cost, coordination of the work force, noise, quality of work, and the acquisition of materials are of more than usual concern.

Although there are many potential disadvantages of working at night, it is believed that through the experience that has been gained and proper planning, the night alternative is feasible for selected work.

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REFERENCES

1. C. D. Lee. Nighttime Construction Work on Urban Freeways. *Traffic Engineering*, March 1965.
2. J. A. Chipps et al. *Traffic Controls for Construction and Maintenance Work Sites*. Vol. I. Report FHWA-RD-75, FHWA, U.S. Department of Transportation, Dec. 1975.
3. *Manual on Uniform Traffic Control Devices*. FHWA, U.S. Department of Transportation, 1978.
4. A. H. Meyer, W. B. Ledbetter, A. H. Layman, and D. Saylak. *NCHRP Report 196: Reconditioning Heavy-Duty Freeways in Urban Areas*. TRB, National Research Council, Washington, D.C., 1978, 60 pp.

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Implementation of Work-Zone Speed Control Measures

STEPHEN H. RICHARDS AND CONRAD L. DUDEK

Recommendations for implementing speed control at construction and maintenance work zones are presented. The following implementation steps are identified and discussed: (a) determining the need for speed reduction, (b) selecting a reasonable speed, (c) selecting a speed control treatment based on effectiveness, practicality and cost, and (d) selecting a location for the speed control treatment implementation. Four speed control approaches are studied: flagging, law enforcement, changeable message signs, and effective lane width reduction. The advantages and disadvantages of each of these approaches are discussed. Limited cost data for each of the approaches are also presented. The conclusions and recommendations are based on the results of field studies and observations at numerous street and highway work zones in Texas.

The issue of speed control through highway work zones has been a topic of concern for several years *(1,2)*. Excessive work-zone speeds can adversely affect the safety of the work crew and motorists. In an attempt to control work-zone speeds, highway agencies have followed standard signing practices, but drivers often do not slow down in response to posted speed limits.

Results of field studies conducted in Texas to evaluate selected methods of slowing traffic in work zones to acceptable speeds are presented elsewhere *(3)*. The methods included flagging, law enforcement, changeable message signs (CMSs), and effective lane width reduction. A detailed description of these methods and their effectiveness is presented elsewhere *(3,4)*. A procedure and several considerations for implementing work-zone speed control measures are presented in this paper.

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The implementation of work-zone speed control involves several steps: (a) determining the need for speed reduction; (b) selecting a reasonable speed; (c) selecting a treatment based on effectiveness, practicality and cost; and (d) selecting a location for treatment implementation. Also presented is a summary of treatment implementation considerations and limitations.

DETERMINATION OF THE NEED FOR SPEED REDUCTION

Although previous research did not specifically address the issue of when an agency should encourage reduced speeds at a particular work zone, after numerous visits to work zones, several important considerations became apparent.

Credibility

Speed control abuse and misuse at a work zone can render a speed reduction attempt ineffective and can damage the credibility of work-zone speed reduction efforts in general. Abusive practices include using unreasonably low speed limits, and leaving reduced speed limits in place after the work activity is removed.

Specific Goal

As with all traffic control efforts, any attempt to reduce work-zone speeds should be founded on an identifiable need. This need should be established based on engineering study, and not on intuition or a sound general policy. Speed reduction should be aimed at decreasing (a) the number, severity, or both, of work-zone accidents; or (b) the potential for accidents at sites where speed-related potential hazards exist.

Speed-Related Potential Hazards

Speed-related potential hazards are those that exist or worsen because traffic is traveling too fast for conditions. Typical examples of speed-related potential hazards are:

1. Hidden or unobvious work-zone features (e.g., subtle changes in alignment, edge drop-offs, etc.);
2. Reduced work-zone design speed (which is a real speed based on such factors as stopping sight distance, superelevation, degree of curvature, passing sight distance, etc.); and
3. Unprotected work space where an errant vehicle could result in catastrophic damage.

Passive Versus Active Control

Passive speed control refers to posting a reduced speed limit on a static sign (e.g., conventional regulatory and advisory signing). It is appropriate for all sites where reduced speeds are desired in the interest of safety. Passive control alone is generally sufficient at sites where the hazards are obvious, and drivers have plenty of time and information available to make reasonable and safe speed decisions without special encouragement.

Active control refers to techniques that restrict movement, display real-time dynamic information or enforce compliance to a passive control. Such techniques include: flagging, law enforcement, changeable message signs (CMSs), effective lane width reduction, rumble strips, Iowa weave sections, and so on. Active control would be needed in situations in which drivers are unable or unwilling to select the appropriate safe speed without active encouragement.

Duration of Potential Hazard

Another practical consideration is time. If a particular work activity will be in progress for an extended period of time (1 year) it would probably be impractical to use active speed control techniques for the life of the project. First, it would be too costly. Secondly, it would be unnecessary because the majority of drivers would eventually become familiar with work-zone conditions and drive at their own comfortable speed. A better approach might be to use active control only during the opening days of the project, and again following major changes in conditions. Passive speed control would be used during other times.

Adverse Impacts

Before attempting to slow traffic at a work zone, it should be recognized that speed reductions can have adverse effects. In particular, speed reduction measures can reduce roadway capacity and cause localized congestion if traffic volumes are moderate to heavy. The congestion, in turn, can increase the potential for rear-end accidents.

SELECTION OF A REASONABLE SPEED

After it has been determined that reduced speeds are desirable and practical, a safe and reasonable speed should be selected. A speed control strategy should be adopted that will reduce speeds to what is safe and reasonable for the conditions. The selected speed should not be unreasonably low but be the fastest speed that can still be considered safe.

Existing Speeds

Several factors influence what is a safe and reasonable speed for a given work zone. First, it should be recognized that drivers will only slow down to a certain level regardless of the presence of a speed control treatment. For example, previous studies *(3)* revealed that reductions in average work-zone speeds ranged from 5 to 20 mph, depending on the type of facility. Based on this finding, suggested maximum speed reductions for different types of roadways are given in Table 1.

TABLE 1 SUGGESTED MAXIMUM SPEED REDUCTIONS BY TYPE OF ROADWAY

Roadway Type	Speed Reduction (mph)
Rural two-lane, two-way highway	10–15
Rural freeway	5–15
Urban freeway	5–10
Urban arterial	10–15

Work-Zone Design Speed

The design speed of the various work zone features (e.g., horizontal curvature, sight distance, superelevation, etc.) also may dictate a safe and reasonable speed. It is very important that the design speed is not significantly lower than what drivers will reasonably expect or tolerate. If the work-zone design speed is too low, even active speed control may not be enough. Suggested maximum speed reductions in work zones by type of highway are given in Table 1.

Work-Zone Conditions

Work zones often involve workers and equipment very near the traffic stream, supply trucks entering and leaving the traffic stream, uneven pavement, shoulder drop-offs, fixed object hazards, rough pavement surfaces, distractions, and a number of other potential safety hazards. Selecting an appropriate speed for a particular set of conditions requires experience, objectivity, and good judgment.

It is extremely important that a reasonable speed for conditions be selected. If an unreasonably low speed is encouraged by the highway agency, drivers will quickly lose respect for the speed control effort. The loss of credibility and respect will result in reduced effectiveness of the speed control technique at the site and possibly other sites.

LOCATION OF SPEED REDUCTION

A speed control treatment should first be initiated 500 to 1,000 ft upstream of the hazardous location within the work zone. This ensures that drivers have adequate time to react, and the speed message will still be fresh in their minds when they reach the potential hazard. This applies especially to the flagging, law enforcement, and CMS speed control treatments that are applied at a point.

The effective lane width reduction treatment is unique because it is applied over a section. The lane width reduction treatment should be initiated approximately 500 to 1,000 ft upstream of the potentially hazardous location within the work zone and continued to a point just past the end of the potential hazard. It is critical to initiate the reduced lane width section before the potential hazard so that drivers have time to adjust their speeds and to focus their attention on the potentially hazardous condition rather than on the discomfort of driving in narrower lanes.

Location Relative to Other Work-Zone Features

The relative location of speed control treatments to other work-zone signing is also important. Ideally, speed control should be initiated after the first advanced sign and in a section that is relatively free of other work-zone signs. This practice lessens the possibility of overloading drivers with too much information and maximizes the amount of driver attention focused on the speed control effort.

Speed control treatments should not be placed in high driver work load areas such as near ramps, intersections, or lane-closure tapers.

Downstream Effects

The effective length of each particular speed control treatment was not evaluated in the studies on which this paper is based. However, it is reasonable to assume that all treatments will lose their impact eventually as drivers travel farther and farther through a long work zone. Therefore, it is likely that, if potentially severe hazards exist and drivers are not slowing down on their own, additional speed control applications (e.g., another flagger station, CMS, or law enforcement officer) may be needed downstream.

SELECTION OF SPEED CONTROL TREATMENT

Regulatory or advisory signing will not slow drivers down at work zones under normal circumstances. However, at the majority of long-duration work zones where drivers become conditioned to the work zone environment and select their own safe and reasonable speed, passive control can reinforce the existing speeds and provide a sound basis of speed enforcement. Also, if used prudently, advisory speeds will warn and advise unfamiliar drivers of common potential hazards experienced routinely in work zones.

With regard to active measures, four speed control methods were focused on in this research: flagging (including a police traffic controller), law enforcement (a stationary patrol car), CMSs, and effective lane width reduction. The selection of one or a combination of these methods for use at a particular work zone should include consideration of a number of interrelated factors including:

1. Duration of potential hazard requiring speed control;
2. Type of facility;
3. Desired speed reduction;
4. Overall cost of treatment; and
5. Institutional constraints (e.g., availability of CMSs, police officers, patrol cars, trained flaggers).

As a guide to speed control selection, the general advantages and disadvantages of the various speed control methods, with respect to the aforementioned factors, are summarized (Tables 2–5). Specific cost and implementation considerations of the various methods are discussed in the following sections.

TABLE 2 GENERAL ADVANTAGES AND DISADVANTAGES OF FLAGGING AND POLICE TRAFFIC CONTROL

Advantages	Disadvantages
Large speed reductions possible	Requires specially trained and conscientious personnel
Agency or contractor has direct control over performance[a]	Fatigue and boredom necessitate frequent relief
Relatively inexpensive for short duration applications	High labor costs for long-duration applications
Little or no disruption to traffic flow	Effectiveness may decrease with continuous use
Quick and easy to implement and remove	Two flaggers (one each side) may be needed on multilane roadways
Suitable for all types of highways and work zones	Additional flaggers may be needed for long sections
	Drivers may have a problem seeing flaggers or police traffic controllers at night; illumination of nighttime flagging stations is recommended
	Flagger safety considerations may preclude the use of flaggers at some work zones

Note: Only the use of a red flag, hand gestures, or both were considered. The effectiveness of the Stop/Slow paddle as a signaling device was not evaluated.

[a]The agency or contractor may not have as much control over a paid police traffic controller as it would over its own personnel. Also, availability of officers may be restricted by the police agency or officer interest. Some officers in urban areas are reluctant to attempt to manually control freeway traffic.

TABLE 3 GENERAL ADVANTAGES AND DISADVANTAGES OF LAW ENFORCEMENT

Advantages	Disadvantages
Large speed reductions possible	Constrained by availability of police officers and patrol cars
Relatively inexpensive for short-duration applications	Agency or contractor does not have direct control over performance
Quick and easy to implement and remove	High cost for long-duration applications
Can be effective at night, especially with lights flashing	Competes with other police functions
Sporadic use may encourage reduced speeds during nonuse periods	Long work zones may require additional patrol car units
Suitable for all types of highways and work zones	Success depends on good cooperation from enforcement agencies

Note: The statements apply to stationary patrol car treatments only, and not to use of a circulating patrol car. The circulating car approach was found to be ineffective *(3)*.

TABLE 4 GENERAL ADVANTAGES AND DISADVANTAGES OF CMSs

Advantages	Disadvantages
Relatively inexpensive for both short- and long-duration applications[a]	Only modest speed reductions possible
Agency or contractor has direct control over performance	Constrained by availability of signs
Little or no disruption to traffic flow	Effectiveness may decrease with continuous use
Quick and easy to implement and remove	Sign maintenance and repair may require technical expertise
Suitable for all types of highways and work zones	
Effective at night and in inclement weather	
May be used in combination with other techniques (e.g., flagger, law enforcement) for best results	

[a]If sign cost is extended over sign life (sign lease cost for a single, short-duration use may be high).

TABLE 5 GENERAL ADVANTAGES AND DISADVANTAGES OF EFFECTIVE LANE WIDTH REDUCTION

Advantages	Disadvantages
Moderate speed reductions possible	Expensive to implement and maintain, for short-duration applications, depending on devices used
Agency or contractor has direct control over performance	May disrupt traffic flow (reduce capacity)
Relatively inexpensive for long-duration applications, depending on devices used	May increase certain types of accidents
Retains effectiveness with continuous use and long-duration use	Device maintenance may be expensive
Speed reduction achieved throughout narrow lane section	May not be as effective on multilane highways
	Not easy to implement or remove

IMPLEMENTATION COSTS

As part of the studies, implementation costs for the various speed control approaches were assessed. The purpose of the assessment was not to attempt a detailed cost evaluation of specific treatments at individual sites, but rather to identify the major cost considerations of each approach. The scope of the research did not include developing relative cost comparisons between the various speed reduction measures.

Flagging

The cost of flagging includes the cost of labor; fringe benefits; equipment (e.g., flag, vest, and hard hat); and transportation to and from the site. It is important to budget for dead time (the time spent waiting for work to get started each day). Even more important is the requirement that flaggers be relieved every 1.5 to 2 hr. This recommendation is based on personal experience of the authors who served as flaggers during the speed control studies, and also on the observation of numerous flaggers' performance over time. Considering all costs, a highway official in Texas estimated that it costs his agency approximately $20 per flagger-hour (in 1983 dollars) *(5)*.

Law Enforcement

The results of a survey of city, county, and state police agencies in Texas regarding the cost of hiring off-duty officers for work-zone traffic control are given in Table 6. From the table, the hourly rates ranged from $10.00 to $22.50, with the average charge at about $15.00 per hour.

Most of the police agencies surveyed do not normally allow officers the use of a patrol car for off-duty work. The agencies said that cars were too scarce. The Texas Department of Public Safety, by state statute, will not allow off-duty officers to use state vehicles or equipment, or even to wear their uniforms.

During the survey, the police agencies were asked about furnishing on-duty officers and patrol cars for work-zone speed control. Most of the agencies said they would provide assistance for no charge at selected sites. However, they do not have the resources to provide men and vehicles on a regular basis.

TABLE 6 COST OF HIRING OFF-DUTY LAW OFFICERS FOR TRAFFIC CONTROL IN 1983 DOLLARS

Agency	Off-Duty Wage Rate ($/hr)
City of Austin	22.50[a]
City of Arlington	20.00
Brazos County Sheriff's Department	10–12
City of Dallas	15.00
City of Ft. Worth	15.00
Harris County Sheriff's Department	15–18
City of Houston	15.00
City of San Antonio	15.00[b]
Texas Department of Public Safety	12–15[c]

[a]Rate includes use of patrol car if approved by city.
[b]Rate drops to $12/hr after 3 hr of continuous service.
[c]State statute prohibits off-duty officers from wearing their uniforms or using any state equipment.

Changeable Message Signs

In some locales, it is possible to rent or lease a CMS for short-term use at a work zone. However, in Texas where the studies were conducted, portable CMSs are not readily available for lease from traffic control suppliers. One supplier, however, offered to lease a three-line, bulb matrix sign for $3,000 per month. This does not include operating costs such as fuel, oil, and routine servicing.

The Texas State Department of Highways and Public Transportation has acquired most of its CMSs by requiring contractors on major projects to buy signs for their projects. Once the projects are completed, the signs are turned over to the state for use on future maintenance and construction projects. The latest bid price received by the state for a three-line sign was just under $50,000.

CMSs require routine maintenance and repair, and the cost of skilled labor and parts can be high. Also, it is common that inoperative signs must be shipped to the manufacturer for repair.

Effective Lane Width Reduction

As noted earlier, the cost of implementing reduced lane widths can vary greatly. The total cost includes the cost of the devices as well as installation, maintenance, replacement, and removal of the devices. The salvage or reuse value of the devices can be subtracted from total costs, however, to yield the net cost to the agency.

TREATMENT ANCHORING

The studies indicated that a speed reduction technique, to accomplish its desired effects, should be associated with (anchored to) an appropriate, reasonable speed. Anchoring refers to displaying a specific speed message along with the speed control technique so that drivers know at what speed they should travel through the work zone. The speed control technique may be anchored to a regulatory speed sign, an advisory speed plate, or a speed message displayed on a CMS. Advisory speed plates are intended for use to supplement warning signs. By anchoring a speed reduction treatment, drivers can better relate to the treatment as a speed reduction device, and the specific meaning or intent of the device is reinforced.

TREATMENT IMPLEMENTATION CONSIDERATIONS

During the course of the research, several observations were made concerning how best to implement the various speed control treatments. Some of the practical limitations of the treatments were also identified. These implementation considerations and limitations are enumerated and discussed in the following sections.

Flagging

Implementation considerations for flagging include the following:

1. Flaggers should be conscientious and dependable workers with good vision, hearing, and physical condition.
2. Flaggers should be properly attired in a fluorescent orange vest with reflective material. They should also wear a cap hard hat. The vest and headgear will enhance the conspicuity of the flagger and connote to drivers that he or she is an official member of the work force with authority to control traffic.
3. For the flagging approaches tested, the flagger should also be equipped with a standard red flag. The flag serves as an attention-getting device and increases the target value of the flagging operation. (Use of paddles was not included in the study.)
4. Flaggers should be well trained in the proper flagging procedures and techniques. The studies revealed that both the Manual on Uniform Traffic Control Devices (MUTCD) and innovative approaches produce relatively large speed reductions. The innovative approach has the advantage of indicating the desired speed to motorists. [As described elsewhere *(3,4)*, the innovative flagging approach involved the use of special hand gestures to supplement the MUTCD flagging procedure for alerting and slowing traffic.]
5. In the interest of personal safety, the flagger should not be in the travel lanes but on the shoulder if it is wide (8 to 10 ft) or just off the pavement.
6. Flagging is well suited for short-duration applications (less than 1 day) and for intermittent use at long-duration work zones. It is likely that flagging would diminish in effectiveness if it were used continuously over several days or weeks.
7. The flagging operation should be anchored to a speed sign. The research did not address whether a regulatory sign, advisory sign, or CMS was a better anchor, but did suggest that any of them would be adequate.
8. Flagging is a physically tiring and boring activity. To be effective, a flagger should be relieved at least every 1.5 to 2 hr.

9. Flagging appeared to be most effective on two-lane, two-way rural highways and urban arterials, where a flagger has the least competition for drivers' attention. On freeways, two flaggers may at times be needed, one on each side of the road, in order to achieve maximum effectiveness.

10. The studies did not evaluate the effective distance of flagging operations (how far speeds remained reduced downstream of a flagger station). However, it is reasonable to assume that in a long work zone (1 mi or more) speeds would eventually rise again. Thus, it may be necessary to establish additional flagging stations at work zones where speed hazards exist over long distances.

11. For nighttime operation, flagger stations should be illuminated.

12. It may be difficult or impossible to flag during inclement weather.

13. Flagger safety should always be of critical concern in the use of the flagging approach to reduce work-zone speeds. If speeds are too high, and sight distance is limited or there is no room for the flagger to stand off the road, then the flagging approach may not be appropriate.

Law Enforcement

Considerations for law enforcement include the following:

1. Where it was tested, manual police traffic control was the most effective law enforcement strategy. (However, a uniformed police officer was no more effective in slowing drivers than a well-trained, properly attired flagger using proper flagging procedures.)

2. A stationary patrol car, positioned next to a speed sign, was very effective in slowing drivers. By turning on the patrol car lights or radar unit, a stationary patrol car may improve its effectiveness marginally.

3. A circulating patrol car was the least effective law enforcement strategy evaluated in reducing overall speed.

4. Many officers apparently are reluctant to attempt to reduce speeds at freeway work zones by manual traffic control hand signals. During the studies, some officers refused to participate in the manual control treatment saying that their services were better utilized performing other traffic control functions. Some officers believed that they would not be effective, and some cited a concern over their personal safety. Officers were particularly hesitant to attempt manual traffic control at the urban freeway site.

5. To increase effectiveness during nighttime operation, a stationary patrol car probably would need to have its overhead emergency flashing lights on. This would ensure visibility of the patrol car to most drivers. The safety effects of a stationary patrol car with emergency lights on were not studied, although no problems were observed during the daylight tests. It is reasonable to assume, however, that there would be situations where the flashing lights would be too distracting and result in a safety hazard.

6. For maximum effectiveness, the patrol car should be highly visible to approaching traffic. The patrol car is only effective when in place, so attempts to pursue and ticket violators should be minimized. Also, it should be noted that issuing tickets in restricted width sections or lane or shoulder closure sections can have disastrous impacts on safety. Thus, if ticketing is desired to possibly further enhance the effectiveness of the stationary patrol car approach, tickets should be issued by a second patrol car unit located downstream of the work area, but in radio contact with the primary unit.

7. The various law enforcement treatments may increase in effectiveness over a period of time as more and more drivers anticipate police presence and the threat of speed enforcement. However, if drivers eventually perceive that they will not be ticketed for violations, the effectiveness may subside. Therefore, for long-term applications, it may be necessary to occasionally issue citations to violators.

8. It is likely that occasional use of the various law enforcement strategies will reduce speeds even when the law enforcement is not present. This was not addressed in the studies.

9. Additional stationary units may be needed to encourage reduced speeds through a very long work zone.

Changeable Message Signs

Considerations include the following:

1. CMSs resulted in only modest speed reductions at the sites where they were tested (urban arterial and freeway sites). It is unlikely that CMSs alone could produce very large speed reductions (greater than 10 mph). These findings are consistent with CMS studies conducted by Hanscom *(6)*.

2. The two types of messages tested (speed versus speed and informational) performed approximately the same.

3. CMSs are appropriate for day and night use.

4. CMSs retain most of their usefulness during inclement weather.

5. CMSs are versatile. The speed message may be changed as conditions change, and the CMSs may be used to display other types of information and warnings as needed. They are easy to install or relocate.

6. The appropriate type and size of CMSs should be used for the conditions. CMS selection and operation considerations are detailed elsewhere *(3)*.

7. CMSs must be properly serviced and repaired. Acquiring necessary parts and expert labor may require shipping the sign to a distant manufacturer or waiting for the manufacturer or his representative to service the sign locally.

8. CMSs, operated continuously for long periods with the same messages, may lose their effectiveness.

9. A survey of traffic control subcontractors conducted as part of this study revealed that CMSs are currently not readily available for lease on a short-term basis. In Texas where all the field studies were conducted, the highway agency requires that its contractors purchase CMSs for use on some major projects. When a project is completed, the sign is turned over to the agency for use at future construction and maintenance sites.

Effective Lane Width Reduction

Considerations include the following:

1. Slight effective lane width restrictions (e.g., 11.5- and 12.5-ft widths) will reduce speeds modestly. Although not tested, it is assumed that even narrower lanes (9 to 10 ft) may greatly lower speeds. However, the studies suggested that lane reduction, if effective, also increases speed variance and erratic maneuvers.

2. In order to implement a lane width reduction technique, it is usually necessary to interrupt traffic flow and expose workers to traffic (workers must get out into traffic and install the devices).

3. There are many devices and strategies available for implementing effective reduced lane widths (e.g., cones, drums, striping, barriers, barricades, etc.). The cost, maintainability, effectiveness, and safety of the various approaches probably varies widely. Only cones were evaluated in the studies.

4. Cones proved to be quick and easy to install and remove. However, they were frequently hit by large trucks and mobile homes when the 11.5-ft treatment was used.

5. Effective lane width reduction appears to be more practical for long-duration applications of several days or more. The time and initial cost to implement are relatively great; however, there is little labor or expense after installation.

6. On roadways with three or more lanes per direction, it may not be possible to accomplish the desired effective lane width reduction in the middle lanes without restriping the roadway.

7. Effective lane width reduction techniques may not suppress speeds long after the end of the narrow sections. Thus, the narrow lanes must be continued throughout the area where reduced speeds are desired.

CONCLUSION

For many years, work-zone speed control measures have been misused and, in some cases, abused. This is especially true for regulatory and advisory speed signing. As a result, driver respect for work-zone speed control efforts has suffered, and many agencies have lost confidence in attempting speed reductions. However, the research documented in this paper and elsewhere *(3)* indicates that traffic speeds can be significantly reduced at some construction and maintenance work zones in the interest of safety. For work-zone speed control to be effective, however, certain implementation considerations must be taken into account. These considerations have been identified and discussed along with the limitations of the various speed-control measures.

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REFERENCES

1. J. L. Graham, R. J. Paulson, and J. C. Glennon. *Accident and Speed Studies in Construction Zones.* Report FHWA-RD-77-80, Midwest Research Institute, Kansas City, Mo., June 1977.
2. J. R. Humphries, H. D. Mauldin, T. D. Sullivan. *Identification of Traffic Management Problems in Work Zones.* Report FHWA-RD-79-4, University of Tennessee, Knoxville, Dec. 1979.
3. S. H. Richards, R. C. Wunderlich, and C. L. Dudek. "Field Evaluation of Work Zone Speed Control Techniques." In *Transportation Research Record 1035*, TRB, National Research Council, Washington, D.C., 1985, pp. 66-78.
4. S. H. Richards, R. C. Wunderlich, C. L. Dudek, and R. Q. Brackett. *Improvements and New Concepts for Traffic Control in Work Zones, Volume 4—Speed Control in Work Zones.* Report FHWA/RD-85/037. Texas Transportation Institute, The Texas A&M University System, College Station, Sept. 1985.
5. S. Z. Levine. Telephone conversation. District Traffic Operations Engineer, District 12, Texas State Department of Highways and Public Transportation, Austin, Sept. 1983.
6. F. R. Hanscom. *NCHRP Report 235: Effectiveness of Changeable Message Displays in Advance of High Speed Freeway Lane Closures.* TRB, National Research Council, Washington, D.C., Sept. 1981, p. 49.

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