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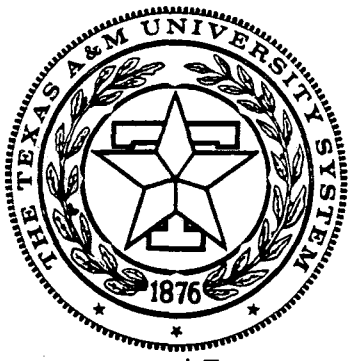

TEXAS
TRANSPORTATION
INSTITUTE

STATE DEPARTMENT
OF HIGHWAYS AND
PUBLIC TRANSPORTATION

COOPERATIVE
RESEARCH

CATALOG OF TRAFFIC CONTROL STRATEGIES AND DEVICES

in cooperation with the
Department of Transportation
Federal Highway Administration

RESEARCH REPORT 321-1
STUDY 2-18-82-321
TRAFFIC CONTROL PLANNING

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16. Abstract
This report is a catalog of several traffic control strategies and devices appropriate for freeway work zones. The strategies and devices were identified during field studies and interviews conducted at numerous freeway work zones in Houston, Dallas, Ft. Worth, San Antonio, Austin and Amarillo, and reviews of several TCPs from several Districts. The strategies and devices summarized are listed below:

Innovative Traffic Management Strategies
- Short-Term Total Freeway Closure
- Traffic Splitting

Supplemental Traffic Management Strategies
- Shoulder Use
- Speed Control
- Entrance Ramp Closures
- Narrow Lanes
- Load Zoning

Motorist Information Devices
- Arrowboards
- Portable Changeable Message Signs
- Highway Advisory Radio
- Special Lane-Blocked Sign
- Special Word Message Pavement Marking

Traffic Control Services
- Flagging
- Law Enforcement

Safety Hardware
- Portable Roadside Barriers
- Crash Cushions
- Temporary Lighting

Implementation
- Corridor Management Team
- Special Traffic Handling Crew
- Advance Notification
- Photographic Documentation

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CATALOG OF TRAFFIC CONTROL STRATEGIES AND DEVICES

by

S. H. Richards

and

C. L. Dudek

Research Report 321-1
Research Study Number 2-18-82-321
Evaluation of Traffic Control Plans at Reconstruction Sites

Sponsored by

Texas State Department of Highways and Public Transportation
in cooperation with
U. S. Department of Transportation, Federal Highway Administration

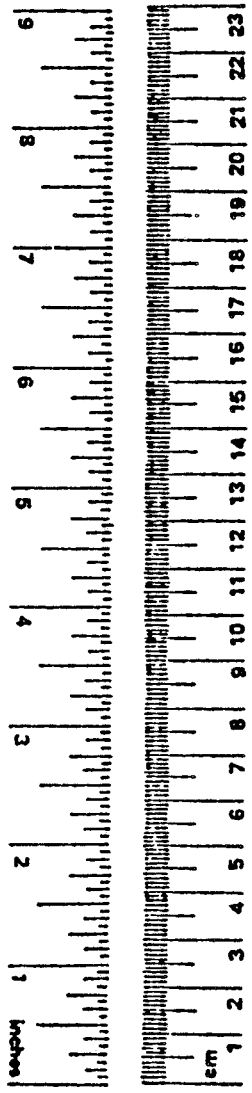
February 1986

TEXAS TRANSPORTATION INSTITUTE
The Texas A&M University System
College Station, Texas

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

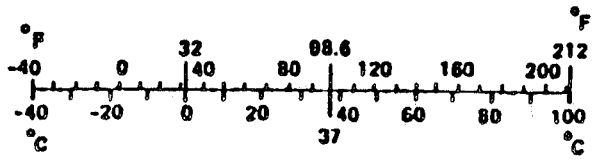
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C



*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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Benjamin W. Bohuslav, Supervising Maintenance Engineer, District 13
Walter Collier, District Maintenance Engineer, District 15
Billie E. Davis, District Maintenance Engineer, District 2
Milton Dietert, Assistant Chief Engineer of Safety and Maintenance Operations, D-18
Herman Gadeke, District Traffic Engineer, District 15
Hunter Garrison, District Maintenance Engineer, District 12
Henry Grann, Supervisory Traffic Engineer, District 18 (Retired)
Herman Haenel, Supervisory Traffic Engineer, D-18T
Bobby Hodge, Supervisory Traffic Engineer, District 2
Steve Levine, Traffic Management Supervisor, District 12
Blair Marsden, Senior Traffic Engineer, D-18T
Silas M. Prince, District Maintenance Engineer, District 11
Lewis Rhodes, Senior Traffic Engineer, D-18T
Russell G. Taylor, Engineering Technician V, District 14
Milton Watkins, District Maintenance Engineer, District 18
John Wilder, District Maintenance Engineer, District 14

INTRODUCTION

Every year, more and more maintenance and reconstruction work is performed on our aging urban freeways. These work activities can have a negative impact on traffic safety and flow unless adequate provisions are made to handle work zone traffic.

The Texas Manual on Uniform Traffic Control Devices (MUTCD) establishes the basic principles for traffic control at work zones. The guidelines and requirements in the Manual provide a basic traffic control framework. However, urban freeway work zones, because of their special characteristics, often require the use of innovative traffic control strategies and devices to supplement those in the MUTCD.

Freeway Work Zones

Urban freeway work zones are characterized by high speeds, heavy traffic volumes, high driver expectancies and a "freeway" cross-section. These characteristics increase traffic control requirements, and also increase the number of traffic control alternatives.

1. High speeds, for example, require that sufficient advance warnings be given to motorists and that workers and work vehicles be protected from errant vehicles.

2. During peak periods, heavy freeway volumes can result in severe work zone congestion. Techniques to reduce mainlane demand and/or increase work zone capacity may need to be implemented.

3. Freeway drivers have come to expect a high level of traffic operation and control. In a freeway environment drivers expect information to be simple, understandable, and executable. If their "expectancies" are violated, drivers may become confused or frustrated.

4. The freeway cross-section may include full-width shoulders, frontage roads, multiple travel lanes, and entrance and exit ramps. At some work zones these features can result in complicated traffic control situations, while at others they can provide traffic control options not available on other types of highways.

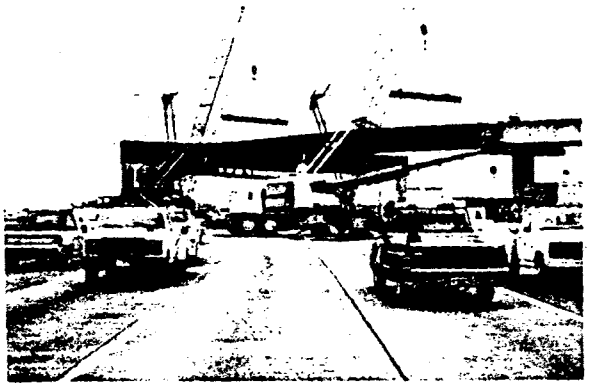
Report Content

This report is a catalog (or "shopping list") of 21 traffic control strategies and devices appropriate for freeway work zones. The report does not attempt to give details on each strategy or device. Rather, brief descriptions of each strategy/device are presented along with typical illustrations. A bibliography is presented so that interested readers may find out more about any of the topic areas.

The 21 work zone traffic control strategies and devices were identified during field studies and interviews conducted at numerous freeway work zones in Houston, Dallas, Ft. Worth, San Antonio, Austin and Amarillo, and reviews of several traffic control plans (TCPs) in several Districts. Some of the strategies/devices are addressed in the Texas MUTCD, while others are not yet recognized in the Manual. If a device is not yet approved, this report will so state.

Applications

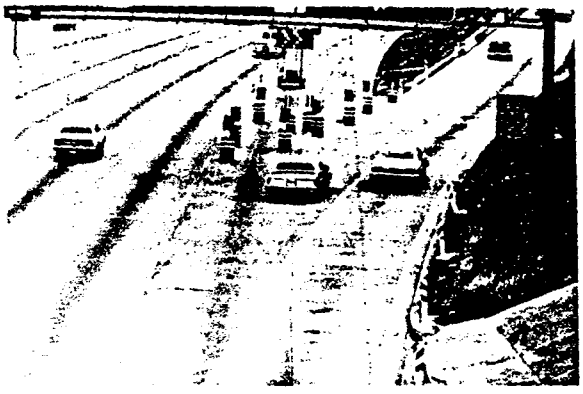
This report is intended to be used as a quick reference guide by District and Division personnel who plan and implement traffic control at freeway work zones. It should encourage technology sharing among the Districts and stimulate innovative thinking in the development of work zone Traffic Control Plans.



Freeway Closure

Trail Blazer

Advance Detour Signing



Converting Single Lane Ramp
Into Two Lane Ramp

SHORT-TERM TOTAL FREEWAY CLOSURE

Application

Certain types of maintenance activities (e.g., bridge joint repair, overhead sign work, pavement repairs, etc.) and construction must be performed across several lanes which may require short-term total freeway closures. Total closures may also be used to perform several maintenance activities simultaneously.

Freeway closures have been implemented in several cities with success. Success, however, depends on proper scheduling, good coordination, advance notification and adequate traffic control on the freeway and along the detour route.

Scheduling

In planning a total closure, it is essential to consider traffic volumes on both the freeway and alternate route(s). Generally, total closures should be scheduled during very low volume periods (e.g., Sundays or late night). During those periods, relatively few drivers will be affected by the closure, and there usually is plenty of extra capacity on the alternate route(s).

Also, freeway closures should not be scheduled at the same time that a special event (e.g., sporting events, fairs, concerts, etc.) is occurring in the area.

Coordination

Freeway closures require the cooperation of many entities such as city traffic departments, law enforcement agencies, and contractors, as well as the various SDHPT sections which will be involved. A pre-closure meeting of all the involved agencies should be held two to four weeks prior to the actual closure to inform and to promote new ideas and suggestions.

During implementation of the closure, one individual should be designated as the Traffic Control Coordinator. This person's primary responsibility should be to insure that the traffic control plan is implemented properly and coordinate traffic control efforts during the closure.

Advance Notification

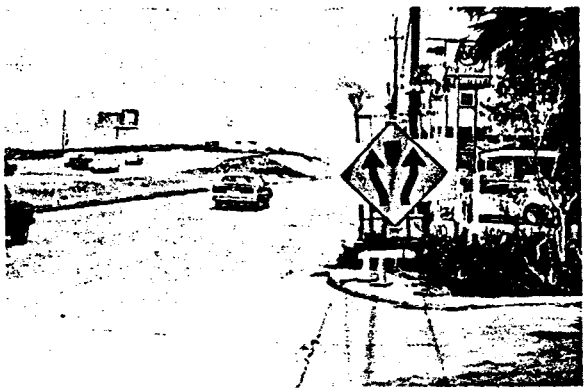
All facets of advance notification discussed elsewhere in this report should be used.

Traffic Control Considerations

A full complement of advance signs is required. All signing should be designed to freeway standards, and special devices, such as arrowboards and CMSs, should be used as needed. Law enforcement personnel should also assist in the traffic control effort as needed.

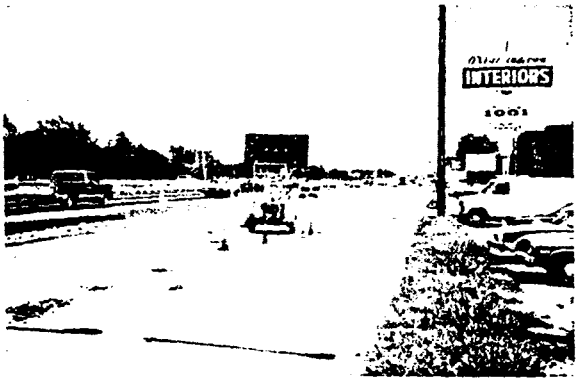
The detour route should have adequate capacity to handle the displaced freeway traffic. It may be necessary to re-time traffic signals, restrict curb parking, prohibit intersection turns and make other temporary traffic control modifications along the detour route. Most important, "trailblazer" signing should be installed along the entire detour route to guide motorists back to the freeway.

At the beginning and end of the detour route, serious congestion may occur if a single-lane ramp is used to remove or return traffic to the mainlanes. If analysis indicates long queues will form, traffic may be encouraged to use several ramps to enter or leave the freeway, whichever the case may be. At some locations, it may be possible to temporarily convert a single-lane ramp into a two-lane ramp. Modification of traffic control devices must be approved by FHWA.

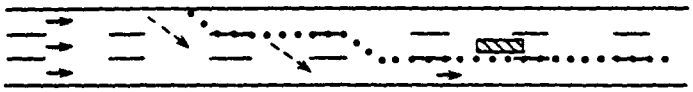


Symbolic Split Sign

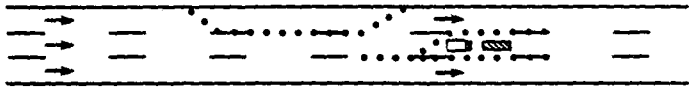
Innovative Lane Blocked Sign



Arrowboard
Traffic Split on Frontage Road



Freeway Standard Multilane Closure



Freeway Traffic Split

TRAFFIC SPLITTING

Application

When work is required on the middle lane of a three-lane section, generally both the middle lane and one of the exterior lanes are closed. This traffic control strategy greatly reduces work zone capacity and, thus can result in severe congestion when traffic volumes are heavy.

If there are shoulders at the worksite, the shoulder-use strategy (see page 7) may be used to increase the capacity of the work zone. However, if there are no shoulders or the shoulders are too narrow, traffic splitting may be considered. Using this approach, only the middle lane is closed and traffic is "split" to both sides of the resulting island work zone.

Effectiveness

Using the traffic splitting strategy, work zone capacities up to 3000 vehicles per hour have been observed. This is approximately double the capacity of a conventional two-lane closure.

Based on studies conducted in Houston, traffic splitting can be accomplished safely if proper traffic control is used. It is recommended, however, that the strategy be used only at relatively short work zones so that drivers entering and exiting at ramps are not tempted to weave through the closed middle lane.

Traffic Control

There is no standard advance signing for a traffic split. However, an innovative lane blocked sign and a symbolic traffic split sign (see photos) have been used in Houston with success. The lane blocked sign has been approved for use for moving maintenance and traffic splits on middle lanes. It is especially effective since it can be adapted to any lane closure configuration. Studies indicated that drivers understand the sign message and respond to it. (See pages 22 and 23 for more details.)

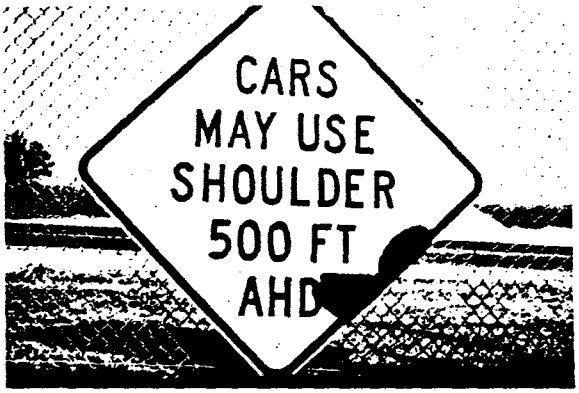
Well upstream of the split area, traffic should be reduced to two lanes, using a standard freeway lane closure. To discourage lane changing in the vicinity of the split, cones may be placed on the lane line beginning at the split and extending upstream for approximately 1000 feet.

Closely spaced cones or other suitable devices are used to "channelize" traffic to both sides of the middle lane work zone and to keep traffic out of the work area. An arrowboard (with left and right arrowheads) may be placed in the closed middle lane just downstream of the split area.

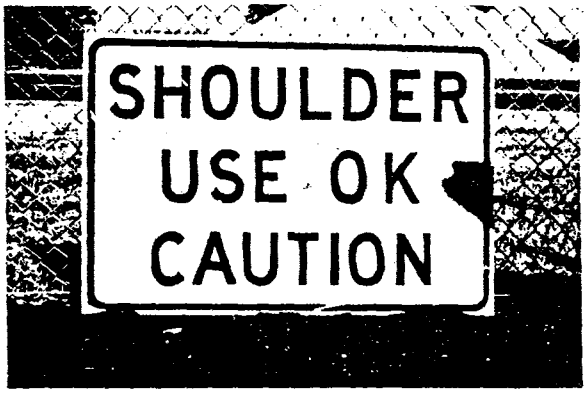
One or more shadow vehicles should be parked in the closed middle lane to protect the work crew and discourage traffic from weaving through the work area. The shadow vehicle(s) may be equipped with a portable crash cushion.

Use on Frontage Roads

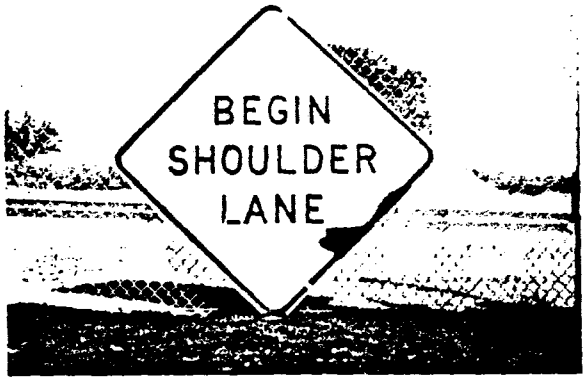
The traffic splitting strategy has also been used effectively during resurfacing operations on three-lane urban frontage road sections. Special attention must be given to intersections, ramps and driveways when the strategy is used on urban frontage roads.



Advance Sign
for Shoulder Use Zone



Sign Used Intermittently
Within Shoulder Use Zone



Sign Used at Beginning
of Shoulder Usage Zone

Sign Used at End
of Shoulder Usage Zone

SHOULDER USE

Application

Generally, when maintenance work is performed in a middle (or interior) freeway lane, both the middle lane and one of the exterior lanes are closed. This provides a large protected workspace, but the multilane closure greatly reduces capacity. Severe congestion can occur when traffic volumes are heavy.

If there are shoulders present at the work zone, they may be utilized temporarily as a travel lane in order to increase work zone capacity. Shoulder-use as it is called, is most applicable to long work zones where congestion would develop if two lanes were closed.

Effectiveness

Shoulder-use has been used successfully at several maintenance work zones in Houston and Los Angeles. Studies have shown that, with the proper traffic control, drivers will begin using the shoulder whenever minor congestion occurs. As traffic demand volumes increase, more and more drivers will move to the shoulder. Under heavy flow conditions, a 10-foot shoulder can carry up to 1500 vehicles per hour, thus greatly increasing work zones capacity.

Traffic Control

District 12 uses the following signs and and channelizing devices to encourage shoulder-use:

1. Advance sign **CARS MAY USE SHOULDER 500 FT. AHD.**
2. **BEGIN SHOULDER USE** sign and a short cone taper to mark the start of the shoulder-use section.
3. **SHOULDER USE OK CAUTION** signs throughout the shoulder-use section.
4. **END SHOULDER USE** sign and a short cone taper to mark the end of the shoulder-use section.

The shoulder-use section should be started in advance of the second lane closure to alleviate the normal bottleneck which would occur at the closure point. It may also be necessary to close or channelize some entrance and exit ramps to avoid operational problems.

Flaggers

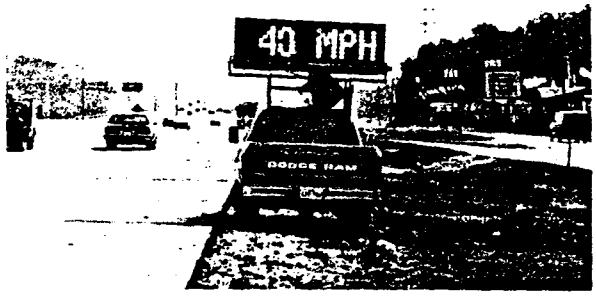
Shoulder-use may be encouraged by stationing a flagger at the **BEGIN SHOULDER USE** sign to direct motorists' attention to the sign. Studies have shown that more drivers will move to the shoulder sooner if a flagger is attracting their attention to the sign.

Discontinuous Shoulders

The shoulder-use strategy will work on sections with discontinuous shoulder (e.g., shoulders are dropped at bridges), provided one of the closed travel lanes can be reopened in the vicinity of the shoulder drop.

Innovative Flagging

Law Enforcement



Changeable Message Sign

SPEED CONTROL

Application

Excessive speeds at freeway work zones can adversely effect the safety of the work crew and motorists. Studies have shown that standard regulatory and advisory speed signs generally do not slow work zone speeds, thus some type of active speed control may be needed in the interest of safety.

Active control refers to techniques which restrict movement, display display real-time dynamic information, or enforce compliance to a posted speed limit. Active speed control techniques include: flagging, changeable message signs (CMSs), law enforcement, and lane width reduction.

Flagging

A properly trained flagger, "anchored" to a speed limit sign, can reduce average speeds at freeway work zones by 5 to 10 mph. The flagger should get the attention of approaching motorists using the "Alert and Slow" signal recommended in the Texas MUTCD. The flagger then points to a nearby speed sign and motions drivers to slow down to the posted speed.

Since flagging is physically tiring and boring, flaggers must be relieved every 1 1/2 to 2 hours.

Law Enforcement

A patrol car, parked just off the travel lanes and "anchored" to a speed sign, can reduce speeds at freeway work zones by 5 to 10 mph. Speed reductions are slightly greater when the patrol car's lights and/or radar are turned on.

A uniformed police officer can effectively slow work zone speeds by manual traffic control, similar to the flagging approach.

Changeable Message Signs

CMSs may reduce freeway work zone speeds up to 5 mph. Speed messages, however, tend to lose their effectiveness if displayed for more than a few days at a time.

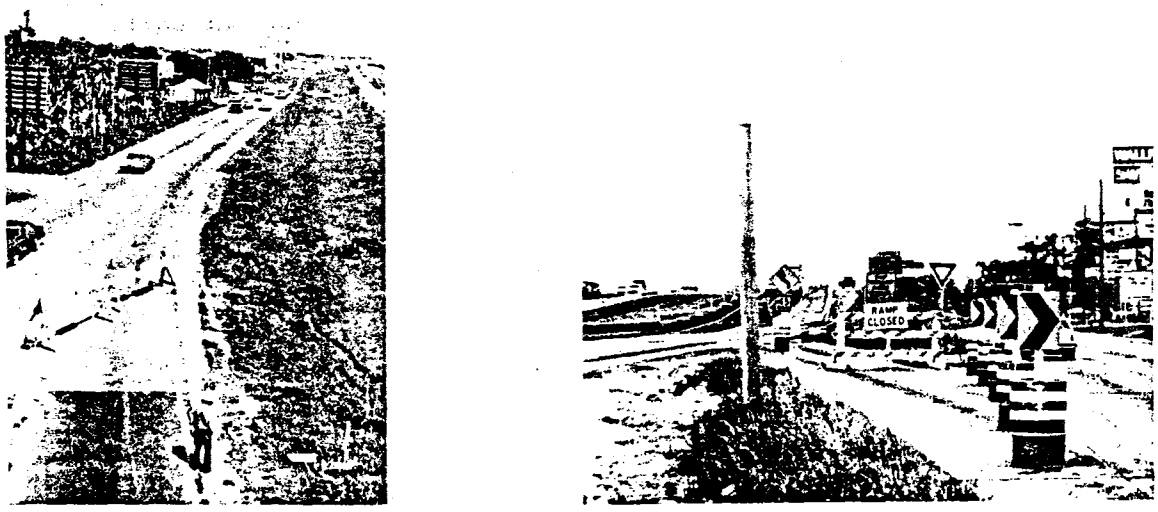
Lane Width Reduction (Narrow Lanes)

Generally, narrow lanes are used at freeway work zones to increase capacity (i.e., increase the number of available lanes). However, the use of narrow lanes will also tend to slow drivers down, but only slightly. For example, average speeds dropped only 4 to 5 mph when 9 1/2-foot lanes were used at a freeway work zone in Houston. The effects of narrow lanes on safety are not fully known at this time.

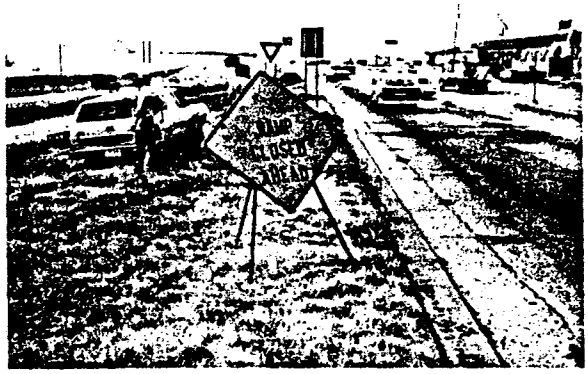
Implementation of Speed Control

Every effort should be made to design work zones to safely accommodate traffic at normal speeds. When it is impossible or impractical to accomplish this goal, safe, effective and economical means should be used to reduce speeds to the appropriate level. At urban freeway work zones, maximum speed reductions of 5 to 10 mph can be expected.

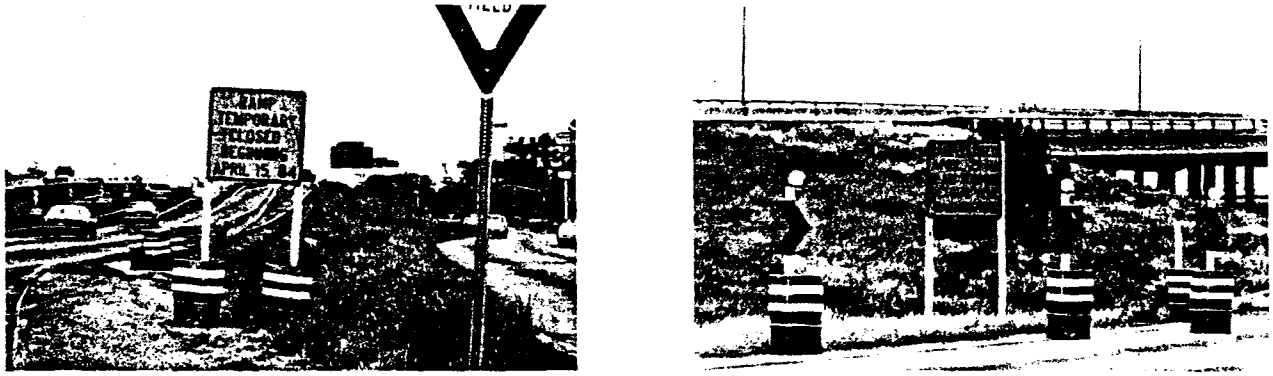
Speed reductions should be aimed at decreasing the number and severity of work zone accidents, or the potential for accidents at sites where speed-related hazards exist. The overuse, prolonged use, or misuse of speed control techniques will damage their credibility and reduce their general effectiveness.



Typical Closures



Advanced Signing



Advance Notification

TEMPORARY ENTRANCE RAMP CLOSURES

Application

Entrance ramps in a freeway work area may be closed to protect the work crew and facilitate the work activity. At freeway work zones with insufficient capacity, entrance ramps at and upstream of the work zone may also be closed to decrease mainlane traffic flow, and thus reduce congestion.

A ramp should be closed only as long as needed (i.e., while the work activity occupies the ramp area or demand volumes on the mainlanes exceed the work zone capacity). Changes in work and traffic conditions should be constantly monitored so that ramps can be opened and closed at the critical time. If ramps are left closed too long or too many ramps are closed at one time, severe congestion may develop on the frontage road.

Closure Techniques

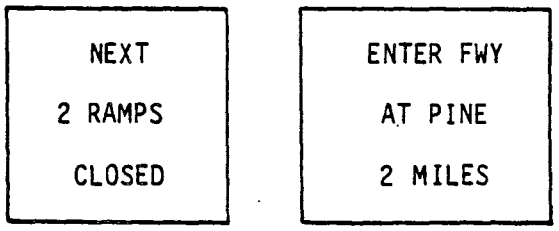
There are several ways to close an entrance ramp, and the most effective technique will depend on site conditions. Some typical closures are shown in the photographs. As a minimum, closely spaced cones could be placed across the full width of the ramp at the ramp-frontage road intersection. This approach would probably be sufficient at low volume ramps for short duration maintenance, provided the frontage road was not congested.

It may be necessary to use more positive traffic control devices to close ramps for long periods or overnight. In these cases, barricades or a parked work vehicle may be placed across the ramp entrance. A flagman or policeman may also be stationed at problem ramps. In addition, police presence may be required to control illegal freeway entry where the outer separation is easily traversed (i.e., where motorists can drive across the grass and easily access the mainlanes).

Signing

Frontage road drivers should be warned by signs that a ramp is closed. As a minimum, one sign should be placed several hundred feet upstream of the closed ramp on the left side of the frontage road (assuming that frontage roads are one-way). Additional signs should be used as needed.

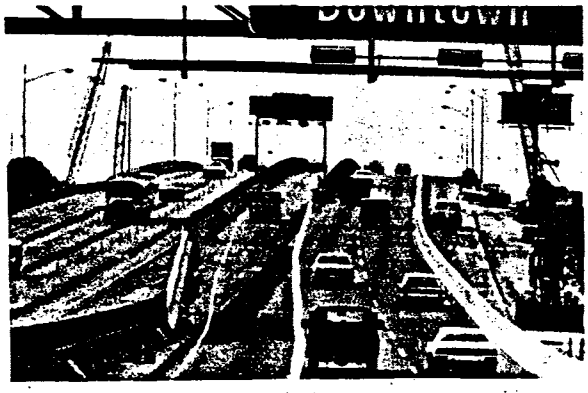
If two or more successive ramps are closed, special advance and guide signing are required to prevent drivers from becoming confused, lost, or worried that they will not be able to enter the freeways. The following special signing messages may be used to warn frontage road drivers that several successive ramps are closed:

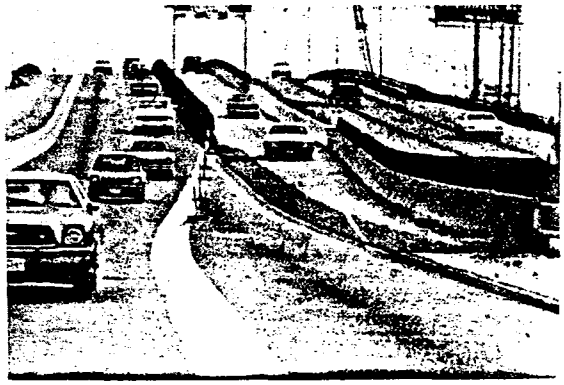


The signing messages may be displayed on two conventional static signs or a changeable message sign in alternating sequence.

Advance Notification

Motorists should be notified in advance of ramp closures. Special signing may be installed at the ramp as the most direct means of advance notification. Newspaper releases and radio reports are also effective.





Narrow Lanes

NARROW LANES

Application

At freeway reconstruction work zones, it is sometimes difficult to provide the necessary work space and still keep enough lanes open to prevent serious congestion. In these situations, the use of narrow lanes may be considered. Lanes 10 to 10 1/2 feet have been used at several freeway reconstruction work zones. Lanes as narrow as 9 1/2 feet have been used on I-45 in downtown Houston. Since the prolonged use of narrow lanes must be approved by FHWA, adequate justification should accompany the request or TCP as appropriate.

Effects on Traffic

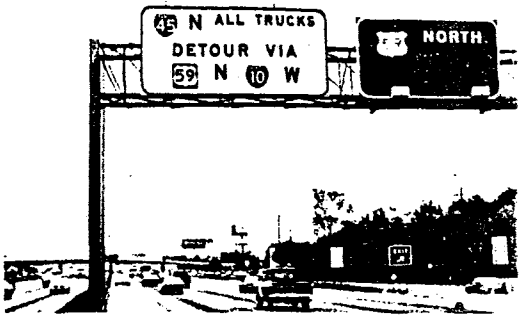
Studies have shown that drivers slow down as they travel through narrow sections; however, only moderate speed reductions (i.e., up to 5 mph) can be expected. In addition, speed variance increases in narrow lane sections.

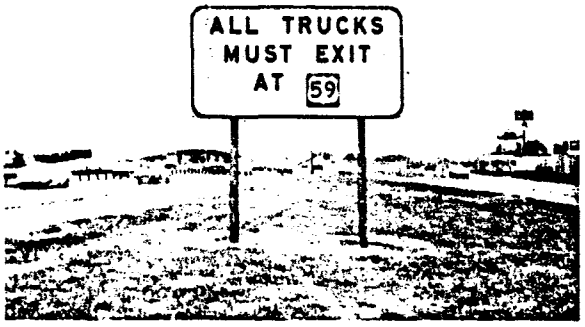
The capacity of narrow lane sections will depend upon the location of the work crew and work zone geometry. Capacities up to 1800 vehicles/hour/lane have been observed at long-term reconstruction sites.

Portable Concrete Barriers

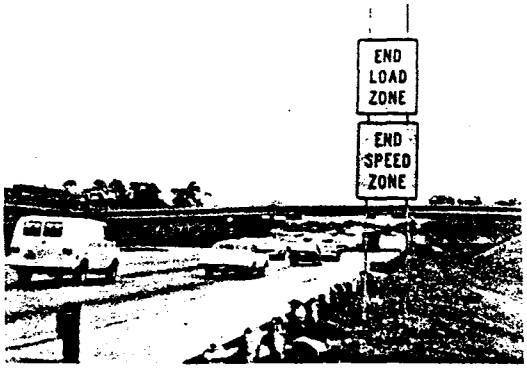
When portable concrete barriers are used in narrow lane sections, the barriers should be at least 1 foot from the edge of the travel lanes. Otherwise, drivers (especially truckers) will "shy away" from the barriers and straddle the lane line, thus affecting traffic in the adjacent lane.

When barriers must be placed very close to a narrow lane, the "effective" lane width may be increased by placing the edgeline on the barrier. This will make the travel lane appear wider, and the edgeline will not get obscured by dirt and debris.





Alternate Route Signing



Load Zone Signing

LOAD ZONING

Application

It may be desirable to prohibit large and/or heavy vehicles from traveling through some freeway reconstruction work zones. This may be effectively accomplished by "load zoning" the work area. Load zoning simply means that vehicles of a certain size or weight are restricted from using a stretch of roadway (i.e., these vehicles must use another route).

There are many work zone situations which may warrant load zoning. Some of the most common ones are cited below:

1. If normal traffic demand exceeds work zone capacity, the level of service at the work zone may be improved by encouraging larger trucks to use other routes.

2. Some work zones may not have sufficient pavement strength to handle heavy trucks and buses (e.g., work zones where traffic is diverted to the frontage road or onto a temporary bypass).

3. Some work zones may possess severe design limitations (e.g., narrow lanes, steep grades, no shoulders, etc.). Traffic safety and operations at these sites may be improved by prohibiting large vehicles.

Implementation

A load zone is established through a Commission Minute and/or City Ordinance. Once a load zone is established, it is implemented by posting the vehicle restrictions on regulatory signs and directing the affected traffic along an alternate route using a system of guide and warning signs. The vehicle restrictions can be stated in terms of vehicle weight, type and/or axle classification. The permit office in the District may have additional requirements and needs to coordinate truck routings given by D-18P in order to fully assist the load zone designer in checking the alternate route.

Diversion Route

In selecting a suitable alternate route, the following guidelines may be helpful:

1. The alternate route should have adequate excess capacity to handle the displaced traffic.

2. The cross-section, geometry and pavement structure of the alternate route should be suitable for large vehicles.

3. Travel time on the alternate route should be approximately equal to or less than the normal route and other available routes.

Signing

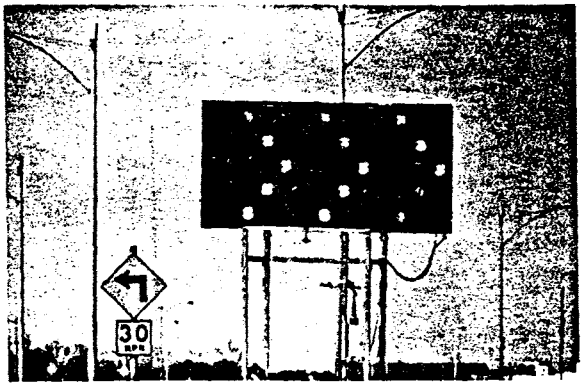
Regulatory signing is used to inform motorists of the presence of a load zone. It is important that load zone signs be located well upstream of the diversion point to the alternate route.

Enforcement

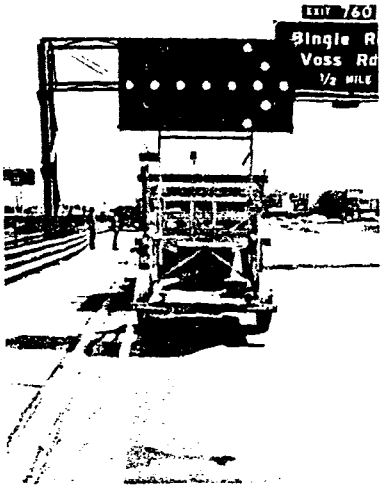
Load zoning must be enforced to be effective. Thus, it is essential that any load zoning effort be coordinated with the appropriate law enforcement agency.

Effectiveness

Load zoning has been used very effectively at freeway reconstruction work zones in Houston and near Beaumont. Compliance rates of 97 to 99 percent were achieved.



Sequential Arrows



Flashing Arrow

Moving Maintenance Operation

ARROWBOARDS

Application

Arrowboards are generally used for day or night lane closures and slow-moving maintenance and construction activities. Guidelines for the use of arrowboards in these situations are presented in Sections 6E-7 through 6E-9 in the Texas MUTCD and on BC (6)-82.

Arrowboards are intended to supplement other work zone traffic control devices. They will not solve difficult traffic problems by themselves, but can be very effective when properly used to reinforce signs, barricades, cones, and other traffic control devices.

Improper Application

Generally, arrowboards should not be used for shoulder or roadside work activities nor should they be used on two-lane highways because the panels can cause unnecessary lane changing. Also, arrowboards should not be used for detours. Instead, the four corner flashing mode should be used.

Effectiveness of Arrowboards

Arrowboards are one of the most effective devices for closing lanes at freeway work zones. They are interpreted by drivers to mean that a lane closure is ahead.

Arrowboards encourage drivers to leave a closed lane sooner than the normal complement of signs and channelizing devices. They are highly visible and can be seen from great distances, making them particularly appropriate for high-speed and high-density conditions.

Types of Arrowboards

There are two common types of arrowboards: 1) flashing arrow and 2) sequential arrow. They may be used interchangeably. In addition, both types can operate in a warning mode (i.e., the four corner lights are flashed as a general warning).

Lane Closures

For left and right lane closures, an arrowboard should be placed at the beginning of the taper on the shoulder. Where there are no shoulders or very narrow shoulders, the arrowboard may be placed in the closed lane behind the taper. Placement at the start of the taper is preferred to placement in the middle of the taper. If more than one lane is closed, an arrowboard should be used at each taper.

If the sight distance to a lane closure is less than 1500 feet, an additional arrowboard may be placed on the roadside upstream of the taper. This supplemental arrowboard will encourage many drivers to vacate the closed lane before seeing the lane closure.

Moving Operations

When a moving maintenance activity occupies a travel lane, a vehicle-mounted arrowboard may be used at the rear of the activity. The arrowboard vehicle should always stay upstream of the maintenance vehicle, where approaching drivers will have time to see and respond to the arrowboard. The vehicle carrying the arrowboard should be equipped with appropriate signing and/or lighting.

Changeable Message Signs

PORTABLE CHANGEABLE MESSAGE SIGNS

Application

CMSs can perform a critical role at urban freeway work zones by furnishing drivers with real-time warnings of problems and unexpected conditions, and advising them of the best course of action. CMSs are especially useful in the following work zone situations:

1. New detours.
2. Change in detours.
3. Introduction of a lane drop where a continuous lane once existed.
4. Special speed control measures.
5. Periodic use of flaggers.
6. Location where sight distance is restricted and congestion occurs due to a lane closure.

Prolonged use of a CMS at the same location and for the same purpose may reduce the sign's effectiveness. It is therefore recommended that CMSs should generally be used for short periods of time (e.g., one to two weeks) and only for special applications.

Types of CMSs

Changeable message signs (CMSs) refer to those signs capable of displaying different messages in response to changing conditions. Types of CMSs include: bulb matrix, disk matrix, rotating drum, tri-color and scroll.

In recent years, CMSs have been made portable by placing them on trailers or pickup trucks. Portable CMSs provide the flexibility to display highlighted information at critical locations in work zones.

Bulb Matrix Signs

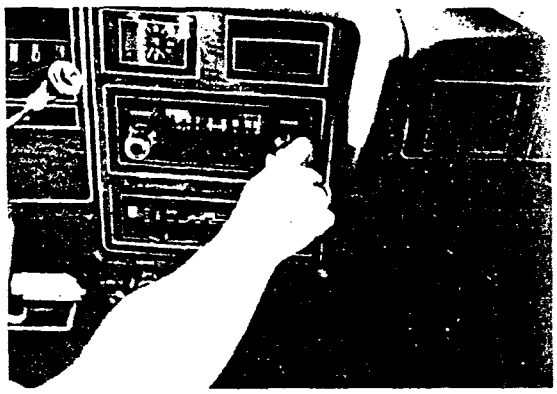
Bulb matrix signs are the most commonly used CMS at freeway work zones. Currently, one-line and three-line portable bulb matrix signs are commercially available. One-line signs are well suited where messages containing 4 words or less will be displayed. Three-line signs can display more information to drivers, and therefore have greater flexibility and utility. For freeway applications, the characters on the sign should be at least 18 inches high.

Operating CMSs

When using CMSs at a freeway work zone, the following general guidelines are recommended:

1. All messages displayed should be reliable, accurate and up-to-date; thus operating CMSs requires special attention and time.
2. The characters (letters and numbers) on bulb matrix CMSs should be at least 18 inches high so that drivers will have time to read the message and respond.
3. As a general rule, CMSs should be placed only on one side of the freeway -- either the left or right side, depending on the need.
4. Bulb matrix CMSs should be dimmed during nighttime use.
5. CMSs should not be used in place of arrowboards to advise drivers of left or right lane closures.
6. Messages should be short enough so that drivers have time to read them. Message length will be dictated by traffic speeds.

Advance Highway Signing



Tuning Dial To 1610

Roadside Transmitter

Beginning of Radio Zone Signing

End of Radio Zone Signing

Application

HAR is a special radio tool that can be used to give motorists up-to-the minute travel information via their AM radios. Work zone warnings, advisories and route directions can be broadcast. An advance highway sign advises drivers where to set the tuning dial to receive the message.

HAR should supplement, not replace, standard traffic control devices used in freeway work zones. HAR should be used for the unusual situations that occur which cannot be handled by the static traffic control devices (e.g., intermittent presence of traffic queues, changing requirements for diversion, etc.).

All HAR installations must be licensed by the Federal Communication Commission (FCC). Designated broadcast frequencies are 530 KHz and 1610 KHz.

HAR Location

The location of an HAR transmitter is restricted by FCC Rules and Regulations to the immediate vicinity of air, train, and bus transportation terminals, public parks and historical sites, bridges, tunnels, and any intersection of a Federal Interstate Highway with any other Interstate, Federal, State, or local highway. Since FCC requires the HAR transmitter be located at a specific site, HAR is generally not used at maintenance work sites but is used at construction sites.

In practice, the trend is to install HAR upstream from major decision points so that drivers can use alternate routes when the need arises. For example, placement of a HAR system upstream from a loop freeway allows traffic to be diverted around construction on the primary radial freeway when congestion becomes excessive due to lane closure(s) or an accident.

HAR Messages

HAR messages are generally recorded for continuous repitition. The message length is adjusted to permit the driver to receive the message at least twice while passing through the stations' coverage zone. Agencies operating HAR must monitor and maintain the system, and must change the message content as the roadway conditions change.

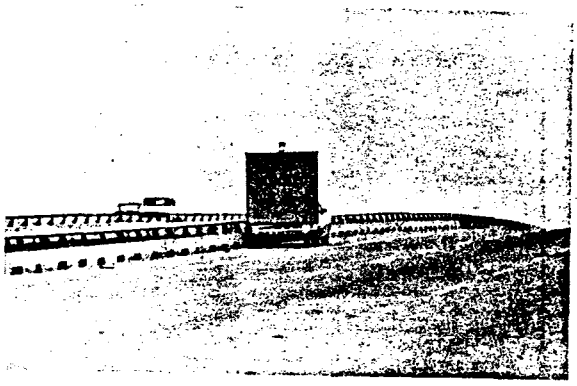
Texas Experience

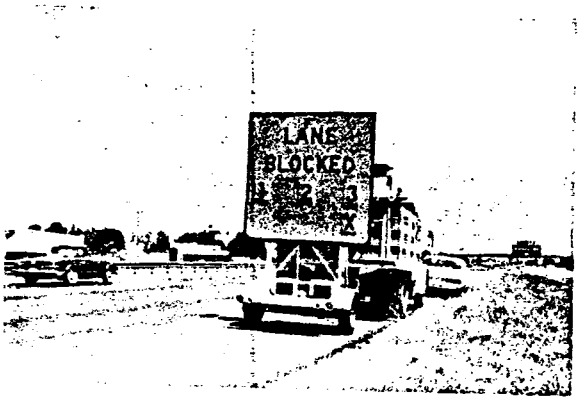
The only documented use of HAR at a work site in Texas was at reconstruction work on I-10 near Beaumont in Chambers County. Some of the findings on a questionnaire survey were as follows: Only 30% of the drivers reported they tried to tune to the HAR station. Approximately 49% of the drivers who did not tune to the station did not see the advance signing for the HAR. Nearly 20% of the drivers said they were very familiar with the work zone and simply did not desire to tune to the HAR broadcasts.

One potential limitation of HAR is the possible interference from commercial radio stations broadcasting near the FCC designated HAR stations.

Advance Sign

The advance sign is very critical to a successful HAR system. It must be very visible and have large letters. It must not be "lost" in the middle of other construction zone signs.





Typical Special Lane Blocked Sign

SPECIAL LANE-BLOCKED SIGN

Application

Drivers need advance warning of lane closures or temporary blockages so they can move into an open lane prior to the point of closure or blockage. On multilane facilities (e.g., freeways, frontage roads and arterial streets) having up to three lanes per direction, the conventional Advance Lane Closed Sign (CW 20-5) can be used for left and right lane closures. Closure of the center lane is more difficult to communicate. With the increased use of the "traffic split" traffic control technique there is a need to effectively describe the center lane closure to drivers.

The communication problem is compounded when there are four or more lanes per direction. Word descriptors like LEFT, CENTER and RIGHT are ambiguous to drivers in designating lane closures in these cases, therefore, signing can become a problem.

The need for advance warning of lane closures also exists for moving maintenance operations on freeways. Generally, no advance notification of a lane blockage is given. On urban freeways, advance notification of which lane is closed could minimize operational problems.

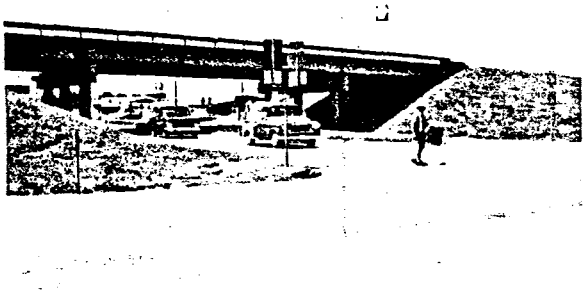
A special lane-blocked sign was developed by TTI and SDHPT and built by District 12 to more effectively communicate lane closures or blockages to drivers. The sign identifies the number of lanes and specifically illustrates which lanes are closed or blocked with a large "X" mounted under the lane number. The lane numbers and Xs are removable to provide flexibility regardless of the number of lanes on the facility and the number of lanes closed. The sign was developed based on national human factors studies of driver understanding of lane closure messages.

Effectiveness

Studies conducted on a three-lane frontage road in Houston during left, center and right lane closures indicated that the special signing performed as well or better than available conventional signs. Drivers understood the sign message and responded by vacating the closed lane. The signing also proved very flexible in that it could be quickly adapted to any lane closure condition. Thus, its use would eliminate the need for large sign inventories and reduce time spent changing signs in the field.

Studies conducted on urban freeways during moving maintenance operations indicated that the special signing results in improved traffic operations in terms of earlier lane changing out of the blocked lane. The sign can be used to warn drivers of a lane blockage on flat tangent and curve sections and at vertical curves where the work vehicles are not in view of oncoming drivers.

For freeway applications, the legend on the sign should be 12 inches high.

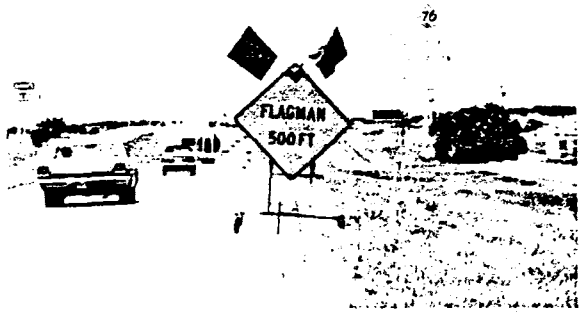


Controlling Traffic at Frontage Road

Directing Traffic Through Work Zones

Innovative Flagging

Proper Attire for Flagger



Approved Signing

Application

At urban freeway work zones, flaggers may perform a variety of critical and somewhat unique traffic control functions, including the following:

1. Control traffic at frontage road intersections and along detour routes.
2. Close entrance and exit ramps.
3. Direct traffic through complicated work zones or at ramps within the work area.
4. Prevent illegal freeway access.
5. Alert traffic to special signing (and enhance motorist response to the signing).
6. Speed control.

Normally, flaggers are best utilized at ramps and frontage road and detour route intersections. Flaggers should be used on the mainlanes only in special situations (e.g., for speed control), since they have difficulty conveying messages to high-speed traffic in several freeway lanes.

Innovative Flagging Applications

Studies have shown that flaggers can effectively reduce speeds up to 10 mph at freeway work zones. For best results, the flagger should get the attention of approaching motorists and then direct their attention (by pointing) to a nearby work zone speed limit sign.

In a similar manner, a flagger can also encourage motorists to read and respond to work zone warning signs (e.g., lane closure and shoulder use signing).

Attire

A flagger should be highly visible in the work zone environment. As a minimum, they should be attired in accordance with the Texas MUTCD (i.e., they shall wear an orange fluorescent safety vest and optional white hardhat or cap). Special uniforms (white overalls and orange vests) were used by flaggers at a major maintenance work zone in Houston with reported success.

Qualifications

Flaggers should be conscientious and dependable workers with good vision, hearing and physical condition. Since flagging is a physically tiring and boring activity, flaggers should be relieved at least every 1 1/2 to 2 hours. Provisions should be made to provide relief flaggers so that flagging stations are always manned by a rested and alert individual.

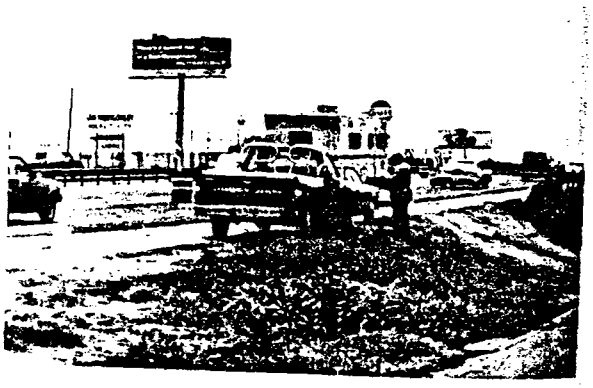
Flagger training and instruction are essential. Flaggers should be familiar with proper traffic control techniques and devices, and know how to use these tools to protect the safety of the work crew and motoring public. Flaggers should also have a basic knowledge of traffic flow principles.

Advance Signing

Whenever a flagger is on duty, the advance flagger sign (W20-7) should be displayed to traffic. When a flagger is not on duty, the sign shall be covered or removed.

Enforcement in Work Zones

Ramp Closure



Control of Illegal Freeway Access

Manual Traffic Control

Active Speed Control

Application

The presence of law enforcement personnel can have positive effects on traffic safety and flow at freeway work zones. Uniformed officers can perform a variety of useful services ranging from work site security patrol to manual traffic control. They can be particularly useful in performing the following traffic management duties:

1. Enforcement of work zone speed limits, load zones and frontage road parking prohibitions.
2. Control of illegal freeway access.
3. Ramp closures.
4. Manual traffic control at intersections and ramps.
5. Removal of accidents and stalls from the mainlanes and accident investigation.
6. Active speed control (e.g., radar enforcement or manual traffic control).

Law enforcement personnel should be enlisted to perform specific traffic control functions, (e.g., those listed above), and that they not be asked to merely "be present" at a work zone.

Communication and Coordination

Whenever law enforcement personnel are utilized at a work zone, it is essential that they know what is expected of them. The job foreman or traffic control supervisor should meet with the officers to discuss their duties and to review the overall traffic control plan. During the work activity, the law enforcement personnel should be routinely informed of the work status and any traffic-related problems which are occurring.

When more than one law enforcement officer is used at a work site, particularly at a major work site, it is important that one of the officers be assigned as supervisor and coordinator of the group. Coordination would insure that law enforcement personnel are repositioned from low activity to high activity locations. Also, it provides flexibility to adapt to changing traffic conditions and to coordinate necessary rest periods.

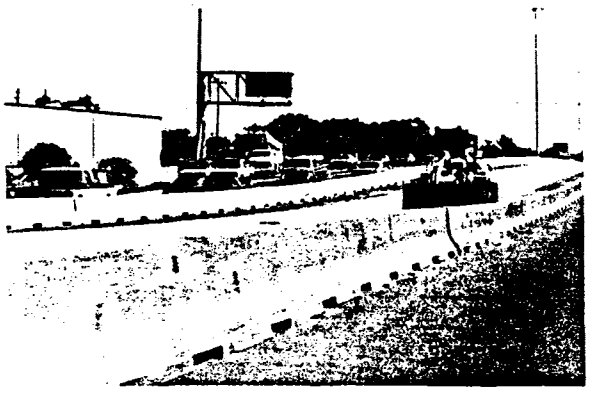
Rest Periods

It is difficult for the officers to control traffic continuously for prolonged periods (e.g., more than 2 hours). If rest periods are not coordinated, rest periods may be taken at the worst time as far as traffic control is concerned. The need for rest periods should be taken into account in the overall traffic management plan since the officers have a profound impact on traffic flow. It may be necessary to have one additional officer at the site to provide the necessary rest period rotation.

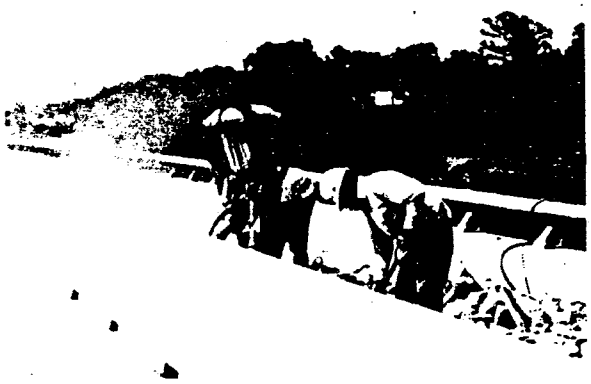
Acquiring Law Enforcement Assistance

In special or emergency situations, police agencies will generally provide on-duty officer assistance. However, most agencies do not have the manpower to provide on-duty officers for routine work zone traffic control.

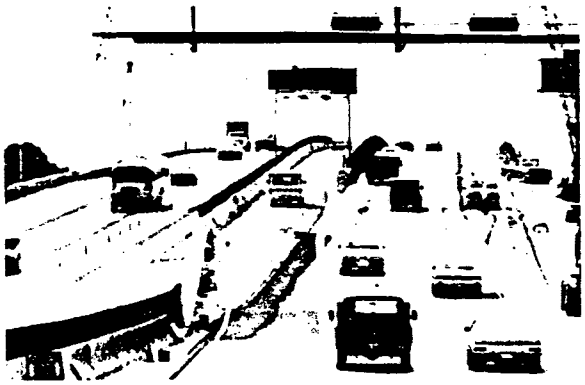
Off-duty police officers may be hired to perform work zone traffic control services. Off-duty officers may or may not be allowed to wear their official uniform (DPS officers are not), and they probably will not have access to an official police vehicle.



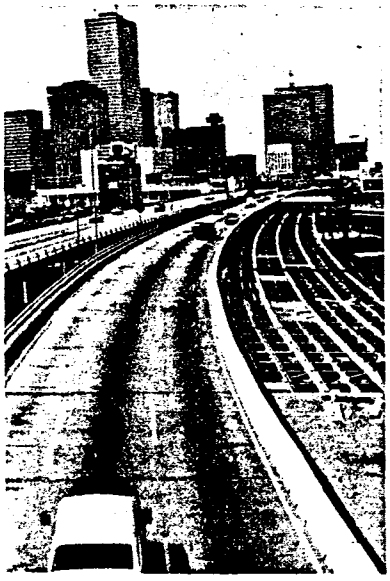
Keep Traffic from Work Areas



Protection for Work Crew



Separates Traffic



Protects Construction

End of Barrier

PORTABLE ROADSIDE BARRIERS

Application

Portable roadside barriers, made of concrete or metal, are designed to contain and redirect errant vehicles. They may be used at freeway work zones to:

1. Keep traffic from entering work areas, excavations or material storage sites.

2. Provide positive protection for workers.

3. Separate two-way traffic, and

4. Protect construction such as falsework for bridges and other exposed objects.

At freeway reconstruction work sites, portable barriers are particularly valuable since they alleviate the need for additional buffer zones between traffic lanes and the work crew and equipment. Thus, more lanes can be kept open and the work zone capacity increased. The use of barriers also allows work to continue during the peak periods and at night if desired.

Safety Performance

Although the total effects of the portable roadside barriers on accidents have not been fully documented, portable roadside barriers are of great safety benefit to the workers at work zones. There are limitations that need to be addressed, however. These limitations are the exception rather than the rule. Cost and implementation time limit the use of these devices in many cases.

Barrier Placement

When lanes are narrowed (e.g., to 11 feet), barriers should be placed at least one foot from the edge of the lanes. This will reduce the tendency of drivers to straddle the lane line.

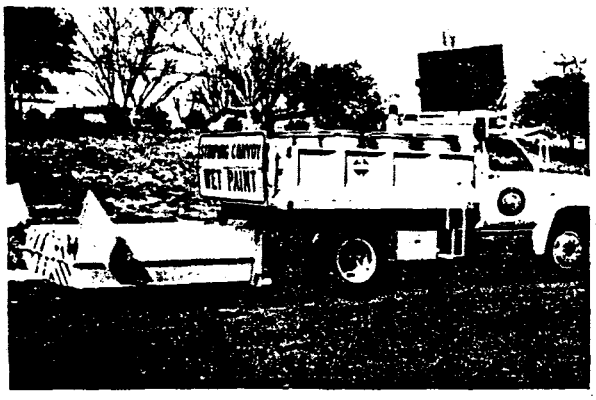
End Treatments

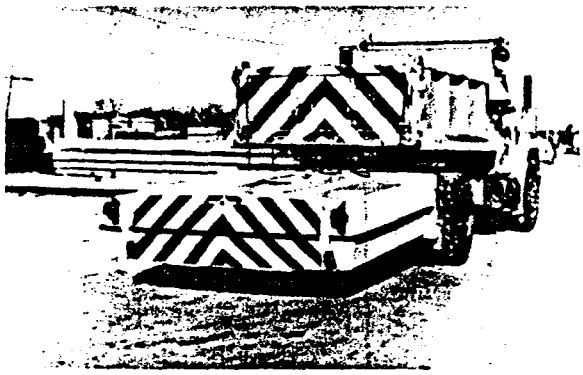
Exposed ends of barriers should have crash cushions to protect traffic, or the ends should be flared away from the roadway by extending the barrier beyond the clear roadside recovery area.

Particular attention should be given to connecting portable or temporary barriers to adjacent existing barriers or guardrails. All connections should develop the full strength of the barrier system(s) and proper transitions must be used. For additional information, see the "Guide for Selecting, Locating and Designing Traffic Barriers."

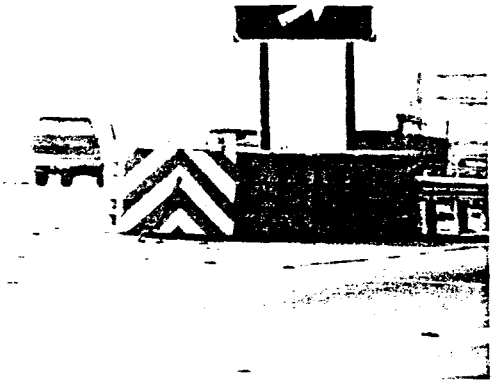
Channelization

Barriers may serve the additional function of channelizing traffic. When used as channelizing devices, barriers should be light in color for increased visibility. Delineators or steady-burn warning lights may be attached to the barrier for channelization. A solid edgeline may be placed on the pavement adjacent to the barrier.





Crash Cushions Mounted on Shadow Vehicles



Crash Cushion in Gore Area

CRASH CUSHIONS

Application

Crash cushions are devices designed to absorb the energy of an impacting vehicle in a controlled manner such that the impact forces on the passengers are tolerable. Crash cushions can be used at freeway work zones to protect traffic from point hazards such as exposed barrier ends, bridge parapets and piers, falsework, etc. Crash cushions may also be mounted on work vehicles to protect the work crew, or on a shadow vehicle to shield a moving maintenance work activity.

Types of Crash Cushions

There are several types of crash cushions available. Sand-filled plastic barrels, steel drums, or a "Guard Rail Energy Absorbing Terminal" are commonly used in work zones to protect point hazards.

Guidelines

Crash cushions should be designed to meet the needs of the particular location. The type and design will depend on the type, length, and width of the hazard. Crash cushion location and design should be incorporated into the Traffic Control Plan.

Whenever crash cushions are used at a work zone, care should be taken to:

1. Install and maintain the crash cushions in accordance with the manufacturers' recommendations.
2. Routinely inspect crash cushions and promptly repair or replace damaged ones.
3. Maintain a sufficient inventory of spare parts to avoid repair delays.

Temporary Lighting in Work Areas

TEMPORARY LIGHTING

Application

Most urban freeways have continuous roadway lighting. On reconstruction projects (e.g., freeway widening or transitway construction), the existing lighting units often must be turned off and relocated. During the time when the permanent lighting is inoperative, temporary lighting may be needed to minimize the nighttime accident potential. In fact, a study conducted in Austin on I-35 found that nighttime accidents may increase by more than 50 percent when urban freeway lighting is turned off.

Guidelines for Use

Currently, there are no guidelines available on when or how to use temporary lighting at urban freeway work zones. The Texas MUTCD does, however acknowledge that such lighting may be beneficial.

Where temporary lighting is used, every effort should be made to provide the minimum lighting levels required for permanent lighting installations. In addition, the lighting units should be protected from vehicle impact by placing them behind temporary barriers or locating them at least 30 feet from the travel lanes. If the units cannot be placed behind barriers or off the roadway, then break-away bases should be used.

District 15 Experience

District 15 used temporary lighting extensively on the FRATT Interchange reconstruction project in San Antonio. On this project, luminaires were mounted on wooden poles in the median. Power was supplied to lighting units by overhead wiring, and the units were protected from traffic by portable concrete barriers.

Floodlighting

Floodlighting is a special type of temporary lighting which is normally used to light the work area so that work can be performed at night. Work zone floodlighting normally is provided by trailer-mounted lighting units powered by small generators. If floodlighting is used, it shall be positioned so that it does not blind approaching motorists (i.e., lighting units should be elevated as much as possible and they should be aimed down toward the pavement). Floodlighting should <u>not</u> be used as a substitute for temporary <u>roadway</u> lighting.

SPECIAL WORD-MESSAGE PAVEMENT MARKING

Application

Word and symbol markings on the pavement may be used to supplement other traffic control devices used for the purpose of guiding, warning or regulating traffic at freeway work zones. Requirements and limitations on the use of these markings are presented in Section 3B-17 of the Texas MUTCD.

At major freeway reconstruction work zones, there are typically many detours, lane closures, ramp closures and other complicated driving conditions. Conventional signing and channelizing devices are used to warn motorists of these conditions and guide them safely through the work zone. However, it is often difficult and/or impractical to place enough signing and channelizing devices at the ideal locations within the cluttered work zone environment. In these situations, special word-message pavement markings may be used to supplement the conventional signing and channelization. Wide stripes have been used successfully at gore areas to enhance traffic operations.

Experience

District 15 used special word-message pavement markings at the FRATT Interchange reconstruction work zone in San Antonio. The word-message markings were installed at major decision points (e.g., in advance of freeway-to-freeway connector ramps) to designate the exit lanes versus the thru lanes. These markings were particularly helpful since the work activity made it impossible to place overhead guide signing in the most desirable locations. The markings were apparently very effective, but they did require frequent maintenance.

CORRIDOR MANAGEMENT TEAM

Application

Major work activities on urban freeways can disrupt police, fire and emergency medical services, as well as local transit operations. They can also prompt more traffic to use the local street system resulting in severe congestion. It is therefore essential that freeway work activities be coordinated with the many local agencies which may be affected. The Corridor Management Team (or Traffic Management Team) provides an excellent means to achieve the needed coordination.

Description

Several cities in Texas have established Corridor Management Teams. As of this writing, Corridor Management Teams are active in Beaumont, Corpus Christi, Fort Worth, Houston, Lubbock, Midland-Odessa, San Antonio, and Wichita Falls. Austin is in the process of forming a team. These teams consist of representatives from the city transportation department, SDHPT, District office, local police agencies, transit agencies and other groups involved in local transportation. The Corridor Management Team functions through formal meetings and informal channels to coordinate metropolitan traffic and transportation activities.

Benefits

The Corridor Management Team, by discussing planned work activities, can anticipate potential problems and solve them before the work even begins. The team approach also allows the various agencies to coordinate their activities and to pool resources if necessary.

Special Traffic Handling Crew
at Lane Closure Work Site

SPECIAL TRAFFIC HANDLING CREW

Application

Freeway work zones can result in serious congestion and traffic safety problems unless special attention is given to work zone traffic management. This special attention can be provided by a Special Traffic Handling Crew. Members of this Crew are specially trained and equipped to install and actively manage traffic at freeway work zones.

Typically, a Crew will consist of a minimum of 4 members, including the Crew supervisor. The duties of the Crew may include: 1) installing, maintaining and removing work zone traffic control devices, 2) coordinating the activities of flaggers and law enforcement personnel, 3) implementing special traffic management strategies (e.g., ramp closures, shoulder usage, frontage road diversion, etc.), and 4) responding to emergency situations (e.g., accidents).

Benefits

The Special Traffic Handling Crew approach offers several benefits. Because of their special training and equipment, the Crew can use the most effective strategies and devices for the particular work zone situation. Thus, congestion and accidents can be minimized. The Crew can also continually monitor work zone conditions and quickly modify the traffic control as needed. This is referred to as active traffic management.

Using a Special Traffic Handling Crew also "frees up" the work force from having to worry about traffic control. This may increase worker productivity and efficiency. The Special Traffic Handling Crew supports the work force by handling the traffic; it does not perform any roadwork.

Training

Training is critical. Crew members, and especially the Crew Chief, should have a basic knowledge of traffic flow principles and of work zone traffic control standards and guidelines. The Crew should also be informed of the latest work zone traffic control technology and hardware.

Equipment

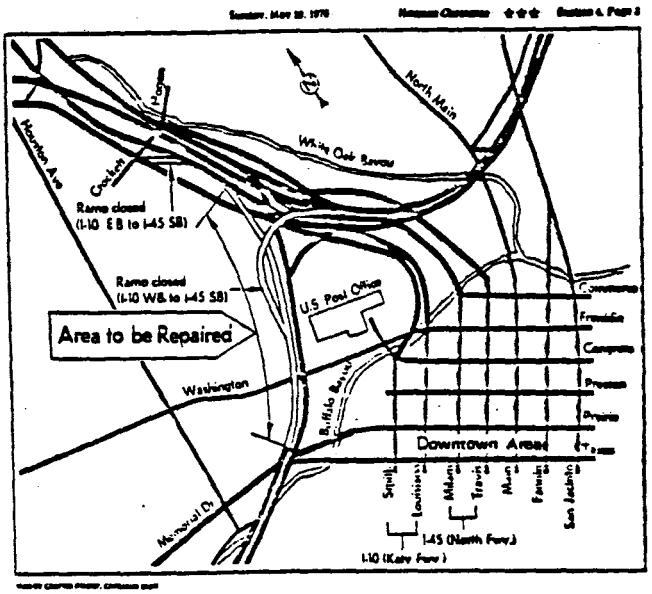
The Crew should have ready access to standard traffic control devices (e.g., signs, cones, arrowboards, barricades, etc.) and also to appropriate innovative devices (e.g., Changeable Message Signs). It is essential that the Crew have appropriate signs and channelizing devices (including temporary pavement marking tape) on hand so that it can respond quickly to changing work zone conditions.

The Crew's vehicle(s) should be highly visible with appropriate markings and lighting devices (e.g., high-level flags, rotating beacon and truck or trailer-mounted arrowboard). It should also be equipped with a two-way radio with their own frequency. District 12, in fact, has developed a special Crew vehicle by modifying a 1-ton truck.

The Texas Department of Highways and Public Transportation says travel on Houston-area freeways Thursday will be affected, weather permitting, by the following projects:

U.S. 59 (Southwest Freeway) northbound at Richmond exit — One lane on each side will be blocked from 9:30 a.m. to 2:30 p.m. for barrel-site repair.

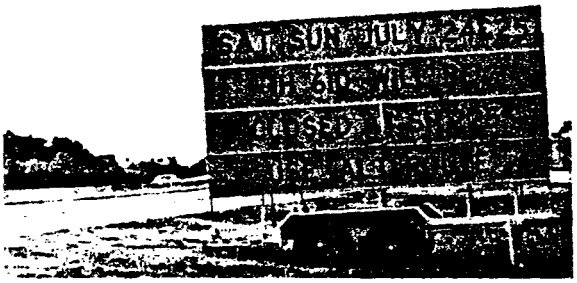
Interstate 45 (North Freeway) northbound from Rankin to FM 1960 — One inside lane will be blocked from 7 a.m. to 3 p.m. for pavement overlay.



The part of Interstate 45 that is scheduled for two years of extensive repairs, beginning Wednesday, is shown here. Southbound lanes will be narrowed and two entrances ramps closed during the first year; then similar work will begin on the northbound lanes. The highway department says heavy trucks, heavy traffic flow and tight concrete contributes to the early need for repairs.

Long Term Road Work

Short Term Road Work



Advance Freeway Closure Signing

Ramp Closure Signing

Application

Freeway reconstruction activities can have a very negative effect on the motoring public, especially if long delays result. To help minimize the negative effects and improve public relations, motorists should be notified of work activities in advance whenever possible. Motorists will then have the opportunity to use different routes or postpone their trips. They may also be more alert and less frustrated as they travel through the work zone.

Advance notification is desirable for all work activities; however, it is most critical for those activities which result in detours, ramp closures, and/or long delays, or performed at unusual time (e.g., night work or weekend work).

Techniques for Advance Notification

Motorists can be given advance notification of a planned work activity in many ways, including the following:

1. Newspaper articles and news releases.
2. Radio and television news broadcasts and spot announcements.
3. Billboards and special advance signs posted along the roadway or in places where large groups of people gather who are likely to be affected by the project.
4. Press conferences.
5. Pamphlets, detour maps, letters, programs, and flyers sent directly to motorists.
6. Door-to-door or telephone contact.
7. Meetings with civic associations, Chambers of Commerce, and other groups.

Newspaper Releases

Typically, a newspaper release will give the location, date and time of the work activity, as well as a description of the work and work zone traffic control strategy (e.g., number of closed lanes). In some cases, a newspaper release may also suggest alternate routes.

Radio and Television Reports

The same types of information that are given in newspaper releases can be presented in commercial radio and television reports.

Portable Signs

Trailer mounted signs, may be installed several days before the scheduled work. Messages giving the location, date, and time of the work, and a description of the work and traffic control can be presented. Alternate routing can also be displayed as needed.

Ramp Closure Signing

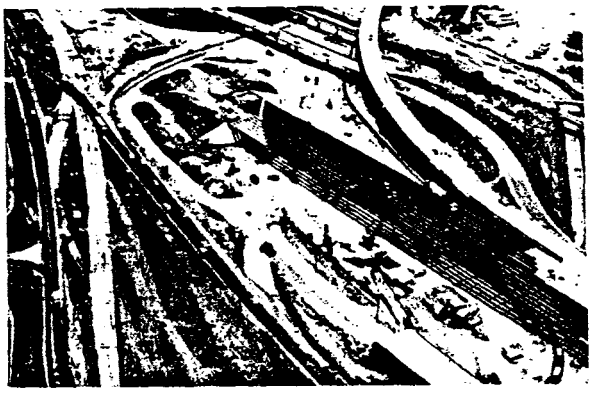
Advance ramp closure notification signs can be posted either on fixed or portable supports at a ramp for several days before a scheduled closure, and will give ramp users the opportunity to find a new route or to postpone or reschedule their trips.

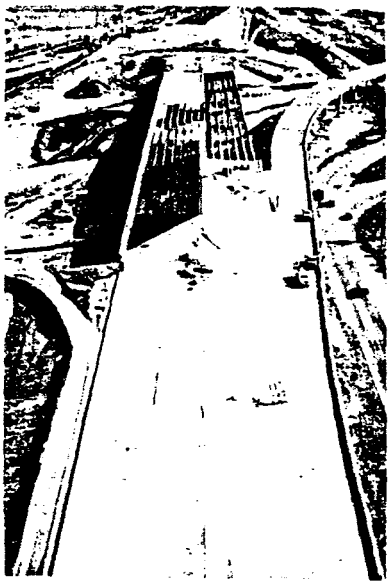
Coordination

Advance notification should be coordinated through one office and directed by one individual (e.g., the District Public Affairs Officer). This will help assure that the proper information about all work is disseminated in a timely and appropriate manner, and that the media will have only one contact person.

Video Taping From Building

Helicopter Used for Aerial Photography





Typical Aerial Photos

Application

Freeway work zones are typically very complex and constantly changing. It would be virtually impossible to remember or keep a detailed written record of every traffic control device, detour, ramp closure, etc., throughout the project life. It is recommended, therefore, that some type of photographic record of the work zone be kept. This documentation, which may consist of photologging, video taping and/or aerial photographs, will provide a permanent record of the traffic control and work status, and may be used to evaluate problem locations and as support evident in tort claims suits.

District 15 Experience

District 15 used a combination of photographic techniques to document the reconstruction of the FRATT Interchange in San Antonio. Every time a new detour was opened or a new work phase initiated, the entire FRATT work zone was photologged. In this manner, signing and barricade changes were documented, and potential traffic control deficiencies were observed and recorded. During the early stages of the project, an attempt was made to document signing changes with a color video. The video pictures, however, lacked the clarity and detail desired by the District.

During the project, aerial photography was used extensively as a traffic control and construction monitoring tool. Color aerial photographs were taken of the work zone at 3-5 month intervals. The photographs were enlarged and placed under plastic. The photos were studied to check work progress, traffic control alternatives, traffic control and detour deficiencies, etc. The plastic coverings over the photos allowed detour alternatives to be sketched directly onto the existing conditions.

IMPLEMENTATION AND CONCLUSIONS

This report provides a reference guide for use by District and Division personnel who plan and implement traffic control at freeway work zones. Twenty-one freeway work zone traffic control strategies and devices are identified and briefly discussed. It by no means is a complete list, but it is a starting point for preparing traffic control plans.

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