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Information from driver studies performed during the first year of the project identified several features and conditions that created confusion and anxiety in traversing the work zone. Many of these conditions represented deficiencies in the work zone traffic control from the standpoint of positive guidance principles.

This report describes the efforts to tailor the application of positive guidance procedures to work zone traffic control installations reviews. Four key steps, hazard visibility assessment, expectancy violation determination, information load analysis, and information needs specification are described in the context of traffic control at potentially complex work zones. A methodology is presented for applying these steps in a field review process to be performed as part of the work zone traffic control installation process.

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IMPROVING TRAFFIC CONTROL EFFECTIVENESS IN COMPLEX WORK ZONES

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1. INTRODUCTION

Work zone traffic control plans are designed to guide drivers past a construction or maintenance site in a clear and positive manner (*1*, *2*). When the traffic control plans are well designed, implemented, and maintained, it is believed that drivers are able to understand what is expected of them and can traverse the work zone with a minimum of difficulty. But when one or more elements of a work zone traffic control plan are missing, conflicting, or ambiguous in their message, drivers are less likely to understand what they are supposed to do.

Previous driver perception and behavior studies conducted on this project uncovered instances in each complex work zone sampled where one or more components of the traffic control present in that zone reportedly "confused" drivers in some fashion (*3*). A fair number of them could be traced back to a partial or full breakdown in the way that fairly well-accepted work zone traffic control principles, guidelines, and/or standards were actually maintained at that location.

Ultimately, it is the actual implementation and maintenance of work zone traffic control principles, guidelines, and standards that define how well a traffic control plan guides and protects motorists approaching and passing through the work zone. Consequently, Texas Transportation Institute (TTI) researchers turned their attention during the second year of this project towards ways of improving the procedures and practices used to implement effective work zone traffic control in the field, and to maintain a high level of traffic control effectiveness throughout the duration of the work activity.

OBJECTIVE OF THE RESEARCH

In this report, researchers describe ways to improve the implementation effectiveness of Texas Department of Transportation (TxDOT) work zone traffic control principles, standards, and guidelines. Researchers performed a thorough review of current work zone traffic control implementation processes and factors affecting implementation, and developed recommended improvements to traffic control implementation and monitoring at complex work zones.

CONTENTS OF THIS REPORT

This report documents the results of the second year research activities on the project. Chapter 2 presents a review of the findings from the first year of the project and describes the relationship between driver confusion in complex work zones and deviations from positive guidance principles. Chapter 3 presents a review of how positive guidance principles and procedures are or should be incorporated into TxDOT work zone traffic control implementation and monitoring policies and practices. Chapter 4 describes a methodology and guidelines for how the positive guidance procedure should be tailored to assist in assessing traffic control at complex work zones once installed in the field.

Finally, Chapter 5 presents a summary of project findings and recommendations for implementation.

2. CHARACTERISTICS OF THE COMPLEXITY PROBLEM IN WORK ZONES

During the first year of this project, TTI researchers used test subjects to evaluate and assess several work zones on Texas freeways where drivers are required to alter their normal driving paths (through temporary lane closures, lane shifts, detours, etc.) (*3*). The goal of these evaluations was to identify the amount and types of conditions and features in these types of work zones that, according to the motorists themselves, created confusion or stress in the driving task. Test subjects, as they drove through work zones in both daytime and nighttime conditions, were asked to provide their thoughts about the difficulty of the driving task as they navigated these zones. Researchers also identified locations and features that were confusing or distracting.

Through these studies, TTI researchers found that all of the work zones that were evaluated had at least one location where subject drivers experienced some degree of confusion or anxiety about their appropriate driving behavior. In fact, as Table 2-1 illustrates, between two and 10 confusing locations were found at each of the work zones. Overall, subjects encountered a confusing situation once every 1.2 miles of work zone. At one site, subjects identified six confusing locations within a 3-mile work zone (an average of one confusing location every one-half mile of work zone).

Table 2-1. Frequency of Confusing Locations Per Site.

Site Number	Site	Site Location	Length (miles)	Number of Confusing Locations
1	I35 Northbound	Hillsboro	11.5	6
2	I35 Southbound	Hillsboro	11.0	10
3	Loop 410 Westbound	San Antonio	7.0	6
4	Loop 410 Eastbound	San Antonio	6.0	5
5	I35E Northbound	south of Dallas	4.0	5
6	I30 Westbound	Dallas	7.0	3
7	I30 Eastbound	Dallas	6.0	2
8	I35E Northbound	north of Dallas	3.0	6
9	I35E Southbound	north of Dallas	6.0	7
	TOTAL		**61.5**	**50**

Researchers categorized these various locations and then identified several typical conditions or features that correlated to the confusing or stressful locations. Some of these typical conditions included (*3*):

- presence of extraneous distracting light sources in the field of vision at night (due to oncoming headlight glare from opposing motorists, from work vehicles parked in the work zone with their headlights still on, or from roadside businesses aligned with the driver's field of view). Each of these different light sources made it difficult for motorists to pick out the correct travel path;
- difficulties in correctly interpreting advance warning signing regarding the temporary closure of a lane just downstream of an exit ramp;
- deviations between the alignment implied by concrete barriers and barrels used adjacent to the travel lanes and the actual roadway alignment (primarily at lane shift and exit ramp locations);
- inconsistencies in what is implied by lane shift signing (in terms of the perceived degree of lateral shift and the amount of steering adjustments required to accomplish the maneuver);
- difficulties in reading all of the message or correctly interpreting what is intended by a particular message on a portable dynamic message sign;
- portable dynamic message signs placed too close to the geometric feature (an exit ramp) it was providing information about, or too far away from the feature it was warning about (a downstream work convoy); and
- lack of agreement between information presented on a sign and the actual roadway condition present at the location (due to a temporary lane closure that blocked a lane that was indicated by advance signing to be available for large trucks).

A key point concerning all of these situations is that they can be traced back to violations of a set of fundamental principles known as positive guidance. Positive guidance combines highway/traffic engineering with human factors methods and procedures to produce a highway information system matched to driver attributes and situational demands (*4*). One of the key facets of positive guidance is the acknowledgment that humans have a limited capacity for detecting, processing, and remembering information as part of their driving activities. The principles and procedures of positive guidance have served the traffic engineering community well for nearly 30 years.

PRINCIPLES OF POSITIVE GUIDANCE

The positive guidance procedure was originally designed as a countermeasure technique to address known problem locations that have been identified through above-average accident frequencies, motorist complaints, or other methods. Once the problem location is known, the process focuses on determining whether the information system at that location needs to be altered in some way to better serve motorists' needs. The process also helps to determine what alterations are necessary. The final intended result is a change in driving behavior that reduces or eliminates the problems observed at that site. Although its original intent is as a problem countermeasure technique, several of the concepts and principles contained in the positive guidance process are relevant to the design and installation of new driver information systems. In fact, the traffic control requirements and typical applications described in the Texas Manual on Uniform Traffic

Control Devices (TMUTCD) and illustrated in the Texas Traffic Control Standard Sheets are strongly rooted in positive guidance principles (*1*, *5*).

In general, the positive guidance procedure consists of the following eight steps:

1. site definition,
2. problem description,
3. hazard identification,
4. hazard visibility assessment,
5. expectancy violation determination,
6. information load analysis,
7. information needs specification, and
8. current information system evaluation.

The first three steps are fairly straightforward, whereas the final step simply compares information needs to what is actually being provided. Consequently, steps four through seven can be considered the "heart" of the positive guidance process.

Hazard Visibility Assessment

The objective of this step is to determine if a hazard can be detected, recognized, and its threat potential assessed in enough time for a driver to respond safely and effectively. The required time a hazard needs to be "visible" is a function of the type of driving maneuver the driver needs to make to avoid the hazard (stop, speed change, and/or direction change) and the operating speed of the vehicle.

Expectancy Violation Determination

One of the most critical components of positive guidance is the concept of driver expectancy. Violations of driver expectancy lead to longer detection, recognition, and response times by drivers, as well as increased frequency of incorrect recognition or interpretation of conditions. Expectancies can be developed from repeated similar experiences over a long period of time (sometimes termed a priori expectancies) or on a few recent experiences (ad-hoc expectancies).

In their simplest form, expectancy violations are created by surprises in the traffic stream. As such, they are highly dependent upon site-specific conditions and the overall "feel" of the roadway environment. Actually traversing a particular roadway segment is the most common method of identifying expectancy violations. Expectancy violation identification can be facilitated during this activity by answering the following questions (*4*):

- Does this section contain features that an unfamiliar driver might find unusual or special?
- Are there first-of-a-kind features encountered in this section?
- Are there any "surprising" features on this roadway section?
- Do roadway characteristics change dramatically through the section?
- Are there forward visibility restrictions (vertical curves, bridge abutments, etc.)?

Information Load Analysis

The objective of this step is to determine a roadway section's overall information load potential. This load consists not only of the formal traffic information sources, but the informal sources as well (general roadway alignment, roadside signing and lighting, other nearby traffic, etc.). Furthermore, the information load is considered in context of what the driver is required to do in terms of controlling the vehicle. Decision points (lane drops or closures, exit ramps, etc.) increase the overall information load at a point, as does more complex information components (i.e., changeable message signs). Similarly, visual clutter and competing information sources in the visual field increase the overall visual load at a location, as drivers are forced to scan and sift through more bits of information. Information sources that are misleading, ambiguous, or confusing also increase the overall information load. Unfortunately, specific definitions on how to measure or calculate information load on an absolute scale do not exist. However, some general guidelines can be provided (*4*).

Information Needs Analysis

The objective of this step is to identify the site-specific information needed to negotiate a particular hazard or series of hazards. The key to this step is matching appropriate information components to the appropriate locations upstream of a hazard. These locations are defined in terms of information-handling zones (*4*). A key item to note from the needs analysis is that information can be presented both too close and too far from the hazard to be used effectively by the motorist. In other words, improperly located information can be as detrimental to positive guidance as missing or incorrect information.

HOW POSITIVE GUIDANCE RELATES TO WORK ZONE COMPLEXITY PROBLEMS

Table 2-2 summarizes the typical reasons test subjects found a work zone feature particularly confusing, along with the positive guidance principles that were violated at that location. One sees that all four steps discussed previously (hazard visibility, expectancy violations, information loading, and information needs) are reflected in the types of problems noted by the drivers. The fact that the problems are directly related to positive guidance deficiencies strongly suggests that a modified application of the positive guidance process in these complex work zones could potentially improve the effectiveness and safety of the traffic control plan at these complex work zones.

As previously stated, existing work zone traffic control design procedures and standards are already rooted in the principles of positive guidance themselves. However, the success of the positive guidance process is ultimately dependent upon proper field implementation and analysis. Since traffic control plans are designed prior to the initiation of a work zone, this field implementation and assessment can only be accomplished after the traffic control plan is actually installed. The importance of this field review step of the process is officially recognized in the TMUTCD and other work zone traffic control guidelines. However, the fact that Tables 2-1 and 2-2 indicate such a prevalence of positive guidance deficiencies implies that the field steps of the process are not being completely successful at this time. This finding has led TTI researchers to more fully explore how work zone traffic control for complex work zones is installed and attended to in the field. Through a more complete understanding of the issues impacting this part of the work zone traffic control implementation, TTI researchers hoped to determine how to assist TxDOT in accomplishing a more complete application of the positive guidance process.

Table 2-2. Relationship between Test Subject Driving Difficulties and Positive Guidance Principles.

Typical Reasons Subjects Reported Being Confused or Stressful at Work Zones	Deviations from Positive Guidance Principles
Difficulty seeing travel path due to extraneous nighttime light sources (vehicles, roadside businesses)	• Visibility of the hazard is reduced due to headlight glare • Presence of visual clutter within the overall information system due to roadside business light sources made path identification difficult
Confusion about temporary lane closures in the vicinity of ramps with long deceleration lanes or auxiliary lanes between adjacent ramps	• Information about which lane is affected is ambiguous when the lane closure signs are not placed properly
Confusion where alignment implied by barriers and barrels and actual travel lane alignment diverge	• Driver expectancy that the roadway alignment will continue to follow the barrier or barrels is violated
Surprise about how much steering control will be required to accommodate the conditions implied by lane shift signing	• Driver expectancy about the magnitude of the maneuver required to accommodate the lateral shift is violated
Confusion about meaning of words or phrases shown on portable dynamic message signs, or because only part of message could be read before passing the sign	• Driver information loading limits are exceeded • Use of terms or phrases not universally understood violates driver expectancy • Information is not “chunked” properly to promote understanding • Visual clutter adding to the overall information load
Portable dynamic message signs placed too close or too far away from the feature for which they are providing information	• Location of information not adequate to allow proper response by driver • Location of information too far upstream violates driver expectancy about presence of downstream hazard
Disagreement between sign information (which lanes to use) and actual lanes available for use during temporary lane closure	• Violates expectancy about proper response required by driver

3. ASSESSMENT OF TXDOT'S WORK ZONE TRAFFIC CONTROL FIELD PROCESSES

OVERVIEW OF TXDOT ORDERS AND CIRCULARS

TxDOT developed a series of administrative orders and administrative circulars in the 1970s and 1980s to address growing concerns about work zone safety. The first administrative order of significance was Administrative Order 33-72, distributed in November 1972. This administrative order was the first instance of statewide establishment of the Highway Traffic Safety Section at the Division of Maintenance Operations level, the Highway Safety Steering Committee at the Headquarters level, and the Field Safety Review Team at the district level. However, it did not focus exclusively on work zone safety issues (although a district could certainly choose to emphasize work zones).

Next, Administrative Circular 35-77, distributed in June 1977, specifically required (among other things) each district to provide frequent work zone traffic control inspections. The circular stipulated that at least one nighttime inspection per month be performed for every work zone, with emphasis given to verifying that the devices provided adequate reflectivity to be visible at night. Also, districts were to keep and review reports of work zone accidents for use in making field improvements to the traffic control plan as needed.

Administrative Order 7-79 and Administrative Circular 32-79 were subsequently distributed in 1979 and together established procedures for development of traffic control plans for all TxDOT work zones. These documents began to define some of the things that field personnel should look for when conducting work zone inspections. Signs, barricades, and markings were all to be examined to ensure that all are present as needed and are in good visible condition. Additionally, Administrative Circular 32-79 created the Traffic Control Devices Inspection Report form, also known as Form 599 (see Figure 3-1).

TxDOT

Form 599 8/96

Traffic Control Devices Inspection Report

Project ______________________________

Inspection Date ______________________________

Time of Inspection: DAY ________ NIGHT ________

Inspection Made by ______________________________

Signature ______________________________
TxDOT Responsible Person for Traffic Control

Signature ______________________________
Contractor Responsible Person for Traffic Control

List of Deficencies

Type of Device								Reason for Deficiency								Location	Action Required		
Sign	Barricade	Warning Light	Channelizing Device (Cone, Drum)	Pavement Marking	Delineation	Barrier	Other	Non-Reflective	Non-Standard Color	Non-Standard Size	Does Not Meet Spec. and/or Stds.	Improperly Used or Located	Missing	Dirty	Other	Approximate Location or Station	Recommended Corrective Action	Date Contractor Made Correction	Verified by (Initials)

General Comments:

See other side for "Guidance for Inspection"

Figure 3-1. Example of Traffic Control Devices Inspection Report Form.

The circular defined the following:

- who was required to perform inspections,
- how any deficiencies were to be recorded, and
- who was to receive copies of the complete form.

Form 599 highlights each of the major devices present within the work zone (signs, barricades, warning lights, etc.) to be examined, and the types of deficiencies to be considered. As Figure 3-1 illustrates, the key deficiency categories include non-reflective devices (for those devices where reflectivity is required), non-standard device color, non-standard device size, improper device use or location, missing devices, and dirty devices. These categories directly or indirectly address some of the aspects of the positive guidance field activities (particularly ensuring adequate device visibility and the proper information locations), but not all. Furthermore, the overall goals of providing adequate hazard visibility, avoiding expectancy violations and information load difficulties, and ensuring information needs are met in the appropriate locations relative to the hazards present are not found anywhere on the form.

In July 1989, Administrative Order 11-89 was distributed to all districts, which established and updated guidelines to improve the management of safety in highway work zones. Specifically, the order was provided to assist all districts in developing District Safety Review Teams, the process of approving traffic control plans, and the responsibilities of both the Contractor's Responsible Person and the Department Responsible Person. The duties of the Department Responsible Person included making routine inspections of work zone projects to ensure compliance with the TMUTCD, documenting any major changes to the traffic control plan, and assisting in the review of any accident that occurred in the work zone. Finally, the order provided that all employees responsible for work zone traffic control design, implementation, and/or implementation should be trained in proper requirements for signing, barricading, and pavement markings found in work zones.

POSITIVE GUIDANCE IN WORK ZONE TRAFFIC CONTROL TRAINING

TTI researchers examined the training available to TxDOT relative to positive guidance principles and procedures as they pertain to work zone traffic control planning and implementation. The primary training available is the *Planning Work Zone Traffic Control* course taught regularly by the Texas Engineering Extension Service (TEEX) and the accompanying refresher courses of the same title. Generally speaking, these courses are designed to provide direct instruction about standards and requirements pertaining to work zone traffic control. Some discussions about driver information needs, response capabilities, and the like are logical extensions of reasons for many of these requirements. As such, there is some level of positive guidance principles incorporated into the classes.

With respect to the "official" positive guidance procedures themselves, the complete *User's Guide to Positive Guidance* (*4*) is paraphrased in an appendix of the student notebook. The material is written at a fairly high level of understanding and is very generic in nature. Specific methods of applying these procedures to work zone traffic control installation and monitoring activities are not included in these materials. Because of the general nature of the information and the large amount of other information that must be covered in these classes, it appears that this appendix is included only for future reference purposes by the student. The key steps of the process as it pertains to initial traffic control plan installation and monitoring (hazard visibility assessment, expectancy violation assessment, information load analysis, information needs assessment) do not appear to receive much attention in the actual course presentation.

POSITIVE GUIDANCE PROCEDURES IN THE INSPECTION PROCESSES

Daily and Bi-Weekly Inspections

Every work zone on TxDOT right-of-way is provided personal inspection by field personnel – normally inspectors – for the duration of the project. The field personnel have the responsibility of inspecting all work zone signing and barricades on a daily basis, ensuring that temporary traffic control for short-term activities are installed appropriately, and ensuring that any work zone signing for daytime projects are not left up overnight.

In addition, Administrative Order 7-79 established the requirement for a more formal inspection to be conducted every other week. This inspection is to be completed in the presence of the Contractor's Responsible Person and is to document in writing any and all deficiencies observed. It is to include the date of the inspection, as well as the dates when the deficiencies were remedied. Once per month the inspection is to be conducted at night, while the others may be conducted during the day. The Traffic Control Devices Inspection Report Form, previously shown in Figure 3-1, is used to document this inspection.

Certainly, it would be ideal if daily inspections were the primary means of identifying and correcting positive guidance deficiencies. Discussions with inspectors and project engineers within several TxDOT district area offices suggest that some degree of screening for positive guidance deficiencies may occur during the traffic control installation for a new project or major phase change and in response to observed motorist difficulties that may result from an improper setup.

District Reviews

Administrative Circular 33-72 directed each district to develop a District Safety Review Team. Each team is to consist of between three and five of the following individuals from the district:

- Assistant District Engineer,
- District Administrative Engineer,
- District Maintenance Engineer,

- District Design Engineer,
- District Traffic Engineer, and/or
- District Construction Engineer.

Administrative Circular 11-89 further defined the role of the team by directing them to consider work zone safety with respect to traffic operations, traffic safety, worker safety, and pedestrian safety. These teams are to perform random checks on each project in their district to ensure that proper standards are being followed.

Traffic Control Review Team (TCRT) Reviews

Administrative Circular 11-89 also documented the role of the Traffic Control Review Team to, "review selected projects, assessing the effectiveness of traffic control procedures and providing annual reports to the administration."

The TCRT is typically comprised of engineers and field personnel with knowledge and experience in work zone traffic control from TxDOT divisions (Construction, Design, and Traffic Operations) and the Federal Highway Administration (FHWA).

During each review, the TCRT inspects a sample of work zones in a given district checking for any noncompliant or potentially confusing layouts. From these inspections, a report is generated for the district engineer detailing the results of the inspection, including photographic documentation of any problems found. These reports help the districts improve their compliance with approved traffic control layouts. Typically the TCRT reviews each work zone in a district about every two to four years.

Each TCRT review consists of a review of the district's use of the Traffic Control Device Inspection Report (Form 599), the availability of work zone accident reports provided to the district offices, training policies, and field reviews of the work zone traffic control on the roadways at the time of the review.

Based on a review of recent reports of several districts, the comments from the TCRT field reviews typically fall in one of four main categories:

- improperly constructed or mounted traffic control devices,
- improper placement or use of traffic control devices,
- damaged or worn traffic control devices, and
- human factors/positive guidance issues.

Because of the recent changes in requirements regarding the crashworthiness of work zone traffic control devices, a considerable amount of TCRT effort and subsequent reporting is devoted to these issues. Similarly, the issues relating to device placement and condition are a major component of the review (as they are on the Form 599 itself). What is encouraging is the fact that this team also places some emphasis on identifying positive guidance issues as part of their field reviews, and generally uncovers some fairly significant deficiencies. Specific examples recently cited by the TCRT memoranda include:

- existing pavement markings leading drivers into a concrete barrier;
- drivers directed to drive on the left of a set of double-yellow lines;
- advance warning signing for a work zone positioned just past the crest of a vertical curve, limiting the sight distance to the signs;
- LANE ENDS MERGE LEFT sign found adjacent to LEFT LANE CLOSED AHEAD, and;
- a STOP sign and a YIELD sign next to each other at an intersection within a work zone.

Figure 3-2 provides an example of the types of driver expectancy violations observed by the TCRT. In the figure, the pavement markings lead right into a concrete barrier wall. In a proper traffic control plan, the pavement markings would have been obliterated.

Figure 3-2. Example of a Driver Expectancy Violation Documented by the TCRT.

Implications for Improvement

Of the various levels of inspection and review of work zone traffic control currently required by TxDOT procedures, the TCRT reviews are where the most direct attention is given to the specific identification of positive guidance deficiencies within the work zone traffic control system. At the other levels of review, emphasis appears to be placed primarily on monitoring the presence and condition of the many traffic control devices present within the overall work zone project. This activity alone can be very extensive and occupy a significant amount of time and attention by field personnel.

TTI researchers believe that there is considerable potential for improvement in traffic control effectiveness in complex work zones by raising the degree of positive guidance attention within the inspection and review process. Unfortunately, positive guidance concepts are currently only discussed in context of traffic control planning and design in current training materials, and not necessarily in how they could be applied in the inspection and review process. One reason for this gap is that the positive guidance procedures themselves have not been consolidated and tailored to the needs of work zone traffic control inspection and review. Therefore, the next chapter in this report is devoted to the development of guidelines tailored to the use of positive guidance procedures in work zone traffic control inspection and review.

4. POSITIVE GUIDANCE GUIDELINES FOR WORK ZONE TRAFFIC CONTROL INSPECTIONS AND FIELD REVIEWS

OVERVIEW

As noted in Chapter 2, the standard positive guidance procedure (*4*) involves several steps. Listed below are those four steps that were identified as the most critical to the overall success of the process:

- hazard visibility assessment,
- expectancy violation determination,
- information load analysis, and
- information needs specification.

The first three steps define potential areas of difficulty in the overall driving environment and are somewhat interrelated (the lack of adequate visibility to a potential hazard such as a lane shift can create an expectancy violation, for example). Meanwhile, the fourth step (information needs specification) provides some techniques for prioritizing what information is needed and where it needs to be received by the driver in context of the actual driving environment.

Positive guidance is the key to effective traffic control, especially within a work zone environment where motorists can encounter a wide variety of changes in the driving environment. This emphasis must exist at both the office level where traffic control plans are prepared and in the field where the plans are ultimately implemented. Whereas past research has utilized positive guidance principles in developing office-level guidance in the form of preplanned typical traffic control device applications and traffic control plan standard sheets, guidance on how these same principles should be applied to field-level implementations and monitoring of work zone traffic control has not. In this chapter, information is presented on how each of the above steps in the positive guidance process relate to a systematic work zone traffic control field inspection and review.

HAZARD VISIBILITY ASSESSMENT

In the user's guide (*4*), a hazard is defined as anything in the roadway environment that could ultimately be involved in, or contribute to, an accident. Fixed objects, moving objects, general roadway conditions (i.e., curves, potholes, etc.), and temporary situations themselves (such as the development of queues) are all possible hazard candidates. Such a broad definition reflects the fact that the current procedures are designed to address all potential types of localized problem areas or features.

In a work zone situation, hazards are introduced into the overall driving environment through temporary changes in alignment, introduction of barriers and traffic control devices adjacent to traffic, and work equipment and materials placed in and around the work zone. Table 4-1 presents a summary of work zone-related hazards that should serve as the starting point for a hazard visibility assessment. These are oriented primarily towards higher-speed, higher-volume conditions that are typically associated with work zone complexity. It is envisioned that users of this methodology would begin with the identification of which of these hazards are presented to traffic and which have potential sight distance limitations. Those features that are protected and not accessible to traffic are not considered hazards (i.e., a portable dynamic message sign (DMS) or arrow panel located behind a concrete barrier would not be considered a hazard).

Table 4-1. Typical Hazards in Complex Work Zones.

Types of Hazards	
• Lane closures • Concrete barriers • Horizontal curves for lane shifts, detours • Exit ramps and bifurcations • Entrance ramps • Lane drops, lane additions	• Driveways • Intersections • Bumps or lifts • Uneven lanes • Pavement drop-offs • Arrow panels, portable DMS, etc. • Construction equipment and materials • Construction area access points

The analyst critiques each instance of a potential hazard (or the cluster if located close to each other) with respect to the sight distance available upstream to see and recognize each hazard while driving at normal operating conditions. Normally, this critique would be done at night to assess worse-case viewing conditions. However, temporary lane closures or other daytime-only setups might warrant daytime assessments.

Any hazards that cannot be seen and recognized within a distance required to make a stop or lane change decision and maneuver (as much as 1500 ft for vehicles traveling at 70 mph, 1200 ft for vehicles traveling at 55 mph) are flagged as potential areas of concern. A potential concern does not automatically imply that the situation represents a dangerous condition. However, it does identify sources where supplemental information (warning signs, better contrast pavement markings, etc.) located at appropriate distances upstream of the hazard might be required (additional details concerning this are included under the Information Needs Specification section).

EXPECTANCY VIOLATION DETERMINATION

Traditionally, work zones themselves have been thought of as instances of driver expectancy violations (*4*, *6*). Within the work zone itself, however, are many different types of features and situations that can violate a driver's expectancy at any one time. Some of these features occur as a result of limited visibility time to a hazard, as discussed in the previous section. Based on the results of the first year of the study and other literature (*3*, *7*), the following work zone features can sometimes cause motorists expectancy problems:

- locations where concrete barriers or channelizing devices, which have been forming a continuous line adjacent to the edge of the travel lane, depart from the travel lane alignment. Most commonly, this discontinuity will occur at exit ramps, construction access points, or lane shift locations;
- discrepancies between permanent guide signing and work zone signs during short-term temporary lane closures;
- lane shifts and detours designed to a lower speed than typically exists on the facility (i.e., utilizing a 55 mph design speed for a lane shift on an urban freeway with 70 mph or higher operating speeds);
- decision points (exit ramps, major freeway bifurcations) that do not automatically convey the correct travel path direction to the motorist;
- exit ramps that are temporarily closed;
- lane joints, dark-colorings from obliterated pavement markings, or concrete/asphalt longitudinal edges that do not line up with actual travel lane alignments; and
- visible pavement markings that do not actually denote current travel lanes or edge lines.

Expectancy violations cannot always be eliminated within the work zone (i.e., longitudinal pavement joints that do not coincide with the temporary travel lane lines). However, when an expectancy violation cannot be eliminated, the formal information system must compensate in some way for the possible expectancy violation (i.e., pavement markings need to be maintained at a higher level of brightness to attract the driver's attention away from the lane joints).

INFORMATION LOAD ANALYSIS

Information load refers to the amount and rate of information being presented to the motorists as they travel the roadway segment. "Information" as defined in this context includes both formal sources (signing, channelization, markings) and informal sources (roadway alignment, lighting, roadside signing, etc.). Drivers may become overloaded if presented with too much information, information that is misleading, or with extensive visual clutter that makes it difficult to determine what information is most urgent for them to receive.

Trying to compute an information load in an overall driving situation is currently not possible, as the cognitive processes associated with the driving task are highly complex and interactive. These processes are dependent upon driver age, emotional state, education, and a variety of other factors. Even so, there are a few conditions that can be checked in the context of work zone traffic control field review that can provide some useful insights into possible improvements. These include:

- *Multiple permanent and temporary signs in the driver's visual field* – locations where more than seven signs (the sum of both permanent roadside and overhead signing and temporary work zone signing) are readable by the driver should be identified as potential information overload conditions (*4*). Each frame of any portable dynamic message signs used should be counted as one sign. Opportunities for moving or eliminating one or more signs should be considered wherever more than seven signs are found.
- *Presence of visual clutter in the vicinity of potential expectancy violations* – roadside business lighting or work zone light can obscure important signing and delineation information drivers use to prepare and traverse lane shifts, detours, exit ramp decisions, etc. Pavement delineation in these areas will need to be adequate to overcome the distractions created by such clutter.
- *Poorly designed dynamic message sign messages* – one of the primary sources of driver confusion and anxiety in complex work zones is the information presented on portable dynamic message signs. Messages should conform to current guidelines (*8*).

INFORMATION NEEDS SPECIFICATION

In this step, field personnel verify that the potential areas of concern (hazards, locations where driver expectancy may be violated, locations of high information load) have adequate advance information to warn approaching drivers of the presence of the hazard and/or the appropriate driving response. This information must be located far enough upstream of the hazard to allow proper perception and response by drivers, but not too far so that it also violates driver expectancy about the existence of the hazard. Unfortunately, objective data on how far is "too far" is currently lacking. Researchers believe that distances exceeding one-half mile between the last (or only) warning sign and the hazard itself begin to exceed the limits of credibility, based on comments received by subject drivers during the first year of this project.

USING THESE STEPS IN A SYSTEMATIC REVIEW PROCESS

The information in this chapter highlights the common types of work zone conditions and features that need to be explicitly examined in the field to identify potential driver path-finding difficulties. Based on a review of available positive guidance training information, TTI researchers believe there is a need for additional attention to these types of positive guidance deficiencies as part of the work zone traffic control implementation and monitoring process.

The researchers believe that this assessment needs to be separated from existing bi-weekly inspections. Whereas the inspections via Form 599 emphasize the proper presence and condition of devices as specified in the traffic control plan, a positive guidance review should be a hazard-based assessment of possible driver path-finding difficulties. The information required on Form 599 is very detailed and extensive. Given the many other job duties of project inspectors and the time now required to complete the documentation for this form, asking for a thorough positive guidance critique during each inspection would diminish the importance of the activity over time and fail to achieve the desired objectives of such an assessment.

It is believed that a specific field review of the traffic control plan once implemented from the perspective of how it addresses driver path-finding needs (using the above steps) would provide the most logical and systematic approach to reducing the frequency of traffic control deficiencies in the field that are creating path-finding difficulties for motorists. Recognizing the lack of specific guidance on how to accomplish such an assessment, TTI researchers have developed a driver-path finding assessment form and procedure to be used when a traffic control plan is first implemented, or whenever significant changes occur in the overall traffic control scheme at a site. The form and procedure are included in the Appendix.

5. SUMMARY AND RECOMMENDATIONS

SUMMARY

Based on a review of data collected from subject drivers during the first year of the project, the majority of driver confusion and anxieties in traversing complex work zone layouts appear to be due to deficiencies in properly addressing the concepts of positive guidance at the work zone. Researchers critiqued current TxDOT procedures regarding the field implementation and monitoring of traffic control at complex work zones, and have determined a need for increased emphasis and a consistent approach to applying the positive guidance process during and after field implementation of the traffic control plan developed for the work zone.

Four critical steps are identified as particularly useful to field personnel once work zone traffic control is installed at a project, and periodically through the duration of the project. These steps are:

- hazard visibility assessment,
- expectancy violation determination,
- information load analysis, and
- information needs specification.

Researchers have developed guidelines for applying the positive guidance procedure as a field inspection and review of newly installed or modified traffic control at potentially complex work zones. These guidelines represent a combination of existing positive guidance documents and results of the first-year studies of test drivers in actual complex work zone locations in Texas.

RECOMMENDATIONS

Based on the findings of this project, TTI researchers believe substantial improvements in traffic control effectiveness at complex work zones can be gained by promoting the regular and consistent application of positive guidance procedures tailored to a field inspection and review process at complex work zones statewide. The researchers recommend that TxDOT take the following actions:

1. TxDOT should issue instructions to the districts and area offices to perform explicit positive guidance reviews of the overall driving environment in all work zones. These reviews should occur at the initiation of major construction projects and each time major changes in traffic control sequencing occur. Those performing the reviews should not be the same individuals who are responsible for the daily or bi-weekly inspections of work zone traffic control. The guidelines presented in the Appendix would help direct the activities of TxDOT personnel in this regard.

2. TxDOT should provide these same instructions to the Texas Engineering Extension Service for incorporation into its work zone traffic control training courses.

FUTURE RESEARCH

The recommended assessment process is an important first step in raising the level of effectiveness of work zone traffic control from the perspective of ensuring adequate driver path-finding performance. However, research is still required to better define acceptable operational parameters of the positive guidance procedure. One of the key needs is a systematic method of assessing and adjusting information load presented to drivers at specific locations within the work zone. The guidelines presented in this report are based on known motorist short-term memory capabilities but do not fully incorporate the complex information scanning and processing functions that occur as a motorist operates a vehicle.

6. REFERENCES

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APPENDIX

POSITIVE GUIDANCE WORK ZONE FIELD REVIEW WORKSHEET

Steps to Complete Work Zone Field Review Form

1. Note the project number, contractor, location, time, and date of the review on the form.
2. Two people, a driver and a recorder, should perform the review.
3. Following the examples in sections I through IV on the review form, note any possible hazard visibility, expectancy, information load, or information need deficiencies in section V of the form.
4. Note proposed remedial action to correct each deficiency in section V.
5. If additional space is required to complete the review, attach additional pages. Mark the appropriate box in section VII to note the use of additional pages.
6. Note the date that the contractor is notified of the deficiencies in section VII.
7. Note the date that the contractor makes the changes in section VII as well.

Guidelines to Consider

The four components of the review (hazard visibility, driver expectancy violation, information load analysis, and information needs specification) are highly interrelated and so should be considered together during the review drive-through. For highly complex work zones, however, it may be necessary to make several trips through the work zone, each time emphasizing one of the four review components.

Particular emphasis should be given to locations just upstream and at decision points (exit ramps, intersections, driveways, locations where speed reductions are required, etc.). The reviewer should consider the driver perspective of each possible decision, not just the most common or primary one.

Messages on portable changeable message signs (CMS) can be a major source of driver confusion in work zones. Reviewers should ensure that the messages conform to the PCMS guidelines included in the TxDOT Barricade Standard Sheets.

The criterion that no more than seven permanent and work zone signs should be visible at one time should be considered only a guideline. Fewer signs may create information load difficulties if they are particularly complex or if the driving task at that location is particularly demanding. Reviewers should exercise their judgment in this assessment.

The reviewers should also monitor other traffic as they traverse the work zone. Locations where brake lights are seen or swerving is an indication of a potential problem area that should be investigated further.

Project ______________________________
Contractor ____________________________
Review Date ____________ Time _________
Reviewers ___________________________

WORK ZONE FIELD REVIEW

I. HAZARD VISIBILITY ASSESSMENT **Note any possible hazard that cannot be seen and recognized from 15 seconds away.** • Does any object, device, or geometric feature require a reaction from approaching traffic?	**EXAMPLES** • Arrow panels • Portable CMS • Moving work vehicles • Traffic queues • Unprotected workers • Construction equipment • Construction material • Lane drops, lane shifts, ramps • Uneven lanes/bumps/lifts • Potholes, damaged pavement • Vertical/horizontal curves
II. DRIVER EXPECTANCY VIOLATION **Note any features that may "surprise" drivers. Also note those features that can "lull" drivers into incorrect decisions or behaviors.** • Does any geometric feature such as a vertical or horizontal curve hide hazards from a driver's view? • Does any feature lead the driver in an unintended direction or into an incorrect decision?	**EXAMPLES** • Curves or lane shifts designed for a lower speed than the remainder of the facility. • Curves or lane shifts where drivers also must make a path decision (i.e., at the gore of an exit ramp). • Exit ramps that are temporarily closed. • Visible lane joints, pavement markings obliterations, or pavement edges that lead off the desired path. • Barriers/barrels adjacent to travel lanes that follow the exit ramp alignment. • Interruptions in channelizing devices, pavement markings, or barriers that mark the travel lanes.
III. INFORMATION LOAD ANALYSIS **Note locations where too much information is visible to be read at one time, and locations where visual clutter distracts drivers from seeing the information being presented.** • Do signs or messages have to compete for the drivers' attention with other information? • Are there ways that the amount of information presented can be spread out or reduced?	**EXAMPLES** • Glare from sun, headlights, or construction lighting preventing drivers from seeing signs and devices. • More than seven permanent and work zone signs in the driver's field of view at one time. • Portable CMS messages that do not follow basic guidelines, long messages, and locations where drivers have to make a path decision at the same time they are to read the CMS. • Visual clutter in the area of high information load, or where path decisions must be made.
IV. INFORMATION NEEDS SPECIFICATION **Advance warning should both warn drivers of the presence of a hazard <u>and</u> direct the driver as to the best course of action.** • Does each hazard or expectancy violation have correct advance information to direct drivers? • Is the advance warning information too close or too far away from the hazard? • Is the proper driving path emphasized enough to overcome the visual clutter that is present?	**EXAMPLES** • A final warning located greater than one-half mile from the hazard. • A warning located less than the stopping sight distance from the hazard (8 seconds at 70 mph). • A warning that does not grab the attention of drivers, such as a small warning sign lost in the visual clutter of other signs. • Temporary pavement markings that do not stand out against the pavement patches, joints, etc. or against the light sources from nearby roadside businesses.

V. WRITTEN SUMMARY OF POTENTIAL HAZARD	
Summary of the deficiency, location, and proposed corrective action.	
Summary of the deficiency, location, and proposed corrective action.	
Summary of the deficiency, location, and proposed corrective action.	
Summary of the deficiency, location, and proposed corrective action.	
VI. ACTIONS Contractor notified of required corrective actions_________ Corrective actions completed_________	**VII. ADDITIONAL COMMENTS** Check here if additional pages are attached ~