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16. Abstract

A three-year study of urban arterial work zones is currently in progress. The objective of the study is to develop improved guidelines for selecting and implementing work zone traffic control on urban arterials. The second year study efforts are documented in a three volume report. The Technical Report appears in Volume 1, which is this document. Volume 2 contains the Appendices for Volume 1, and Volume 3 contains the data used in the research analysis.

This volume includes a description of the study activities performed during the first and second years, the preliminary findings of the study, preliminary guidelines for urban arterial work zones, and a description of activities planned for the final year of the study.

The study activities of the first two years confirm the need for improved guidelines. Current research and guidelines do not thoroughly address the topic. A survey of local agencies indicates a variation in the significance given to work zone traffic control on arterials. Traffic data indicates a decrease in operational efficiency in the vicinity of the construction zones studied. Surveys of motorists indicated they do not fully understand all construction signs and are concerned about the impacts of the construction on their mobility.

The preliminary findings and preliminary guidelines included in this volume address a number of areas related to urban arterial work zones including traffic signals, left turns, lane widths, accidents, construction activities, driver needs, and public relations.

Data collection and analysis will continue during the final year of the research study. The findings and guidelines in this report will be reviewed with SDHPT staff to evaluate the appropriateness and ease with which they can be implemented.

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METRIC (SI*) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
LENGTH				
in	inches	2.54	centimetres	cm
ft	feet	0.3048	metres	m
yd	yards	0.914	metres	m
mi	miles	1.61	kilometres	km
AREA				
in^2	square inches	645.2	centimetres squared	cm^2
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yd^2	square yards	0.836	metres squared	m^2
mi^2	square miles	2.59	kilometres squared	km^2
ac	acres	0.395	hectares	ha
MASS (weight)				
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
VOLUME				
fl oz	fluid ounces	29.57	millilitres	mL
gal	gallons	3.785	litres	L
ft^3	cubic feet	0.0328	metres cubed	m^3
yd^3	cubic yards	0.0765	metres cubed	m^3

NOTE: Volumes greater than 1000 L shall be shown in m^3.

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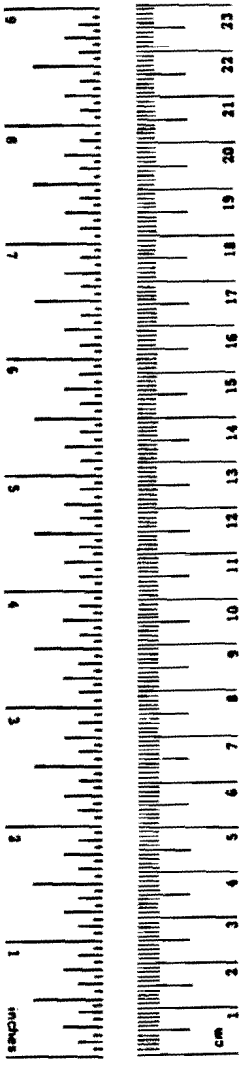

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
LENGTH				
mm	millimetres	0.039	inches	in
m	metres	3.28	feet	ft
m	metres	1.09	yards	yd
km	kilometres	0.621	miles	mi
AREA				
mm^2	millimetres squared	0.0016	square inches	in^2
m^2	metres squared	10.764	square feet	ft^2
km^2	kilometres squared	0.39	square miles	mi^2
ha	hectores (10 000 m^2)	2.53	acres	ac
MASS (weight)				
g	grams	0.0353	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams (1 000 kg)	1.103	short tons	T
VOLUME				
mL	millilitres	0.034	fluid ounces	fl oz
L	litres	0.264	gallons	gal
m^3	metres cubed	35.315	cubic feet	ft^3
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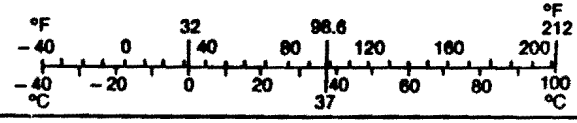

These factors conform to the requirement of FHWA Order 5190.1A.

* SI is the symbol for the International System of Measurements

TRAFFIC CONTROL GUIDELINES FOR URBAN ARTERIAL WORK ZONES

VOLUME 1 - TECHNICAL REPORT

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Research Report 1161-3, Volume 1
Study Number 2-18-89-1161

Design Process for Work Zone Speed Control
and
Traffic Control Guidelines for Urban Arterial Street Work Zones

Sponsored by
Texas State Department of Highways and Public Transportation
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Federal Highway Administration

Texas Transportation Institute
The Texas A&M University System
College Station, Texas 77843

October 1990

ABSTRACT

A three-year study of urban arterial work zones is currently in progress. The objective of the study is to develop improved guidelines for selecting and implementing work zone traffic control on urban arterials. The second year study efforts are documented in a three volume report. The Technical Report appears in Volume 1, which is this document. Volume 2 contains the Appendices for Volume 1, and Volume 3 contains the data used in the research analysis.

This volume includes a description of the study activities performed during the first and second years, the preliminary findings of the study, preliminary guidelines for urban arterial work zones, and a description of activities planned for the final year of the study.

The study activities of the first two years confirm the need for improved guidelines. Current research and guidelines do not thoroughly address the topic. A survey of local agencies indicates a variation in the significance given to work zone traffic control on arterials. Traffic data indicates a decrease in operational efficiency in the vicinity of the construction zones studied. Surveys of motorists indicated they do not fully understand all construction signs and are concerned about the impacts of the construction on their mobility.

The preliminary findings and preliminary guidelines included in this volume address a number of areas related to urban arterial work zones including traffic signals, left turns, lane widths, accidents, construction activities, driver needs, and public relations.

Data collection and analysis will continue during the final year of the research study. The findings and guidelines in this report will be reviewed with SDHPT staff to evaluate the appropriateness and ease with which they can be implemented.

IMPLEMENTATION STATEMENT

This study was sponsored by the Texas State Department of Highways and Public Transportation with the major objectives of establishing a comprehensive work zone speed control design process and developing improved traffic control guidelines applicable to urban arterial work zones. The results of this research effort will provide more uniform implementation of work zone speed zoning and speed control measures as well as lead to improved operations, and safety for both workers and drivers in urban arterial work zones.

DISCLAIMER

The contents of this report reflect the views of the authors who are responsible for the opinions, findings, and conclusions presented herein. The contents do not necessarily reflect the official views or policies of the Federal Highway Administration or the Texas State Department of Highways and Public Transportation. This report does not constitute a standard, specification, or regulation.

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SUMMARY

Urban arterials are being required to carry a greater traffic load than in the past. Therefore, arterial construction has increased in order to provide additional capacity for the vehicular demand. The SDHPT has established the PASS (Principal Arterial Street System) program for the upgrading of major arterial streets. The resulting construction has led to a recognition of the lack of adequate guidelines for work zones on urban arterials.

One objective of this three year research study is to develop improved guidelines for selecting and implementing work zone traffic control on urban arterials. Study activities during the first two years include a literature review, selection of study sites, data collection at three study sites, two motorist surveys, and a review of current practice. The data collected as part of this study includes traffic volumes, travel times, and accident histories.

Second year efforts related to the urban arterial work zone study are documented in three separate reports. Research report 1161-3, Volume 1, "Traffic Control Guidelines for Urban Arterial Work Zones - Technical Report" (this document) provides a brief description of research activities and includes the preliminary findings and preliminary guidelines developed during the first two years of study. Research report 1161-3, Volume 2, "Traffic Control Guidelines for Urban Arterial Work Zones - Appendices" contains several appendices which provide additional detail about specific research activities summarized in Volume 1. Research report 1161-3, Volume 3, "Urban Arterial Work Zone Data" contains data and supporting documentation related to the study sites and surveys.

Early research efforts focused on identifying and evaluating reference material addressing urban arterial work zones. The literature review indicated a discrepancy between the availability of research information on freeway and rural highway work zones, and that on urban arterial work zones.

Early in the research study, three study sites were identified where appropriate data could be collected. The study sites selected include a 7 mile segment of F.M. 1960 in

Houston, 6 miles of S.H. 6 in Houston, and a 2 mile segment of Abrams Road in Dallas. Data collected at the study sites includes traffic volumes, travel times, and accident records. Data has been or will be collected during the preconstruction and construction periods at most of the study sites. Preliminary analysis of the data was used in identifying preliminary problems and preliminary guidelines.

Two motorist surveys were conducted in conjunction with this project. The first survey was administered on F.M. 1960 in Houston and the second on Abrams Road in Dallas. Both surveys were similar in format and delivery. The surveys were developed to ascertain knowledge about work zone signing in general, determine confusing or problematic areas of the signing, and elicit information from motorists about construction project concerns that may not be related to the understanding of traffic control devices. The surveys were conducted at shopping areas and drivers license offices by asking participants to respond to a series of pictures and questions related to the work zone in the area of the survey.

Discussions were held with city and state traffic personnel in order to determine the current practice of traffic control on urban arterial work zones. A survey was conducted of traffic engineers from local transportation agencies. A survey of city traffic engineers indicated that there is variation in the degree in which urban arterial work zone traffic control is stressed. Several of these individuals indicated the Texas MUTCD did not sufficiently address work zone traffic control on urban arterials.

The research activities of the first and second year have identified a number of preliminary findings related to urban arterial work zones. Most of these issues identify areas where guidelines may result in improved safety and efficiency in arterial work zones. Three categories have been developed for classifying the major issues: 1) traffic control and operations, 2) construction activities, and 3) driver needs.

Preliminary findings related to traffic control and operations address traffic signals, left turns, lane widths, pedestrians, traffic diversion, accidents, and transit. Preliminary findings related to construction activities address lane striping, barriers, lane closures, scheduling, crossovers, and grades. Preliminary findings related to driver needs address street signing, business signing, enforcement, and public relations.

An analysis of the preliminary findings led to the development of preliminary guidelines for use on urban arterial work zones. The preliminary guidelines are divided into those related to the traffic control plan, traffic control devices, construction or contractor activities, and public relations.

One year of research remains on this project. Activities during the third year will include continuing previous study efforts and performing additional activities to evaluate the preliminary guidelines contained in this report.

CHAPTER 1

INTRODUCTION

The arterial street systems of major Texas cities are being forced to carry an expanding share of the traffic burden as a result of the continued increase in congestion on the freeways in these cities. The Texas State Department of Highways and Public Transportation (SDHPT) recognized this fact and, in September 1987, the Highway Commission gave approval to a $100 million project for the overhaul and upgrading of major urban arterial streets. The intention of this program is to relieve a portion of freeway traffic congestion by providing additional capacity and improving traffic flow on the urban arterials. This ambitious program is entitled PASS (Principal Arterial Street System) and is fully endorsed by the cities of Arlington, Austin, Corpus Christi, Dallas, El Paso, Fort Worth, Houston, and San Antonio.

The successful completion of construction associated with the PASS program requires the assurance of safety for motorists and workers within major urban arterial work zones while keeping traffic moving at acceptable speeds and volumes. A portion of this study has been funded to identify areas where the safety of urban arterial work zones can be improved and to then develop guidelines to address these areas. Such guidelines will provide additional direction beyond that found in the *Texas Manual of Uniform Traffic Control Devices* (MUTCD) (1) or in previous research.

Urban arterial work zones possess many unique characteristics not found in rural or freeway work zones. Some of the typical urban arterial work zone characteristics include: high traffic volumes, large turning movements, large number of driveways and the vehicular movements associated with these driveways, narrow right-of-way and the restricted work area resulting from the narrow right-of-way, difficulty of providing barrier protection between the work area and the travel lanes, end treatments of barriers at driveways and intersections, visibility restrictions related to barrier placement, and maintaining access to businesses and residences.

Study Objectives

Study 1161 is a two part research study intended to address two different areas of concern related to work zones. These areas of concern are urban arterial work zones and work zone speed control. The major objectives of these two areas are:

1) Develop improved guidelines for selecting and implementing work zone traffic control on urban arterials.
2) Develop a comprehensive design process for selecting and implementing appropriate speed zones, devices, and techniques for speed control in work zones.

Study Research Reports

Prior and current research efforts on this study have been documented in several different research reports prepared by the Texas Transportation Institute. First year efforts related to the urban arterial work zone portion of the study were described in Research Report 1161-1, "Traffic Control Study of Urban Arterial Work Zones". This report describes the data collection efforts of the first year, but does not include any findings or guidelines. This report was not published, but is available from the Texas Transportation Institute.

Second year efforts related to the urban arterial work zone study are contained in three separate volumes. Research report 1161-3, Volume 1, "Traffic Control Guidelines for Urban Arterial Work Zones - Technical Report" (this document) provides a brief description of research activities and includes the preliminary findings and preliminary guidelines developed during the first two years of study. Research report 1161-3, Volume 2, "Traffic Control Guidelines for Urban Arterial Work Zones - Appendices" contains several appendices which provide additional detail about specific research activities summarized in Volume 1. These appendices address the literature review, study site selection, data collection and analysis, motorists surveys, and review of current practice. Research report 1161-3, Volume 3, "Urban Arterial Work Zone Data" contains data related to the study sites and surveys. Specific data includes traffic volumes, travel times, accidents, and motorist survey instruments.

First year research efforts related to work zone speed control are described in research report 1161-2, "Catalog of Work Zone Speed Control Measures". Second year research efforts will be described in research report 1161-4, which will be submitted separately from the urban arterial work zone reports.

CHAPTER 2

STUDY DESCRIPTION

Research Approach

The research activities associated with this study are intended to evaluate urban arterial work zones and to develop guidelines which may improve traffic flow and safety in these areas. The activities include collecting traffic and accident data at three sites in Texas, reviewing related research activities and literature, evaluating motorists' understanding of work zone traffic control devices, and discussing traffic control with SDHPT and city personnel. Each of these activities is described in greater detail in the following section of this chapter. The information gained from each of these activities was reviewed and analyzed to determine issues and concerns which impact traffic control in urban arterial work zones. Preliminary guidelines have been developed to address these areas.

Research Activities

The following subsections briefly describe the major highlights of research activities performed as part of this study. More detailed descriptions of these activities may be found in the corresponding appendices in Volume 2 of this report.

Literature Review

Early research efforts focused on identifying and evaluating reference material addressing urban arterial work zones. The literature review indicated a discrepancy between the availability of research information on freeway and rural highway work zones, and that on urban arterial work zones. Nevertheless, a number of references were found to contain some degree of pertinent information about the desired subject matter. Some previous research efforts have documented the lack of information on urban arterial work zones and indicate a need to expand the National MUTCD in this area. Additional research material will be evaluated as it becomes available.

The National *Manual on Uniform Traffic Control Devices* (MUTCD) (2) contains standards for the use of all traffic control devices, including those devices used in work zones. Texas has its own version of the MUTCD (1) for use on all streets and highways in the State of Texas. The Texas MUTCD basically follows the National MUTCD, although some modifications have been made to meet State laws or more closely fit conditions in Texas. References to the MUTCD in this report refer to the Texas MUTCD.

Part VI of the MUTCD addresses "Traffic Control for Street and Highway Construction, Maintenance, Utility and Emergency Operations." This part of the MUTCD does not specifically address work zone traffic control on urban arterials, as it does with expressways and limited access facilities. However, this has not always been the case. The 1961 edition of the National MUTCD (3) dealt with urban applications of work zones. This section was dropped from the 1971 edition of the MUTCD for unknown reasons.

Part VI of the National MUTCD is currently undergoing a revision process. The 2nd draft of revisions (4) indicates a small increase in referencing urban area construction zones. However, the additional material does not address many of the problem areas related to urban arterial work zones.

A Virginia study (5) specifically addressed accident characteristics within urban area construction zones. This study utilized a statistical analysis of accident and traffic data to determine the impacts of urban work zones. Some of the conclusions cited by this report include:

- Accident rates on urban multilane highways increased on average about 57 percent when compared to the accident rate prior to the work zone, although the amount of increase depended on the type of traffic control used.
- Accident rates on urban two-lane highways increased on average about 168 percent when compared to the accident rate prior to the work zone, although the amount of increase also depended on the type of traffic control used.
- Although there is a general lowering of average speeds, speed variance tends to increase during urban work zone activities.
- Statistical analysis of accident and traffic control data indicated that the most

effective combination of traffic control devices for urban multilane work zones are cones, flashing arrows, and flagmen.

- Statistical analysis of accident and traffic control data also indicated that accident frequency was higher when barricades were included with other traffic control devices than when the other devices were used without barricades. No explanation was provided as to why barricades had such an impact on accidents.
- Statistical analysis of accident and traffic control data indicated that the most effective combinations of traffic control devices on urban two-lane highways are cones and flagman or static signs and flagman. The analysis also showed that flaggers are a very effective means of traffic control on urban two-lane work zones.

The Literature Review is described in greater detail in Appendix A of Volume 2.

Study Site Selection

Early in the research study, three study sites were identified where data could be collected. The study sites had to meet several qualifications including: located on an arterial street in an urban area, construction duration of at least one year, and a convenient location for data collection. Tables 1, 2, and 3 contain information about the study sites.

The Abrams Road site represents a change from the original choice of a study site in the Dallas area. During the first year of the study, Skillman Avenue was selected as the study site. However, there were several delays in getting the project out for bid and the project principal investigator and technical coordinator determined that it was desirable to change the study site to Abrams Road.

The research activities related to selecting study sites are described in greater detail in Appendix B of volume 2.

Table 1. F.M. 1960 Information

Location: Northwest metropolitan Houston area (see Figure 1)
On State highway system: Yes
Limits: I.H. 45 to S.H. 249
Length of construction: 7 miles
Date construction began: January 1988
Construction completion date: December 1989
Type of construction: Widen roadway from 4 lanes with continuous left turn lane to 6 lanes with continuous left turn lane
Traffic control requirements: Two lanes open in each direction
Number of intersections: 50
Number of traffic signals: 27
Number of driveways: 360
Type of adjacent development: strip commercial, retail, residential

Table 2. S.H. 6 Information

Location: Northwest metropolitan Houston area (see Figure 1)
On State highway system: Yes
Limits: U.S. 290 to Clay Road
Length of construction: 6 miles
Date construction began: September 1988
Construction completion date: April 1991 (projected)
Type of construction: Widen roadway from 4 lanes with continuous left turn lane to 6 lanes with continuous left turn lane
Traffic control requirements: Two lanes open in each direction
Number of intersections: 25
Number of traffic signals: 11
Number of driveways: 155
Type of adjacent development: strip commercial, residential

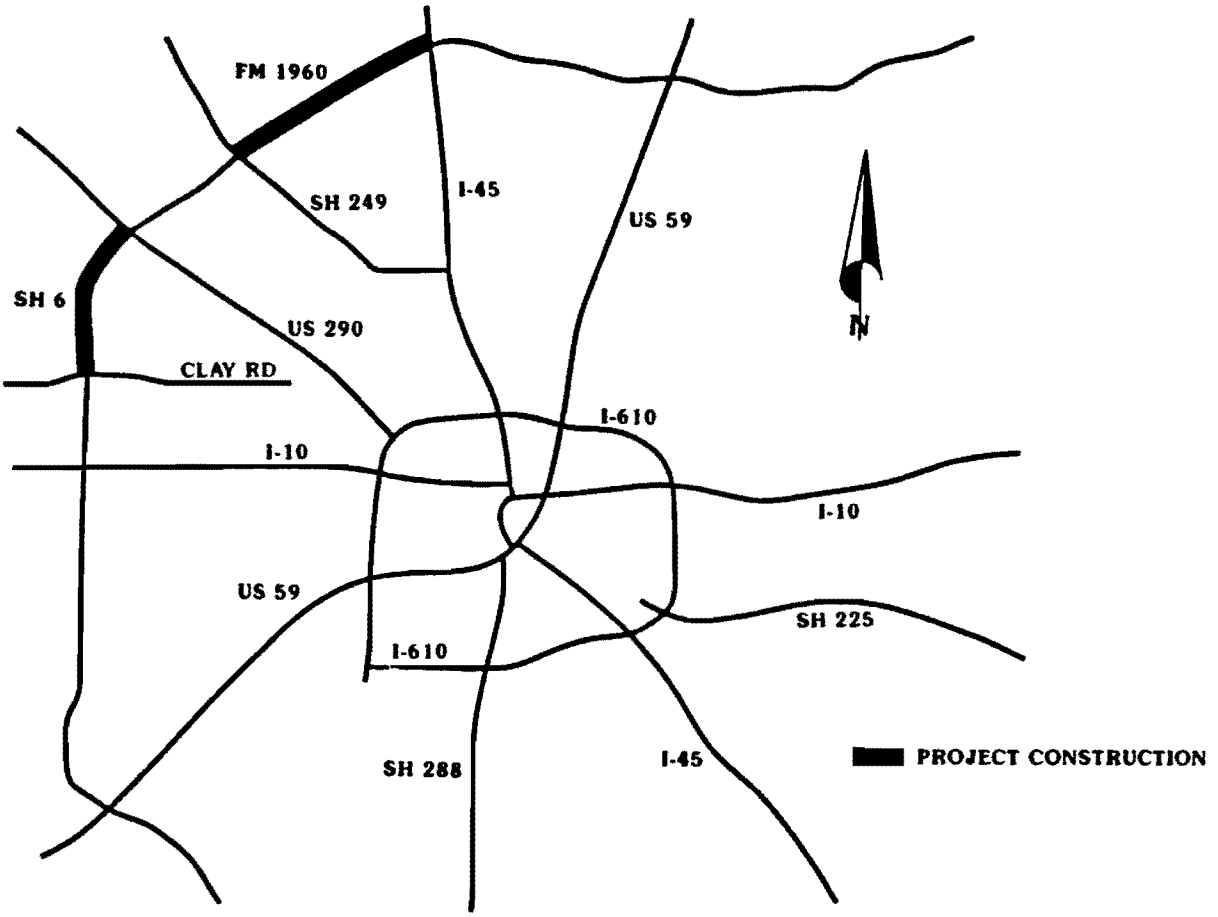


Figure 1. F.M. 1960 and S.H. 6 Study Sites

Table 3. Abrams Road Information

Location: north Dallas (see Figure 2)
On State highway system: No
Limits: Kingsley to Meadowknoll
Length of construction: 2 miles
Date construction began: July 1989
Construction completion date: July 1991 (projected)
Type of construction: Widen roadway from 4 lanes with no median to 6 lanes with raised median
Traffic control requirements: Two lanes open in each direction
Number of intersections: 12
Number of traffic signals: 4
Number of driveways: 17
Type of adjacent development: strip commercial, residential

Data Collection

Data was collected at all three of the study sites. The collected data includes traffic volumes, travel times, and accident records. Preconstruction data was collected at the S.H. 6 site. Data was collected during the construction period at all three sites. Post construction data has been collected at the F.M. 1960 site, and will be collected at the other sites when construction is completed. The available data was then analyzed with the following objectives in mind:

- Determine the impacts of construction on traffic movement through the urban arterial work zones.
- Identify situations where guidelines may result in better safety or traffic flow through arterial work zones.
- Develop potential guidelines for urban arterial work zones

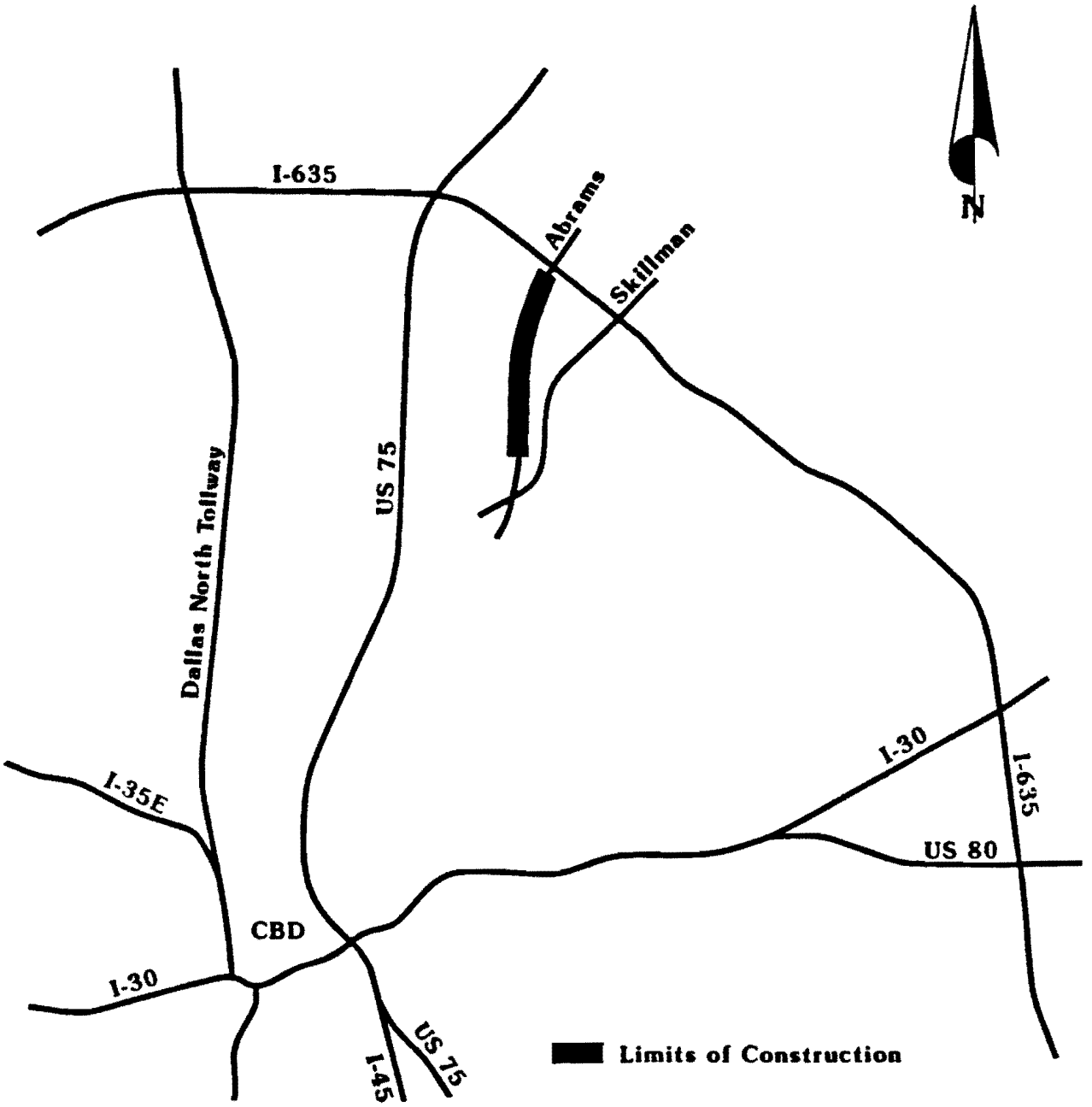


Figure 2. Abrams Road Study Site Location

Travel time data was collected at each of the three study sites in order to measure the quality of traffic movement before, during, and after construction. The travel runs were made approximately twice a year using the average-car method.

An analysis of the data indicated that travel times during the construction period were higher than both the pre- and post construction periods. The higher travel times indicate a reduction in speeds and appear to be the result of construction actions such as narrower lanes, loss of signal progression, interference from construction activities, limitations of sight distance, access restrictions, and removal of the continuous left turn lane.

Daily traffic volumes were collected at several locations on the arterial streets and major cross streets during the same time periods as the travel time data. These volumes were used to indicate motorists' response to the construction, changes in travel demand, and potential diversion to other routes.

The general trend showed a decrease in volumes when construction began, and an increase following construction. Traffic volumes were highly variable throughout the construction period. The only post construction volumes available at the present time are from F.M. 1960 and these are higher than the pre-construction volumes.

Changes in traffic volumes during the construction period may be attributable to several different factors. Motorists may initially avoid the confusion in the construction area, but return after traffic has adjusted to the construction conditions. Seasonal changes in travel demand may account for some of the variations. Changes in construction phasing or traffic control may also have impacted traffic volumes during certain time periods. Increases in traffic volumes after completion of construction are probably due to the increased capacity and reduced travel time on the newly completed roadway.

Traffic accident data collected to this point in time has been used to provide an indication of the safety impacts of arterial construction. The accident data was obtained from the Department of Public Safety Master Accident File for both Houston study sites. Accident data for the Abrams Road site will be obtained from the Dallas Police Department.

Five years of data have been analyzed, including the three years preceding construction (1985-1987) and the first two years of construction on F.M. 1960 and S.H. 6 (1988-1989). The initial accident analysis indicates that the frequency of accidents during the construction period increased significantly when compared to the preconstruction period. On F.M. 1960, the average of the accident rate (accidents per million vehicle miles) for the two years of construction was 37 percent higher than the average accident rate for the three years preceding construction. On S.H. 6, the average accident rate for the two years of construction was 110 percent higher than the average accident rate for the three years prior to the start of construction. All types of accidents (right angle, rear end, side swipe, and other) increased during the work phase at about the same proportion as the total accidents in the work zone.

Data collection and analysis activities are described in greater detail in Appendix C of Volume 2.

Motorists' Surveys

Two motorist surveys were conducted in conjunction with this project. The first survey was administered on F.M. 1960 in Houston and the second on Abrams Road in Dallas. Both surveys were similar in format and delivery.

The surveys were developed to meet the following objectives:

- To ascertain knowledge about work zone signing in general.
- To determine confusing or problematic areas of the signing.
- To elicit information from motorists concerning problems with the construction projects that may not be related to understanding traffic control devices.

Survey participants were first asked to respond to questions regarding work zone signs and other forms of traffic control devices that were presented in a booklet of photographs. This set of questions was followed by a series of photographs or signs and scenes from the reconstruction project with corresponding questions. The third segment of the interview was a discussion with the participant of their opinions about various aspects of the reconstruction

project. A brief set of biographic questions concluded the interview. The interview time averaged approximately 10 minutes.

The surveys revealed that some motorists do not fully understand some signing used in work zones. The surveys indicate that the signs described below were not well understood by portions of the Houston and Dallas survey participants.

The **Advance Construction** sign was correctly interpreted by 66 percent of the respondents in the Houston survey and 69 percent in the Dallas survey. The difference between the standard **Two-Way Traffic** yellow warning sign and orange construction sign, was correctly identified by 54 percent of the Houston respondents. Fifty percent of the Dallas respondents correctly identified the difference between the two signs. Only 16 percent of the Dallas respondents could discern the directional clues of the orange and white **Hazard Marker** (vertical panels). The behavioral response to the placement of the standard **Crossover** sign was interpreted incorrectly by 45 percent of the Houston survey respondents and by 47 percent of the Dallas survey respondents. A significant amount of the respondents interpreted the **Low Shoulder** sign incorrectly in both the Houston and Dallas surveys, 87 percent and 82 percent, respectively.

Motorists' concerns or perceptions related to the Houston construction project seem to be associated with the excessive length (in miles) of the project (stated by 23 percent of respondents), turning problems (18 percent), and increased travel delay (13 percent). The Dallas area project concerns were concentrated around the construction work taking too long (24 percent) and the hazardous road conditions (25 percent). However, the perception of 91 percent of the Houston respondents and 84 percent of the Dallas respondents was that the benefits of widening the roadway are worth the inconveniences they experience during the reconstruction.

The Motorists Surveys are described in greater detail in Appendix D of Volume 2.

Review of Current Practice

Discussions were held with city and state traffic engineering personnel in order to determine the current practice of traffic control on urban arterial work zones. A survey of traffic engineers from local transportation agencies indicated that there is variation in the degree in which traffic control is stressed. Most cities are not directly responsible for the development of a Traffic Control Plan. Several agencies indicated the Texas MUTCD did not sufficiently address work zone traffic control on urban arterials. Contact with local and state agency personnel will be continued throughout the course of the project. Some telephone interviews of additional city and county personnel may be performed during the third year of the study, if needed.

Discussions were also held with selected SDHPT staff personnel. These discussions resulted in findings similar to those of the agency survey. Appendix E of Volume 2 describes the review of current practice activities in greater detail.

CHAPTER 3

PRELIMINARY FINDINGS

The research activities of the first and second year have identified a number of areas where urban arterial work zone guidelines may be useful. Several of these areas are not fully addressed in current work zone traffic control guidelines, if addressed at all. Guidelines addressing these areas could result in safer and more efficient movement of traffic through the arterial work zone. In most cases, the engineer or contractor must use their best judgement to determine the most appropriate alternatives for planning and supervising construction activities on urban arterial work zones. Three categories have been developed for classifying the major areas: 1) traffic control and operations, 2) construction activities, and 3) driver needs. Although there may be overlap between categories, areas have been placed in the category with which they are primarily concerned. General descriptions of the major areas are provided in the following sections. Preliminary guidelines for specific problems are described in Chapter 4.

Traffic Control and Operations

Traffic control and operational issues include those difficulties related directly to specific traffic control devices, the traffic control plan, traffic operations, or traffic flow. The following issues have been identified:

Traffic Signals

Traffic signals are among the most important of the traffic control devices on arterial streets. The overall capacity of the arterial is typically limited to the capacity of the signals on that arterial. When traffic signals operate at a less than optimal level, congestion and traffic flow problems may result. Undesirable impacts of decreased signal performance include increases in congestion, travel times, motorists' frustration levels, and traffic signal violations. The following aspects of traffic signal operation were found to be affected by urban arterial construction activities.

Phasing and Timing Changes

Changes in traffic volumes, traffic patterns, and lane arrangements affect the signal phasing and timing. Preconstruction phasing and timing sequences may no longer be appropriate and may, in fact, create additional congestion. Additionally, changes in construction phasing also impact the appropriate signal phasing and timing patterns.

During construction, the contract typically calls for the contractor has responsibility for traffic signal operation. However, contractors may not have the expertise to make the signal phasing and timing changes appropriate for the traffic conditions. Additionally, they may not keep adequate records of phasing and timing changes made by their personnel creating a potential liability concern.

Loss of Signal Actuation Capability

When construction takes place at an actuated intersection, the detection capability of the signal operation is normally lost. Loss of detection occurs because lanes may be adjusted so that detectors are no longer in a single lane or because detectors are damaged or removed as the result of construction activity. Loss of actuation also affects how pedestrian movements at the intersection must be handled. Pedestrian issues are described in the pedestrian section.

Loss of Progression Capability

Utility adjustment or excavation activities may remove the hardwire interconnection between traffic signal controllers. When this occurs, progression between signals can no longer be maintained.

Intersection Blockage

During periods of heavy congestion, many motorists will enter the intersection during a green indication. However, the heavy congestion prevents the vehicle from clearing the intersection before the red indication appears. At this point, the vehicle then becomes an obstacle to cross street traffic which has the right-of-way. Continued repetition of this scenario may lead to gridlock.

Intersection blockage may occur due to congestion resulting from several different activities including inefficient operation of downstream signals, downstream capacity restrictions such as lane closures, large traffic generators downstream, and other reasons.

Turning Maneuvers

The reasons supporting a reduction in lane widths also support the removal of left turn lanes at intersections. However, this removal does not eliminate motorists' desire to make left turns. As a result, a left turn vehicle will block the inside lane while waiting for a gap to make a left turn. Removal of left turn lanes becomes especially critical at major signalized intersections. Heavy left turn volumes and the lack of adequate gaps result in poor operations and congestion. Prohibiting left turns may not be an acceptable alternative.

Turning radii may also be reduced at intersections, driveways, and crossovers. The temporary radius may cause a turning vehicle to encroach on adjacent travel lanes, particularly if the lanes are of a reduced width.

Lane Widths

Travel lanes of reduced width are often utilized in work zones to provide room for construction on one side of the right-of-way. Reduced lane widths may range from 10 feet to 11½ feet. Reduced lane widths may create a feeling of discomfort in the driver, resulting in slower speeds. Side swipe accidents may increase. Turning maneuvers onto the arterial become more difficult and vehicles may encroach on adjacent lanes.

Pedestrians

Pedestrians are not normally present in significant numbers on most urban arterials in Texas. This sometimes results in an ineffective accommodation of pedestrian needs, such as placing pedestrians between traffic and the work area, restricting or eliminating access to pedestrian buttons at signalized intersections, requiring pedestrians to walk in muddy or dirty areas, reducing the visibility of crosswalks or eliminating them entirely, eliminating the refuge area on divided arterials, and failure to adjust pedestrian crossing or clearance times.

Traffic Diversion

The presence of construction on urban arterials may induce drivers to divert to alternate routes. This diversion may reduce demand and congestion through the work zone, but may also burden the alternate route, exceeding the alternate route's ability to meet the traffic demand. The amount of diversion is difficult to predict.

Traffic Speeds

Typically, average speeds in a work zone do not decrease from the preconstruction speeds, although the speed variance may increase. While lower speeds may be desirable for a work zone, portions of the driving public may not observe speed restrictions. This can lead to a greater variability in vehicle speeds in the work zone.

Accidents

An increase in arterial work zone accidents may occur due to the many changes that occur to the roadway system. Several changes, previously mentioned in this section, that could contribute to increased accidents because of driver unfamiliarity are: signal phasing and timing, intersection blockage due to congestion, reduced lane widths, and the removal of left-turn lanes. Additional factors that may contribute to increased accidents are: sight distance restrictions due to barriers, grade differences at crossovers, and driver overload.

Transit

The presence of a work zone can seriously impact transit operations. The presence of a work area may require elimination or relocation of bus stops and waiting areas. Passenger demand may also be influenced by the inconveniences associated with construction. Buses stopping at the near side of an intersection reduce the capacity of the intersection. In the case of a four-lane roadway without turn lanes, flow through the intersection may be stopped when a bus stops in the outside lane and a left-turning vehicle in the inside lane waits for a gap to turn. Buses stopping on the far side of the intersection may cause traffic to queue and block the intersection.

Construction Activities

Issues associated with construction activities include those difficulties related directly to performing construction activities, contract specifications, or protection of construction areas. The following issues have been identified:

Lane Striping

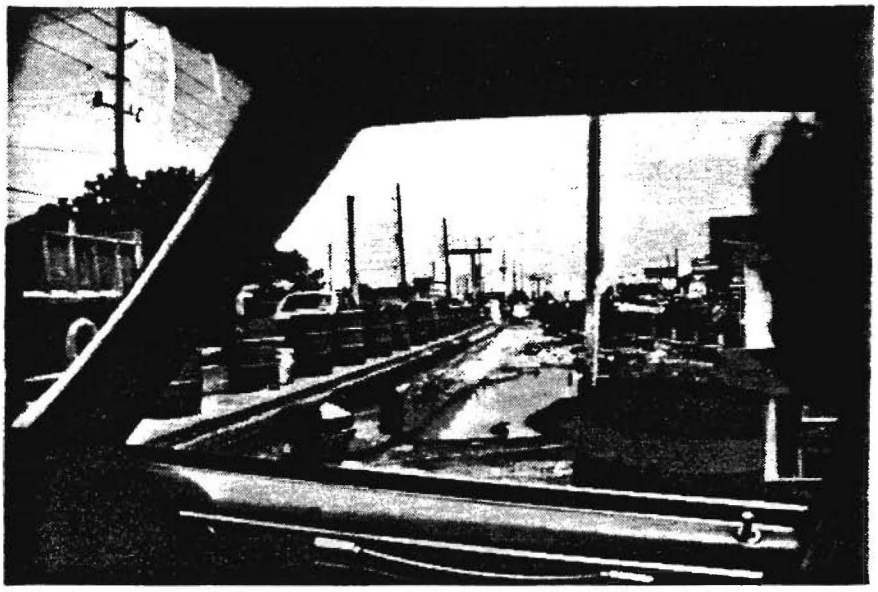
The relocation of traffic lanes requires old striping to be removed and temporary striping to be placed. Removal of pavement markings is a vital, but difficult task. Covering pavement markings with paint or asphalt may work only until worn off by traffic, and may serve as a pavement marking itself. When striping is burned, scrapped, or chemically removed from the pavement, the scar may have the appearance of pavement markings.

The pavement surface in a work zone is often rough and consists of different pavement colors. In this environment, painted markings may not have the needed contrast and durability. Temporary markings may not adhere to the pavement surface in the desired manner. Bad weather may hamper driver identification of temporary pavement markings.

Barriers

Temporary barriers, both concrete safety shape and drum mounted guardrail, are used widely in work zones to prevent motorists from encroaching on work areas and to insure the safety of the worker. However, the use of barriers in work zones presents many complications, including sight distance restrictions, end treatment requirements, reduced nighttime or adverse weather visibility, and placement restrictions.

Sight distance restrictions result when the drums, guardrail, or vertical panels mounted in the drums obstruct the vision of a motorist attempting to enter the arterial from a roadway perpendicular to the guardrail. When viewed from a small angle, the drums may restrict driver vision as illustrated in Figure 3. Additionally, when viewed at a small angle from the arterial, gaps in the drums and guardrail are hard to distinguish, making it difficult to find driveways and crossovers. The requirements of the work area prevent the barrier



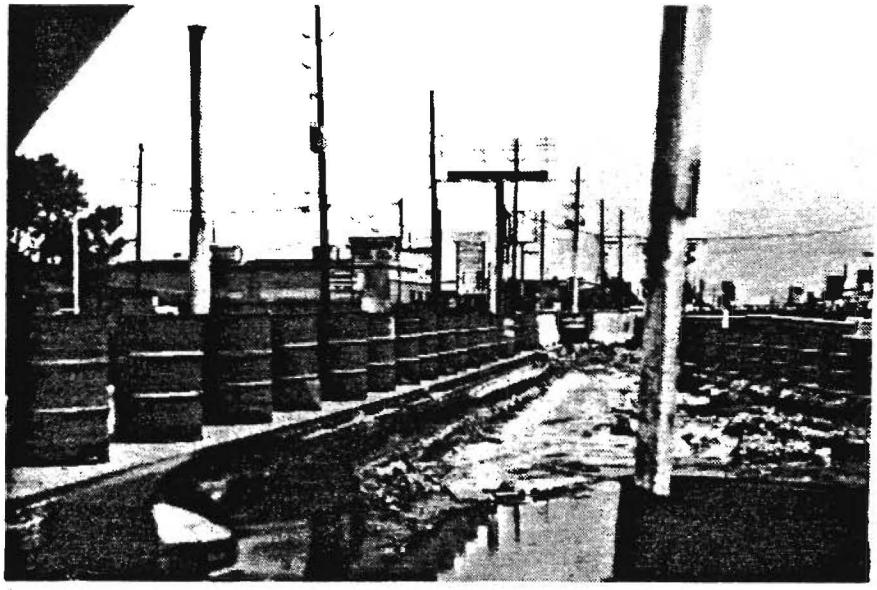


Figure 3. Sight Distance with Construction Drums.

from being tapered away from the roadway near the vicinity of a driveway or crossover.

The many driveways, intersections, and crossovers in an urban area dramatically increase the exposure of barrier ends. At the present time, there is no effective method of protecting these barrier ends while protecting motorists and the work area.

Barriers can become difficult to see during nighttime periods or during periods of adverse weather. This situation can be compounded in a work zone where the performance of reflective devices may become degraded due to dirt accumulations.

The restricted area of arterial work zones often requires barriers to be placed against the edge of an excavation area. A barrier located at the edge of a dropoff may be pushed over the dropoff when impacted, thereby reducing the performance of the barrier.

Lane Closures

Lane closures are a necessary part of construction activity, although they may have a significant impact on traffic flow. Detrimental effects of lane closures include queues which block signalized intersections, compounding peak period traffic congestion, unpredictable lane changing, and blocking driveways and crossovers.

Scheduling

The scheduling of the project or work activities may adversely affect traffic flow. Morning and evening peak periods occur on a daily basis and place heavy demands on the facility. The Christmas shopping season places heavy demands on facilities in heavy retail areas between Thanksgiving and New Year's Day. Recreational areas have seasonal peaks during which arterial demand is the heaviest.

The curing requirements of materials also impact project scheduling and traffic flow. Numerous difficulties are related to the time spent waiting for concrete to cure before vehicles are allowed to travel on it. Additionally, the public does not understand the need for the concrete to cure and perceives dry concrete which is not open to traffic as an

inefficient construction practice.

Crossovers

When construction is taking place in the center of the roadway, with traffic moving on each side of the work area, access across the work area is limited to intersections and crossovers. Limiting access across the arterial between intersections moves the turning movements to the intersections, in some cases, placing an even heavier demand on overworked traffic signals. Too many crossovers impair the contractor's ability to work effectively. Crossovers may be difficult to see in an area with drums and guardrails. Crossover signing is not uniform. Narrow two-lane crossovers may not allow a vehicle to turn into the crossover when another vehicle is occupying one of the two lanes.

Grades

Grade differences between the old and new pavement surfaces or excavation may cause sight distance and operational difficulties at crossovers, driveways, and intersections. The sight distance restrictions due to drum mounted guardrail are compounded when the vehicle is on a slope and the driver's eye height is lowered. Severe grade differences may hamper the operation of vehicles with large overhangs, low clearances, or towing a trailer. The issue is especially acute with the smaller undercarriage clearance and low profile tires found on many modern vehicles.

Driver Needs

Issues related to driver needs address how motorists' obtain information about the construction, how they perceive the construction activities and the usefulness of the project, how they navigate through the work zone, and how the construction impacts their travel habits. The following issues have been identified:

Street Signing

Construction activities often remove or obstruct street signs, block numbers, and property addresses. As a result, drivers have a difficult time finding destinations and navigating through the work zone.

Business Signing

Construction activities often reduce or restrict access to retail establishments. Business owners perceive the reduced access as having a negative impact on business, requiring measures to improve the visibility and access of the business. This includes placing business signs in the right-of-way, often attached to an official traffic control device, and hiring off-duty police officers to assist vehicular access.

Enforcement

The restricted right-of-way associated with arterial construction also reduces the ability to enforce traffic laws. Police may not have an acceptable location to observe traffic and are hesitant to issue citations when it may be hazardous to do so. The lack of enforcement will be noticed by the public with time and will breed disrespect for the traffic laws. This may result in increased accidents and poor operations.

Public Relations

The driving public and retail businesses have a strong interest in the progress of construction activities on urban arterials. Typically, this interest does not develop until after construction begins and the severity of the impacts are realized. The media does not provide the type of detailed knowledge desired by the regular users of the arterial.

CHAPTER 4

PRELIMINARY GUIDELINES

The preliminary findings described in Chapter 3 identified some of the major concerns of urban arterial work zones. This chapter addresses those concerns by identifying some preliminary guidelines which the research indicates may be appropriate for urban arterial work zones.

It should be stressed that these guidelines are preliminary and subject to change. These guidelines have not been evaluated for their applicability and the inclusion of these guidelines in this interim report does not imply that they are recommended or required on urban arterial work zones.

The preliminary guidelines described in this chapter are divided into four general types, those that address 1) the traffic control plan 2) traffic control devices, 3) construction or contractor activities, and 4) public relations related to the project.

Traffic Control Plan

The following preliminary guidelines may provide useful guidance in developing and implementing the traffic control plan for any arterial construction project.

- Left turn lanes should be provided at major signalized intersections.
- A minimum of one crossover should be provided between each pair of traffic signals.
- A crossover should be wide enough so that a vehicle turning into the crossover from the arterial will not encroach upon the opposing lane in the crossover.
- Provide an enforcement area or areas for police activities.
- Satisfy requirements for freeway traffic control plans on high speed, high volume arterial work zones, whenever possible.

- The outside lane should be the wider lane in areas with a large number of driveways and intersections.
- Provide generous turning radii at driveways and intersections.
- Do not utilize speed restrictions in work zones, if possible.
- Relocate bus stops to mid-block locations or to off-street parking areas.
- Projects should not be scheduled to begin construction between Thanksgiving and New Year's Day.
- Evaluate traffic operations on potential alternate routes. Make low cost geometric improvements and modify traffic signal operation as appropriate to manage the traffic diverting from the arterial work zone.

Traffic Control Devices

In general, the traffic control devices currently used in work zones are sufficient to meet the needs of the motorist and contractor. There is little need for new traffic control devices, only some modifications in the manner in which these devices are utilized. The preliminary guidelines addressing traffic control devices are divided into signs, markings, signals, and construction and maintenance operations.

Signs

- Place large street signs with block numbers at all signalized intersections, mounted over the street.
- Provide street signs at non-signalized intersections whenever possible.
- Utilize SDHPT policy for providing signing for business interest.

Pavement Markings

- Use raised pavement markers in conjunction with or in lieu of, lane stripping.

Traffic Signals

- Temporary signal installations should use 12" signals lens.
- Signal phasing and timing should be adjusted with each change in construction phasing. Signal operation should be checked in the field after each adjustment.
- The operating agency should assume responsibility for determining phasing and timing changes and for record keeping.
- Actuated controllers in a work zone should be converted to pretimed operation.
- Adequate time should be provided for the pedestrian to cross from the pedestrian push button to halfway across the far travel lane.
- Time base coordination should be used to provide progression through a work zone encompassing several traffic signals.
- Short cycle lengths should be utilized to reduce queue backup into the intersection.

Construction and Maintenance Operations

- Drums spacings should be reduced in areas where drivers might try to drive to the other side of the drums.

Construction or Contractor Activities

The preliminary guidelines given below provide guidance for activities which will take place during the construction period and which are performed by the contractor.

- Develop coordination between the contractor and emergency response groups.
- Schedule lane and intersection closures for off-peak periods.
- Lane closures or traffic restrictions should be removed prior to peak periods.

- High early strength concrete may be used in driveways and intersections to decrease the wait before being opened to traffic.
- Request police presence on project to control violations even if enforcement is not possible.
- Temporary pavement or driving areas at locations with severe grade differences should provide adequate sight distance for small vehicles and provide adequate undercarriage clearance.

Public Relations

The following preliminary guidelines may help to keep motorists informed about the project status and reduce frustration levels with the responsible agency and contractor.

- Hold a public hearing whether requested or not and work hard to generate attendance.
- Hold regular public meetings during the construction period to update progress of the project, answer questions, and identify problem areas.

CHAPTER 5
CONCLUSIONS

Arterial streets are becoming an important part of the overall street and highway network in the major urban areas. The capacity of many arterials is being increased so that they can relieve a portion of freeway congestion by serving as alternate routes. Capacity improving construction projects have pointed out the lack of guidelines specifically addressing work zone traffic control on these facilities. This research project was funded in order to develop guidelines for use on urban arterial work zones.

During the first two years of this three year study, a number of research activities have been undertaken including a review of the literature, selection of study sites, collecting traffic volume, travel time and accident history data, surveys of motorists in arterial work zones, and a review of current practice. These activities have evaluated several areas associated with urban arterial work zones, leading to a number of preliminary findings, and resulting in the development of some preliminary guidelines.

The literature review determined that there is a lack of research specifically addressing urban arterial work zones, although some portions of other work zone research addresses limited aspects of urban arterial work zones. Discussions with traffic engineers at the local and state level indicated a desire for improved guidelines and pointed out some of the major areas of concern. An analysis of the travel time, traffic volume, and accident history data provided an indication of the travel characteristics of motorists through these work zones and some of the potential areas needing to be addressed. Surveys of motorists traveling through urban arterial work zones indicate that although some do not fully understand the traffic control devices used, they are more concerned with other impacts of the work zones, such as limitations on access, difficulty in direction finding, and travel delays.

Some of the areas evaluated in this study relate to traffic signals, left turns, lane widths and striping, pedestrians, traffic diversion, accidents, transit, barriers, lane closures, scheduling, median crossovers, temporary grades, street and business signing, law enforcement, and public relations.

The preliminary guidelines identified to date address most of the issues of concern. There are specific guidelines for addressing the traffic control plan, traffic control devices, construction operations, contractor activities, and public relations. The preliminary guidelines included in this report are not intended for field implementation at this time. These preliminary guidelines will be carefully evaluated during the final year of this study.

Study Limitations

The traffic data collected in this study represents conditions at only three urban arterial work zones in two cities of the state. As a result, the results of the data analysis may not be representative of all areas. Additionally, the guidelines which are being developed as part of this study have not been through a rigorous field testing and evaluation period.

Summary of Preliminary Guidelines

The preliminary findings described in Chapter 3 and the respective preliminary guidelines from Chapter 4 are summarized in Table 4.

Future Activities

Research efforts will continue on this project during the third and final year of this study. During this year, study activities will have several major focuses, including:

- Meet with SDHPT staff in several districts to discuss problem areas with urban arterial work zones and to obtain input on the preliminary findings and guidelines contained in this report.
- Use computer simulation to evaluate the relationship between traffic signal operation and lane closures and determine if appropriate guidelines can be developed.
- Continue reviewing literature to identify and evaluate related research activities.
- Continue collecting construction and post construction data.
- Continue analysis of data.
- Refine proposed guidelines, as appropriate.

Table 4. Summary of Preliminary Findings and Guidelines

PRELIMINARY FINDINGS	RESULTING PRELIMINARY GUIDELINES
Construction changes traffic volumes, patterns, lane arrangements, signal phasing, signal timing, and signal head arrangements.	Signal phasing and timing should be adjusted with each change in construction phasing. Signal operation should be checked in the field after each adjustment. Temporary signal installations should use 12" signals lens.
Contractors do not have adequate traffic signal timing and phasing experience.	The operating agency should assume responsibility for determining phasing and timing changes and for record keeping.
Construction results in loss of signal detection capability.	Actuated controllers in a work zone should be converted to pretimed operation.
Construction results in loss of progression capability.	Time base coordination should be used to provide progression through a work zone encompassing several traffic signals.
Intersection blockage may occur due to downstream construction activities.	Short cycle lengths should be utilized to reduce queue backup into the intersection.
Loss of left turn lanes at intersections results in left turning vehicles blocking through lanes.	Left turn lanes should be provided at major intersections.
Turning radii may also be reduced causing vehicles to encroach on adjacent lanes.	Provide generous turning radii at driveways and intersections.
Reduced lane widths are often used due to restricted right-of-way.	The outside lane should be the wider lane in areas with a large number of driveways and intersections.
Construction compromises pedestrian operations.	Adequate time should be provided for the pedestrian to cross from the pedestrian push button to halfway across the far travel lane.
Drivers divert to alternate routes to avoid construction.	Make geometric improvements and modify traffic signal timing, as appropriate.
Drivers may not observe work zone speed restrictions, leading to an increased variance in vehicle speeds.	Do not utilize speed restrictions in work zones, if possible.
Accidents increase in work zones.	Satisfy requirements for freeway traffic control plans on high speed, high volume arterial work zones, whenever possible.
Transit operations hampered by construction.	Relocate bus stops to mid-block locations or to off-street parking areas.
Old pavement markings or removal scars may remain visible. Temporary pavement markings may not have adequate visibility, particularly in bad weather.	Use raised pavement markers in conjunction with or in lieu of, lane stripping.

(continued on the next page)

Table 4. Summary of Preliminary Findings and Guidelines (continued)

PRELIMINARY FINDINGS	RESULTING PRELIMINARY GUIDELINES
Temporary barriers present sight distance restrictions, end treatment requirements, reduced visibility, and placement restrictions.	No preliminary guideline is proposed.
Lane closures may result in traffic congestion.	Schedule lane and intersection closures for off-peak periods.
Traffic peaking characteristics place heavy demands on traffic operations in work zones.	Projects should not be scheduled to begin construction between Thanksgiving and New Year's Day. Lane closures or traffic restrictions should be removed prior to peak periods.
Pavement curing times slow progress and irritates the public.	High early strength concrete may be used in driveways and intersections to decrease the wait before being opened to traffic.
Lack of crossovers limit access and increase the demand on traffic signals. Too many crossovers limit contractor's efficiency.	A minimum of one crossover should be provided between each pair of traffic signals.
Narrow two-lane crossovers may not allow a vehicle to turn into the crossover when another vehicle is occupying one of the two lanes.	A crossover should be wide enough so that a vehicle turning into the crossover from the arterial will not encroach upon the opposing lane in the crossover.
Grade differences between old and new pavements may create sight distance or operational difficulties.	Temporary pavement or driving areas at locations with severe grade differences should provide adequate sight distance for small vehicles and provide adequate undercarriage clearance.
Reduced visibility of street signing creates direction finding difficulties.	Place large street signs with block numbers at all signalized intersections, mounted over the street. Provide street signs at non-signalized intersections whenever possible.
Construction requirements limit visibility of business signing and access.	Utilize SDHPT policy for providing signing for business interest.
Restricted right-of-way limits area available for enforcement. Lack of enforcement may breed disrespect for traffic laws.	Provide an enforcement area or areas for police activities. Request police presence on project to control violations even if enforcement is not possible.
Drivers may not receive adequate information about the progress of construction and the traffic impacts of construction activities.	Hold a public hearing whether requested or not and work hard to generate attendance. Hold regular public meetings during the construction period to update progress of the project, answer questions, and identify problem areas.

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