

**Working Paper:  
Literature Search – Task 1**

**Project 2003-27:  
Identification of Traffic Control Devices for Mobile and Short Duration Work  
Operations**

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## TABLE of CONTENTS

	Page
Background	1
Objectives	3
Research Approach	3
Work Zone	4
Manual on Uniform Traffic Control Devices	6
Temporary and Mobile Operations	6
Mobile operations on the shoulder	6
Mobile Operations on a two-lane road	6
Mobile operations or Temporary Road	
closure on a two-lane road	7
Mobile operations on a multilane road	7
Literature Search	12
Work Zone Safety Technology	12
Fluorescent Signs for Work Zone	12
Reflectorized Suits	12
Drone Radar and Speed Indicator/Displays	13
Remotely Operated Autoflagger	13
Truck Mounted Attenuators and Message Boards	13
CB Wizard Alert System	14
Rumble Strips	14
Intrusion Alarm	14
Lane Merger System	14
Law Enforcement	20
Enforcement Activities and Funding	21
Cooperative Enforcement	21
Dedicated Enforcement	22
Motorist Information, Education And Outreach Systems	23
TRB, NCHRP and Proceedings Literature	26
Manufactures and Suppliers	30
Bibliography	31
References	33

## Table of Figures

	Page
Figure 1: Increasing Traffic and Construction Work	2
Figure 2: Typical Work Zone	5
Figure 3: Mobile operations on the shoulder	8
Figure 4: Mobile Operations on a two-lane road	9
Figure 5: Mobile operations on a two-lane road using flaggers	10
Figure 6: Mobile operations on a multilane road	11
Figure 7: Iowa DOT Fluorescent yellow-green sign background	16
Figure 8: Drone Radar Equipment	17
Figure 9: Truck Mounted Attenuators	18
Figure 10: ITS Technology Dynamic Lane Merger Sign	19

## **BACKGROUND**

Work zones are a necessary part of meeting the needs of our nation's aging transportation infrastructure. With the highway infrastructure getting older and requiring consistent maintenance, it is believed that there will be more work zones in future. These work zones coupled with traffic on highways is a major source of future congestion. Due to this congestion, there are more chances of crashes expected, which is a major cause of concern. This increased frequency of work in the work zones makes it necessary to work at day and nighttime, requiring special precautionary measures to avoid hazards. It is estimated that work zones contribute to about 24% of highway delay making people more frustrated due to loss of time. This is graphically shown in Figure1.<sup>(1)</sup>

The detailed studies and research in to work zone crashes showed that there may be several reasons for their occurrence. These include inattentive driving and tailgating by drivers, improper lane merging and maneuvers, disruption of traffic due to closed lanes and inappropriate use of traffic control devices etc. However, crash rate is also affected by the vehicular class, with trucks being the major part of all types of work zone crashes. In addition trucks make a higher proportion of fatal crashes in work zones than in non-work zone areas. The maximum-recorded figure for the work zone fatalities is 833 in the year 1994. Though the number of fatalities in work zones has declined each year since then but 771 fatalities in 1995 and 719 fatalities in 1996 are still a major concern and emphasize the need for continuous work zone safety. Approximately 55 percent of work zone fatalities occur in rural areas but there is a less chance that all these rural accidents are accounted for in the national data. According to a study conducted by the American Association of State Highway and Transportation Officials (AASHTO), work zone accidents tend to be more severe than other accidents and involve more fatalities.

Due to large number of injuries and fatalities in work zones, the need for the improvement of work zone working atmosphere was felt and State DOT's along with other agencies started working on that. Different agencies like SHRP and

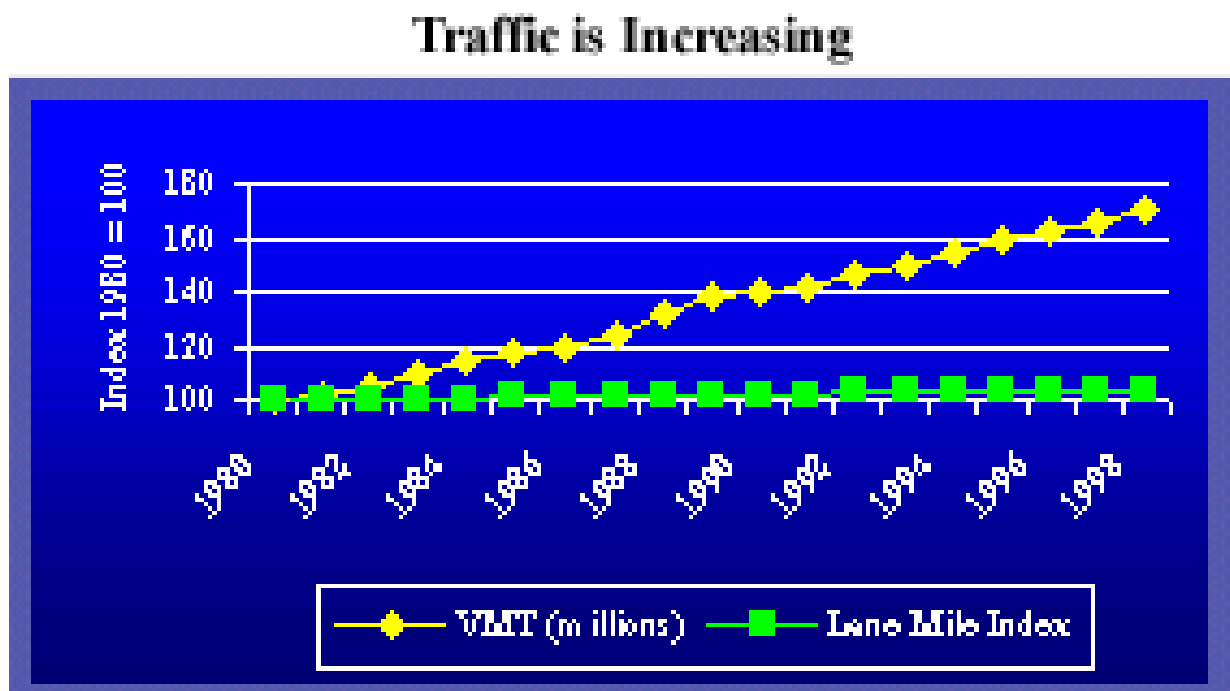
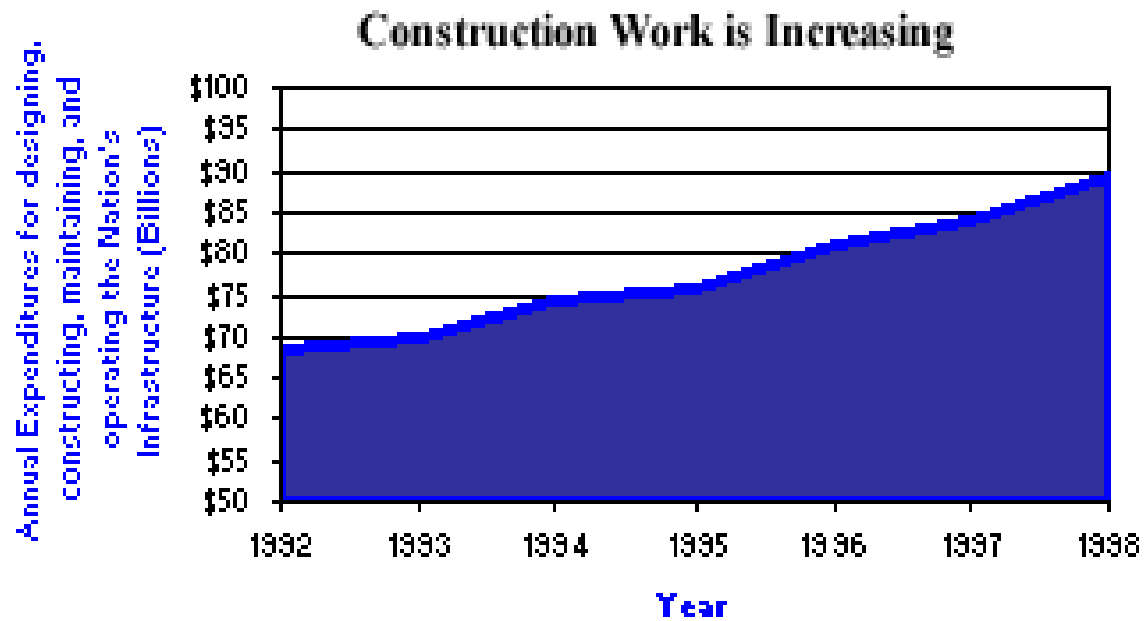


Figure 1: Increasing Traffic and Construction Work.

TRB began evaluating the performance of traffic control devices. Some of the devices produced encouraging results whereas it was noteworthy to see few of them as cause of crashes themselves. This research for NJDOT deals with the identification of technologies and devices for mobile short duration work zone activities like pothole patching and crack sealing etc, with the objective of ensuring worker safety and motoring public. The study will also provide guidelines for the application of safety features after being researched for their effectiveness.

## **OBJECTIVES**

The objective of this research project is to study mobile and short duration work zone safety with particular attention to the identification of work zone safety devices, information systems for the reduction of safety and congestion, and implementation of innovative techniques to reduce delays and crashes due to work zones. The specific objectives of the study are to:

- Identify state-of-the art work zone technologies to improve worker safety in mobile work zone and short term maintenance operations,
- Identify motorist information systems for work zone traffic control to reduce delays and crashes,
- Identify “best practices” for the use of law enforcement to improve work zone safety,
- Identify key issues to be considered from public outreach and educational information systems.
- Provide improvements for maximum protection of the motoring public and workers in the work zone and in the set up of the work zone, and meet the current standards established by internal policies of the NJDOT.

## **RESEARCH APPROACH**

This literature research focuses on identification, evaluation and recommendations for the implementation of technologies and safety devices for highway maintenance workers and motoring public. The research team searched extensively through different sources of information to gather the relevant

material. Among the considerations were the websites of State DOT's, Transportation Research Board (TRB), Strategic Highway Research Program (SHRP), Federal Highway Authority (FHWA) and Texas Transportation Institute (TTI). Variety of Publications such as Better Roads, Roads & Bridges and Public Works Magazine were looked upon to get valuable details.

## **WORK ZONE**

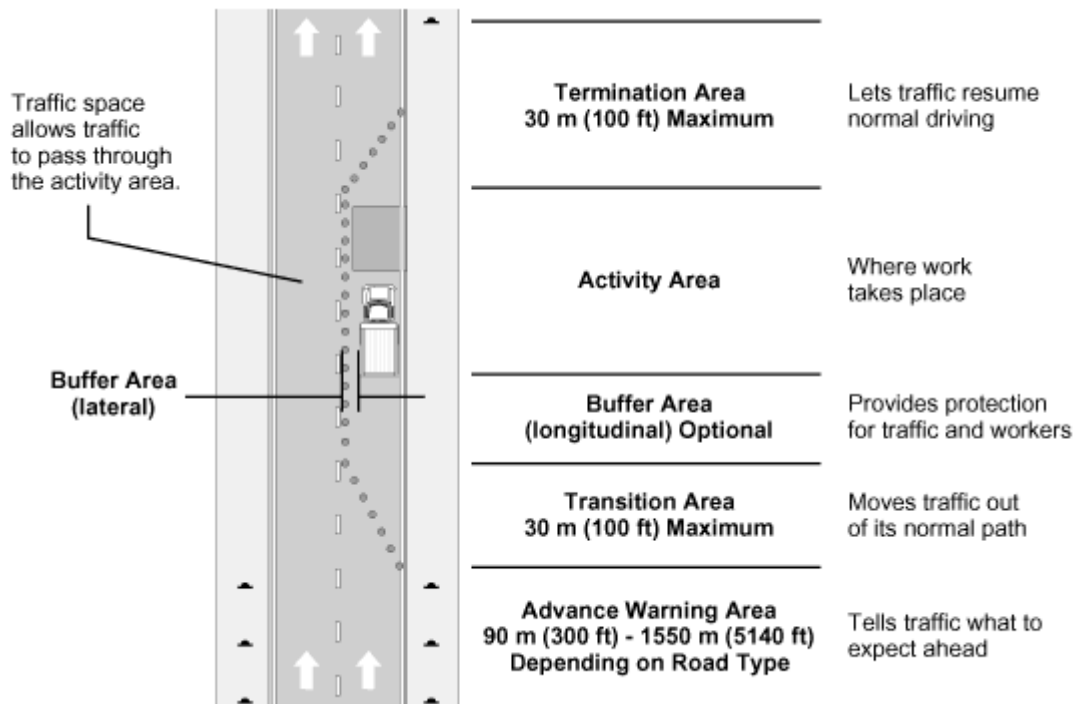
A work zone is an area of a traffic way with highway construction, maintenance, or utility-work activities. A work zone is generally marked by signs, channelizing devices, barriers, pavement markings, and construction/maintenance work vehicles. It extends from the first warning sign or flashing lights on a vehicle to the end of roadwork sign or the last traffic control device. A work zone may be for short or long durations and may include stationary or moving activities. The work zone activities can be categorized into the following:

- Long-term stationary activities: It consists of highway construction such as building a new bridge, adding travel lanes to the roadway and extending an existing roadway.
- Mobile highway maintenance activities: It consists of highway repair work such as crack sealing and pothole repair etc.
- Short-term stationary activities: It consists of utility work such as repairing of electric, gas, or water lines on the highway.

Mobile work zones can be further categorized as:

- Intermittent Mobile Operations: These operations like litter cleanup, pothole patching, or utility operations, involves frequent stops and is similar to stationary operations.
- Continuous Moving Mobile Operations: These operations include work activities in which workers and equipment move along the road without stopping (mowing, pavement striping, street sweeping, or herbicide spraying), usually at slow speeds.





**The Five Defined Areas of the Common Work Zone**

**Figure 2: Typical Work Zone**

## **MANUAL ON UNIFORM TRAFFIC CONTROL DEVICES**

Part VI of the *Manual on Uniform Traffic Control Devices* (MUTCD<sup>(3)</sup>) provides the design and application specifications to meet the special demand for uniform standards for traffic control during construction and maintenance operations on streets and highways in the United States. Temporary traffic control devices (cones and other channelization devices) and advanced warning signs (flagger ahead and lane closure) are used to direct traffic around construction zones. The criteria for design will vary based on environmental conditions such as illumination, weather, traffic speed and other factors of consideration. Although each work zone will have individual traffic control plans based on the type and location of worksite, all traffic control plans will have similarities that are inherent to every work zone.

There are four typical applications of short duration/mobile operations described by the MUTCD. These are listed below, and illustrated in the attached diagrams.

1. Mobile operations on the shoulder (TA-4) Shown in Figure 3
2. Mobile Operations on a two-lane road (TA-17) Shown in Figure 4
3. Mobile operations on a two-lane road using flaggers (TA-13) Shown in Figure 5
4. Mobile operations on a multilane road (TA-35) Shown in Figure 6

### **Typical Applications for Temporary and Mobile Operations mentioned in the MUTCD Part VI**

#### **1. Mobile operations on the shoulder (TA-4)**

This operation requires the following equipment:

- Adequate traffic control signs describing Road work ahead.
- Optional arrow panel
- Optional Truck mounted attenuator (TMA)
- Shadow vehicle with “shoulder work” sign

#### **2. Mobile Operations on a two-lane road (TA-17)**

This operation requires the following equipments.

- Shadow vehicle with optional arrow panel
- Sign with appropriate work type
- Optional Truck mounted attenuator

### **3. Mobile operations or Temporary Road closure on a two-lane road using flaggers (TA-13)**

This applies to road closures not exceeding 20 minutes during the daytime.

This operation requires the following equipments.

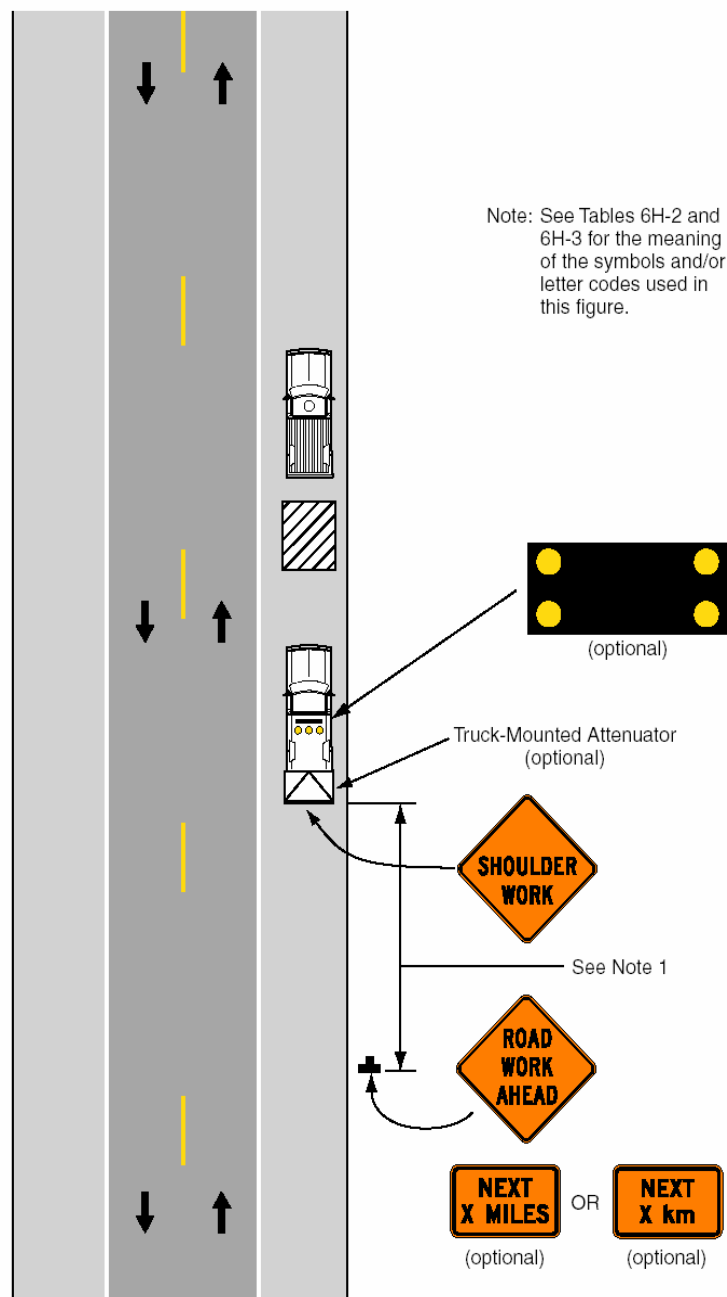
- Flagger
- Signs
- Optional Truck mounted attenuator
- Provide adequate buffer space depending on the speed limit.

### **4. Mobile operations on a multilane road (TA-35)**

This operation requires the following equipments.

- Arrow panels
- Adequate traffic control signs.
- Shadow vehicles with “lane closed” sign

The typical applications figures are provided in the following pages. The figures show the position and type of equipments to be used in temporary and mobile operation. All work zones should strictly adhere to the MUTCD requirements regarding signs and equipment during a work zone operation.



Typical Application 4

Figure 3: Mobile operations on the shoulder

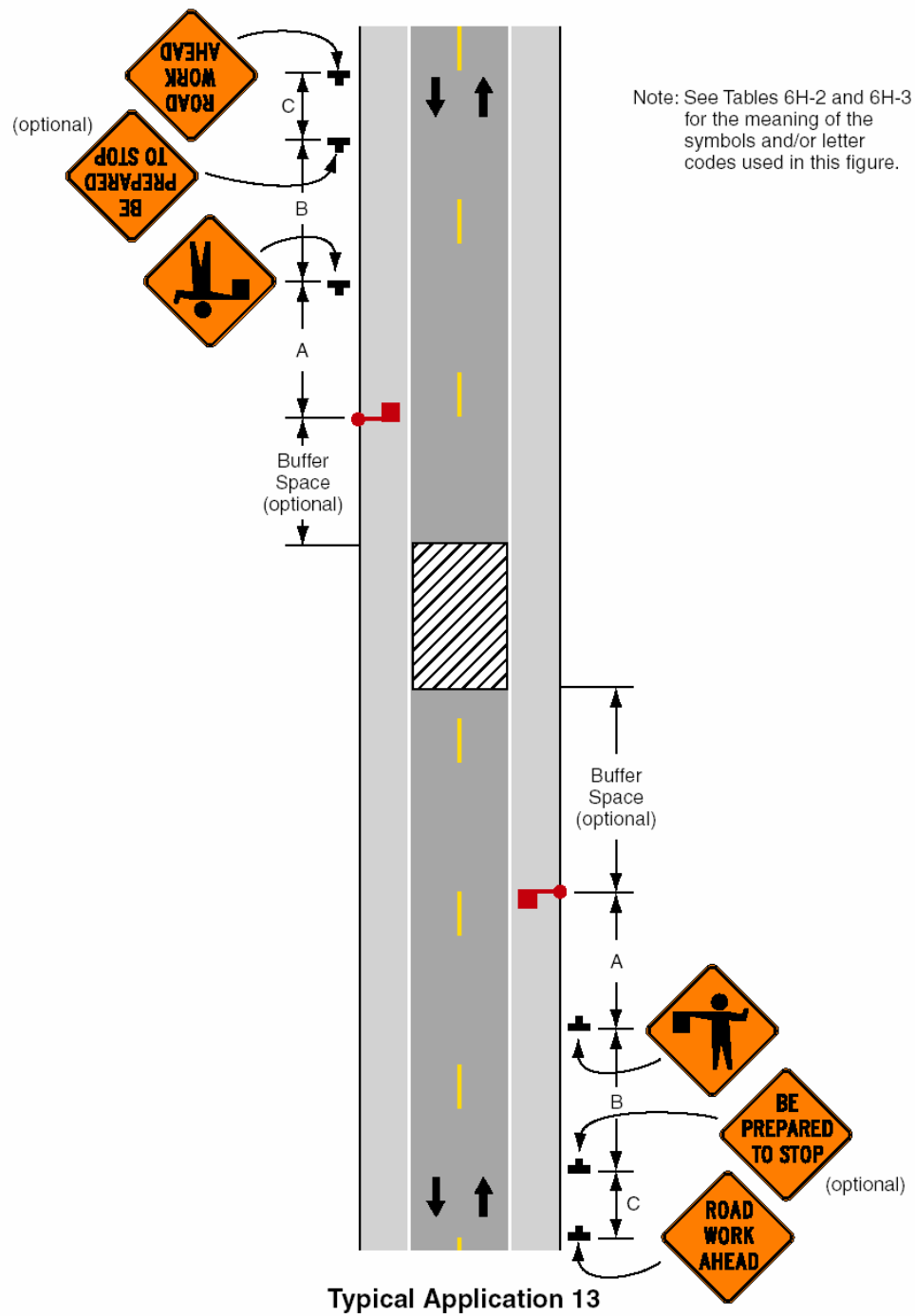
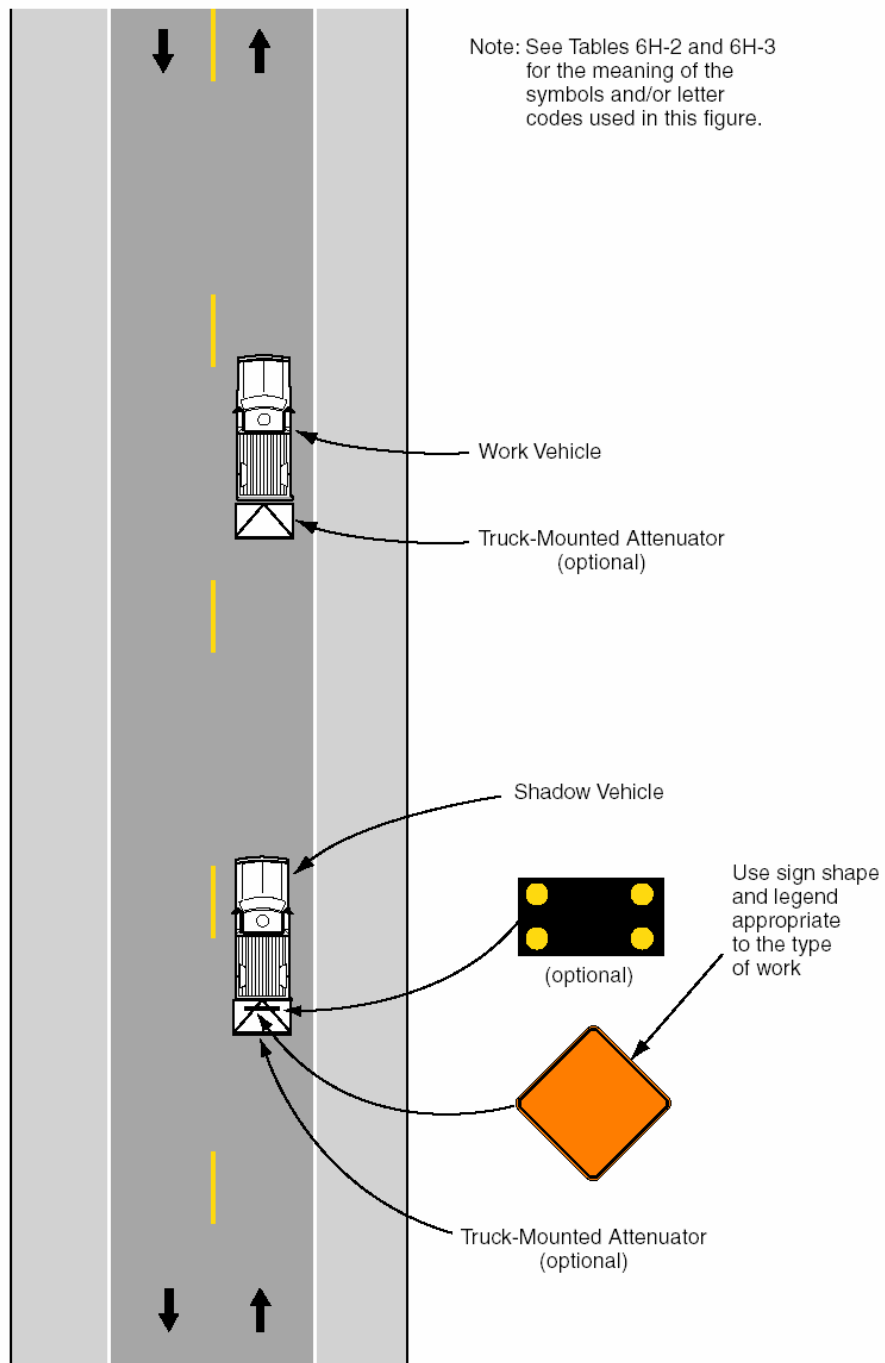
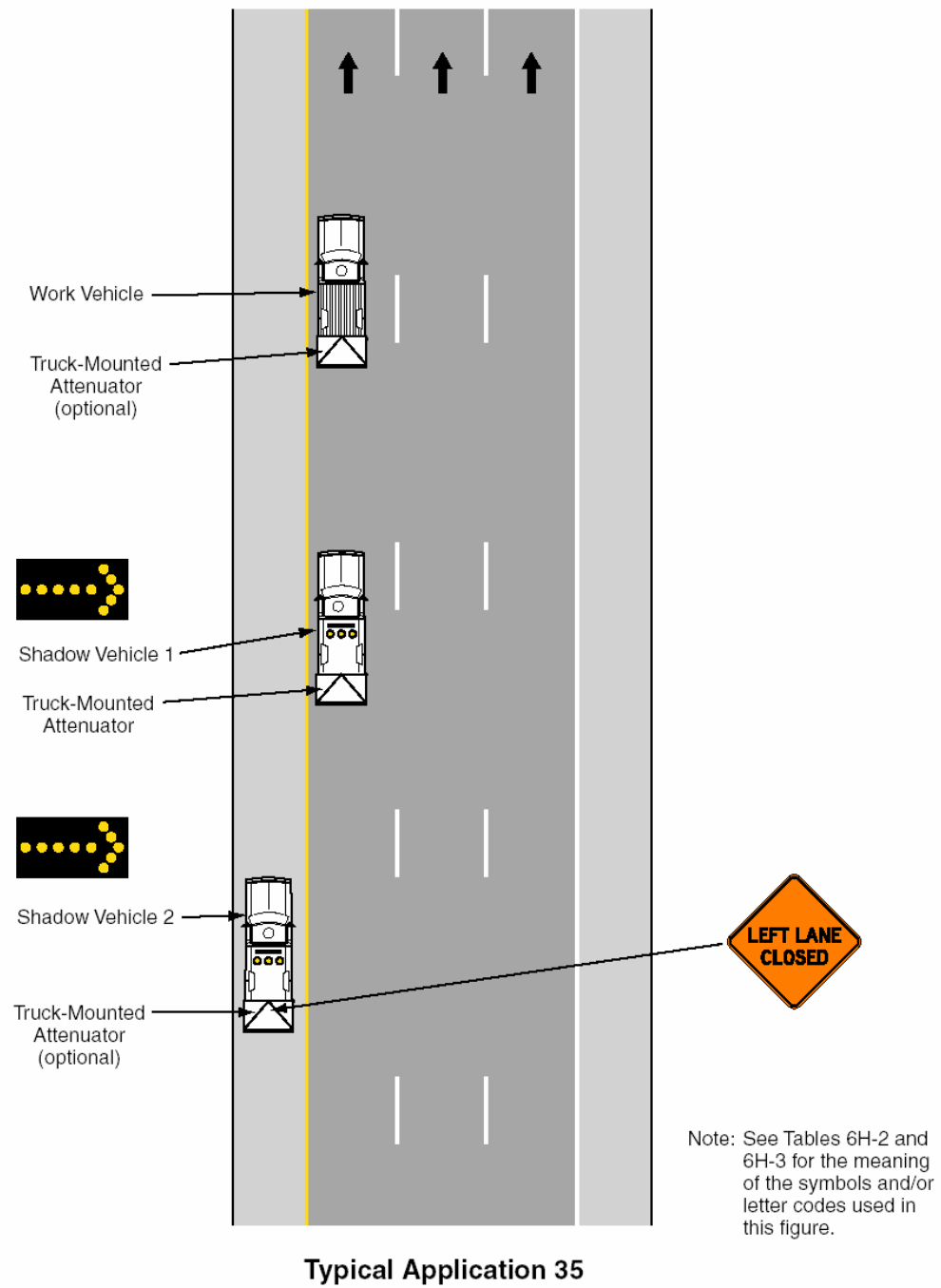


Figure 4: Mobile Operations on a two-lane road (TA-17)



**Typical Application 17**

**Figure 5: Mobile operations on a two-lane road using flaggers**



**Figure 6: Mobile operations on a multilane road (TA-35)**

## **LITERATURE SEARCH**

The literature research focused on safety technologies, motorist information systems, law enforcement, and outreach and education systems for the motoring public. A concentrated effort was made to search for mobile and short duration work zone safety technologies which would be used in field evaluation tasks. A list of researched organizations, agencies and web sites is shown in the bibliography. Specific references are shown in the text.

### **Work Zone Safety Technologies**

The research found numerous devices and technologies which were applicable to all work zones. The devices below were selected for their application to mobile and short duration work zones.

#### **Fluorescent Signs for Work Zone**

The **Iowa DOT** <sup>(11)</sup> is using fluorescent signs for their mobile work zone operations. These illuminated signs (fluorescent being the background) were developed to get the driver's attention approaching the work zones and are shown in Figure 7. The illuminated part may be yellow or green and gives a clear visibility to motorists. These signs are mounted on the back of trucks. The DOT claims that they are producing good results.

#### **Reflectorized Suits**

The FHWA Best Practices Guidebook and Better Roads Magazine <sup>(4,5)</sup> note the importance of improved reflectorized suits for workers. Reflectorized Suits were developed to increase visibility of workers during nighttime maintenance work on highways. California DOT and Iowa DOT have introduced this apparel for their workers. In addition, the Texas DOT uses Fluorescent yellow-green vests and hardhats for improving worker visibility. Reflexite North America has developed its Brilliance Series reflective trim. Brilliance Series surpasses new standards with highly reflective trim that uses enclosed micro prismatic technology to enhance daytime brilliance, as well as improving visibility when wet.



### **Drone Radar and Speed Indicator/Displays**

The purpose of Drone Radar is to reduce speed in work zones resulting safer work areas. Drone radar as shown in Figure 8, is generally placed on portable changeable message sign/signs (PCMS) and since PCMS has the power, it activates Drone Radar. Radar alerts the inattentive drivers before approaching the transition area. A study by Dr. Patrick McCoy <sup>(7)</sup> showed that radar speed displays have been effective, although their working depended on their proximity to work zone area. The Ohio DOT and Massachusetts DOT are employing this device and have found it to be satisfactory. The Virginia DOT is also using Unmanned (Drone) Radar detectors to inform drivers approaching the work zone.

### **Remotely Operated Autoflagger**

This device as the name indicates is remotely operated (controlled by one person) and increases the safety by removing floggers from the traffic lane. Minnesota DOT is using these Slow/Stop Signs and their results were found encouraging. They are low in cost and easily deployable. A study done on the maintenance workers asking them to point out the most hazardous job related to controlling traffic in work zone, nine out of ten the answer came out to be the flagger. <sup>(8)</sup>

### **Truck Mounted Attenuators and Message Boards**

Trucks / trailers can carry different devices to inform motorists of work zone presence as shown in Figure 9. Texas Transportation Institute <sup>(13)</sup> tested a speed control device placed on the back of a trailer and found it very effective as the drivers slowed by an average of 5 mph while passing through work zones. Potable Changeable Message Signs (PCMS) can also be fixed on the top at the back of trucks or trailers. The message changes with the progress of work going on in the construction zone to provide real-time information. The message can be varying speed limit or some warning message like change of lane, congestion ahead etc. alerting the drivers to slow down, because of highway maintenance going ahead. Energy Absorption Systems tested the first truck-mounted impact absorption device that can withstand the force of up to 4,410lbs, traveling at up to

62 miles/hr., meeting both mandatory and optional National Cooperative Highway Research Standards.<sup>(5)</sup>

### **CB Wizard Alert System**

The device is a portable radio that broadcasts real-time work zone information and safety tips to citizens through radio channels. This device is especially good for truckers by letting them know about the traffic patterns through latest updated news. With Certificate of Approval issued in January 1998, Penn DOT is using the device.<sup>(4)</sup>

### **Rumble Strips**

The driving force for using the rumble strips is to alert motorist for the approaching work zone. Rumble strips generally come in yellow or orange color and Ohio State is using it in their work areas. They are not effective in reducing speed significantly; however they are effective in providing audible warnings to drivers.<sup>(4,9)</sup>

### **Intrusion Alarm**

Intrusion alarm developed under the SHRP provides safety to workers in the work zone either by audio or visual means, when a motorist intrudes into the work zone. The Vermont DOT is using these alarms to inform the workers well before the danger. Example of audio intrusion alarm is a flashing strobe light, which activates as soon as a driver by mistake enters in the danger part of a work zone. The biggest benefit is that the workers get few seconds to clear out of danger way.<sup>(10)</sup>

### **Lane Merger System**

This ITS technology is designed for all work zone applications. The dynamic lane merger as shown in Figure 10, creates a no passing zone by using a series of trailer mounted traffic signs with flashing beacons. The equipment is mounted on a trailer so that it is portable. The device automatically reacts to changing

queue length and flow conditions and adjusts the length of the no passing zone. The Michigan DOT is using the device on Interstate work zones.



Figure 7: Iowa DOT Fluorescent yellow-green sign background.



Figure 8: Drone Radar Equipment



Figure 9: Truck Mounted Attenuators



Figure 10: ITS Technology Dynamic Lane Merger Sign

## **LAW ENFORCEMENT**

With the highway infrastructure ageing and work zone related crashes continuing to increase across the nation; safety of road users (motorists) and workers has become a top priority for transportation agencies. Although traffic control devices have an important role to play in ensuring safety of workers, there are other means, which should be used to improve the overall working conditions of work zones. However, there is no doubt in the fact that most of the crashes take place by inattentive and erratic drivers who drive recklessly through the work zones and don't comply with the warning signs or devices. A very handy booklet was published "Work Zone Safety-Guidelines for Construction, Maintenance, and Utility Operations", by Transportation Information Center: TAP and University of Wisconsin: Madison, giving a detailed layout for mobile zone maintenance operations. <sup>(6)</sup>

A lot of research has been done to find ways of enforcing traffic regulations through work zones and the presence of police personnel / law officers was found to be an effective and efficient mean to ensure safety of workers, by making the motorists drive slowly through work zones. The use of extra enforcement in work zones is a common practice in many states nowadays and these activities appear to be increasing. The California DOT has developed a program known as the Construction Zone Enhanced Enforcement Program or Maintenance Zone Enhanced Enforcement Program (COZEED/MAZEED) by which the California Highway Patrol is contracted to enforce speed compliance in work zones. The primary goal of this program is to maintain reasonable levels of safety and mobility in work zones. <sup>(4)</sup> Penn DOT has been working on a program "Work Zone Traffic Control Congestion and Delay". The objective of the program is to reduce the number of crashes through the work zone by employing law enforcement personnel. <sup>(4)</sup> In 1994, New Jersey established a dedicated New Jersey State Police (NJSP) Construction Unit assigned to New Jersey DOT construction projects. This unit assists the New Jersey DOT in monitoring and enforcing provisions of the approved traffic control plans. All members of this unit



must receive specific work zone safety training.<sup>(15)</sup> A number of other states like Florida, Minnesota, New Hampshire and South Dakota have been using law enforcement to control the traffic flow in work zones and ensure safety of highway maintenance workers and motorists alike.

Police presence and enforcement efforts generally involve the use of law officers in two strategies: stationary and mobile. An officer stationed at a specific location significantly increases speed limit compliance in that immediate area. A moving police vehicle can cover a larger area but may be less effective at speed reduction. Police enforcement relies on personal observation supplemented with technology. To improve the working of law personnel in work zone, different devices are used to achieve optimal performance. One of them is an innovative device known as Radar Gun. The device is used by police officer sitting in a vehicle at some distance from the moving traffic, who check the traffic violations and speeders in highway construction or maintenance zones and radios a fellow officer in a patrol car to pursue and ticket violators, once they get out of work zone to avoid hazards and congestion near the work area. Ref: The Detroit News-Work Zone Speeders Targeted.<sup>(14)</sup>

### **Enforcement Activities and Funding**

If extra police enforcement is desired for a construction or maintenance project, one of two options could be negotiated by agencies: cooperative enforcement or dedicated enforcement.

#### ***Cooperative Enforcement***

Cooperative enforcement is defined as services for which a police agency agrees to participate at a predefined level, without direct compensation. On-duty officers are assigned to patrol work zones when possible. A disadvantage of this practice is that officers may not be available when needed (lane closures, setting up and taking down traffic control devices, directing traffic in during congested times). However, the level of service provided by the law enforcement agency may be appropriate on some projects, and cost to the transportation agency is minimal.

### ***Dedicated Enforcement***

Dedicated enforcement is defined as services for which a law enforcement agency is reimbursed under a formal agreement with either a state or local agency, or a contractor. Typically, arrangements are made with the police agency before the project begins to establish the assignment of officers and reimbursement of costs. Funding sources for extra enforcement include revenues generated from enhanced fines in work zones, general construction funds, FHWA funds, specifically allocated state funds, and particularly when enforcement is included as a contract item, project construction funds. A significant advantage of dedicated enforcement is that required officers and equipment are generally available when needed.

Training of law officers prior to work zone duty does not appear to be commonly required, though the value of focused training is being recognized in some states. Its true that there are numerous benefits of introducing police officers in work zones, but, high labor costs, manpower shortages, and the many other demands placed on law enforcement makes universal enforcement presence at all work zones impossible.

## **MOTORIST INFORMATION, EDUCATION AND OUTREACH SYSTEMS**

The enforcement of police in the work zone is a strict way to make people follow the traffic rules while passing through the highway maintenance area, educating them is another way to get the things done and avoiding extra expense of police as well. Though the safe and efficient flow of traffic through construction and maintenance work zones is a major concern to transportation officials, it is a due right of highway workers and traveling public. Work zones are a temporary inconvenience but they are necessary to develop improved and safer roads for everyone. Mobile and short-term road maintenance operations are one of the most difficult situations to face with in work zone safety. The erection of work zones puts both motorist and worker at risk and agency wants to protect crews and motorists and stay efficient too. There is an urgent need to educate both drivers and workers nationwide and different states have launched work zone awareness and education programs.

With safety as a key issue, there are some basic principles almost accepted nationwide for the traffic flow through the work zones.

1. Drivers should stay alert.
2. Obey posted speed.
3. Expect the unexpected as work zone conditions change constantly
4. Minimize distractions like using mobile phones or changing radio stations and avoid eating / drinking too.
5. Obey work zone signs and watch for the workers.
6. Drive and merge cautiously and shouldn't tailgate.
7. Obey the flagger and follow his directions
8. Be patient as work zones cause delay.
9. Try an alternate route to avoid a backup.
10. In case of mobile work activities like painting, road patching and mowing, drivers should stay focused, as they will not see the workers immediately after they see the warning signs.

The Maryland DOT work zone safety program emphasizes the use of different sources like television, Internet, telephone hotline, in-vehicle route guidance, highway advisory radio and electronic kiosks to get the real time information of travel delays due to work zones.<sup>(16)</sup> Washington State DOT came up with a new idea of satisfying the public by answering the questions generally asked by the public. Indiana DOT recently introduced the driver education program through DOT personnel. The program educates students of particular traffic control devices that they were never aware of before. INDOT also developed a strategic plan recently for reducing congestion in work zones because of large complaints from the motoring public about long delays in work zones. The plan also involves providing awareness and understanding to the public.<sup>(4)</sup> Minnesota DOT produced a document titled: Guide to establishing speed limits in highway work zones. To ensure safer work zones for the highway workers, the document served educated people in training classes throughout the State of Minnesota.<sup>(4)</sup>

Different states across the country are also encouraging promotions and advertisements to bring awareness among the people. Some widely used and appealing slogans are:

- Please slow down, my daddy (or mommy) works here.
- Stay Alert!!! Keep your mind in the zone.
- Drive as if our lives depend on you. They do!!!
- See ORANGE!!! We are in the Work Zone Together
- Beat the Creep!!!
- Slow Down!!! It won't kill you
- Give 'em a BRAKE!!!
- Traveling Together: One full bus equals 45 cars

Like drivers, workers need to be guided by educating them to make sure the existence of a work zone with all its parameters in place. i.e. all the devices should be in right place and working properly. Secondly if it's the night operation

then all devices should be reflectorized or illuminated so that all the maintenance vehicles should be within the vicinity of a work zone. In addition, workers with specific traffic control responsibilities should be trained in traffic control techniques, device usage and placement. Don't assign untrained workers the responsibility for setting up and maintaining the system. Workers should be given true information and all devices and signs should be removed that are not in use, meaning that there should be minimum hindrance to the free flow of normal traffic. Drivers should not be made to think, respond, brake rapidly by awkward placement of devices and usage of signs. Another important thing to note is that safety features may provide adequate warning for a vigilant driver, but may be inadequate for an inattentive driver. It means that drivers should be guided in a clear and obvious manner throughout the work zone.<sup>(17)</sup>

## TRB, NCHRP and Proceedings Literature

Meyer, Eric., *Midwest Smart Work Zone Deployment Initiative: Kansas' Results*, Mid-Continent Transportation Symposium Proceedings, University of Kansas, Lawrence, Kansas, 2000.

During 1999, the Departments of Transportation from the states of Kansas, Nebraska, Iowa, and Missouri conducted a pooled-fund study of innovative devices designed to improve the safety and efficiency with which highway maintenance is conducted. In the state of Kansas, a total of nine devices were evaluated, including lighted raised pavement markers, CB-radio warning systems, and radar-triggered speed displays, among others. This paper gives an overview of the devices evaluated and summarizes the results of each of the evaluations. All of the products showed potential for improving work zone safety and operations. Some of the products require further development before they can be recommended for widespread deployment. The four products which seemed to show the most promise were orange removable rumble strips; the Vertical SafetyCade—designed to replace the reflectorized drum – radar –triggered speed display, and an experimental configuration of lightguard lighted raised pavement markers used to delineate a crossover in an interstate work zone. In all cases, pneumatic hoses were used to collect the data. In most cases, one to two days of data were collected before and after device installation (or activation).

Shaik, Nawaz M., *Evaluation of Three Supplementary Traffic Control Measures for Freeway Work Zones*, Mid-Continent Transportation Symposium Proceedings, University of Kansas, Lawrence, Kansas, 2000.

Controlling traffic in work zones to improve safety has long been a major concern for highway agencies. Three traffic control devices: white lane drop arrows, orange rumble strips, and the CB wizard alert system—were tested for their effectiveness in improving merging and reducing speed and speed variance at an interstate highway work zone in Missouri. Results of

implementing the white lane drop arrows and the CB wizard alert system indicate decreases in the percentage of vehicles in the closed lane, mean speed, and speed variance. It also appears that the CB wizard alert system may be more effective than the white lane drop arrows. The CB wizard alert system in conjunction with the orange rumble strips did show similar reductions, but they were much smaller in comparison to the CB wizard alert system alone.

Faulkner, Michael J.S., *Field Evaluation of Moving Maintenance Operations on Texas Urban Freeways*, In Transportation Research Record 864, Washington, DC. 1982.

Problem areas identified during the observation of five moving maintenance operations on Texas urban freeways are discussed. The operations included striping and the installation of raised pavement markers. The identified problem areas were grouped into two categories: problems related to freeway design and operational problems. Problems related to freeway design occur at entrance and exit ramps and major interchanges or result from horizontal and vertical curvature. Operational problems include the improper use of arrowboards, the lack of uniform procedures for freeway entry and exit, large spacing between caravan vehicles, and unnecessary lane blockage by the caravan. The recommended solutions to the problems are improved communications, effective advance signing, controlled caravan length, caravan positioning procedures observed during certain operation:, and modifications to procedures observed in others.

Faulkner, Michael J.S., *Protective Vehicles*, In Transportation Research Record 864, Washington, DC. 1982.

**Shadow vehicles** are used in moving lane closures. A truck follows the operation a short distance behind, giving physical protection from traffic. Its purpose is to provide protection for the crew and their vehicles involved in the maintenance activity. The minimum size for a shadow vehicle is a two-ton truck

equipped with a rear-mounted crash cushion. If a collision occurs, the crash cushion softens the blow to the drivers of both vehicles.

A **barrier vehicle** is parked in advance of a maintenance worksite. It is a heavy, unoccupied vehicle and is very carefully positioned so that it will intercept errant vehicles, without rolling ahead into the work area. The purpose of a barrier vehicle is to provide physical protection for crews in the cone zone. The barrier vehicle may be equipped with a truck-mounted crash cushion.

The **Advance Warning Vehicle** is stationed a considerable distance in advance of a moving or stationary maintenance operation. Its purpose is to display sign messages which will advise motorists of what to expect ahead. If the vehicle encroaches on a freeway lane, it is fitted with a truck-mounted crash cushion.

The objective of the District Driver Training Program is to eliminate preventable vehicle accidents. To meet this objective, two programs are undertaken - one of prevention and one of cure. The prevention consists of screening the driving record of each potential employee who could be expected to drive a vehicle as part of the employee's work and providing Defensive Driving Training. The cure program is a refresher driver training (a minimum of three hours) every four years for employees who drive on state business and appropriate disciplinary action for problem drivers of state equipment. Caltrans is also working with the California Association of Safety Educators to develop a curriculum, including a video tape, for use in more than 900 driver education classes statewide. This ongoing program educates new generations of drivers in how to drive safely near work zones.

Hanscom, Fred R., *Service Vehicle Lighting and Traffic Control Systems for Short-Term and Moving Work Zones (Phase II)*, National Cooperative Highway Research Program, Project 17-06A, TRB, Washington, DC 1990.



This comprehensive research report published by TRB was developed due to the growing concern of increasing frequency of hazards during moving and short-term work zone operations. The research was very thorough and effective in a way that it encompassed different possible formations of mobile maintenance operations. Eleven categories of short-term and moving work zones contained corresponding traffic control devices, vehicle warning light systems and driver actions respectively. Though studies supported traffic control devices (TCD) applications and guideline development, it was also found that accident reduction was the ultimate measure of device effectiveness.

This research mainly focused on human response to warning lights varied by the type of light both in closed field and operational tests. It was found during research that no one light is maximally effective in both transmitting information and gaining attention. The reason for this was that rotating and strobe lights, which were effective in getting driver's attention, were not as useful in providing speed and closure rate information especially when the service vehicle was stopped. Conversely flashing lights, which worked really well for giving speed info, were not effective in providing clear clue of working zone to drivers from long distances. Therefore several of the lighting recommendations combine the two types of light in order to ensure optimum information transmission and conspicuity.

Apart from the findings related to different types of lights functioning's, cost benefit analysis was developed to aid in making some of the decisions. Some of the devices like shadow vehicles were found to be very effective in producing desired results but involved substantial costs as well. Therefore separate cost-effectiveness criteria were included as a basis for agency-specific decisions regarding its use.

## **MANUFACTURERS AND SUPPLIERS**

The search of manufacturers and suppliers of highway safety products began with Better Roads Magazine – Manufacturers and Suppliers Directories, Public Works Magazine – Products Directory, and the Thomas Register. These sources provided web links to manufacturers and suppliers, and a “google” search provided information on specific products such as truck mounted attenuators, vests and signs. The following manufacturers and Suppliers were contacted or are being contacted by telephone and through the internet for products, specifications, and costs of highway safety products:

- PULNiX America, Inc.
- Trinity Industries
- Energy Absorption Systems
- National Sign and Signal
- Safety Technologies
- Sign CAD Systems
- TAPCO – Traffic & Parking Control Co.
- National Signal, Inc
- Transpo Industries, Inc
- US Traffic Corporation
- Vista Start Smart
- Ingol Highway Products
- Lecol Industries
- Trademark Safety Inc
- Highway Safety products

Information on products and services from these companies will be available at the April 16, 2004 NJDOT Quarterly Report meeting.

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