction ahead began at milepost 145.5. (The accident occurred 2.6 miles after the first sign at milepost 142.9.) At milepost 144.5, a message board indicated that the right lane ahead was closed. Three additional sets of signs followed (one sign of each set on each side of the roadway) indicating the distance to the lane closure. The taper for the lane closure began at milepost 143.25, and two flashing arrow panels were located at milepost 143.0.

The driver of the combination vehicle was cited by the Wisconsin State Patrol for (1) inattentive driving, (2) false entries in his daily log book, and (3) operating in excess of the hours of service regulations. The driver had been keeping two daily log books and had been on duty for 71 hours in the 8 days before this accident. A postaccident inspection of the combination vehicle by the Wisconsin State Police Motor Carrier Safety Officer found no equipment violations.

About 4 a.m. on August 14, 1989, a loaded tractor semitrailer was eastbound on I-84 near Sterling, Pennsylvania. The truck was traveling in a 4.7-mile-long construction zone in which the right lane was closed and traffic was channeled to the left lane. At two bridge locations, concrete barriers were used to further reduce the left lane. The barrier extended 5.5 feet into the left lane, reducing the left lane to a width of about 7 feet. Pre-construction pavement markings had not been obliterated. To pass through the work area on the bridge safely, drivers of combination vehicles had to move left and pass through the work area with the left wheels of their vehicles traveling on the 4-foot-wide shoulder between the left edgeline and the bridge parapet wall (see figure 15). As the truck was

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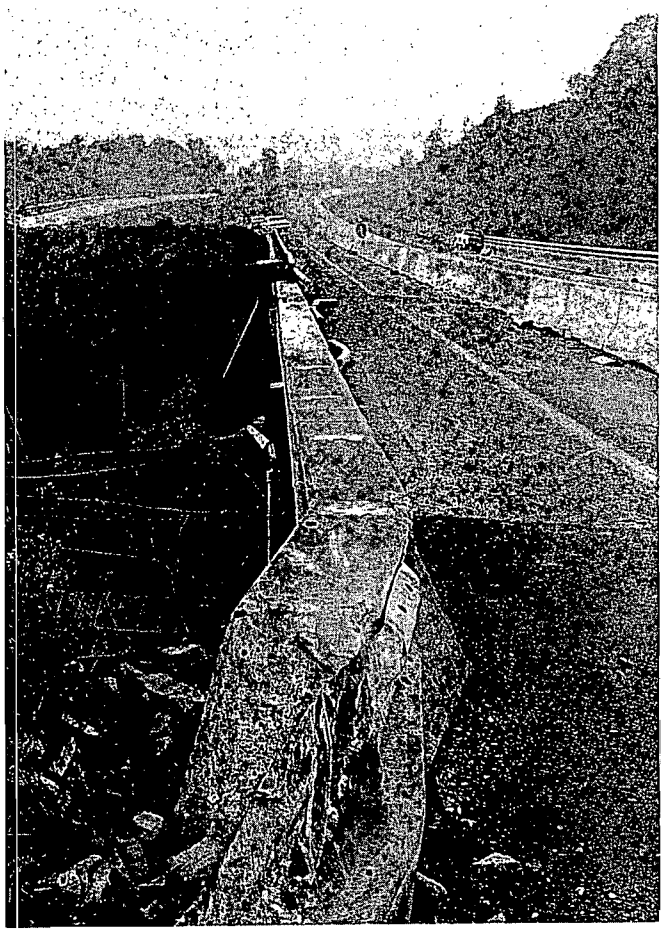
[31] Disposition of these recommendations is discussed later in this chapter.

Figure 14.--Vehicle damage, Blooming Grove, Wisconsin, November 1989



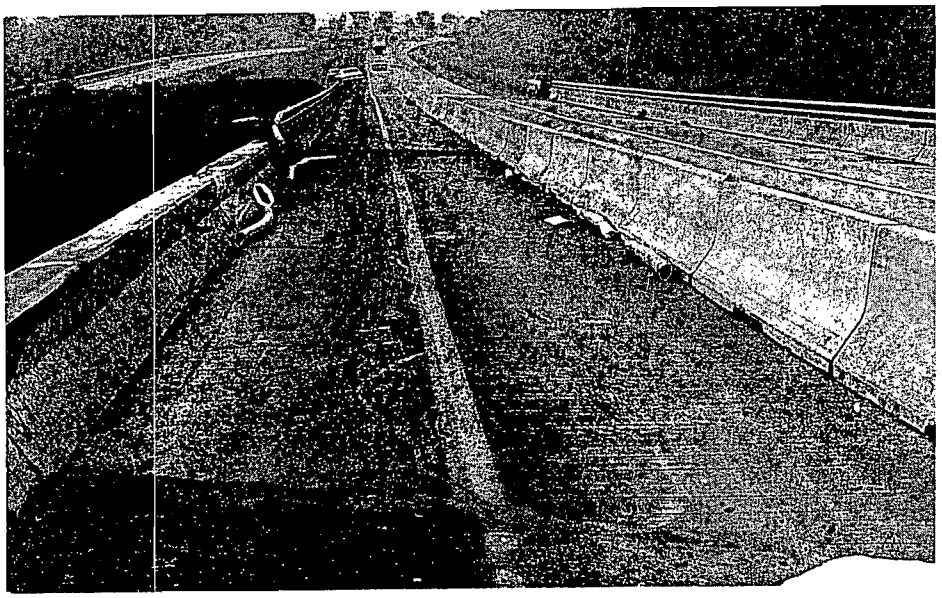


Figure 15.--Construction work zone area, near Sterling, Pennsylvania, August 14, 1989

approaching the second bridge location (about 2.5 miles into the zone), the truck struck the tapered section of the concrete barrier near the centerline, veered left, struck the guardrail, and mounted the bridgerail. After traveling on top of the bridgerail for 96 feet, the truck crossed over the rail and dropped 63 feet to the creek embankment below, landing on its roof. The driver was killed.

A truckdriver following the accident truck stated that the truck had been swerving on the roadway for about a mile and traveling between 40 and 50 mph. A truck in front of the accident vehicle observed the swerving and tried to radio on the citizen band to wake up the driver. The posted speed limit in the zone was 55 mph. However, there were advisory speed plates that reduced the advisory speed to 35 mph in 5-mph increments.

During the afternoon following the accident, the Pennsylvania Department of Transportation began making improvements at both bridges in the work zone to provide motorists increased visibility of the lane closure and better guidance through the narrow, shifted left lane. A flashing arrow panel and a line of vertical panels with yellow lights was placed in the right lane ahead of the tapered concrete barrier. The existing yellow edgeline was obliterated and a wider lane was established by installing a temporary, taped yellow edgeline at the outer edge of the 4-foot-wide left shoulder. Raised pavement reflectors were installed to highlight the entrance of the widened left bridge lanes. Similar reflectors were installed on the inner walls of the barriers and bridge parapets to guide motorists through the bridge. In addition, regulatory 35-mph speed limit signs were erected. Had these additional work zone safety devices been in place before August 14, 1989, they might have effected changes in the performance of the fatigued driver and the accident might have been averted.

About 4:40 a.m., on June 26, 1989, a 1989 Freightliner tractor pulling a semitrailer loaded with 44,100 pounds was traveling westbound through a work zone on I-70 in Bond County, Central Township, Illinois. Interstate 70 had two lanes in each direction; however, only one lane in each direction was open at the time of the accident because of an ongoing resurfacing operation. About 5.4 miles into the work zone and about 4.2 miles after the roadway had narrowed to one lane (left lane), the truck crossed into the closed right lane and struck three type I barricades[32] that were located on the lane line at intervals of 200 feet. The truck crossed the closed right lane and entered the milled north shoulder, going over a pavement edge dropoff, which measured between 6.4 and 8 inches. The truck traveled about 232 feet along the shoulder and struck an unoccupied pavement profiler that was parked on the milled north shoulder. The truck ignited, and the truck and profiler burned in the resulting fire. The driver and codriver were killed.

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[32] As defined by the MUTCD, a barricade is a portable or fixed device having from one to three rails (type I has one rail, type II has two rails, and type III has three rails) with appropriate markings and is used to control traffic by closing, restricting, or delineating all or a portion of the right-of-way.

Based on information contained in the driver's log book recovered from the wreckage, an Illinois State Police Motor Carrier Safety Officer determined that the driver had violated the 10-hour driving rule. The driver was in excess of the 10-hour limit by 3 hours 40 minutes at the time of the accident.

The investigation of the June 1989 accident on I-94 in Chicago, Illinois (previously discussed in the chapter "Truck Mounted Attenuators") revealed that the driver of the Cadillac that struck three workers, killing two of them, stated that he fell asleep and woke up after hitting drums that were used to separate the workers from the traffic. The accident occurred about 8:30 a.m. In the 48 hours before the accident, the driver had slept about 4 1/2 hours (from 12:30 a.m. to 5:00 a.m.) in his car at a rest stop.

Although in most cases, the signs and layout of the work zone met the recommended practices described in the MUTCD, the use of additional work zone safety devices and procedures that alert the various senses may have effected changes in the performance of the above fatigued drivers.

Accident Involving Older Driver

Considerable research has been done on older drivers and the need to compensate for deteriorating faculties that result from the aging process. The results of this research on the aging driver population should have application to drivers in general and specifically for drivers in work zones that are fatigued, inattentive, and under the influence of alcohol or drugs. The following work zone accident illustrates this issue.

About 2 p.m. on April 26, 1989, a 1985 Dodge sedan, occupied by a 77-year-old driver and two passengers, ages 70 and 74, were southbound in a construction zone on the New York State Thruway in South Nyack, New York. In this area of the construction zone, the left lane was closed and the two other lanes were open. The Dodge was traveling in the left open lane (center lane) in the area of milepost 16.8 when it veered to the left, went between traffic cones delineating the left side of the second lane, crossed the closed third lane, and crashed into the rear of a dump truck that was stopped on the left shoulder. The three occupants of the Dodge were killed, and the truckdriver reportedly received minor injuries. The front seat occupants of the Dodge were using the available restraints, whereas the rear seat passenger was not restrained. It was unknown if the truckdriver was using a restraint.

A witness traveling southbound in the right lane and drivers of several cars to the rear of the Dodge stated that the car suddenly swerved to the left for no apparent reason and ran into the back of the truck. The witness further stated there were no cars in the immediate vicinity in front of the Dodge and no one cut the vehicle off. The witness also stated that he did not see any brake lights come on prior to impact.

The road construction was a lane widening project lasting several years. About 10:00 a.m. that morning, highway work crews had closed the southbound

left lane about 1.7 miles prior to the crash site. A series of lane closures and road construction advisory signs had been placed on the left shoulder starting about 1,000 feet before the beginning of the left lane closure. Orange cones were used for the taper and to close the left lane. The left shoulder had been closed and delineated with barrels for several weeks before the accident. In the area of the accident site, the barrels were moved from the shoulder and placed in line with the cones to provide more room for dump trucks that were being loaded in the area. The speed limit was 55 mph.

A faded dashed white line ran diagonally for about 200 feet from the left edge of the center lane, across the left lane and onto the shoulder, intersecting the position where the dump truck was parked. A solid yellow line also ran diagonally for about 200 feet from the edge of the closed left lane, across the shoulder and intersected a dirt area in the work zone near the center barrier. The faded white line and the solid yellow line appeared to be parallel to each other. There were no skid marks prior to impact.

The reason the driver changed lanes so abruptly is unknown. The autopsy indicated that the driver did not have heart failure before the crash. Although it is possible the driver may have been distracted or incapacitated in some other manner before the crash, it is also possible that the varying barrel and traffic cone pattern may have confused the elderly driver and he chose to follow the remnants of old lane markings that led into the truck. Any driver could have been confused by the remnants of old lane markings; however, the older driver may not be able to react as quickly to conflicting traffic cues.

The Safety Board continues to believe that there is a need to alert and educate all drivers about the effects of fatigue and a need to prevent commercial vehicle drivers from exceeding the hours of service regulations and maintaining double log books. The Board's position on these issues is well documented.[33] Nevertheless, the Safety Board also believes that research should be pursued to explore design changes in the work zone area that will protect the inattentive or slightly impaired driver. The FHWA has concurred with the thrust of the Safety Board's Safety Recommendations H-91-27 and -29, discussed previously, and is currently conducting research in this area.

Having reviewed the wording of Safety Recommendations H-91-27 and -29, the Board believes that there is some overlapping with respect to the intent of these two safety recommendations and that the Board can more succinctly define the full range of drivers that we attempted to address in these recommendations--those drivers with somewhat degraded sensory perceptions, whether the degradation is from inattentiveness or impairment. Therefore, the Safety Board is superseding H-91-27 and -29 with a new recommendation urging the FHWA to conduct research to develop design changes in work zones that will aid drivers with degraded sensory perceptions resulting from aging, inattentiveness, or impairment. As previously recommended, the FHWA should

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[33] "Fatigue, Alcohol, other Drugs, and Medical Factors in Fatal-to-the-Driver Heavy Truck Crashes" (NTSB/SS-90/01).

use the results of this research to design better and more meaningful work zone traffic advisories and safety features. Because of the expected increase in the construction and maintenance activities on the Nation's interstate system in the next few years, the increase in highway funding, and the increasing number of older drivers, the Safety Board encourages the FHWA to make the necessary resources available to fulfill the intent of the Board's recommendations as quickly as possible.

Accidents Involving Alcohol

For 1990, FARS indicated that in 197 of the 681 fatal accidents in work zones, the police reported that alcohol was involved. In addition, 43 drivers involved in fatal accidents in work zones were charged with alcohol or drug violations. The California Department of Transportation reported that in less than 2 months in 1990, drivers under the influence of alcohol killed five highway work zone workers.

> To deal with the everyday threat of the DWI [driving while intoxicated] driver, it is imperative that such drivers be treated as drivers who need the best of navigational aids, that the layout of work area delineation be very visible day and night and present no surprises with abrupt or misleading geometrics....Drinking drivers acquire much of the same deterioration of faculties that may be caused by aging. The need for light at night increases, visual acuity deteriorates, reaction time slows and complex decisions become more difficult. The raising of the design visual acuity standard should result in a favorable impact in terms of safety enhancement for the legally drinking driver as well as the sober driver.[34]

Six accidents investigated by the Safety Board in conjunction with this study involved alcohol. In four of the accidents, the blood alcohol content (BAC) level was above .212 percent, and in the fifth it was at .182 percent. The Safety Board recognizes that with drivers' BACs at these high levels, very little, in terms of improved traffic control advisories, can be done to protect against the driver. Rather than attempt to improve designs to protect against drivers at these high impairment levels, the Safety Board continues to believe that every effort should be made to keep these drivers off the roads. It is unrealistic, however, to expect to eliminate alcohol entirely from the driving environment. For the legally drinking driver or the slightly impaired driver whose sensory perceptions are somewhat degraded and whose reaction time slows, the type of design changes discussed above should have a favorable impact.

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[34] Anderson, Roy W., "Part II: Worker Safety in Street and Highway Work Zones--The Drunk Driver Threat," Transafety Reporter, June 1990.

COMPLIANCE WITH EXISTING GUIDELINES

About 7:34 a.m. on October 9, 1986, a charter intercity tour bus was traveling westbound in the right lane on State Route 495 in North Bergen, New Jersey, en route to Washington D.C. As it approached the Kennedy Boulevard exit on Route 495, it suddenly veered left into the adjacent lane, struck the left rear of a passenger car traveling in that lane, then went further into the eastbound contraflow lane, and struck a transit bus transporting commuter passengers to New York City. One passenger aboard the transit bus was fatally injured, and 26 other occupants aboard both buses sustained serious to minor injuries.

The section of roadway in which the accident occurred was within a construction work zone for rebuilding a viaduct. To provide working room for the rehabilitation of the viaduct, the westbound traffic lanes were narrowed and shifted.

In its 1986 report of that accident investigation, the Safety Board reached the following conclusions, among others:

- The temporary lane line striping was not properly aligned.
- The traffic control plan did not include all necessary sign changes required to safely and adequately facilitate traffic flow through the construction zone.
- The New Jersey Department of Transportation local aid safety inspector did not adequately review and inspect the traffic control plans for the construction zone site.
- The New Jersey Department of Transportation safety inspector assigned to the viaduct project failed to recognize the misaligned striping and deficient signing.

Although guidelines existed for proper signing and striping, the traffic control techniques used in the construction area were not in compliance with the guidelines. Accidents investigated in conjunction with this safety study revealed several instances in which the traffic control techniques and devices were clearly not in compliance with existing guidelines. The lack of compliance raises concern about the adequacy of monitoring and reviewing traffic control plans by State department of transportation officials and the adequacy of the FHWA's emphasis on recurring problems. In addition to the lack of compliance with flagging guidelines, as evidenced in the Effingham, Illinois accident on June 15, 1988, two specific problems--pavement edge dropoffs and the obliteration of conflicting pavement markings--highlight this concern.

Conflicting Pavement Markings

The MUTCD addresses the issue of conflicting pavement markings. "Conflicting pavement markings shall be obliterated to prevent confusion to vehicle operators....The intended vehicle path should be clearly defined during day, night, and twilight periods under both wet and dry pavement conditions." The Traffic Control Devices Handbook provides similar guidance, stating: "Inappropriate markings should be removed to eliminate any misleading cues to drivers under all conditions of light and weather."

Despite this guidance, the investigation of the South Nyack, New York, accident (previously discussed in the chapter "Human Performance Factors"), in which the 77-year-old driver suddenly veered into the closed left lane and crashed into the rear of a dump truck, revealed that all preconstruction pavement markings had not been obliterated. Although the reason for the driver's sudden maneuver to the left lane is unknown (all occupants of the vehicle were fatally injured), it is possible that the old pavement markings caused the driver to become confused and the driver followed the old pavement markings when he veered to the left.

The investigation of the Sterling, Pennsylvania, accident on August 14, 1989, (previously discussed in the chapter "Human Performance Factors") in which the driver of the combination unit was killed, revealed that old pavement markings had not been obliterated. The preconstruction yellow edgeline was not obliterated and may have confused the already fatigued driver about the exact location of lanes (see figure 15).

The FHWA has addressed this issue in the past. In a memorandum dated January 7, 1988, FHWA headquarters encouraged regional administrators to "Monitor projects to assure that both temporary and permanent pavement markings and signing are properly applied and removed in work zones. Inappropriate traffic control devices are still being left in place. Division offices should review the States' policies, procedures, and projects."

Pavement Edge Dropoffs

The previously mentioned Roadside Design Guide developed by the AASHTO Task Force for Roadside Safety provides guidance on the need to protect uncompacted shoulders and pavement edge dropoffs. In addition, the FHWA has recognized this problem over the years. In December 1986, the FHWA addressed the issue in a memorandum to regional administrators based on observations during field reviews. This "information was to provide guidelines to States in the development of their own dropoff policy. Any dropoff is considered hazardous, but those greater than 2 inches, left overnight, and immediately adjacent to traffic have a high accident potential." Again in 1987, the FHWA encouraged its regional and division offices to work with States in the development and implementation of policies for pavement edge dropoffs.

Despite this guidance, accidents investigated by the Safety Board in conjunction with this study indicate that the problem continues to exist.

About 10:14 p.m. on September 14, 1989, a 1988 Ford truck tractor in combination with two trailers was northbound on two-lane, two-way U.S. Highway 63 near the northern limits of Portia, Arkansas. The driver stated that as he was approaching oncoming traffic, his right tires went off the pavement. The combination vehicle traveled off the right edge of the asphalt onto a soft shoulder that was under construction. After the combination vehicle traveled about 300 feet along the shoulder, the rear trailer broke loose and rolled onto its right side. The trailer received moderate damage. The driver was not injured.

The contractor had been doing shoulder work on both sides of the travelway on the 1.4-mile project, even though Arkansas highway construction specifications stated that "shoulder material shall not be cut from the edge of the pavement on both sides of any section open to traffic." The shoulder material was a soft clay material, and in some areas of the project, the shoulder was 12 inches below grade. Because of rain on the day of the accident, the shoulders in the accident area were soft and muddy.

About 1 hour after the above accident, a second truck tractor in combination with one semitrailer, also traveling northbound, was being directed around the accident scene. As the combination vehicle was being directed to the left side of the travelway, the truck went off the edge of the asphalt onto the muddy shoulder. As the driver attempted to turn back to the right, the combination unit rolled onto its left side.

On August 3, 1989, construction work was being performed on 2.5 miles of State Highway 28, a two-lane highway, near Distant, Pennsylvania. The construction work involved building up the roadway and adding a passing lane. A "Road Construction 1/2 Mile" sign was the first sign to warn motorists of the construction ahead. In the next 1/2 mile, there were 10 signs posted on the shoulder of the southbound lane: a regulatory sign, 4 warning signs, and 5 construction signs. The first three construction signs marked the distance to the construction zone. The next sign read "Be Prepared to Stop," and the last sign indicated the start of construction. The speed limit approaching and through the construction zone was 55 mph.

Approaching the construction zone southbound, the southbound lane and northbound lane were 10.25 feet wide and 12 feet wide, respectively. Within the construction zone, the southbound and northbound lane widths were 7.67 feet and 13 feet, respectively. Within the first 20 feet of the construction zone, there was a 5-inch dropoff on the outside edge of the southbound lane. Over a distance of 20 feet, the 5-inch dropoff increased to 6.5 inches onto an 8-inch-wide ledge. There was another dropoff of 6.5 inches at the outside of the ledge for a total dropoff of 13 inches from the pavement surface. No signs were posted to warn of the dropoffs or reduced lane width for the southbound lane, and pavement markings were not added to delineate the reduced southbound lane width.

The MUTCD states that "Road Narrows" signs (2C-20) (W5-1) are intended for use in advance of a transition on two-lane roads where the pavement is reduced abruptly to a width such that two cars cannot pass safely without

reducing speed. Based on the wording of the MUTCD, the use of these signs is not mandatory.

About 5:15 a.m., on August 3, 1989, a southbound truck, with its lights on, loaded with 2,000 pounds of liquid nitrogen, was approaching the construction zone. Upon entering the construction zone, the southbound truck went off the pavement. The right front tire rode on the 8-inch-wide ledge (a 6.5-inch dropoff) while the right rear tires rode outside of the ledge (a 13-inch dropoff). After travelling a short distance, the truck came back onto the pavement, crossed the southbound and northbound lanes, and hit a drainage culvert on the east side of the roadway. The truck then rolled over 360 degrees and came to rest in the ditch. The truckdriver sustained a broken leg.

Drivers of trucks following the southbound truck estimated that the southbound truck was travelling about 25 mph because of fog in the area at the time of the accident.

The above accidents suggest that States are not adequately monitoring work zone projects to determine if contractors are complying with existing guidelines. The problem may well be a financial one, in that adequate funding is not available for the review and monitoring process. However, more emphasis needs to be placed on these problem areas by FHWA division offices and State transportation officials. The FHWA reviews annually each State's work zone traffic safety program and conducts on-site reviews of work zone projects. The States, however, are ultimately responsible for their or their contractors' compliance with existing guidelines. The Safety Board believes that AASHTO, in cooperation with the FHWA, should develop a program to enhance compliance with existing guidelines regarding work zone safety features. The States may need to allocate a percentage of the funding for projects for monitoring and compliance purposes.

WORK ZONE SAFETY PROGRAMS

Background

From 1972 to 1982, 20 California Department of Transportation (Caltrans) workers were killed in construction work zones. As a result, in 1982, Caltrans initiated an educational program entitled "Give 'Em a Brake" that provided information on work zone safety through the use of billboard space, public service advertisements on radio and television, presentations to driving classes, bumper stickers, and posters. From 1982 to 1987, five Caltrans employees were killed, and according to Caltrans, California experienced a major reduction in the number of employee fatalities, injuries, and lost work days by 1989.

All but nines States have initiated work zone safety programs similar to the "Give 'Em a Brake" program since 1982 when California implemented its program. The AASHTO Subcommittee on Public Affairs issues a semiannual newsletter, "Work Zone Safety," that highlights some of the States' initiatives in this area. Iowa, for example, uses a percentage of its road use taxes to place advertisements on television about work zone safety. Pennsylvania and Delaware have doubled the fines and penalties for motorists' violations in work zones.

In 1988, the Commonwealth of Virginia reported a 70-percent reduction in the number of traffic deaths in construction work zones (from 33 to 10) from the previous 3 years. This reduction was attributed to the implementation of better traffic and project planning, increased safety training, higher quality work zone designs and more effective signing, more police visibility, and a large public awareness campaign. A portion of the awareness campaign included a special section on work zone safety in the Virginia driver's manual.

The North Carolina Department of Transportation has introduced a new logo sign that will be used at major construction zone sites. The logo, which reads "Work Zone--Stay Alert," illustrates the trend to improve motorists' awareness of the dangers in work zones. North Carolina has also established hot line numbers for specific construction and maintenance zone projects. These numbers enable motorists to contact directly the engineer in charge of a given project.

The programs initiated by the States vary from limited efforts, such as occasional news releases and public service announcements, to full year-round campaigns that involve the development of videos and educational programs for high schools, incorporation of work zone safety in driver education programs, improved traffic control devices and advisories, and onsite use of police officers for enforcement purposes. The emphasis with most of the States' programs when first implemented was to educate motorists about the dangers in work zones in order to protect the workers. Some State programs now focus on the need for drivers to recognize the dangers work zones create for motorists and have incorporated engineering, enforcement, and educational

activities into their programs. The underlying issue with each of these activities is excessive speed in work zones and the need for motorists to adhere to speed limits and warnings.[35] Some examples of these activities follow.

Engineering: Improved Traffic Control Devices and Advisories

In its report of the Sutton, West Virginia, accident, the Safety Board stated that the use of oversized speed limit signs in work zones may prompt inattentive drivers to slow their vehicles, noting that the Minnesota Department of Transportation has used 7- by 10-foot speed limit signs in moving maintenance projects and has reported good compliance with reduced speed limits through the zones.

Also in that report, the Safety Board highlighted the need for additional devices and procedures that appeal to the various senses to alert an approaching driver to the presence of a work zone. The Safety Board stated, "Installation of 'rumble strips' at decreasing intervals may cause an otherwise inattentive driver to perceive that his speed approaching a work zone is too high. Progressively decreasing the spacing of drums or barricades may also produce an awareness of excess speed."

The activities of the Strategic Highway Research Program[36] have resulted in several improvements to work zone safety. The specific objectives of their activities with respect to work zones were to improve productivity, communications, and conspicuity of workers and equipment; to reduce congestion; and to save lives. Several ideas have been developed and tested in the field, including a remotely driven shadow vehicle equipped with a TMA, portable speed bumps, a flashing stop/slow paddle, an infrared instrusion alarm, and a queue-length detector. The Safety Board supports these engineering endeavors to improve work zone safety.

Enforcement

During 1989, 369 officers of the Missouri State Highway Patrol worked more than 1,460 hours in construction zone enforcement programs and issued tickets for 1,748 violations, of which 1,088 were for speeding. A comparison of 1989 work zone accident data in Missouri with 1988 data, when an enforcement program was not in place, revealed that total accidents were reduced 15 percent, and that both fatal and injury accidents were reduced 26 percent. The Missouri State Highway Patrol considered the enforcement

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[35] The Fatal Accident Reporting System indicates that speed is reported as a factor in more than 30 percent of the fatal accidents.

[36] The Strategic Highway Research Program is an organization created under the National Research Council to develop and evaluate new technology for improving maintenance and safety.

program a success and continued the program during 1990, when 2,227 tickets were issued for violations.[37] Other States, including Indiana, Kentucky, Maryland, and Wisconsin, are using police at construction work zone sites and have experienced substantial reductions in the number of accidents and speeding violations.

A study was conducted in 1989 on an urban freeway in New York to determine the effects of police officers as traffic managers in reducing speeds at work zones.[38] The study concluded that "It is apparent that use of uniformed traffic control personnel has been an effective tool in regulation of safe management of traffic." The study found that the average speed for all traffic was reduced to the posted limit of 40 mph, that the dangerous top 5 percent of speeders were slowed to an average of 52 mph, and that accidents were substantially reduced.

By July 1991, Michigan State Police and highway engineers had added radar devices to their "Give 'Em a Brake" work zone safety campaign. The campaign is an effort to persuade motorists to slow down in highway work zones. The license plates of speeding motorists are photographed, and the vehicle owners are then advised by letter from the State Police that the driver was detected exceeding the posted speed limit in a work zone. The Michigan Department of Transportation is also field testing six lighted radar controlled signs that display the speed of vehicles approaching an active work zone.

Some States become involved with the engineering and enforcement aspects of a work zone site during the planning stages. The Arizona Department of Public Safety, for example, developed a checklist to improve safety at construction work zone sites. Excerpts of that checklist follow:

- Establish ongoing coordination and communication with traffic and maintenance engineers.
- Have appropriate personnel attend preconstruction conferences.
- Periodically inspect all construction sites to ensure adequacy of traffic control devices.

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[37] The highway official who provided information on the number of violations did not have data on the accident reduction rate.

[38] Frederick, Richard; Walker, Donald D.; Knapp, Eric S.; and Richard, Terrance M. 1989. Field evaluation of work zone speed control techniques. New York State Department of Transportation.

Education: Programs that Target Specific Drivers

Safety officials familiar with work zones cite concern for trucks in work zones. Twenty of the investigations conducted for this study involved trucks. The FARS data indicate that 26.6 percent of the fatal accidents in work zones on the Interstate system involve trucks. Truckdrivers must be educated as to the dangers of the work zones and the need to use additional caution. The Safety Board's preliminary examination of the Commercial Driver License (CDL) program indicates that the level of training and testing on the specific issue of work zone safety could be improved. The Safety Board intends to examine more closely the entire CDL program and may issue recommendations on this subject in the near future.

North Carolina recently revised its driver manual to include a section that addresses its work zone safety program, "Work Zone-Stay Alert." Some States incorporate a section on work zone safety in the high school driving curricula. In Minnesota, the issue of work zone safety is addressed at an early age--kindergarten through 6th grade, with emphasis on moving/maintenance operations such as snow plowing. As new traffic control devices and advisories are introduced into the work zone environment, educational courses may need to be reviewed and updated.

Although various agencies and associations, including the FHWA and AASHTO, have encouraged the development of work zone safety programs, no agency or association has taken the lead to direct a nationwide work zone safety program. The variation and range of work zone safety programs at the State level and the expected increase in construction and maintenance work zone activity in the coming years suggests that a uniform program at the national level, analogous to Operation Lifesaver, the rail/highway grade crossing program, is needed. The FHWA and AASHTO are the appropriate agencies to take the lead in developing a national program that should address engineering, enforcement, and education. To adequately address these three areas of the program, the participation of other organizations should be enlisted, including the National Highway Traffic Safety Administration, the National Safety Council, the American Automobile Association, the American Trucking Associations, Inc., the International Association of Chiefs of Police, the American Road and Transportation Builders Association, the Associated Builders and Contractors, Inc., the American Traffic Safety Services Association, the American Association of Motor Vehicle Administrators, the International Bridge, Tunnel, and Turnpike Association, the National Association of Governor's Highway Safety Representatives, the Highway Users Federation for Safety and Mobility, and the Professional Truck Driver Institute of America. Funding for enforcement and education programs could be provided by a percentage of FHWA's apportionments to States for highway construction.

CONCLUSIONS

1. The usefulness of Fatal Accident Reporting System (FARS) data for work zone accidents is limited (1) because FARS does not distinguish between persons driving highway maintenance vehicles within work zones from other drivers who crash in work zones while traversing the work zone site, and (2) because of the inconsistent ways in which States document work zone related accidents.

2. The lack of exposure data for work zone accidents makes it difficult to compare accident rates in work zones with accident rates on roads elsewhere.

3. Although positive separation of opposing traffic in two-lane, two-way operations is beneficial, this is particularly so on the interstate system because of the high speed limits on these roadways.

4. Truck-mounted attentuators used on vehicles in moving maintenance operations and on barrier vehicles at stationary work zone sites can substantially reduce the severity of accidents in these work zones.

5. The lack of data on the effectiveness of truck-mounted attenuators when impacted at various angles and offsets and at speeds in excess of 45 mph limits the ability to determine the ways in which the devices can be used.

6. More guidance is needed on the applicable uses of truck-mounted attenuators in short-term moving/maintenance operations and at long-term stationary construction sites to improve the protection of motorists and workers in these operations.

7. Because of the likelihood of rear-end collisions, vehicles equipped with truck-mounted attenuators need to be equipped with lap/shoulder restraints and headrests to provide drivers the maximum protection possible.

8. The lack of information in the Manual on Uniform Traffic Control Devices on such factors as posted speed limits, actual vehicle speeds, commercial vehicle deceleration rates, road conditions, and topography contributed to the inadequate placement of flaggers at work zone sites.

9. The lack of compliance with existing guidelines on traffic control techniques and devices in several accidents indicates that the monitoring and reviewing of traffic control plans by State department of transportation officials and the Federal Highway Administration may not be adequate.

10. Although some work zone enforcement and educational programs have reduced the number and severity of accidents in work zones, the variation in State programs and the expected increase in construction and maintenance work zone activity in the coming years indicates a need for a national work zone safety program.

RECOMMENDATIONS

As a result of this safety study, the National Transportation Safety Board made the following safety recommendations:

--to the National Highway Traffic Safety Administration:

Revise the reporting of work zone fatalities to distinguish between persons driving highway maintenance vehicles within work zones and other drivers who crash in work zones while traversing the work zone site. (Class II, Priority Action) (H-92-32)

Review, in conjunction with the Federal Highway Administration, all State accident report forms, select the data elements that comprehensively document work zone accidents, and encourage the States to incorporate these data elements into their accident report forms. (Class II, Priority Action) (H-92-33)

--to the Federal Highway Administration:

Review, in conjunction with the National Highway Traffic Safety Administration, all State accident report forms, select the data elements that comprehensively document work zone accidents, and encourage the States to incorporate these data elements into their accident report forms. (Class II, Priority Action) (H-92-34)

Develop a program to collect exposure data for construction work zones on the interstate system. (Class II, Priority Action) (H-92-35)

Conduct research, in conjunction with industry, to determine the effectiveness of truck-mounted attenuators when struck at various angles and offsets and at speeds in excess of 45 mph, and analyze the safety benefits and shortcomings of using truck-mounted attenuators in such high-speed environments. (Class II, Priority Action) (H-92-36)

Eliminate in figure TA-35, "Mobile Operation on Multilane Road," in the proposed revisions to the Manual on Uniform Traffic Control Devices, the depiction of vehicles equipped with truck-mounted attenuators positioned astraddle pavement edgelines. (Class II, Priority Action) (H-92-37)

Encourage, in cooperation with the American Association of State Highway and Transportation Officials, State highway departments to (1) incorporate headrests and lap/shoulder restraints into the specifications for the purchase of new vehicles given that the vehicles may at times be equipped with truck-mounted attenuators and (2) retrofit existing vehicles used for that purpose. (Class II, Priority Action) (H-92-38)

Revise the Manual on Uniform Traffic Control Devices to require positive separation of opposing traffic when two-lane, two-way operations on one roadway of a normally divided highway are implemented on the interstate system and incorporate this information into the Traffic Control Devices Handbook. (Class II, Priority Action) (H-92-39)

Revise the Manual on Uniform Traffic Control Devices to provide guidance on the placement of flaggers at work zone sites based on factors such as posted speed limits, actual vehicle speeds, commercial vehicle deceleration rates, road conditions, and topography. (Class II, Priority Action) (H-92-40)

Conduct research to identify design changes in work zones that will aid drivers with degraded sensory perceptions resulting from aging, inattentiveness, or impairment. Use the results of this research to design better and more meaningful work zone traffic advisories and safety features. (Class II, Priority Action) (H-92-41)

Develop, in cooperation with the American Association of State Highway Transportation Officials, a program to enhance compliance with existing guidelines regarding work zone safety features. (Class II, Priority Action) (H-92-42)

Develop, in cooperation with the American Association of State Highway and Transportation Officials, a national work zone safety program that integrates substantive enforcement and public information and education efforts. Enlist the support of those organizations and associations that can provide expertise in the areas of engineering, enforcement, and education. (Class III, Longer Term Action) (H-92-43)

Refer, in the Manual on Uniform Traffic Control Devices and the Traffic Control Devices Handbook, to the guidance on the applicable uses of truck-mounted attenuators to be incorporated in the Roadside Design Guide. (Class II, Priority Action) (H-92-44)

Determine if a combination of efforts, such as speed reductions coupled with onsite enforcement and positive barriers, may be needed at work zones when commercial vehicles are a relatively large percentage of the average daily traffic. (Class II, Priority Action) (H-92-45)

--to the American Association of State Highway and Transportation Officials:

Incorporate, into the Roadside Design Guide, guidance on the applicable uses of truck-mounted attenuators in short-term moving/maintenance operations and at long-term stationary construction sites. (Class II, Priority Action) (H-92-46)

Encourage, in cooperation with the Federal Highway Administration, State highway departments to (1) incorporate headrests and lap/shoulder restraints into the specifications for the purchase of new vehicles given that the vehicles may at times be equipped with truck-mounted attenuators and (2) retrofit existing vehicles used for that purpose. (Class II, Priority Action) (H-92-47)

Develop, in cooperation with the Federal Highway Administration, a program to enhance compliance with existing guidelines regarding work zone safety features. (Class II, Priority Action) (H-92-48)

Develop, in cooperation with the Federal Highway Administration, a national work zone safety program that integrates substantive enforcement and public information and education efforts. Enlist the support of those organizations and associations that can provide expertise in the areas of engineering, enforcement, and education. (Class III, Longer Term Action) (H-92-49)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

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Adopted: May 12, 1992

APPENDIX A

EXCERPTS FROM MANUAL ON UNIFORM TRAFFIC CONTROL DEVICES

INTRODUCTION

Traffic control devices are all signs, signals, markings, and devices placed on, over, or adjacent to a street or highway by authority of a public body or official having jurisdiction to regulate, warn, or guide traffic.

The need for high uniform standards was recognized long ago. The American Association of State Highway and Transportation Officials published a manual for rural highways in 1927 and the National Conference on Street and Highway Safety published a manual for urban streets in 1929. But the necessity for unification of the standards applicable to the different classes of road and street systems was obvious. To meet this need, a joint committee of the American Association of State Highway and Transportation Officials and the National Conference on Street and Highway Safety developed, and published in 1935, and original edition of this Manual of Uniform Traffic Control Devices. That committee, though changed from time to time in organization and personnel, has been in continuous existence and has contributed to periodic revisions of the Manual, including this 1988 edition. The committee's name was formally changed to the National Committee (NC) on Uniform Traffic Control Devices.

APPENDIX A

Part I. GENERAL PROVISIONS

1A-1 Purpose of Traffic Control Devices

The purpose of traffic control devices and warrants for their use is to help insure highway safety by providing for the orderly and predictable movement of all traffic, motorized and non-motorized, throughout the national highway transportation system, and to provide such guidance and warnings as are needed to insure the safe and iniformed operation of individual elements of the traffic stream.

Traffic control devices are used to direct and assist vehicle operators in the guidance and navigation tasks required to traverse safely any facility open to public travel.

Guide and information signs are solely for the purpose of traffic control and are not an advertising medium.

1A-2 Requirements of Traffic Control Devices

This Manual sets forth the basic principles that govern the design and usage of traffic control devices. These principles appear throughout the text in discussions of the devices to which they apply, and it is important that they be given primary consideration in the selection and application of each device.

The Manual presents traffic control device standards for all streets and highways open to public travel regardless of type or class or the governmental agency having jurisdiction. Where a device is intended for limited application only, or for a specific system, the text specifies the restrictions on its use.

To be effective, a traffic control device should meet five basic requirements:

1. Fulfill a need.
2. Command attention.
3. Convey a clear, simple meaning.
4. Command respect of road users.
5. Give adequate time for proper response.

In the case of regulatory devices, the actions required of vehicle operators and pedestrians should be specified by State statute, or by local ordinance or resolution which are consistent with national standards. Uniformity of meaning is vital to effective traffic control devices. Meanings ascribed to devices in this Manual are in general accord with the Uniform Vehicle Code of the National Committee on Uniform Traffic Laws and Ordinances, which is the nationally recognized standard in this area.

Simply stated, uniformity means treating similar situations in the same way. The use of uniform traffic control devices does not, in itself, constitute uniformity. A standard device used where it is not appropriate is as objectionable as a nonstandard device; in fact, this may be worse, in that such misuse may result in disrespect at those locations where the device is needed.

1A-3 Responsibility for Traffic Control Devices

The responsibility for the design, placement, operation and maintenance of traffic control devices rests with the governmental body or official having jurisdiction. In virtually all States, traffic control devices placed and maintained by State and local officials are required by statute to conform to a State Manual which shall be in substantial conformance with this Manual. Many Federal agencies have regulations requiring standards in conformance with the Manual for their control device applications. I-8 (c) Rev. 5

The Uniform Vehicle Code has the following provision in Section 15-104 for the adoption of a uniform Manual:

> "The (State Highway Agency) shall adopt a manual and specification for a uniform system of traffic-control devices consistent with the provisions of this act for use upon highways with this State. Such uniform system shall correlate with and so far as possible conform to the system set forth in the most recent edition of the Manual on Uniform Traffic Control Devices for Streets and Highways, and other standards issued or endorsed by the Federal Highway Administrator."

Under authority granted by Congress in 1966, the Secretary of Transportation has decreed that traffic control devices on all streets and highways in each State shall be in substantial conformance with standards issued or endorsed by the Federal Highway Administrator.

1A-3.1 Placement Authority

Traffic control devices shall be placed only by the authority of a public body or official having jurisdiction, for the purpose of regulating, warning, or guiding traffic. No traffic control device or its support shall bear any advertising or commercial message, or any other message that is not essential to traffic control.

Any unauthorized sign placed on the highway right-of-way by a private organization or individual constitutes a public nuisance. All unofficial and nonessential signs should be removed.

With proper authority being given, construction contractors and public utility companies are permitted to erect construction and maintenance signs at work sites to protect the public, equipment, and workers, provided that such signs conform to the standards of this Manu-

APPENDIX A

All traffic islands shall be installed by the authority of the public body or official having jurisdiction. For those islands that are elements of street and highway design and are included in the design of the street or highway, no specific authority is required.

All regulatory devices, if they are to be enforced, need to be backed by applicable laws, ordinances, or regulations. Effective traffic control depends not only on appropriate application of devices, but on reasonable enforcement of regulations as well. Standards in this Manual are based on that concept.

1A-4 Engineering Study Required

The decision to use a particular device at a particular location should be made on the basis of an engineering study of the location. Thus, while this Manual provides standards for design and application of traffic control devices, the Manual is not a substitute for engineering judgment. It is the intent that the provisions of this Manual be standards for traffic control devices installation, but not a legal requirement for installation.

Qualified engineers are needed to exercise the engineering judgment inherent in the selection of traffic control devices, just as they are needed to locate and design the roads and streets which the devices complement. Jurisdictions with responsibility for traffic control, that do not have qualified engineers on their staffs, should seek assistance from the State highway department, their county, a nearby large city, or a traffic consultant.

1A-5 Meanings of "Shall," "Should" and "May"

In the Manual sections dealing with the design and application of traffic control devices, the words "shall," "should" and "may" are used to describe specific conditions concerning these devices. To clarify the meanings intended in this manual by the use of these words, the following definitions apply:

1. SHALL-a *mandatory* condition. Where certain requirements in the design or application of the device are described with the "shall" stipulation, it is mandatory when an installation is made that these requirements be met.

2. SHOULD-an *advisory* condition. Where the word "should" is used, it is considered to be advisable usage, recommended but not mandatory.

3. MAY-a *permissive* condition. No requirement for design or application is intended.

APPENDIX B

EXCERPTS OF PROPOSED REVISIONS TO THE MUTCD REGARDING TMAs

Notes for Figure TA-35
Mobile Operation on Multi-lane Road

1. Vehicles used for these operations should be made highly visible with appropriate equipment, such as: flashing lights, rotating beacons, flags, signs or arrow panels.

2. Protection vehicle #2 should be equipped with an arrow panel and truck-mounted attenuator.

3. Protection vehicle #1 should be equipped with an arrow panel. An appropriate lane closure sign should be placed on protection vehicle #1 so as not to obscure the arrow panel.

4. Protection vehicle #1 should travel at a varying distance from the work operation so as to provide adequate sight distance for traffic approaching from the rear.

5. Where adequate shoulder width is available, protection vehicle #1 may drive fully on the shoulder.

6. On high-speed roadways, a third protection vehicle should be used -- vehicle #1 on the shoulder (if possible), vehicle #2 straddling the edge line, and vehicle #3 in the closed lane.

7. Arrow panels shall be as a minimum Type B, 60" x 30".

8. Work should normally be accomplished during off-peak hours.

APPENDIX B

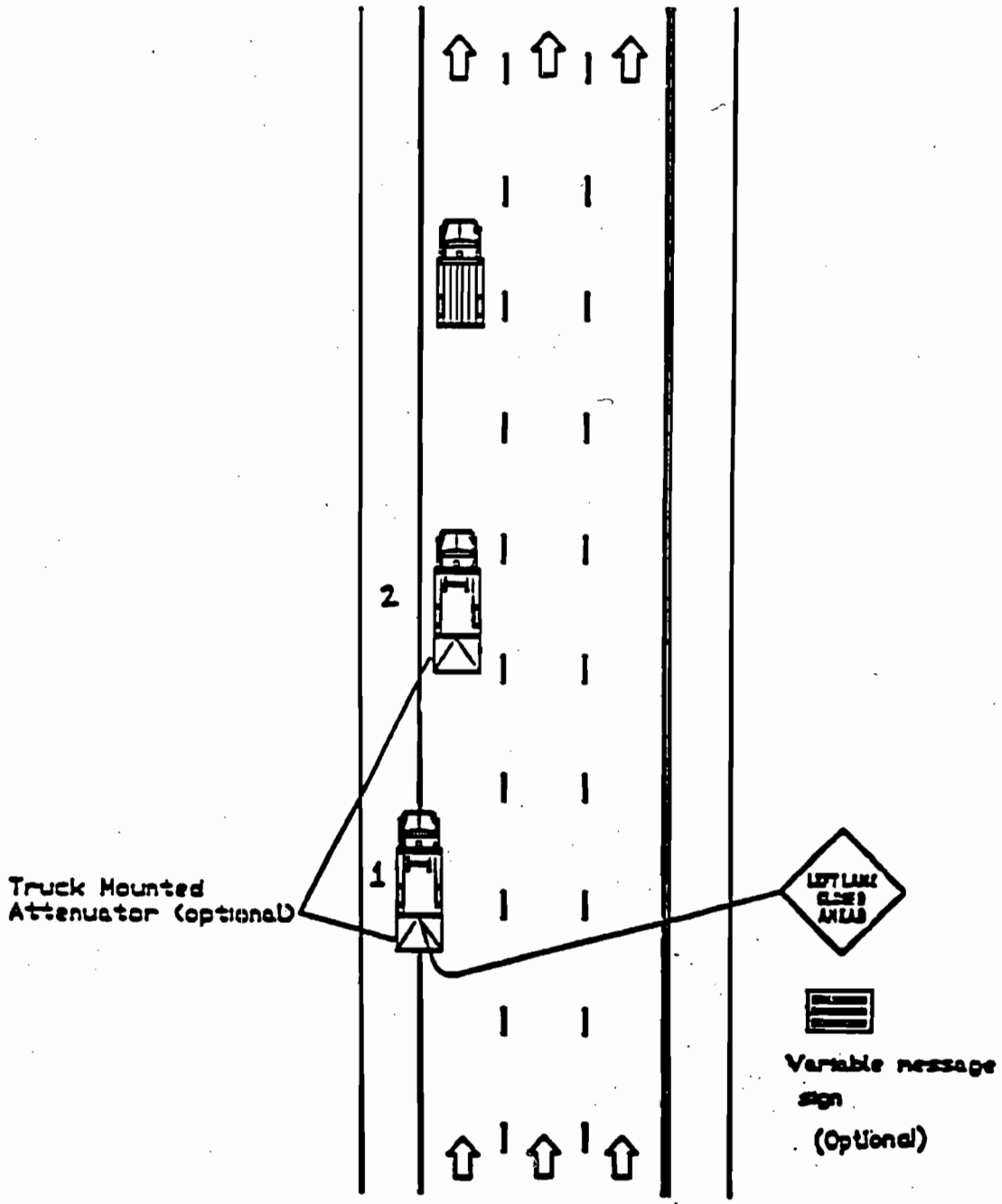

FIGURE TA-35 MOBILE OPERATION ON MULTILANE ROAD

APPENDIX C

MANUFACTURER'S SAFETY INSTRUCTIONS WHEN USING TRUCK-MOUNTED ATTENUATORS

MANUAL
FOR
ALPHA 1000 TMA WITH HEAVY DUTY BACKUP
MODELS 2590 & 2590J
90 DEGREE TILT UNITS

This booklet is intended to supply useful data on the ALPHA Truck Mounted Attenuator (TMA). Completely read and understand this entire manual prior to installing and/or operating the Energy Absorption Systems, Inc. TMA. Included in this manual are the following:

Questions regarding this unit should be directed to:

Energy Absorption Systems, Inc.
One East Wacker Drive, Suite 3000
Chicago, Illinois 60601
Phone: (312) 467-6750 - Customer Services Department

SAFETY INSTRUCTIONS

A. THE CARTRIDGE SHOULD BE RIGIDLY FASTENED TO THE TRUCK AND SHOULD BE 11" TO 13" OFF THE GROUND AND LEVEL. THE CARTRIDGE SHOULD BE LEFT IN THE DOWN POSITION WHENEVER THE TRUCK IS BEING USED AS A SHADOW VEHICLE.

B. THE JACKS SHOULD NEVER BE LEFT IN THE DOWN POSITION WHILE THE UNIT IS ATTACHED TO THE TRUCK. (NOTE: THE REARMOST JACK WILL PROJECT APPROXIMATELY 2" BELOW CARTRIDGE WHEN IN THE UP POSITION). THE BACKUP JACK WHEELS SHOULD BE FULLY RETRACTED BEFORE ROTATING THE JACKS TO THE HORIZONTAL POSITION.

C. MAKE SURE THE BOLT ON THE HYDRAULIC RAM CLEVIS FACES DOWN.  MAKE SURE 1" DIA. PINS IN HYDRAULIC RAM ARE IN POSITION AND RETAINING PINS ARE INSTALLED CORRECTLY.

D. BEFORE RAISING OR LOWERING UNIT, THE OPERATOR MUST BE SURE ALL PERSONS ARE STANDING CLEAR OF UNIT AND SHOULD BE TRAINED AS TO PROPER UNIT OPERATION. THE LATCH PIN MECHANISMS SHOULD BE SEATED COMPLETELY IN THEIR LOCKED POSITION BEFORE PEOPLE WALK DIRECTLY BEHIND AN ELEVATED UNIT. (TO FULLY LOCK THE UNIT IN THE UP POSTION CONTINUE TO ACTIVATE THE "UP" SWITCH FOR 5 SECONDS AFTER THE CARTRIDGE REACHES THE VERTICAL POSITION. VISUALLY INSPECT TO MAKE SURE THE LOCKING PINS ARE IN THEIR FULL LOCK POSITION BEFORE WALKING BEHIND THE CARTRIDGE.)

E. TO PREVENT POSSIBLE SECONDARY IMPACTS WITH THE ERRANT VEHICLE, HEAVY OBJECTS OR BALLAST MUST BE PROPERLY ANCHORED TO THE TRUCK TO PREVENT SHIFTING DURING AN IMPACT. ANCHOR STRAPS SHOULD BE CAPABLE OF RESISTING A 20 G ACCELERATION OF THE TRUCK.

F. THE RESPONSIBLE AGENCY FOR THE TRUCK SHOULD INSPECT IT FOR ADEQUATE OPERATOR SAFETY EQUIPMENT (I.E., SEAT BELTS, HEAD-RESTS, ETC.).

G. FAILURE TO COMPLY WITH THESE INSTRUCTIONS CAN RESULT IN IMPROPER UNIT PERFORMANCE AND POSSIBLE PERSONAL INJURIES..

APPENDIX D

TEXT AND STATUS OF SAFETY RECOMMENDATIONS I-89-1 THROUGH -3

Safety Issue: Fatigue of transportation system operators.

Safety Recommendation Number: I-89-1, -2, & -3

Date Issued: May 12, 1989

Action First Addressed by Board: This is the first Department-wide approach to the human fatigue issue. On a modal basis, safety recommendations go back as far as the marine investigation of the September 21, 1972, collision of the tug CAROLYN and its tow the barge WEEKS NO. 254 with a span of the Chesapeake Bay Bridge/Tunnel. As a result of that investigation, Safety Recommendations M-74-2 was addressed to the Coast Guard calling for studies of the effects of fatigue and manning levels.

Current Status: Open--Acceptable Response

Classification: I-89-1 and -2 Class II -- Priority Action
I-89-3 Class III -- Longer Term Action

Addressee: Secretary, Department of Transportation

Source of Safety Recommendation: Various Modal Accident Investigations with Operator Fatigue as a central issue.

Safety Recommendation Text:

I-89-1
Expedite a coordinated research program on the effects of fatigue, sleepiness, sleep disorders, and circadian factors on transportation system safety.

I-89-2
Develop and disseminate educational material for transportation industry personnel and management regarding shift work; work and rest schedules; and proper regimens of health, diet, and rest.

I-89-3
Review and upgrade regulations governing hours of service for all transportation modes to assure that they are consistent and that they incorporate the results of the latest research on fatigue and sleep issues.

APPENDIX D

Latest Position of Addressee and Safety Board:

On September 12, 1990, the Department of Transportation (DOT) provided Safety Board staff with an in depth briefing of the efforts being made to define and correct the problems associated with human fatigue, work-rest cycles, and other matters associated with staffing and hours-of-work. This effort will be long and complex. There will be progress but a full solution to the problems should not be expected in the near future. A copy of the minutes of the DOT/Safety Board staff meeting is attached.

The DOT provided an extensive update of cross modal activities in this area at a Board briefing held at Safety Board headquarters on Thursday, September 5, 1991.

APPENDIX D

NATIONAL TRANSPORTATION SAFETY BOARD
OFFICE OF SAFETY RECOMMENDATIONS

Meeting: U.S. Department of Transportation and Modal Administrations
Date: Wednesday, September 12, 1990
Time: 10:00 am
Room: NTSB Board Room

Topic: **Safety Recommendations I-89-1, -2, and -3: Human Fatigue in Transportation.**

On May 12, 1989, the Safety Board issued a letter of recommendation containing three safety recommendations to the Secretary, Department of Transportation related to human fatigue in transportation. These safety recommendations are:

I-89-1:
Expedite a coordinated research program on the effects of fatigue, sleepiness, sleep disorders, and circadian factors on transportation system safety. (Class II, Priority Action)

I-89-2:
Develop and disseminate educational material for transportation industry personnel and management regarding shift work; work and rest schedules; and proper regimens of health, diet, and rest. (Class II, Priority Action)

I-89-3:
Review and upgrade regulations governing hours of service for all transportation modes to assure that they are consistent and that they incorporate the results of the latest research on fatigue and sleep issues. (Class III, Longer-Term Action)

The Secretary of Transportation responded on August 11, 1989, citing ongoing human factors research in the various modal administrations of DOT; the DOT Research and Development Coordinating Council; the then proposed DOT National Transportation Policy statement; and ongoing reviews of policy regarding dissemination of educational materials and hours-of-service regulations in the various modal administrations. The Secretary promised to keep the Safety Board appraised of progress.

The Safety Board replied to the DOT response on October 10, 1989, placing these safety recommendations in an "Open--Acceptable Response" status pending the promulgation of the DOT National Transportation Policy statement.

Since we had not received further response from the DOT, it was agreed at an earlier meeting between Chairman Kolstad and Secretary Skinner, that staff level meetings would be held to review the status of all safety recommendations addressed to the DOT. The fatigue/work-rest cycle/hours-of-service safety recommendations are the first to be discussed as such a meeting. Attached are lists of those attending for both the DOT and the Safety Board.

APPENDIX D

Specifically within the highway mode, the Office of Motor Carrier Safety reported on the ongoing, extensive two-phase, baseline study which was, at the time, into its second year. It was reported that the study was designed to determine the incidence of fatigue in commercial truck drivers and then to develop effective countermeasures to that fatigue. Data was to be collected during actual revenue runs on both long and short-haul trips.

The two phases of the study are:

Phase 1: Collection and analysis of over-the-road data.
Phase 2: Testing of countermeasures.

The study was designed to be completed in 4+ years. However, there has already been some slippage because of changes in the work plan. The study is being coordinated through a technical consultation group made up of representatives from Government, labor, industry and the academic community. Through the technical consultation group, the FHWA study will be fully coordinated with a companion study being carried out by the American Trucking Association.

The Safety Board realizes that this kind of effort is necessary and that it will require a great deal of time to complete. These safety recommendations are being held in an "Open--Acceptable Response" status pending the completion of the described efforts.

APPENDIX E

SAFETY BOARD'S LETTER OF JANUARY 22, 1992, ADDRESSING STATUS OF SAFETY RECOMMENDATIONS H-91-27 THROUGH -29

JAN 22 1992

Honorable T.D. Larson
Administrator
Federal Highway Administration
Washington, D.C. 20590

Dear Mr. Larson:

We have reviewed your September 20, 1991, response to the National Transportation Safety Board's Safety Recommendations H-91-27 through -31. These recommendations were issued to the Federal Highway Administration (FHWA) as a result of the Board's investigation of the multiple vehicle collision and fire in a work zone on Interstate 79 near Sutton, West Virginia, on July 26, 1990.

Safety Recommendation H-91-27 asked the FHWA to conduct research to determine what characteristics of work zone traffic advisories work best to counter driver inattention, and how to provide more readily understandable displays of critical information. The FHWA is to use the results of this research to design better and more meaningful work zone traffic advisories. The Safety Board notes that the FHWA through the Strategic Highway Research Program (SHRP) is developing a series of work zone traffic control devices. The FHWA will consider developing and evaluating the improved traffic control devices that result from this research. We appreciate receiving progress reports. Safety Recommendation H-91-27 has been classified as "Open--Acceptable Response."

Safety Recommendation H-91-28 asked the FHWA to encourage the use of work zone safety devices and procedures, such as "rumble strips" that alert the various senses. The Safety Board is pleased to learn that the FHWA will continue to encourage the development and implementation of devices that interact with various human senses. Furthermore, the FHWA recently conducted a work zone traffic control symposium. Various types of material presented at the symposium are now being assembled into a report. We look forward to receiving a copy of the report. Pending further response from your office, Safety Recommendation H-91-28 will be classified as "Open--Acceptable Response."

Safety Recommendation H-91-29 asked the FHWA to encourage the use of the "design driver" concept, which assumes that some drivers are impaired or inattentive, in designing work zone safety features and signing. The Safety Board understands that the FHWA is studying ways of improving safety along

the lines of the "design driver" concept. The research emphasizes designing for the older driver. We would appreciate receiving additional information on the research and development on the intelligent vehicle/highway system as it develops. Pending further response from your office, Safety Recommendation H-91-29 will be classified as "Open--Acceptable Response."

Safety Recommendation H-91-30 asked the FHWA to revise Section 6F-5 of the Manual on Uniform Traffic Control Devices (MUTCD) to establish recommended distances for posting flaggers at work zones based on the legal speed limit approaching the zone. The Safety Board notes the FHWA's position that the recommended distances for posting flaggers at work zones are adequately covered in the MUTCD, and that these distances exceed the stopping sight distances for the range of legal speed limits that are encountered at work sites. (In a further response to this recommendation, the FHWA referred to the MUTCD provision regarding placement of an "Advance Flagger Sign" at a distance of 500 feet in advance of the flagger placement point. However, the Board's recommendation did not address placement of a sign, but rather of the flagger.)

The Safety Board believes that the provisions of Section 6F-5 of the MUTCD should be revised by either deleting the sentence concerning "desirable" distance from the MUTCD or including in the MUTCD a detailed matrix table based on various speeds and stopping distances. Because of the institution of higher speed limits (65 mph) on certain highways, such a revision will enhance motorist safety and will aid in effectively implementing Safety Recommendation H-91-31 (see below) by placing flaggers ahead of the work site at distances sufficient to provide adequate time to sound the warning envisioned by this latter recommendation. Pending your review of our comments, Safety Recommendation H-91-30 will remain in an "Open--Acceptable Response" status.

Safety Recommendation H-91-31 asked the FHWA to add a section to the MUTCD encouraging or requiring the use of audible warning devices, such as horns, by work zone flaggers to alert highway workers of the approach of an erratic vehicle. The Safety Board understands that the FHWA will consider adding information to the manual that will encourage flaggers to carry and use such devices. Pending further response from your office, Safety Recommendation H-91-31 has been classified as "Open--Acceptable Response."

We appreciate your commitment to transportation safety.

Sincerely,

Original Signed By
James L. Kolstad

James L. Kolstad
Chairman

cc: Mr. Donald R. Trilling
Office of Transportation Regulatory Affairs
Washington, D.C. 20590

*U.S. Government Printing Office : 1992 - 311-951/60004