Guidelines

For Work Zone Designers

Traffic Control Design Overview

DEPARTMENT OF
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TRAFFIC OPERATIONS &
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Most State and many other transportation departments in the U.S. maintain roadway and/or work zone design manuals containing State specific regulations, policies, and design guidance for their designers and consultants to use. However, those manuals vary widely in the depth of coverage and the work zone design topics offered. National work zone design guidelines are lacking. This series of guidelines for work zone designers covers various work zone safety design topics for states, design manual decision makers, editors, and subject matter experts to develop or enhance their own guidance materials.

"Guidelines for Work Zone Designers – Traffic Control Design Overview" provides a general overview in designing a work zone and is not intended to be a stand-alone document for designing work zone traffic control plans. State, county, local, and tribal transportation agency subject matter experts, should use this material as reference material to augment their own work zone design policies and guidance.

The material in this guide was gathered from existing State design manuals, considered as best state-of-the-practice by the authors and worthy of sharing with other states, and from state-of-the-art work zone safety and traffic management research documents developed by the Transportation Research Board, the FHWA and other institutions.</td></tr>
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0. Foreword

Designing highways, bridges, and other transportation infrastructure is both a science and an art. Good design requires careful balancing of a wide range of technical, social, financial, and environmental considerations, many of which affect road user safety. To aid designers, many State Departments of Transportation (DOTs) guide staff and consultants on agency design policies by issuing highway and bridge design manuals. In addition, county, municipal, tollway authorities, and tribal transportation departments have their own design manuals.

This document is part of a series of work zone design guidelines developed by the Traffic Operations and Safety Laboratory (TOPS Lab) at the University of Wisconsin through a grant provided by the Federal Highway Administration (FHWA). The intention of the documents is to serve as a framework to assist agency technical editors and subject matter experts in preparing relevant sections in their design manuals. The documents in this series are not stand-alone design manuals, but may have application for designers as a reference document for a specific task. Highway agencies may adapt and modify the information in this document into their design manuals after considering their own operational experiences, traffic conditions, terrain, climate, organizational structures, risk management policies, legislation, and case law.

Guidance included in this document represents the authors' opinions of good practices. This document is not a national standard, policy, or regulation. Reference in this document to any specific commercial products, processes, or services, or the use of any trade, firm or corporation name is for the information and convenience of the reader, and does not constitute endorsement, recommendation, or favoring by FHWA or the authors.

Two font colors are used in this document to assist agency design manual editors in adapting the prototypical guideline material for their state-specific guidelines:

Black color normal text identifies narrative, text, and other materials ready for consideration for incorporation into agency-specific guidelines, with relatively little revision.

Italicized purple color text identifies commentary material and other issues that are likely to need modification to reflect agency-specific policies, organizational structures and choices, and require further considerations.

Note: Blue color is used to designate section heading numbers and titles in this Guide.

Designers face many challenges in providing consistent and proper Temporary Traffic Control (TTC) designs due to the increased number of construction projects that require accommodating existing high traffic volumes during construction, often in close proximity to the work areas. In addition, there is more construction work done during hours of darkness in order to minimize traffic interruptions. Finally, there is more pressure to complete projects in shorter time to reduce driver frustration brought about by work zone congestion. The overall goal of this Overview Design Guide is to help States decrease the number of work zone fatalities and injuries, and try to help alleviate driver frustration in work zones by improving traffic flow *through work zones. The Overview Design Guide intent is to provide States with a broad overview of material to consider incorporating in their design manuals for the benefit of their project designers.*

The terms construction staging, phasing, and sequence of operations are considered synonymous terms used to describe the order in which work operations are carried out. These terms used in the TTC plans explain how the contractor will complete work operations using the required equipment and material to complete one part of the project at a time. The rationale for dividing up the work is to allow separate space for contractors to safely perform the necessary work and to reduce the impacts of work operations on all traffic, including pedestrians, transit users, and property access. A State may choose to use each of these terms for a specific definition, in which case the terms and their definitions should be clearly spelled out in their work zone development manuals and guides, and use them consistently throughout all their work zone documents. For example, a State may reserve the term "staging" to only mean a period of time in which work is concentrated in one section of the project site and "phasing" to the sequence of completing a portion of the project one part at a time or how the contractor will position their equipment and materials.

1. Work Zone Management Fundamentals

1.1 Introduction

When considering improvements to highway and street infrastructure, the common tendency is to focus on the final product. This is certainly important, as this is what the public will be experiencing during the majority of the time while the facility is in use. However, when construction activities require improvements to existing facilities, normal traffic patterns are going to be disrupted. Managing these disruptions through provisions to ensure the safety and mobility of the traveling public while maintaining project constructability is an enduring challenge for designers.

Unfortunately, expertise in the principles of design for the physical elements of infrastructure – geometrics, pavement, structures, hydraulics, lighting, and so forth – does not naturally translate into an understanding of how to manage the complex and dynamic interplay of live traffic and phased construction. This document presents an overview of the issues that a designer should consider as they approach designing traffic control for highway construction projects.

1.2 Focus for Traffic Control Design

Good management principles for transportation improvement projects incorporate elements to ensure that traffic management issues are addressed proactively starting in project planning and continuing through construction. A key concept is the use of a Transportation Management Plan (TMP) to consolidate information relating to traffic management issues. Depending on the complexity of the project, a TMP may include information on strategies that will be deployed to improve the mutual safety of workers and the traveling public, or to provide for ongoing communication and coordination with local residents through a public information campaign. However, all TMPs will contain a Temporary Traffic Control (TTC) Plan. The TTC plan describes in detail how the project will be built and how traffic movements (including all modes present in the vicinity of the project) will be maintained during each construction phase, frequently including plan-view layout drawings of temporary travel ways, and temporary Traffic Control Devices (TCDs) including markings, signs, signals, barriers, and other devices.

A properly developed TTC plan is a crucial piece of documentation wherein the designer communicates to the contractor how the project is to be built, and represents a significant part of the contract documents that form the agreement between the contractor who actually builds the project and the owner-agency that is paying them to do it. A clear, detailed, and well thought-out TTC plan can assist in a project being constructed safely and efficiently, but a poorly written, incomplete, insufficiently detailed, or nonexistent TTC plan frequently causes disagreements between the contractor and owner-agency that result in delays, cost overruns, change orders, litigation, or questions of liability when something goes wrong. As will be discussed in this Guide, the designer's role in developing a suitable TTC plan requires knowledge and judgement to consider factors beyond a tunnel-vision focus on the "end product". Factors that should be considered include:

- Ensure the TTC plan will allow the contractor to construct the improvement project to meet the contract quality requirements.

- Develop the necessary TTC plan design instructions as concisely as possible to ensure there is sufficient clarity and unambiguity for the contractor to implement the TTC plan and construction engineering staff to inspect the work.
- Show sufficient detail in the plans or notes to fit the construction project circumstances to provide safety and traffic flow during the project. To accomplish this, the TTC plan may have components that range from merely referencing the application of appropriate Manual on Uniform Traffic Control Devices (MUTCD) devices, how and where State Highway Construction Standards and Specifications, and State Standard Special Provisions are applied, and finally to the incorporation of unique design details and special provisions.
- Provide a high degree of TTC plan design consistency with other highway improvement projects with similar traffic characteristics to the project.
- Require traffic control devices placed no sooner than required and remove all temporary traffic control devices as soon as the work is completed.
- Disrupt traffic flow only to the degree necessary to safely construct the project.

1.3 Regulatory Requirements

1.3.1 Manual on Uniform Traffic Control Devices (MUTCD) [1]

The MUTCD is an authoritative publication with nationwide applicability. The national standards for managing traffic in work zones are in Part 6 of the MUTCD. The MUTCD sets forth basic principles and prescribes standards for the design, application, installation, and maintenance of traffic control devices used on all highway projects in the U.S. Therefore, all TTC plans shall be consistent with the standard provisions in the MUTCD. In addition to standards, the MUTCD provides guidance, options, support information, as well as example layout designs that provide fundamental applications for using traffic control devices.

The MUTCD example layout designs, referred to as Typical Applications in Section 6H, are the fundamental building blocks where State Standard Detail Drawings originate. Developing project specific detail design drawings uses a combination of features from various typical application design drawings to cover the conditions required for the specific site conditions needed by the designer to implement the construction project. The MUTCD drawings typically represent the minimum solutions for the situation depicted. Therefore, to enhance the safety and mobility for their specific project design, the designer may choose to add more traffic control devices in the design. The typical application drawings use the standards, guidance, support, and options contained in Part 6. Modifications, enhancements, and combining the typical drawing must follow the Part 6 provisions for the specific traffic control devices and techniques.

1.3.2 Work Zone Safety & Mobility Rule [2]

The Federal Highway Administration (FHWA) published in 2004 updated regulations that govern traffic safety and mobility in highway and street work zones on all Federal-aid highway projects. The regulations are contained in 23 CFR 630 Subpart J, and titled "Work Zone Safety and Mobility Rule" (Rule). This Rule requires States develop and implement a policy for systematically managing work zone impacts across all stages of project development (frequently referred to as the agency *"Work Zone Safety and Mobility Policy")*. This State policy includes processes, procedures, and guidance for their planners and designers to use as they develop individual projects. While this policy was only required on Federal-aid projects, states are encouraged by the FHWA to use this policy for all of their projects.

An outcome this regulation addresses is the development of Transportation Management Plans (TMPs), as previously mentioned in Section 1.2. *Depending on the agencies approach, a TMP may address a specific project, a series of projects, a program of similar projects, or it can reflect an agency-wide strategy for all construction projects. While the Federal Rule only strictly applies to Federal-aid projects, good practice and the favorable experience of agencies who have judiciously applied the requirement for a TMP more broadly have encouraged the widespread adoption of TMPs as a general best practice for highway construction projects.*

The TMP process begins in the planning phase of a project to identify the project scope, potential construction staging approaches, and preliminary traffic management strategies. While all improvement projects following the Rule will have a TMP, the scale of the project TMP will vary widely based on characteristics and expected work zone impacts of individual or classes of projects.

The TMP development process will vary based upon the State's work zone policies, but at a minimum will always include a Temporary Traffic Control (TTC) plan. The Federal Rule goes on to define projects of extended duration, with notable impacts to normal traffic patterns, or occurring in heavily populated or congested areas as "significant" projects. *States or local agencies may establish additional criteria for projects that are to be defined as "significant".* Significant projects warrant the inclusion of two additional elements into the TMP: a Transportation Operations (TO) component and a Public Information (PI) component. The TO plan describes operational strategies to be employed to assist in traffic management, such as the use of law enforcement or queue warning systems. The PI plan addresses specific activities that will be undertaken to involve local stakeholders to help them understand how they will be affected by the project and to include them in planning and project development as appropriate. Much like the TTC plan communicates the intent of designers to the contractors, the TO and PI plans communicates the intent of designers to a broader audience of community leaders, traffic managers, and other public entities that will be instrumental in keeping transportation modes operating efficiently while the project is being built.

The designer needs to assure all commitments made in the TMP process that the project contractor will have involvement with or have responsibility for implementing are carried forward as part of the TTC plans before finalizing the Plans, Specifications, and Estimates (PS&E). This will ensure prospective contractor bidders have an opportunity to consider the TMP provisions in preparing their project bid proposals and should help to avoid potential project change orders.

1.3.3 Roadside Design Guide [3]

A reference document used by States in developing their work zone design standards, policies, or guidance material; standard detail drawings; and standard specifications is the American Association of State Highway and Transportation Officials (AASHTO) Roadside Design Guide (RDG). The RDG Chapter 9, "Traffic Barriers, Traffic Control Devices, and Other Safety

Features for Work Zones" describes the application of safety features, function, and structural requirements of temporary traffic barriers, temporary traffic control devices, and other roadside safety features used in work zones. Designers may also use Chapter 9 to obtain design guidance and good practices on the appropriate use of temporary barriers, traffic control devices, and other roadside safety features for their TTC plans.

2. Basic Principles of Work Zone Management

In order to prepare a well-designed individual project TTC plan, a designer must have a thorough understanding of the overall scope of the construction project and other nearby projects. If a formal TMP has been developed, or is in the process of being developed, it is the responsibility of the designer to ensure commitments in the TMP are followed through in the TTC plan. Regardless of whether a TMP is developed, the designer has a responsibility to establish and maintain communication with other highway jurisdictions, especially local agencies located near the project, throughout the TTC plan development. Coordination is critical if other projects, regardless of agency jurisdiction, are identified that may have an impact on the project TTC plan. The context of work involved, and where the proposed project limits and timelines may fit together with other nearby projects, is critical to ensure an acceptable TTC plan is developed and delivered.

2.1 Safe System Principles

The Safe System approach is a relatively new way of thinking about the interaction of roads, road user behavior, vehicles, and speeds. An international group of safety experts representing 21 countries published the Safe System approach in 2008 as the result of a three-year cooperative effort [4]. High-ranking officials represented the United States in this effort from the Federal Highway Administration (FHWA), the Federal Motor Carrier Safety Administration (FMCSA), and the National Highway Traffic Safety Administration (NHTSA).

In the past, transportation safety efforts were often fragmented due to the difficulty of coordinating engineering, enforcement, and educational efforts overseen by various agencies and organizations. The Safe System approach tries to overcome these difficulties by showing the benefits to roadway safety can be enhanced when responsibilities are shared among all creators, managers, and users of the transportation system. To reduce casualties, safer roads and roadsides, safer vehicles, safer speeds, and safer road user behavior (Figure 1) are all needed.

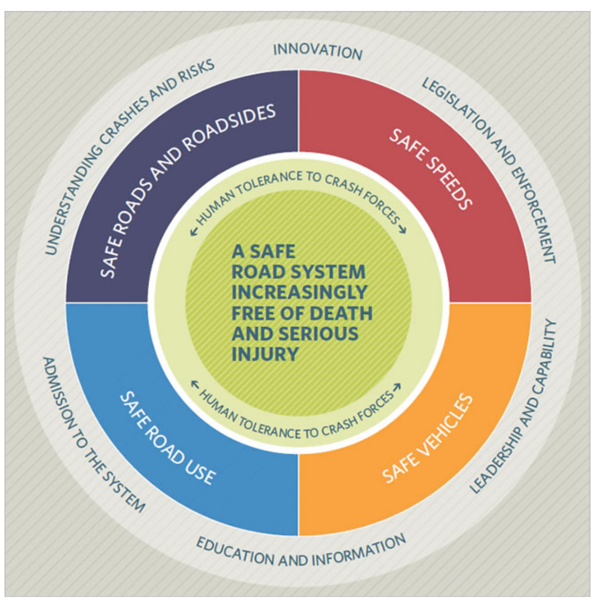

Figure 1. Elements of the Safe System
Source: © 2017 New Zealand Transport Agency

In order to create a Safe System, it is necessary to recognize that all humans make errors and take risks—even road users who are well educated and law-abiding. Although it is probably not possible to prevent all crashes, the objective is to prevent crashes that result in death and serious injury. Roads, vehicles, road users, and speeds interact continuously. In a Safe System approach, increased crash survivability occurs when potential failures are identified in one part of the system and mitigation treatments developed using other system safety elements.

An example of a Safe System approach is the proper design of roadsides and installation of positive protection (Figure 2). Even a well-maintained roadway built to high standards can become an environment where minor driving mistakes can have dire consequences. In work zones, positive protection can reduce the consequences of driver error, if designed and installed correctly. For example, barriers can reduce the likelihood that a driver who strays out of the lane will become involved in a fatal crash. Nevertheless, it is important to deploy positive protection judiciously so that the barriers themselves do not become an obstacle that increases crash risk.

Figure 2. An unforgiving driving environment.
Source: FHWA Vegetation Control for Safety Guide

2.2 Work Zone Impacts Considerations

The core themes that designers strive to achieve for their work zones are safety, mobility, and constructability. Therefore, these themes need to be assessed throughout the planning and designing stages for highway projects. These themes can be stated as goals:

- Maximize the safety of road users and highway workers.
- Maximize the mobility and accessibility on roadways during construction.
- Plan, design, and build the project as effectively and efficiently as possible.

To achieve these goals, an iterative process is required in the work zone design process and is based on impact assessments. The challenge for the work zone designer is to find the best balance between these key priorities. The goal of having an effective and efficient TTC plan includes the constructability issue.

The following list of issues that assessments need to cover for safety, mobility, and constructability include the following:

- Project characteristics.
- Travel and traffic characteristics.
- Corridor, network, and community issues.
- Design, procurement, and construction options.
- Work zone design and safety issues.
- TTC strategies.
- Transportation operations strategies.
- Public information strategies.

The FHWA has produced a guide entitled, "Work Zone Impacts Assessment: An Approach to Assess and Manage Work Zone Safety and Mobility Impacts of Road Projects [5]." The FHWA guide has a thorough discussion on assessing construction impacts, including a list of examples of useful information that may be gathered for use in the assessment process. The list is shown in Appendix A.

Some States have developed comprehensive processes with considerable details for assisting designers to develop and assess their TTC plans. An example is the New York DOT process, Appendix B. The New York example uses a flow chart and supplemental tables to assist the work zone strategy evaluation process and the impacts the various strategies will have based on gathered data. A detailed description is included for each step in the flowchart.

Other States have developed a more abbreviated, general process guide for their designers to use to develop TCCs. An example that the Florida DOT uses is shown in Appendix C.

The impacts assessed are the situational constraints that will drive the development of the construction sequence of operations, identifies the work zone traffic control that is most appropriate to meet the project requirements, considers the local environment, and best suits the needs of the traveling public. Situational constraints include factors relating to the physical space, the local environment, corridor mobility needs, prevailing traffic patterns, and the need to address specific safety concerns, such as safely accommodating all user types throughout the duration of the project. The level of detail on these assessments becomes more detailed as the design progresses.

On projects identified as "significant" in the TMP process, (see Section 1.3.2), more comprehensive plans for identifying and assessing transportation operation strategies and public information strategies are developed and result in a stand-alone work zone planning product.

2.3 Design Controls

A work zone TTC plan provides an implementation strategy a contractor can follow that will allow for completion of a successful construction project, with minimum disruption to vehicle traffic, pedestrians, and bicyclists, and provide a safe environment for workers. The following design criteria are essential elements designers must consider to achieve this objective.

2.3.1. Number of Driving Lanes

A highly desirable design element is to maintain the same number of lanes through the work zone as existed prior to the start of construction, at least during peak, high volume periods. Achieving this design element is done by using various management strategies, such as constructing temporary lanes, using shoulders as temporary lanes, reducing lane widths, or removing lanes for work operations only during low travel periods, such as night hours. This examination should include coordination with constructability reviews to assure the project is built efficiently and safely.

2.3.2. Lane and Shoulder Widths

Avoid reductions in lane and shoulder widths through the construction area as much as possible. However, this is frequently not practical given the constraints of the available right-of-way and space needed for construction operations. If reducing the number and/or widths of lanes is necessary, consider deploying traffic operation and safety measures, such as allowing contractors to reduce the number of lanes only to periods when traffic flow is least congested, for example during night hours. If space is limited, it is often more desirable to reduce shoulder widths to maintain normal lane widths. The following are suggested lane and shoulder width guidelines for work zones:

- *Rural and Urban High Speed Freeways and Expressways:*
    - *Desirable – 12 foot wide lanes and shoulder widths the same as before construction.*
    - *Rural Minimums – 11-foot wide lanes with 2-foot shoulders, with one 12-foot lane in each direction. For lengthy projects when minimum shoulder widths are required, consider using infrastructure techniques that enhance incident management capabilities.*
    - *Urban Minimums – 10-foot wide lanes with 1-foot shoulders and traffic operation treatments used, including detour routes for wide vehicles. A minimum of 11-foot wide lanes on Interstate highways, except one 12-foot lane in each direction.*
- *Undivided highways:*
    - *Desirable – Same lane and shoulder widths as before construction.*
    - *Minimums – 10-foot lane widths and 1-foot shoulder widths.*
- *Ramps:*
    - *Desirable – Same lane and shoulder widths as before construction.*
    - *Minimums – 10-foot lane widths and 1-foot shoulder width, with detour route available for wide vehicles if total ramp width is less than 14 feet.*

2.3.3. Geometrics

The TTC plan should provide an adequate roadway alignment for drivers to maneuver safely through the construction area at all times of the day. The design should avoid frequent and abrupt changes in roadway geometrics such as sudden lane narrowing, lane drops, or lane shifts that require drivers to make rapid steering maneuvers. It is desirable to keep a uniform design speed for the geometric elements through the entire work zone.

2.3.4. Roadside Slopes, Obstacles, and Drop-Offs

The clear zone is the relatively flat area that extends outward from the edge of the traveled way before encountering non-breakaway critical slopes or obstacles. Standard clear zone widths are often unachievable in order to satisfy traffic mobility and constructability issues. Designers must assess whether to accept the increased safety risk with reduced clear zones, or whether to use mitigation strategies, such as using positive protection or reducing speed limits.

The AASHTO Roadside Design Guide clear zone widths for work zones is shown in Table 1 [3].

Table 1. Example of Clear-Zone Widths for Work Zones

Speed Limit (miles/hour)	*Clear Zone Width (feet)*
60 or greater	*30*
45 to 55	*20*
40	*15*
35 or less	*10*

The most common treatment considered to minimize a shortage of clear zone widths is to use temporary positive protection devices to keep motorists from encountering non-traversable slopes or hazardous obstacles. Temporary positive protection devices are capable of containing and/or redirecting errant vehicles. The most frequently used positive protection units are temporary concrete barriers. The ability to evaluate positive protection crashworthiness was published in the 1993 National Cooperative Highway Research Project (NCHRP) Report 350. Updated roadside safety hardware crashworthiness evaluation criteria was developed in 2009, and further updated again in 2016, and are published in the AASHTO Manual for Assessing Safety Hardware (MASH) [6].

Besides reducing risk to vehicle occupants in areas that have less clear zone available, temporary positive protection devices can also eliminate or reduce the following risks [3]:

- Reduce the likelihood of traffic entering work areas such as excavations or material storage sites;
- Provide protection for workers;
- Separate two-way traffic;
- Protect construction such as falsework for bridges and other exposed objects; and
- Separate pedestrians from vehicular traffic.

However, temporary positive protection devices come with their own set of risks, therefore designers should follow their State work zone policies and guidelines in determining whether positive protection devices are needed.

Elevation difference between adjoining lanes or the edge of the traveled lane and shoulder as traversed by the wheel of a motor vehicle are “drop-offs”. These changes in elevation along highways present exposure to risk for highway users, especially vulnerable users such as motorcyclists or inexperienced drivers. Reducing or eliminating this risk in work zones can be accomplished by increasing the lateral distance from the nearest traveled lane to the drop-off, providing a taper transition (especially useful for use in adjoining lanes or drop-offs at edge of shoulders), installing a positive protection barrier, or reducing the work zone speed limit.

2.4. General Constructability Overview, and User Constraints and Accommodations

The proposed TTC plan must allow the contractor to construct the project in accordance with the construction specifications and within the allotted time. Therefore, the designer should review the TTC to identify any safety, operational, or logistical problems that would prohibit the timely completion of the project. Special attention is required during the design process on how the contractor will have access to the work site, including the delivery of materials, identifying potential locations for storing and producing materials, and worker parking. On complex interchanges and lengthy projects, at least one useable worksite delivery plan should be identified, including how delivery trucks can safety accelerate and decelerate into and out of the traffic flow for each construction phase.

Other important constructability elements evaluated during the design process include:

- The maneuverability of traffic through the horizontal and vertical alignment constraints during all construction phases.
- Adequate positive protection to separate opposing traffic, workers, and equipment.
- The work area needed for equipment maneuverability and construction inspection.
- Anticipated oversize and overweight load requirements for construction vehicles to reach the work site.

However, the constructability elements must be designed so as to also fulfill the needs of all road users, including motorists, bicyclists, and pedestrians which includes persons with disabilities in accordance with the Americans with Disabilities Act of 1990 (ADA), Title II, Paragraph 35.130.

2.4.1. Worker Safety Considerations

The safety of construction workers on the project is as important as the safety of motorists, pedestrians, and bicyclists traveling through the work zone. Since temporary traffic control zones often present constantly changing conditions that may be unexpected by motorists, there is an increased risk and vulnerability to workers on or near the traveled way.

If positive protection is determined not necessary in work areas to shield motorists from roadside hazards, positive protection may still be determined to shield workers to increase their safety, and typically their productivity.

Designers should follow their State developed policies and guidance for determining if positive protection devices are mandated for the conditions present to separate the work space and motorized traffic. When conditions fall outside of mandated use, an engineering study is conducted to determine if positive protection devices are needed to shield workers from traffic. Variables typically analyzed include:

- Operating speed
- Traffic volume
- Length of time workers are exposed

- Type of roadway facility
- Length of work area
- Type of construction work
- Curvature and alignment of roadway.

Additional guidance are in the companion FHWA Guide in this series called “Guidelines for Work Zone Designers - Positive Protection” and the ATSSA “Guidelines on the Use of Positive Protection in Temporary Traffic Control Zones.” [7], [8]

2.4.2. Pedestrian Accommodation and Consideration

The MUTCD Part 6 provides standards, guidance, and support for pedestrian accommodations and consideration in all TTC plans. A standard in Section 6D.01 states, “If the TTC zone affects the movement of pedestrians, adequate pedestrian access and walkways shall be provided. If the TTC zone affects an accessible and detectable pedestrian facility, the accessibility and detectability shall be maintained along the alternate pedestrian route.” Another standard in Section 6D.02 states, “When existing pedestrian facilities are disrupted, closed, or relocated in a TTC zone, the temporary facilities shall be detectable and include accessibility features consistent with the features present in the existing facility.” Further guidance in Section 6D.01states, “A smooth, continuous hard surface should be provided throughout the entire length of the temporary pedestrian facility. For accommodating wheelchairs, there should be no barriers, such as curbs, abrupt changes in grade, terrain that could cause tripping, or a barrier to wheelchairs. The geometry and alignment of the facility should meet the applicable requirements of the “Americans with Disabilities Act Accessibility Guidelines for Buildings and Facilities (ADAAG).”” [9]

Therefore, to assure proper pedestrian accommodation on all TCC plans, the following design elements are used:

- Provide pedestrians with a safe, convenient travel path that replicates as nearly as possible the most desirable characteristics of sidewalks or other walkways that existed prior to the construction project.
- Separate pedestrian movements from vehicle traffic using positive protection devices and/or MUTCD approved traffic control devices. This includes provisions to avoid conflicts with work site vehicles, equipment, or operations.
- Pedestrian accommodations through work zones must include provisions for the disabled at the same or greater level of accessibility as the existing facility.
- Using pedestrian travel pathways for placing vehicular temporary traffic control devices are not desirable. If no feasible alternative exists, exercise care to assure the traffic control devices do not interfere with the use of the facility by people with disabilities.
- Assure temporary transit loading and unloading pads, and shelters if used, are accessible.
- If pedestrians are detoured or diverted at an intersection, midblock, onto a temporary walkway, etc., designers should include sufficient details in the TTC plans for contractors to construct the temporary walkway.
- Physically close the full width of the sidewalk/pedestrian way at the closure point and provide proper detour signing.

2.4.3. Bicycle Accommodation

Directing bicyclists to take alternate routes should not lead them into conflicts with mainline traffic, work site vehicles, or equipment moving through or around traffic control. If the work zone interrupts the continuity of an existing shared use path or bicycle route system, provide signs directing bicyclists through or around the work zone and back to the path or route. The bicyclist should not have to use the same path as pedestrians unless the path is designed to accommodate both modes of travel.

2.4.4. Freight Accommodation

Work zones usually have an adverse effect on traffic capacity, which is often further degraded when the route is a high volume freight corridor. Therefore, it is important to have sufficient anticipated large truck volume information during the design process and checking that large trucks can maneuver through the work zone. Temporary lane widths and geometrics at intersection turning movements are perhaps the most important considerations. Other considerations include placing weight restrictions on temporary structures and height clearance restrictions where fall protection or scaffolding is installed below bridge rehabilitation work. Requiring large trucks to take detour routes and restricting trucks to specific lanes by the use of regulatory signs are methods to minimize the effect.

On oversize and overweight designated freight networks, it is important that these vehicles can safely navigate the work zone. If these vehicles need to travel within the work zone, special attention throughout the design is required to assure accommodation will not be problematic during all construction phases. Eliminating or restricting the oversize and overweight permits for these vehicles may be necessary, but only after the effect on commerce is carefully considered.

2.5. Speed Management Principles

Establishing lower speed limits in work zones, either through regulation or warning, does not ensure drivers will reduce their speeds, unless drivers perceive the need to slow down, usually through noticeable geometric changes or construction work that requires constraints on traffic flow. The most effective way to obtain better compliance when regulatory speeds are reduced is to have increased active police speed enforcement.

While engineering techniques can have some influence on traffic speed in work zones, they typically cannot be the only technique used to obtain the desired traffic speed outcome. Engineering, education/awareness, and enforcement measures can influence motorists, promote work zone awareness, and achieve safer work zones.

2.5.1. Establishing Target Speeds

Establishing regulatory and advisory speed requires consideration of many variables and factors. Arbitrary speed limit reductions alone erode a motorist's confidence in the need for reducing their travel speed, especially when no work operations are underway.

Many States have established guidance and procedures to achieve speed limit consistency in work zones. An example is the distance a speed limit should remain the same if workers are not present. In long work zones with several intermittent activity areas where it has been determined that a regulatory speed limit reduction is necessary at each activity area, the preconstruction posted speed limit is normally restored between activity areas when the activity areas are separated by 2 miles or greater.

Some States have developed procedures to assist their designers for establishing planned advisory and regulatory speed limits for TTC plans. The New York DOT procedures use flow charts, Appendix B & C, for their designers to establish work zone advisory and regulatory speed limits.

2.5.2. Methods to Achieve Speed Reductions in Work Zones

Achieving speed reductions are more likely to occur by combining and coordinating engineering, education/awareness, and enforcement techniques together. Coordinating speed reduction plans should begin during the early TMP process so the engineering techniques can be incorporated into the TTC design plans. Influencing speed reductions, regardless of the posted speed limit, often occurs if work zone techniques such as flagging, variable message signs, lane shifts, and lane-width reductions are used. Other engineering measures including static warning and advisory speed limit signs, width restrictions, channelizing chicanes, portable variable message signs with radar detectors displaying excessive speeds, and use of intelligent transportation system technologies may also be considered in the design process.

Active law enforcement is usually the most effective measure to encourage motorists' compliance with posted regulatory speed limits and other traffic regulations within work zones. The need for police presence and enforcement should be determined as early as possible during the project design phase and coordinated with enforcement agencies to ensure that enforcement activity is feasible and can be as effective as possible. Research on types and effectiveness of work zone enforcement methods, and average speed reductions are shown in the table in Appendix D.

Public awareness and education campaigns with information about the reduction in speed limits can also be useful.

3. Work Zone Traffic Management

3.1. Traffic Management Principles Overview

Accommodating existing traffic demand, including what to do with traffic that cannot be accommodated within a reduced-capacity work zone, and providing a safe work environment are critical elements in the TTC project development process. Work zone management strategies are defined by identifying the needs and problems encountered by the public as they travel through or around the work zone and those of the contractor's work force as they work to construct the project. Often there are alternative methods to handle temporary traffic patterns. Therefore, the objective for the designer is to identify the best strategy to optimize the competing goals of minimizing construction costs, ensuring project quality is not compromised, maintaining an acceptable level of operational efficiency to the traveling public and adjacent property owners, and maximizing traffic and worker safety.

3.2. Work Zone Traffic Management Techniques

Maintaining acceptable transportation service for existing traffic during construction operations require traffic management planning. On large, significant projects, the planning and analysis begins during the Transportation Management Plans (TMPs) development and approval process. However, for less significant, smaller projects, the TTC plan design may occur concurrently with the overall project design and without an early focus. However, regardless of when traffic management planning occurs, it is a critical element in the PS&E process.

When substantial traffic and safety impacts are anticipated on a project, a larger planning and design effort is needed. Besides using conventional construction management techniques listed below, other traffic operation and public involvement strategies, such as traffic demand reduction measures, incident management, and advanced traveler information systems, are useful. In addition, examine whether constructing permanent facilities with wider cross sections, such as shoulders, to accommodate temporary traffic during a later construction sequence, and/or innovative construction techniques, should be incorporated to minimize impacts. Nevertheless, in all cases, a strategy should be selected to carry traffic through or around the facility under construction using a system of infrastructure and temporary traffic control (TTC) methods.

The following strategies are often employed for construction work zones:

- One-Lane, Two-Way Traffic Control,
- Lane constriction,
- Intermittent closure,
- Lane closure,
- Two-way operation on one-side of a divided highway,
- Using shoulder, or portion of shoulder, as a driving lane(s),
- Construct temporary bypass lane(s),
- Diverting a portion of the traffic, and
- Full road closure with all traffic diverted.

On some projects, a single strategy may work best to complete all the construction operations. However, more frequently, a combination of strategies is used, including strategies together at the same time, or separately for accomplishing a specific work operation. An example when two strategies are used together is the use of a lane closure combined with using a shoulder as a driving lane. Some of the identified strategies are also considered mitigation strategies, meaning that they are used to offset negative consequences such as reduced capacity and access limitations for one or more other strategies.

The final report for NCHRP Report 581: Design of Construction Work Zones on High-Speed Highways provides detailed design guidance on many of these strategies [10].

3.2.1. One-Lane, Two-Way Traffic Control

Alternating traffic on one-lane of roadway in a work zone is a traffic management technique that allows construction work in the closed lane. This technique only applies to two-lane roadways. Providing opposing direction of travel requires traffic to take turns using the single, open lane. The traffic control method to allocate the use of the open lane is done by various methods that include using construction workers whose responsibility is to "flag" approaching traffic using "Stop" and "Slow" sign paddles, temporary and portable traffic signals (PTSs), and STOP or YIELD sign control. There are variations and enhancements to the "flagging" method including "flag transfer" to assist in communicating between flagger stations, pilot car to guide a queue of vehicles in the open lane, and automated flagger assistance devices (AFADs).

This traffic management technique requires adherence with Part 6 of the MUTCD. A key consideration that a designer must consider before using this technique besides only being applicable to two-way roadways is the impact the technique will have on capacity. Capacity reduction increases as the length of the one-way segment increases. In addition, construction operations will take place in close proximity to traffic operations. Therefore, application of this strategy is generally limited to lower volume, two-lane, two-way roads.

The safety to human flaggers positioned in or on the edge of high-speed roadways directing traffic to stop, slow, and/or shift lanes has been the focus of recent attention. To overcome this safety challenge, AFADs and portable temporary signals are now acceptable automated technologies in the MUTCD. Some States have tried these devices and recent research evaluations have been conducted to assess the state-of-the-practice of these methodologies. [11] *Additional guidance on how other States manage one-lane traffic control on a two-lane rural highway can be obtained in the NCHRP Synthesis 525, "Practices in One-Lane Traffic Control on a Two-Lane Rural Highway."* [12]

3.2.2. Lane Constriction

Lane constriction is a traffic management strategy where one or more travel lane widths are reduced to less than normal, non-construction, design widths. This technique has application for all types of roadway configurations and is often associated with right-of-way limitations. The purpose for constricting lane widths is to retain the same number of travel lanes that existed prior to construction. The constricting lane width strategy is often combined with other strategies, such as using some or most of one or both shoulder widths for driving lanes. The use of this strategy often results with traffic in close proximity to construction operations, which may result in possible undesirable conflicts among construction equipment operations, workers, and roadway traffic. In addition to safety concerns, the proximity may interfere with construction quality. This strategy should only be used after considering the impacts, including the temporary lane widths, duration of the constriction, length of the constriction, volume and classification of vehicles, along with the cost associated with avoiding the constriction.

This strategy may affect the ability of the temporary facility to accommodate effectively large vehicles. To mitigate this shortcoming, designating specific lanes for trucks with normal lane widths while constricting other lanes for non-truck traffic may be possible. It is also beneficial to coordinate with *the oversize vehicle permit issuing agency* in making this decision on truck lane widths.

3.2.3. Lane and Shoulder Closures

When maintaining traffic through a project and creating the space needed for work operations, or to create buffer space for enhancing safety for workers and traffic, traffic lanes or shoulders may be closed. Traffic is accommodated by moving traffic, also called shifting traffic, to other portions of the roadway. Lane and shoulder closures may be used for either long term, such as an entire construction sequence, or short-term, such as only when work operations are underway. The types of devices used to separate traffic lanes from the work area may be positive protection safety hardware, longitudinal barricade channelizers, or other types of MUTCD traffic control delineators. The duration a lane is closed will frequently affect the type of devices used between the open traffic lane and workspace.

The design of lane and shoulder closures should include the following desirable elements:

- Design lane and shoulder closure tapers in accordance with MUTCD requirements, except where intersections or other site situations may necessitate shorter tapers.
- Start closures at locations that provide optimum visibility of the roadway ahead in order to provide motorists with sufficient opportunity to see stopped or slow traffic.
- Lane closure locations should take advantage of available escape paths such as wide medians and shoulders and avoid bridges and underpasses.
- Closures should be located away from other conflict points such as on-ramps and intersections whenever possible.
- On freeways where multiple lane closures are required and there are only short lengths between lane closures, such as *one mile or less* apart, the entire length is normally treated as a single work zone with a continuous lane closure.
- A longitudinal buffer between the downstream end of the lane closure taper and the start of the work area, while not mandatory per the MUTCD, is desirable. This buffer provides an enhanced margin of safety for workers and motorists.

3.2.4. Diversion

Diverting traffic is a traffic management strategy where vehicles in one or both directions are shifted from a route under construction to a temporary roadway. The temporary roadway is constructed and used just for the time while the permanent infrastructure is constructed. This strategy compensates for the removal of permanent travel lanes from service and eliminates or at least minimizes the loss of traffic capacity. These temporary diversion lanes are sometimes referred to as a shoofly or runaround.

A diversion strategy provides substantial separation of traffic away from the new construction work, although generally not as much as detours. In some cases, substantial costs may be involved for constructing the temporary facilities which may include the need for extra right-of-way. Diversions are often used for bridge projects, including bridge replacements, but may also be useful for other types of construction projects. When used for bridge projects, a temporary bridge or culvert is often needed, and the time and cost to construct this throwaway feature should be analyzed.

3.2.5. Full Road Closure

Closing a road completely is a traffic management strategy that removes all traffic from one or both directions of a roadway or a ramp. Closing a roadway or a ramp typically involves establishing a detour. This technique is often referred to as an exposure control technique since traffic cannot interfere with workers.

The biggest advantage to this strategy is efficiency, allowing the contractor to conduct construction operations without interference from traffic, which should also extend to improving the quality of the construction since optimum construction techniques may be used. A reduction in construction time can typically result since the contractor will be able to work without any disruption from traffic.

On routes where access is not controlled, such as where driveways are present, or pedestrian accommodation is required, the TCC plan must provide acceptable accommodation. The TCC plan must provide direction to the contractor on the minimum time requirements and procedures for local access.

Full road closure is especially desirable when there is unused capacity on roads running parallel to the closed roadway. The technique works well for tunnels, bridges, projects involving significant underground work within small right-of-ways, and projects that involve significant grade changes to an existing alignment. The strategy can be applied to any functional class of roadway or roads with any amount of traffic volume. When planning this technique on high volume or limited access routes, significant advanced planning during the TMP development is required due to the high volume of traffic normally associated with these type of facilities. The TMP should include a Traffic Operations Plan component as well as a Public Information component. The TCC designer should assure any commitments made during the TMP development process that affect the TCC plan are carried out, especially items the contractor will be responsible to implement.

Contractor costs associated with closing a road are usually insignificant. However, finding feasible alternative routes that can accommodate additional traffic may be a significant challenge. In addition, there frequently are at least some negative impacts on the alternative route and higher user costs for the detoured traffic.

Frequently, traffic operation and safety enhancements are necessary on detour routes. If any improvement work to the detour is required as part of the contract, it is essential to complete the improvements prior to the start of work in the closed road.

3.2.6. Short Term or Intermittent Closure

Short term or intermittent closure is a work zone strategy where all traffic stops in one or both directions for a relatively short time to allow a specific construction operation to use the entire road. Several construction operations that benefit from this technique include erecting bridge beams over a road, conducting demolition or blasting operations, placing transverse overhead utility lines, or moving cranes or other large construction equipment across travel lanes within the work zone. Since the strategy focuses on a specific short-term work operation, identifying the best time for undertaking the operation may be necessary.

Agency policy may restrict the use of a complete stoppage strategy for certain types of facilities, such as freeways, to only a certain time of the day, such as *2 a.m.,* or allow a maximum closure time, such as *10 minutes.*

When longer work operations require closure, such as demolition of a bridge passing over or near a traveled road, this strategy may not be appropriate and detours should be established when it would not be safe to traverse past the work operation.

A variation of this technique is to create a rolling roadblock using vehicles with flashing lights to slow or "pace" traffic. The rolling roadblock drives in advance of the work operation in order that by the time the queue of traffic reaches the work operation, the work operation has been completed and traffic can proceed without stopping or stopping only for a brief time. The rolling roadblock uses pace vehicles forming a moving blockade across all lanes well in advance of the actual work site. As the pace vehicles reduce speed, they create a traffic gap, thus allowing very short-term work accomplished without completely stopping traffic. Typically, law enforcement vehicles are used as the pace vehicles and occupy all lanes of traffic to prevent any vehicles from passing at highway speeds. Ramp closures and careful coordination are essential to assure that no vehicles enter the roadway ahead of the pace vehicles.

3.2.7. Two-way Operation on One Side of a Divided Highway

Two-way traffic operation on one side of a normally divided highway is a traffic management strategy used on expressways and freeways and on rural and urban divided highways. This technique is usually considered an exposure control mitigation technique because the number of TTC stage changes are often minimized compared to other traffic management strategies, and often allows for accelerated construction by allowing construction on the closed side of the divided highway without any interference from proximity to driving lanes and time of day restrictions. In addition, traffic and worker safety are enhanced by separating traffic from work areas and expediting material delivery since this technique separates traffic from the work area by either a wide median or positive protection devices.

To establish the counter directional traffic pattern, temporary roadway median crossovers are a standard way to move traffic from the closed side of roadway to the adjoining roadway as shown in Figure 3 and 4. If only one lane in each direction is provided, this technique is sometimes referred to as two-lane, two-way operation (TLTWO), because one lane of a normally two lane, one-way roadway is converted to operate with one-lane in each direction in its most basic form.

In order to work as efficiently and safely as possible, evaluate safety and capacity factors in the design process to assure the number of lanes provided will be adequate.

If the remaining lanes have insufficient capacity, supplemental strategies, such as using shoulders for driving lanes, temporary or permanent embankment widening, and/or reducing lane widths, should be considered to create additional temporary driving lane capacity. If traffic congestion is still anticipated after creating the maximum number of temporary lanes and capacity enhancements, other traffic mitigation strategies should supplement this strategy to address traffic back up queues.

The other important design consideration is the type of traffic control features that will separate the counter directional traffic. The MUTCD Section 6G.15 provides standards and support for the methods used. The MUTCD requires, as a minimum, the use of channelizing devices or a raised island between the opposing traffic in addition to pavement markings and signing. The MUTCD does not permit the use of pavement markings and signing as the sole separation method. Whether to specify positive protection or not is a major TTC project design decision. *Despite the higher cost for using temporary portable concrete barriers, this method of shielding traffic from the opposing direction has become a common practice for the safety benefits it provides in TWTLO situations in some states.* If positive protection will separate opposing traffic, sufficient space for the positive protection hardware is needed and lateral buffer space is desirable.

Identifying crossover locations is extremely important for safe and efficient operation of this technique. Desired crossover locations should be on tangent, level sections with both roadways on about the same profile elevations and avoiding close proximity to bridges and interchanges. If avoiding crossovers near interchanges is not possible, it may be necessary to create additional crossovers to reach ramps to provide access for all traffic movements. Because of challenges to the local highway system caused by closing ramps, it may be necessary to keep ramps open by creating additional crossovers. *A common practice is for States to develop their own Standard Detail Drawings for crossovers and transitions to assure statewide consistency and compliance with the MUTCD* [13].

If interchange ramps or rest areas are located within the crossover footprint or in the two-way operation section, consideration should be given to closing the access points to prevent driver confusion or erratic behavior. Decisions on necessity to provide access, such as interchanges on freeways and intersections on expressways, may influence the number of crossovers needed and their locations. Additionally, substantial grade differences between one-way roadways or within median topography can influence the feasibility and cost of a temporary crossover roadway. Even under favorable conditions, temporary crossover roadways are a significant cost consideration.

Figure 3. Work zone crossover – maintaining two lanes in each direction
Source: Nebraska Department of Roads, Report P581 Optimal Design of Work Zone Median Crossovers 9/10/2010. Karen Schurr

Figure 4. Work zone crossover – TWTLO with single lane developed prior to crossover
Source: FHWA photo, Sept/Oct 2010 Public Road

3.2.8. Temporary Plating

When underground construction cannot be completed in one work period and a traffic lane or pedestrian walkway is needed before the underground work is resumed, 1 *and ½-inch* temporary steel plates or other structural supports can be used to carry moving traffic over the excavation. One or more steel plates are anchored securely (Figure 5) by milling existing asphalt pavement to butt the steel plates against the adjoining pavement. *A minimum of 12-inch overlap on all sides of the excavation where traffic will be approaching or leaving the steel plates is recommended. The use of wedges or other non-asphaltic devices for leveling to eliminate any plate rocking and assure the surface is flush surrounding the installation is also recommended.* The use of compacted temporary asphalt to fill all gaps between the plates and existing pavement surfaces to assure moving traffic cannot shift the steel plates is a good practice. [14] In lieu of asphalt, proprietary plate anchoring systems are also commercially available.

When only using temporary steel plates for pedestrian or local traffic conditions, such as operating speeds less than 35 mph, laying steel plates on the existing pavement to cover the excavation and building a 12-inch temporary asphalt mix wedged, feathered taper around the edges of the steel plates is a common practice.

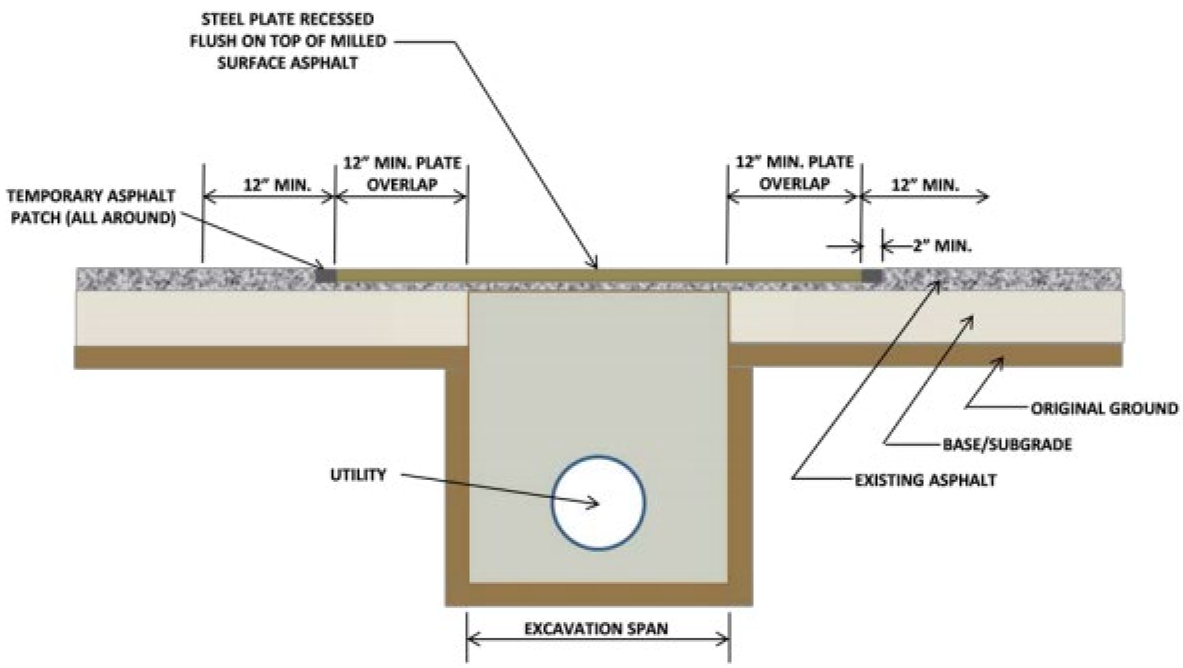

Figure 5. Temporary Plating Recessed into existing asphalt pavement.
Source: City of Charleston, S.C.

3.3. Frequent Constraints Affecting TTC Plan Traffic Management

3.3.1. Coordination with other Projects

If there are adjoining construction projects, coordination is required to assure that construction operations are compatible and do not interfere with each other and all TTC plans are compatible. In order to eliminate or minimize change orders before advertising projects for letting, resolve potential conflicts with adjoining construction projects. This is especially critical if the projects are under the control of another jurisdiction or agency. If construction operations must be coordinated or completed on adjoining projects, detailed specific information must be included in the project bid contract document to avoid potential change orders.

3.3.2. Utilities

Identifying and locating all utilities within the highway right-of-way or acquired right-of-way for a construction project should be accomplished during the development of the TMP and available to the designer developing the TTC plans. In order to reduce work operation conflicts between utility and highway contractors and potential change orders to highway contracts, relocating utilities prior to the start of the construction project is desirable. The State should have a process to assure the utility relocation TTC plans follow the same work zone traffic management principles for handling traffic as the primary construction project.

Where utility relocation and adjustment is not feasible prior to the commencement of construction operations and done concurrently with project construction operations, the utility work operations must be closely coordinated with construction operations. Coordination requirements should be fully explained in the contract document, including any traffic control strategy that is mandated for the utility company to follow or whether the utility operations can use the contractor TTC set-up. The work necessary to relocate major utility conflicts done concurrently with the construction contractor operations can have a major influence on staging of construction projects and therefore often affects work zone management strategies.

3.3.3. Drainage

Accommodating storm water is essential during construction operations and therefore may dictate that certain work zone management strategies may not be used. An example is filling or reducing ditch capacity for use as a temporary driving lane.

In addition, TTC plans that use temporary portable concrete barriers should be reviewed to assure that storm water can leave the driving lanes by directing the water under or around the ends of the barriers.

3.3.4. Pedestrian Access and Lateral Crossings

Accommodating property owner access, including both businesses and residential, where work zone impacts interfere with normal access and lateral crossings may require constructing alternate facilities for pedestrians and bicyclists. As a minimum, providing signage or information to direct motorists, pedestrians, and bicyclists to alternate access and crossing locations is essential. Alternate access facilities should be included to provide at least equivalent service to the properties and lateral crossings that existed prior to the construction project. Accommodating individuals with disabilities in accordance with the Americans with Disabilities Act of 1990 is required and is specified as a standard in MUTCD 6D.02 for all projects. The standard is stated as follows, "When existing pedestrian facilities are disrupted, closed, or relocated in a TTC zone, the temporary facilities shall be detectable and include accessibility features consistent with the features present in the existing pedestrian facility. Where pedestrians with visual disabilities normally use the closed sidewalk, a barrier that is detectable by a person with a visual disability traveling with the aid of a long cane shall be placed across the full width of the closed sidewalk."

The alternate facilities should provide a smooth, firm, stable, slip-resistant, and continuous hard surface throughout the entire length of the temporary pedestrian facility. Minimize abrupt changes in grade or terrain that could cause tripping or be a barrier to wheelchair use. The TTC plans should include requirements that mandate accessible facilities and crossings throughout the duration of the project. Additional guidance for pedestrian accessibility is in the companion FHWA Guide in this series called "Guidelines for Work Zone Designers – Pedestrian and Bicycle Accommodation". [15]

3.3.5. Special Events and Holidays

Most States have restrictions in their standard construction specifications with certain holidays that contractors shall not perform construction operations that interfere with traffic. Include these restrictions in the contract to reduce traffic delay and inconveniences caused by larger traffic volumes from non-typical traffic patterns, such as tourist or family travel periods. The start or completion of staging plans may be desirable around these restricted operation periods to accommodate maximum volumes on available lanes before switching to a new traffic pattern.

Identifying special local or statewide events that generate unusually large traffic volumes in the construction corridor may also dictate the type of construction management concept that may or may not operate efficiently. Identifying when non-events will occur in the corridor may also be desirable for specifying when certain types of traffic management must occur to best accommodate certain types of work, such as complete road closure of roadway to install a major lateral storm water crossing or place overhead bridge beams.

3.3.6. Transit Facilities

Coordinating with transit agencies is necessary to assure transit users are accommodated during the construction project. Transit route detours are sometimes unavoidable such as when all motor vehicles are detoured. However, if vehicle traffic is not detoured, transit users expect the same accommodation and service through the work site as before the construction. Details for the construction and maintenance of temporary facilities, including requirements to comply with the Americans with Disabilities Act of 1990, are required during the construction duration. The accommodation may range from erecting signing that directs users to temporary transit stop locations to constructing temporary boarding and refuge pads.

3.4. Constructability Concepts to Accommodate Pedestrians on Urban Projects

On urban projects, accommodating pedestrians and providing access to adjoining property can pose significant challenges. Identifying the sequence of operations is a critical step to assure the project is "constructible" by contractors and provides accommodation to adjoining business and property owners throughout the project. Often the best sequence of operations for the public may require dictating the sequence to the contractor with minimum or no provision for change. This allows the contractors to bid accordingly and prevents potential need for change orders once the construction commences.

For a comprehensive discussion on pedestrian accommodation and various staging methods that may be appropriate, see Section 7 in the companion FHWA Guide in this series called "Guidelines for Work Zone Designers – Pedestrian and Bicycle Accommodation". [15]

3.5. Traffic Management Exposure Control Measures

Federal regulations 23 CFR 630 Subpart K defines exposure control measures as traffic management strategies to avoid or reduce the number of work zone crashes involving workers and motorized traffic by eliminating or reducing traffic through the work zone or diverting traffic away from the workspace. Many exposure control measures also serve as types of traffic control.

Exposure control is partially accomplished by diverting some or all traffic away from the work site, reducing the duration to complete the project, or altering the time of day when work is allowed. Typical strategies include road closures, diversions, median crossovers to create TLTWO on one side of a normally divided highway, ramp closures, rolling roadblocks, work during night or off-peak hours, and accelerated construction techniques. All of these techniques reduce the traffic exposure, and when used in combination with conventional construction traffic management techniques, enhance the effectiveness of the conventional method for handling work zone traffic.

The benefits and considerations of various types of traffic management control measures are shown in the FHWA Work Zone Guidelines on Use of Use of Exposure Control Measures, Appendix E.

3.5.1. Off Peak or Night Work Zone Operations

If it is not possible to achieve a reasonable balance of traffic impacts for daytime construction using other traffic management techniques, the feasibility of working during off-peak travel times such as nighttime (Figure 6) and weekends should be evaluated. This exposure control measure is especially useful where work operations can be broken into multiple, repetitive phases, usually eight hour or less work operations. Travel lanes should be able to be removed from service relatively quickly for the work operation and can be returned to service quickly to accommodate peak traffic demands. Special construction techniques, such as rapid cure concrete material, has application with this measure.

Night work construction is frequently considered when lane closures are required on high volume roadways such as commuter routes. Night operations may also be considered in combination with other traffic management techniques. Construction activities done at night frequently requires trade-offs, including potential safety issues that require special consideration. Additional guidance for nighttime construction is provided in the companion FHWA Guide in this series entitled, “Guidelines for Work Zone Designers – Illumination for Night Construction.”[16]

Appendix F is an exhibit from New York DOT that lists factors affecting the nighttime construction decision and summarizes the advantages and disadvantages of nighttime construction.

The NCHRP Report 475, entitled A Procedure for Assessing and Planning Nighttime Highway Construction and Maintenance, presents a decision process to assist highway agencies in evaluating night work alternatives against other work schedules [17].

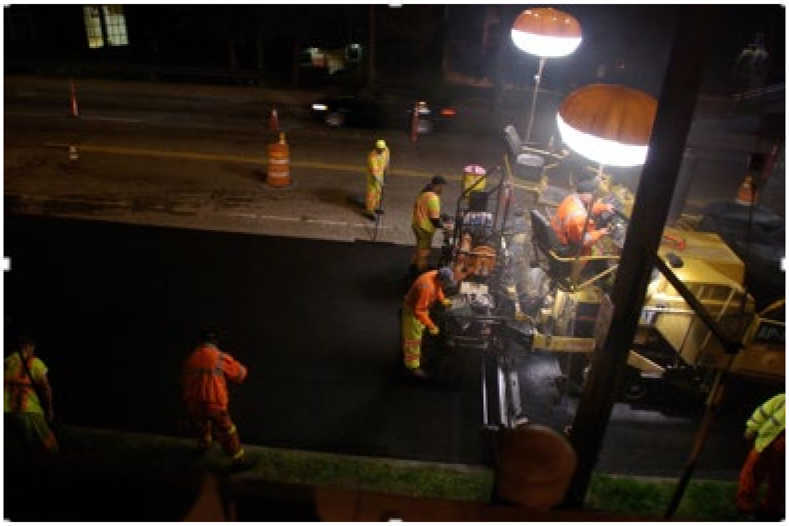

Figure 6. Night asphalt paving operation using balloon lights.
Source: © Pavementinteractive.org

3.5.2. Innovative Construction Techniques to Expedite Completion [18]

There are innovative bridge, pavement, and embankment construction techniques that can expedite construction resulting in less work zone traffic delays and inconvenience. Since expedited construction reduces worker exposure to traffic, many of these techniques can serve as exposure control measures.

Accelerated bridge construction refers to the many types of bridge design and construction techniques for expediting bridge construction. It is now possible to construct bridge superstructures away from the new road alignment and move it into place by rolling, launching, sliding, or lifting it into place. Replacing bridges within one work shift is now possible instead of using conventional construction that may take months or even years. Accelerating the completion of concrete joint repairs and slab replacement can also be accomplished by using prefabricated panel sections.

Besides greatly reducing traffic delays and inconvenience, these techniques may also reduce overall construction costs.

3.5.2.1. Prefabricated Bridge Elements and Systems (PBES) [18]

Time-consuming bridge construction tasks can be accomplished offsite from the work zone by building prefabricated bridge elements and systems, including prefabricated substructure elements such as footings, abutments, pier columns, retaining wall stems, and superstructure elements including partial and entire decks. PBES units (Figure 7) can be constructed offsite and brought to the project location ready to erect. Formwork erection, placing steel reinforcement and concrete, concrete curing time, and formwork removal can all be accomplished without inconveniencing traffic.

In some cases, it may be necessary to have suitable staging areas if large PBES units are constructed adjacent to the project site so that the installation does not interfere with travel lanes remaining open for traffic.

PBES may be highly desirable and beneficial for improving construction quality, reducing construction costs, as well as reducing work zone congestion.

Figure 7. Bridge construction using PBES techniques such as columns and pier caps
Source: FHWA Center for Accelerating Innovation – EDC-2

Modular precast concrete wall systems are prefabricated elements joined in different ways to create a wall system. [18] There are two common types of prefabricated wall systems: mechanically stabilized earth and modular block retaining walls. In addition to requiring less right-of-way for embankments, this construction method can usually accelerate construction time and thus reduce traffic congestion within the work zone.

3.5.2.2.Slide-In Bridge Construction (SIBC) [19]

A SIBC technique (Figure 8) allows a new bridge super structure to be built on temporary supports usually parallel to an existing bridge. During construction of the new structure, traffic continues uninterrupted on the existing bridge. When the new bridge is constructed and ready to be moved into place, the road is closed temporarily and traffic detoured, the existing structure is either demolished or removed, and the new structure is positioned ("slid") into place and tied into the approaches. Removal and transfer can often be accomplished within 72 hours, which can greatly eliminate the disruption to traffic. Variations on this approach include sliding an existing bridge to a location parallel to the original alignment where it can serve as a temporary detour bridge while constructing the new structure on the original alignment.

Figure 8. SIBC eliminated phased construction at the I-80; Echo Road Project, Utah
Source: FHWA Construction website – Slide-in-Bridge Construction Implementation Guidance

3.5.2.3.Leave-in-Place Formwork

Conventional temporary formwork usually uses wood components that are removed once cast-in-place concrete has hardened sufficiently to support itself. This removal process typically requires lane closures. Leave-in-place, also known as stay-in-place formwork, typically constructed of steel or other non-deteriorating material, if properly designed, may streamline work operations and reduce the amount of time, if any, traffic lanes are required to be removed from service.

3.5.2.4.Rapid Embankment Construction

Expanded Polystyrene (EPS) Geofoam (Figure 9) is an embankment fill system comprised of large blocks of expanded polystyrene. The EPS blocks are placed behind a conventional abutment or around the piles of an integral abutment. Figure 9 shows a typical EPS Geofoam embankment prior to placement of the roadway structure and side slopes. Besides speeding embankment construction, the benefits of this system include its lightweight (1-2 pounds per cubic foot), and the elimination or reduction of pre-load settlement times. The design considerations for this system include a layer of subbase required below the pavement to distribute wheel loads, protection of the foam blocks from gasoline spills, and the system not be used where the water table will be above the bottom of the EPC blocks which would cause uplift forces.

Figure 9 . Expanded Polystyrene (EPS) Geofoam
Source: FHWA Accelerated Bridge Construction Manual

3.5.2.5.Precast Concrete Panel Pavement Systems [20]

Precast concrete panel pavement technologies are an effective pavement rehabilitation technique to reduce work site construction time and greatly reduce traffic disruption (
Figure 10). The technique uses prefabricated concrete panels constructed offsite and transported to the work site on truck trailers for rapid replacement of failed concrete pavement sections. The applications for this technology include repairing isolated concrete panels, intersection and ramp rehabilitation, urban street rehabilitation, and rehabilitation of longer mainline pavement sections. Actual removal and replacement can be accomplished by saw cutting the old concrete section, removing the old concrete, preparing the foundation by reshaping/grading the base, lifting the new panel into place, and filling joints with accelerated curing concrete material. Performing the saw cutting operation can sometimes be done as a separate work operation in advance of the actual slab replacement operation to increase the number of slabs that can be replaced during one work period. The controlling factor before opening to traffic is the time required for the joint material to cure. Removing and installing precast concrete panel installation is often done during off-peak traffic periods, typically at night. *There are a number of variations on the precast slab/panel design, fabrication, and installation techniques available for States to consider.*

Figure 10. Installing Precast Concrete Panel Pavement Section
Source: FHWA SHRP2 Solutions website

3.5.3. Contracting Strategies to Expedite Completion [21]

Expediting contract completion using innovative contacting strategies have been tried. Shorter construction time will often reduce worker and motorist exposure and therefore improve work zone safety.

3.5.3.1.Incentive-Disincentive (I/D)

This bidding strategy involves the use of financial incentives and/or disincentives in the construction contract to reduce construction duration that inconveniences the public, or to better ensure the completion of a critical stage by a certain date such as the removal of a detour that affects a special event or school opening.

3.5.3.2.A+B Bidding

Cost plus time, commonly known as A+B bidding, is a bidding technique to determine the winning contractor. The A value is the traditional bid amount for contract items and work performed under the contract. The B value is the time factor to complete the work. The B bid value is a combination of time to complete the work multiplied by the cost per day. The State establishes the value for the time unit based on user costs or other established monetary value of early completion. The bidder provides the estimated days/periods to complete the contract or identified parts of the contract (phases). Therefore, B equals number of time units bid multiplied by the owner agency's established costs per time unit. The bid is the sum of the A and B values, with the lowest value submitted being the winning bid.

This bidding method can minimize the time required to complete work thus reducing the amount of traffic inconvenience. This practice also encourages contractor innovation related to efficient construction methods. Using the A+B and I/D processes has shown construction time can be decreased thus also keeping user costs to a minimum. The bid method is used most often on high traffic volume urban rehabilitation projects; however, it can be applied to all types of facilities and all types of work where there is a need to “accelerate” the completion of the project.

Many A+B contracts also include an incentive/disincentive (I/D) provision to discourage the contractor from overrunning the time bid for completing the work and to reward the contractor if work is completed earlier than the time bid. The State’s estimate for number of days or hours of lane/road closure time is critical in this practice. This baseline estimate helps an agency determine how much acceleration benefit a bid is providing to justify paying an incentive. This practice may add to project cost, thus the decision to use an I/D clause should be project specific. The best time to consider this contract strategy is early in the TMP process when evaluating the traffic management strategies.

3.5.3.3.Lane Rental

Lane rental is a strategy where the roadway user cost, calculated by estimating user delay costs that result from lane closures, is transferred to the contractor performing the work. This process involves a charge assessed to the contractor when a portion of the roadway is obstructed and unavailable to traffic. The lane rental charge can vary according to time of day, day of week, number of lanes impacted, and duration. The contractor’s bid includes an estimate of the number of hours that closures will be in place with the actual payment to the contractor based on the actual use of closures.

The purpose of this strategy is to minimize motorist delay by encouraging the contractor to work during non-peak hours and accelerate construction on the work requiring a lane closure. Rental charges are based on conservative, real numbers, such as changes in highway capacity, wages lost to delay, and average gasoline prices in the area, etc. This technique is most applicable to high-volume/high-speed freeways and rehabilitation and reconstruction projects, such as urban and rural projects involving flagging operations.

Like A + B bidding, the amount of total lane rental charges a contractor proposes for a project can be combined with the cost for the work items to determine the successful bidder. The contract provides rental fee rates in dollars per lane per unit of time - daily, hourly, or fractions of an hour. Rental fee rates are dependent on the number and type of lanes closed and may vary for different hours of the day for a project.

3.5.3.4.Design-Build

There are three fundamental project delivery methods for constructing highways: 1) design-bid-build (DBB), 2) design-build (DB), and 3) construction manager/general contractor (CM/GC). Historically, the most widely used method has been DBB and agencies have a breadth of expertise and staffing to execute this delivery method. However, DBB can present challenges to important project objectives, such as meeting a short project delivery date and trying new and innovative technologies which have the ability to reduce work zone traffic delays. The FHWA Every Day Counts initiative notes that through accelerated project delivery, the DOTs can often reduce project durations by as much as 1 to 2 years on major projects. Accelerated project delivery provides opportunities for significant cost savings and safety improvements since shortened project durations can reduce labor costs as well as work zone safety risks.

Research shows that DB and CM/GC can reduce time and costs on highway projects. A report to Congress by the FHWA summarizes the performance of DB projects stating that on average DB projects may reduce overall project duration by 14%, decrease the total cost by 3%, maintain the same level of quality, and lessen the number of change orders as compared to DBB projects. [22]

3.6. Improving Corridor Communication and Coordination using ITS

Coordination of roadway construction projects in a traffic corridor and using Intelligent Transportation Systems (ITS) technology applications can reduce work zone impacts and help better manage traffic in the work zones. Using new, innovative strategies and techniques, such as traffic queue management approaching a work zone and speed management techniques, can help minimize travel delays and improve motorist and worker safety. Queue management systems, especially when coupled with traffic information strategies, can alert drivers to a queue of vehicles ahead caused by a work zone so they can slow down safely. Speed management solutions, especially variable speed limit (VSL) systems, dynamically manage work zone traffic based on real-time conditions such as congestion and weather. Combining VSL with automated enforcement can increase driver compliance with displayed speed limits. Both queue and speed management use a range of technologies for detection including Bluetooth® sensors and probe vehicles.

4. Evaluating Work Zone Traffic Management Strategies

NCHRP Report 581, Design of Construction Work Zones on High-Speed Highways, provides a table, shown below, with a brief summary of work zone management strategies, their advantages (strengths), and disadvantages (weaknesses). These strategies are not necessarily separate, individual choices. In fact, several of them do not provide a complete and workable solution. Use of a full road closure requires one or more additional strategies (e.g., detour or diversion). Some of the strategies are mitigation strategies, meaning that they can be used to offset negative consequences (e.g., reduced capacity and access limitations) for one or more other strategies. [10]

Table 2. Summary of Work Zone Strategies [10]

Strategy	Summary	Advantages	Disadvantages
Alternating one-way operation	Mitigates for full or intermittent closure of lanes. Used primarily with two-lane facilities.	Low agency cost and low non-transportation impacts; flexible, several variations available.	Requires stopping of traffic; reduces capacity.
Detour	Reroutes traffic onto other existing facilities.	Flexible; cost varies depending on improvements to detour route; in some cases, only TTC needed.	Usually reduces capacity; service and infrastructure on existing roads may be degraded; may need agreement of another agency.
Diversion	Provides a temporary roadway adjacent to construction.	Separates traffic from construction; reduced impact on traffic.	Cost may be substantial, especially if temporary grade separation of hydraulic structure involved; right-of-way often required.
Full road closure	Closes the facility to traffic for a specified (limited) duration.	Generally also involves expedited construction; separates traffic from construction.	Some form of mitigation is needed (detour, diversion, etc.); potentially significant traffic impacts.
Intermittent closure	Stops traffic for a short period.	Flexible and low agency cost.	Useful only for activities that can be completed in short time; requires stopping traffic.
Lane closure	Closes one or more travel lanes.	Maintains service; fairly low agency cost if temporary barriers are omitted.	Reduces capacity; may involve traffic close to active work.
Lane constriction	Reduces traveled way width.	Maximizes number of travel lanes.	Traveled way width is less than desirable; may involve traffic close to active work.
Median crossover	Maintains two-way traffic on one roadway of a normally divided highway.	Separates traffic from construction; right-of-way not required.	Reduced capacity; not consistent with approach roadway; relatively costly; interchanges need special attention.
Use of shoulder	Uses shoulder as a travel lane.	Fairly low cost, depending on shoulder preparation.	Displaces traditional refuge for disabled vehicles; debilitates shoulder pavement structure; cross slopes may be problematic.

Source: NCHRP 581, Design of Construction Work Zones on High Speed Highways, G.L. Ullman, Texas A&M, 2007

4.1. Freeway and Expressway Work Zone Traffic Management Strategies

Managing traffic on long duration freeway and expressway projects often requires multiple traffic management techniques/strategies, breaking the construction into multiple work and traffic stages/phases. The top priority for the designer is to assure motorist and worker safety by finding a balance between accommodating traffic with a minimum delay and allowing contractors to construct the project as efficiently as possible.

Sometimes combining these techniques/strategies in a single stage can enhance the capacity and safety for motorists and workers. However, designers should assure that at least one viable staging plan is available for contractors to build the project. The staging plans developed by designers are included in the PS&E for contractor consideration during the bidding process.

A significant challenge for designers is developing a methodology for contractors to use during the actual time when switching from one traffic control set-up to the next. Altering traffic movement from one traffic control-staging plan to the next staging plan is often specified as an off-peak hour requirement. Consider including PS&E specifications on how law enforcement assistance will be obtained and contractor responsibilities for planning advance public notification when significant traffic staging changes are required. State expectations are the responsibility of the designer for these traffic modifications and should be included in the TTC plan special provisions.

Freeway and expressway TTC traffic operations present a different set of requirements and challenges than conventional highways. Specifically, there are higher volumes, higher operating speeds, and restricted access control. Some types of traffic management techniques used on conventional highways, such as alternating one-way flow, are inappropriate. Since freeways and expressways are access controlled, pedestrian and bicyclists are not present within the access-controlled portion of the project. However, safe and adequate crossing points for pedestrians and bicyclists to reach the other side at interchanges and access points are still essential and their movement possible throughout the duration of the project.

There are other additional sources, many containing more details about methods, techniques, and strategies for managing traffic in work zones, including Chapter 4 in the FHWA final rule on developing and implementing transportation management plans for work zones. [23]

5. Special Situations

5.1. At-Grade Railroad Crossings in or Near Work Zones

An engineering study of all railroad grade crossings is an essential design element in the development of temporary traffic control plans when railroad grade crossings are within or in close proximity of the work zone to determine the potential for vehicles to queue onto the railroad tracks. Adjusting the transition area and/or buffer space is an appropriate countermeasure so that upstream congestion caused by a lane drop, for example, does not reach the railroad crossing. If this is not feasible, other traffic operation measures, such as flagging by railroad authorities, may be necessary after coordination with railroad authorities *and the State agency with jurisdiction for approving traffic operations at railroad grade crossings.* Coordination with railroad authorities is essential in developing the traffic control plan, and sufficient lead-time for this coordination is critical.

In order to avoid vehicle entrapment on railroad crossings caused by queuing traffic at a signalized intersection, railroad traffic signal preemption will allow any stopped traffic on the tracks to clear the railroad crossing when trains are approaching. When traffic control plans will alter the capacity of signalized intersections within the project, conduct an engineering study to determine if traffic signal preemption is warranted. If a preemption system is already in place, determine if any signal timing adjustments are warranted. The MUTCD guidance for conducting an engineering study of traffic control near railroad and light rail crossings in proximity to signalized and circular intersections is in Section 8C.9 and 10 of the MUTCD. [1]

The railroad authority for operating trains on crossings within or near the work zone should be included in the inter-agency coordination and communication plan for the project.

5.2. Watercraft Safety at Navigable Waters Work Zone Bridge Construction

Bridge construction can impact the operation of certain waterways and associated navigation on the waterway below a highway bridge construction project. These impacts should be determined during the project development process, and the mitigation measures may be included as part of the highway work zone TTC plan.

The United States Coast Guard Office of Bridge Programs has requirements and oversight responsibilities for constructing and repairing bridges over navigable waters in the United States and all international bridges. The Coast Guard Office of Bridge Programs maintains a website with information on Coast Guard bridge regulations, procedures, and guidance. In addition to the extensive involvement by the Coast Guard during the environmental review process, culminating with the issuance of the required Coast Guard Bridge Permit, a separate bridge lighting application, per 33 CFR§118, is required to be submitted to the Coast Guard for approval [24]. The bridge lighting application provides appropriate watercraft navigation lighting and signing requirements for bridges that cross over waterways with significant nighttime navigation. The lighting and signing application process is also in the Coast Guard Office of Bridge Programs website, and lighting and signing examples are in the Coast Guard Bridge Lighting Manual, also found at the Coast Guard Bridge Programs website [24]. In addition to the final navigation lighting and signing in the construction plans, temporary watercraft and navigation safety requirements may be part of the work zone plan. Similar to roadway traffic control in work zones, specifications should include appropriate navigation lighting and signing for each construction stage, as well as how and when to make temporary waterway navigation and lighting changes. For technical guidance on the navigation equipment specifications, refer to the U.S. Coast Guard CH-7 TO AIDS TO NAVIGATION MANUAL – TECHNICAL, COMDTINST M16500.3A.

5.3. Recreational Watercraft on Non-navigable Waterways Work Zone Bridge Construction

Bridge construction projects over non-navigable waterways may pose risks for recreational watercraft. If the construction will occur when boating is expected to be present and it is necessary to close the waterway for construction purposes, a safe portage route with sufficient landings on each side of the project to accommodate light watercraft should be considered. There should be appropriate guide and warning signs for each direction along the waterway directing the boaters to the landings, as well as marking the closed portion of the waterway with buoys and signs.

If the construction can occur without closing the waterway, potential higher risk conditions may be present at the construction site. For these conditions, provide adequate safeguards for safe watercraft passage. Safeguards may include adequate guide and warning signs positioned either on shore or on buoys. If watercraft routinely use the waterway during hours of darkness, consider providing appropriate waterway warning lights.

The U.S. Coast Guard pamphlet entitled U.S. Aids to Navigation System describes and demonstrates the navigational aids used on navigable waterways [25]. While the pamphlet's primary audience is recreational boaters on navigable waterways, the pamphlet provides information that can assist highway designers developing warning lights, buoys, and signs for recreation boaters on non-navigable waterway projects as well.

6. Constructability, Bidability, and Quality Control Plan Reviews

All States have processes in place for conducting reviews throughout their construction plan development process that lead up to the completion of their contractor bid package, frequently referred to as the project Plans, Specifications & Estimate. States have different names for these process reviews and occur at different stages and type of project. Individuals, staff teams, and independent teams are used to conduct the reviews, and every State has their own process. Some States use out-side agency reviewers, and for some projects, contractors are used on review teams to obtain independent opinions. Common names used by States for these reviews may include constructability reviews, biddability, or quality control plan reviews. Using these types of reviews are recommended good practices, and maintenance of traffic and TTC plan development should always be included in the course of these reviews.

The Indiana DOT (INDOT) review processes uses the term constructability and their design manual defines the purpose of their review as follows: "Constructability reviews are intended to improve the effectiveness of a set of plans, specifications and bid documents. The plans should be clear for the contractor to be able to provide accurate bids and understand INDOT's requirements during construction. The basic objective of the Constructability Review is to seek out overlooked problems that increase costs, impair the schedule, and decrease quality and safety margins."[26]

Many states use checklist formats for conducting these construction plan development process reviews. An example of the checklist used by INDOT for conducting a constructability review at the 95% PS&E plan complete stage for maintenance of traffic and traffic control plan is included as Appendix G.

7. Sources for Additional Information

- FHWA Work Zone Safety & Mobility Rule Implementation Materials. https://ops.fhwa.dot.gov/wz/resources/final_rule.htm.

- NCHRP Synthesis 413: Techniques for Effective Highway Construction Project in Congested Urban Areas.

- NCHRP 581: Design of Construction Work Zones on High-Speed Highways.

- NCHRP Web-Only Document 105: Final Report for NCHRP Report 581.

- TRL Report PPR 658: Reducing Congestion at Road Works. https://trl.co.uk/reducing-congestion-roadworks.

- Irish DOT: Guidance for the Design and Management of Traffic at Road Works.

- AASHTO Roadside Design Guide.

- AASHTO Policy on Geometric Design of Highways and Streets (Green Book).

- FHWA Accelerated Bridge Construction website https://www.fhwa.dot.gov/bridge/abc/.

- FHWA Decision Making Framework for Prefabricated Bridge Elements and Systems (PBES), Manual Publication Number FHWA-HIF-06-030, May 2006 (process of planning a successful ABC project).

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Appendix A: Work Zone Impacts Assessments

Project Characteristics	▪ Project type. ▪ Project size, extent, duration, and complexity. ▪ Roadway classification ▪ Area type (urban, suburban, rural).
Travel and Traffic Characteristics	▪ Traffic demand and volumes. ▪ Seasonal and temporal variations in demand (hourly, daily, or weekly). ▪ Occurrence of special events. ▪ Percentages of different vehicular volumes (autos – Single-Occupancy Vehicle, High-Occupancy Vehicle; trucks; or buses). ▪ Type of travel (commuter or tourist), freight corridor, transit corridor. ▪ Public and private facility access issues. ▪ Potential impacts of weather. ▪ Other such similar characteristics.
Corridor, Network and Community Issues	▪ Impacts of the project at both the corridor and network levels including parallel corridors, alternate routes, the transportation network, other modes of transportation, and impacts of other work zones in the vicinity of the project, either at the corridor level or the network level. ▪ Impacts on nearby transportation infrastructure such as key intersections and interchanges, railroad crossings, public transit junctions, and other junctions in the transportation network. ▪ Impacts on evacuation routes in the vicinity of critical transportation or other infrastructure. ▪ Impacts on affected public properties, including parks, recreational facilities, fire stations, police stations, and hospitals. ▪ Impacts of the project on affected private properties, including businesses and residences.
Design, Procurement and Construction Options	▪ Temporal alternatives for work performance such as season, month, day of week (weekend versus weekday), and time of day (night time versus day, off-peak versus peak). ▪ Alternative lane closure strategies such as full closure, partial closure, crossovers, multiple lane closure, single lane closure, and impact of alternative traffic management strategies on lane-closure decisions. ▪ Alternative design solutions that address the durability and economy of maintenance of the roadway. ▪ Alternative design solutions and strategies that impact decision-making on right-of-way (ROW) acquisition. ▪ Alternative construction staging plans, and construction techniques and methodologies (e.g., accelerated construction techniques) that may have varying types and severity of work zone impacts. ▪ Alternative contracting methodologies such as design-build, A+B bidding, and incentive/disincentive contracting.

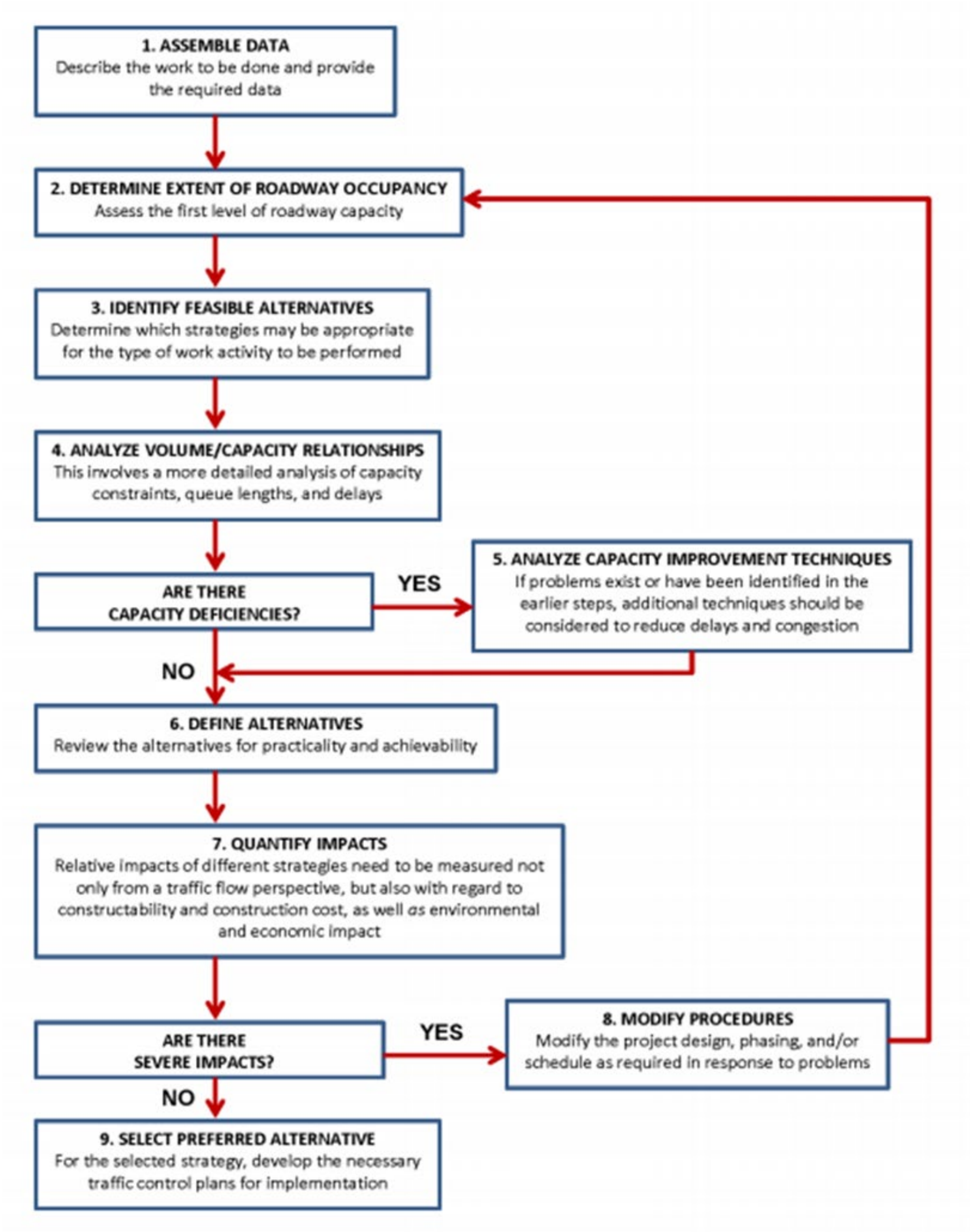
Source: FHWA Work Zone Impacts Assessment: An Approach to Assess and Manage Work Zone Safety and Mobility Impacts of Road Projects

Appendix A (continued)

Work Zone Design and Safety Issues	■ Cross-sectional issues such as lane widths, shoulder availability and widths, and number of lanes available for travel. ■ Longitudinal issues such as taper widths, taper lengths, and stopping sight distance. ■ Horizontal and vertical sight distance. ■ Project signing and advance warning. ■ Roadside devices and safety. ■ Work area separation, channelization, and protection (e.g., positive separation, barrels, cones, clear zone considerations, construction zone intrusion detection). ■ Work area and worker delineation (visibility, retroreflectivity, etc.). ■ Work site access and access points. ■ Visibility issues (e.g., night-time work, lighting, fog). ■ Curvature and gradient – vertical and horizontal. ■ Speed – posted speed limits, speed zoning, etc. ■ Work zone enforcement (e.g., use of uniformed police officers and/or patrol cars, active enforcement using radar guns and/or automated enforcement).
TTC Strategies	■ Traffic safety and capacity requirements. ■ Alternate route scenarios. ■ Potential impacts on other corridors, nearby intersections/interchanges, and the larger transportation network. ■ Project signing and advance warning. ■ Lane closure types and strategies (full-closure, lane-width restrictions, cross-overs, positive separation, etc.). ■ Work zone and work area configurations. ■ Traffic safety and control checklists for developing a TMP.
TO Strategies	■ Depolyment of ITS technologies for work zone traffic monitoring and management. ■ Provision of real-time traveler information to the public, including web-based information. ■ Application of transportation systems management (TSM) and corridor management strategies, including mitigation treatments for alternate routes (e.g., traffic signal timing adjustment on affected corridors), and alternate modes (e.g., public transit subsidies, incentives, and special programs). ■ Coordination of transportation management with existing regional transportation management centers (TMCs). ■ Conduct of mobility and safety reviews and audits. ■ Speed enforcement and management in work zones using either police officers or automated techniques. ■ Traffic incident management plans for work zones. ■ Policies on work zone traffic management during emergencies (e.g., hurricane evacuations).
PI Strategies	■ Provision of project and work zone information prior to the commencement of the work in order to make the public aware of the expected work zone impacts and the State's actions to mitigate the impacts. ■ Recommendations to the public on commuter alternatives, such as information on alternate routes and/or modes. ■ Provision of information on changing conditions on the project during implementation (e.g., changes in lane closure scenarios, construction staging, construction times, or alternate routing). ■ Obtaining public input for the development of appropriate work zone impacts management strategies during the planning and design phases of the project; refinement of work zone management strategies during project implementation; and feedback on performance of the work zone and the project following the completion of the project. ■ Dissemination of information through brochures, pamphlets, and media sources including newspapers, television, radio channels, and web sites. ■ Public meetings and hearings. ■ Coordination and cooperation with affected public and private parties.

Source: FHWA Work Zone Impacts Assessment: An Approach to Assess and Manage Work Zone Safety and Mobility Impacts of Road Projects

Appendix B: New York DOT Process for Identifying and Evaluating Work Zone Impact Management Strategies



Source: New York DOT Design Manual Chapter 16
Maintenance and Protection of Traffic in Highway Work Zones, Exhibit 16-20.

Appendix B (Continued)
Detailed Description of the Numbered Steps in the Flow Chart

Step 1. Assemble Data - To analyze the impact, gather data about the highway including existing road conditions, operational features, horizontal and vertical restrictions, and peak and off-peak speed and traffic volume data. Gather project information including the type of work to be done, project and work limits, tentative schedule, and potential detour routes. Gather community information including jurisdictions involved, business access, emergency facilities locations, schools, other user groups (bicyclists, pedestrians, etc.), activities or events, and designated access routes. The extent and type of data assembled depends on the complexity and size of the project.

Step 2. Determine the Extent of Roadway Occupancy - During construction, most projects require occupancy of some portion of the traveled way or shoulder by the construction activity. The extent the roadway is occupied by construction activities and used for buffer space, and unavailable for use by traffic, is known as roadway occupancy. Roadway occupancy results in a reduction in capacity of the roadway, and defines a number of constraints that are accounted for in the traffic control strategy. Both spatial requirements and time durations of the roadway occupancy must be determined.

Step 3. Identify Feasible Alternatives - Identify feasible strategies using the following tables, guides, and charts or from other sources such as the FHWA's website Work Zone Impact Management Strategies:
https://ops.fhwa.dot.gov/wz/resources/publications/trans_mgmt_plans/sec4.htm

Appendix B (continued)
Work Zone Impact Management Stategies

Temporary Traffic Control (TTC)		
Control Strategies	**Traffic Control Devices**	**Project Coordination, Contracting and Innovative Construction Strategies**
☐ Construction phasing/staging ☐ Full roadway closures ☐ Lane shifts of closures - Reduced lane widths to maintain number of lanes (constriction) - Lane closures to provide worker safety - Lane shift to shoulder/median to maintain number of lanes ☐ One-lane, two-way operation ☐ Two-way traffic on one side of divided side of divided facility (crossover) ☐ Reversible lanes ☐ Ramp closures/relocation ☐ Freeway-to-freeway interchange closures ☐ Night work ☐ Weekend work ☐ Work hour restrictions for peak travel ☐ Pedestrian/bicycle access Improvements ☐ Business access Improvements ☐ Off-site detours/use of alternate routes	☐ Temporary signs - Warning - Regulatory - Guide/Information ☐ Variable Message Signs (VMS) ☐ Arrow panels ☐ Channelizing devices ☐ Temporary pavement Markings ☐ Flaggers and uniformed traffic control officers ☐ Temporary traffic Signals ☐ Lighting devices	☐ Project coordination - Coordination with other projects - Utilities coordination - Right-of-way coordination - Coordination with other transportation infrastructure ☐ Contracting strategies - Design-build - A+B bidding - Incentive/disincentive clauses - Lane rental ☐ Innovative construction techniques (precast members, rapid cure materials)

Source: New York DOT Design Manual Chapter 16
Maintenance and Protection of Traffic in Highway Work Zones, Exhibit 16-19.

Appendix B (continued)
Work Zone Impact Management Stategies (continued)

Transportation Operations (TO)			
Demand Management Strategies	**Corridor/Network Management Strategies**	**Work Zone Safety Management Strategies**	**Traffic/Incident Management and Enforcement Strategies**
☐ Transit service Improvements ☐ Transit incentives ☐ Shuttles services ☐ Ridesharing/ carpooling incentives ☐ Park-and-ride promotion ☐ High-occupancy vehicle (HOV) lanes ☐ Toll/congestion pricing ☐ Ramp metering ☐ Parking supply management ☐ Variable work hours ☐ Telecommuting	☐ Signal timing/ coordination improvements ☐ Temporary traffic signals ☐ Street/ intersection improvements ☐ Bus turnouts ☐ Turn restrictions ☐ Parking restrictions ☐ Truck/heavy vehicle restrictions ☐ Separate truck lanes ☐ Reversible lanes ☐ Dynamic lane closure system ☐ Ramp metering ☐ Temporary suspension of ramp metering ☐ Ramp closures ☐ Railroad crossings controls ☐ Coordination with adjacent construction site(s)	☐ Speed limit reduction /variable speed limits ☐ Temporary traffic signals ☐ Temporary traffic barrier ☐ Movable traffic barrier systems ☐ Crash-cushions ☐ Temporary rumble strips ☐ Intrusion alarms ☐ Warning lights ☐ Automated Flagger Assistance Devices (AFADs) ☐ Construction safety supervisors and inspectors ☐ Road safety audits ☐ TMP monitor/ inspection team ☐ Team meetings ☐ Project on-site safety training ☐ Safety awards/ Incentives ☐ Windshield surveys	☐ ITS for traffic monitoring/ management ☐ Transportation Management Center ☐ Traffic screens ☐ Call boxes ☐ Mile-post markers ☐ Tow/freeway service patrol ☐ Photogrammetry ☐ Coordination with media ☐ Local detour routes ☐ Contract support for incident management ☐ Incident/emergency response plan ☐ Dedicated (paid) police enforcement ☐ Cooperative police enforcement ☐ Increased penalties for work zone violations

Source: New York DOT Design Manual Chapter 16
Maintenance and Protection of Traffic in Highway Work Zones, Exhibit 16-19.

Appendix B (continued)

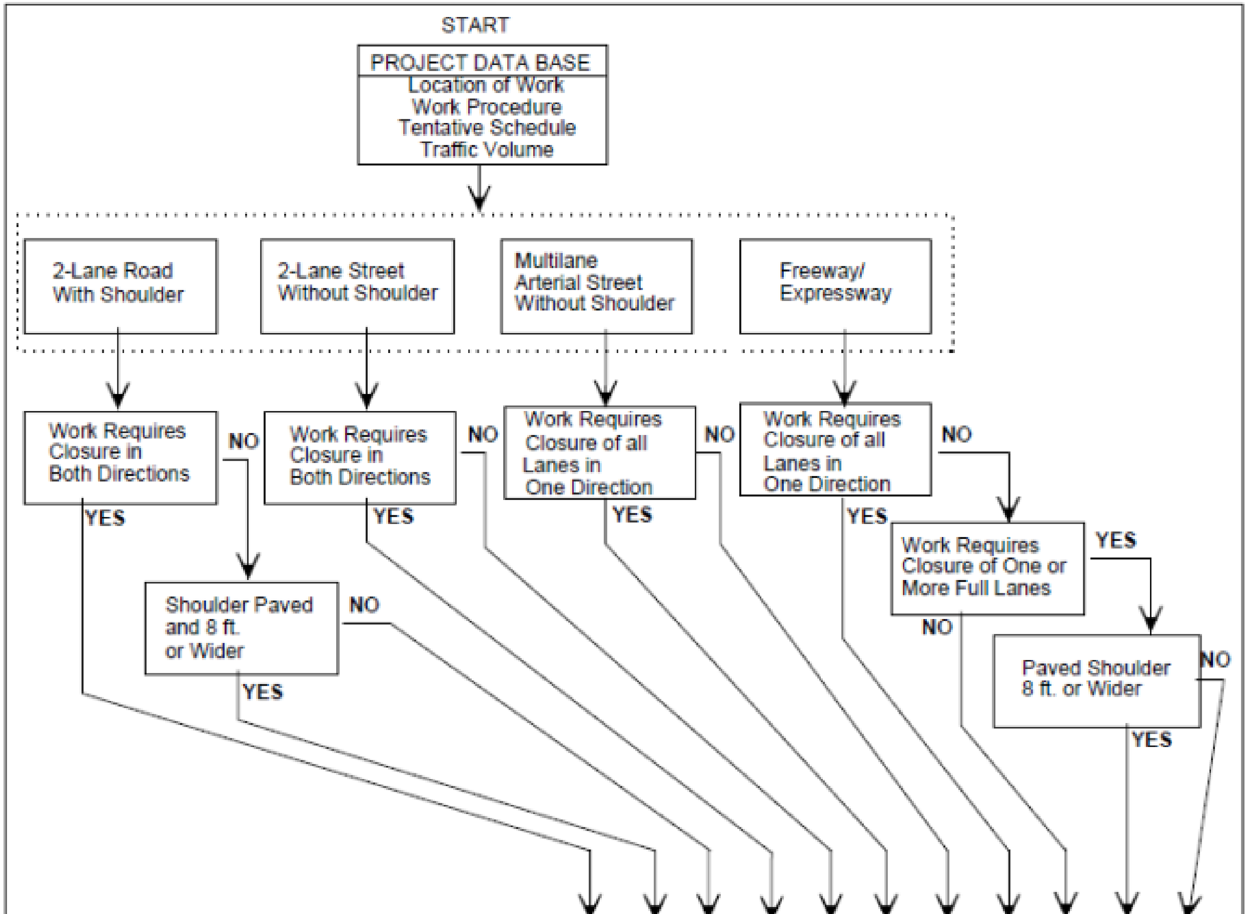
The following table contains descriptions of the basic types of work zones, along with parameters to consider for using a certain type of work zone.

Description of the Basic Types of Work Zones

Lane Constriction • Lane widths are reduced to retain the number of lanes normally available to traffic. • Applicable only if the work area is mostly outside the normal traffic lanes. • May depend on the availability of shoulders. • Least disruptive of all work zone types.
Lane Closure • Close off one or more normal traffic lanes. • May require capacity analysis to determine whether serious congestion will result. • Use of shoulder or median as a temporary lane may mitigate the capacity problems.
Alternating One Way Flow • Uses one lane for both directions of traffic. • Traffic must be controlled and coordinated with the use of flaggers or traffic signals.
Temporary Bypass (Diversion) • Requires the total closure of the roadway in one or both directions. • Traffic is diverted to a temporary roadway constructed within the highway right of way. • Requires extensive preparation of the temporary roadway to withstand the traffic loads.
Intermittent Closure • All traffic in both directions must be stopped for a short period of time to allow the work to proceed, after which, traffic is allowed to proceed. • Normally applicable only on very low-volume roadways.
Crossover, including Two-lane Two-way Operation • The traffic in one direction is rerouted across the median to the opposite traffic lanes. • May also require the use of the shoulder and/or lane constrictions to maintain the same number of lanes. • Consideration must be given to separation devices, crossover design, and length before selecting this strategy. Long work zones can be a delay concern for drivers. • Refer to Section 16.4.7.4 for further guidance.
Use of Shoulder or Median • The shoulder or median serves as a temporary lane. • Must determine if there are underpasses or other vertical clearance issues. • Must determine if shoulder or median will adequately support the expected traffic loads. • Must determine if the traffic can be transitioned safely to the temporary lane. • May be used in combination with other work zone types or as a separate technique. • Potential drainage and rollover concerns.
Detour • Requires total road closure and rerouting of traffic to existing off-site facilities. • Particularly desirable when there is unused capacity on roads running parallel to the closed roadway. • May require improvements to existing roadway(s) to make it suitable to carry detoured traffic.

Source: New York DOT Design Manual Chapter 16
Maintenance and Protection of Traffic in Highway Work Zones, Exhibit 16-21.

Appendix B (continued)
Guideline for Evaluating Feasible Types of Work Zone Strategies



ALTERNATIVE WORK ZONE TYPES											
LANE CONSTRICTION (Use part of the shoulder, if necessary.)		Y	Y						Y		
LANE CLOSURE							Y		Y	Y	Y
SHARED RIGHT OF WAY		Y	Y		Y						
TEMPORARY BYPASS ROAD	Y		Y					Y			
INTERMITTENT TOTAL CLOSURE	Y			Y				Y			
CROSSOVER						Y		Y			
USE OF SHOULDER (As full lane)		Y								Y	
DETOUR TO EXISTING ROAD	Y		Y	Y	Y	Y	Y	Y		Y	Y

Y Feasible Alternative

Source: ***Planning and Scheduling Work Zone Traffic Control***

Source: New York DOT Design Manual Chapter 16
Maintenance and Protection of Traffic in Highway Work Zones, Exhibit 16-22.

Step 4. Analyze Volume/Capacity Relationships - An analysis of capacity constraints, queue lengths, and delays. This step in the process is a detailed investigation of the volume/capacity relationships of the different strategies identified from the previous step, and the consequent general levels of congestion that may develop. NCHRP Report 475, entitled A Procedure for Assessing and Planning Nighttime Highway Construction and Maintenance, provides the principles for analyzing capacity of work zones and comparing alternative work zone management strategies, including the estimation of user costs and evaluation of the costs of accidents related to work zone activity.

The following excerpt from NCHRP Report 475 explains why it is important that project capacity impacts be evaluated by individuals' familiar with the project details, as well as familiar with overall normal congestion in the region and community: "There is no widely accepted definition of "unacceptable" congestion. It is often not the same among urban and rural areas, and even among different areas within the same state. "Unacceptable" congestion must therefore be determined by local norms. Typically, the determination of whether congestion is unacceptable on a given project involves consideration of changes in level of service during construction, queue length/duration and resulting delay, and disruption of access to businesses and travel patterns throughout the community. Another critical consideration is whether a queue grows so large that it blocks other intersections or interchanges. This is called 'spillback' and often has large negative delay and safety consequences that the profession cannot calculate at this time. The agency responsible for the work must determine what level of congestion and delay is unacceptable for each project based on the impact of the project on the community."

- Work Zone Capacity - The roadway capacities of the various work zone strategies should be determined to compare them to the traffic volumes that will use the facility. Due to constrained space for traffic on the project and a shortfall of available capacity on alternative routes, the project traffic demands may be less than the normal traffic demands, but may still exceed those for which the work zone is designed. When project traffic demand exceeds capacity, a queue will develop and an estimate of queue length can be calculated. Depending upon the length and duration of the queue, certain strategies may have to be abandoned, unless measures can be taken to increase capacity or reduce demand. Examples of such measures include restricting construction work to certain hours of the day or night, or certain days of the week, removing parking along the streets or roads involved, and diverting traffic to other facilities with available capacity.

- Queue Delay, Size, and Duration - When demand volume exceeds capacity, congestion will occur and a queue will form. The duration of the congestion, the amount of delay, and the size of (number of vehicles in) the queue may be calculated using the procedure and equations given in Chapter 2 of the FHWA's Publication Work Zone Road User Costs - Concepts and Applications. Due to the many project type and location variables, exercise engineering judgment to determine the need for an analysis and the depth of the analysis when one is needed.

Step 5. Analyze Capacity Improvement Techniques - If, after the initial analysis, unacceptable capacity deficiencies are still anticipated on all feasible alternatives, additional work zone impact management strategies should be considered to mitigate delays and congestion.

Step 6. Define Alternatives and Work Zone Impact Management Strategies - Review the alternatives for practicality and achievability.

When the capacity improvement techniques analysis is completed, some of the strategies may be unacceptable. Components that must be included in defining the Work Zone Impact Management Strategies are below:

- Basic construction sequence, e.g., on multilane highways, reconstruction by halves, parallel/adjacent reconstruction, serial/segmental reconstruction (two-lane, two-way operations), complete closure, or a combination of sequences.
- Overall construction time period or construction seasons and how they will affect user costs.
- Traffic management strategy through the construction area with segment-by-segment delineation for each phase of construction and definition of the time for each segment and phase.
- Traffic diversions including identifying all routes to use and necessary associated improvements for diversions and detours.
- Proposed temporary detours.
- Specific traffic control plans showing the traffic control devices for each strategy.

Step 7. Compare Impacts – Consider relative impacts of different work zone traffic management strategies from a traffic flow, safety, constructability, construction cost, environmental, and economic perspective.

Appendix C: Florida DOT Sample TTC Plan Development Outline

Step #1 Understand the Project:

- Review the scope.
- Field reviews. Examine the plans early in the plans development process.
- Look at plan-profiles and cross sections for general understanding.
- Review PD&E study for any constraints.
- Consider transit and bicycle/pedestrian needs during construction.
- Coordinate with the District Bicycle/Pedestrian Coordinator.
- For complex projects, consider developing a TTC plan study and other possible strategies such as public awareness campaigns, alternate route improvements, service patrols, etc.

Step #2 Develop Project Specific Objectives - What are your objectives? Examples might be:

- Use barrier wall to separate workers from traffic.
- Close road if adequate detour exists.
- Maintaining 2-way traffic at all times.
- Maintaining roadway capacity during peaks.
- Maintaining business/resident access.
- Maintaining transit operations.
- Maintain existing bicycle and pedestrian access.
- Minimize wetland impacts.
- Expedite construction.

Step #3 Investigate TTC Plan Alternatives

- Develop some rough alternatives considering what could be used to accomplish the work, such as constructing temporary pavement and/or temporary diversions, using auxiliary lanes, placing 2-way traffic on one side of divided facility, using detour routes, etc.
- Check condition of any proposed detour routes. If the detour route is off the state system, additional documentation of the agreements with local agencies will be required.
- Minimize interruption of local transit operations.

Step #4 Develop a Construction Phasing Concept

- Examine existing facility versus what is to be built. This is a major task on jobs other than resurfacing.
- Coordinate with bridge designer.
- Involve the Construction office as early as practical for input on alternate traffic control plans.
- If a temporary State owned panel bridge is required contact the Maintenance Office.
- Color or mark the plan-profile sheets to show existing roadway versus new construction. Then, check station by station, the plan sheet against cross section sheets. Make notes on plan sheets as to drop-offs or other problems.

Use profile grade lines or centerlines for reference points.

- Make notes on plan sheets or notepad as to "decisions" that you make along the way.

Step #5 Examine/Analyze Alternatives Which Meet Objectives (for each phase)

Evaluate proposed alternatives that meet the stated objectives

- Examine pros and cons of various alternatives.
- Consider how much work and expense is involved for each alternative.
- Consider detour/transition locations, signal operations during construction, how to handle buses, bicycles, pedestrians, service vehicles, etc.

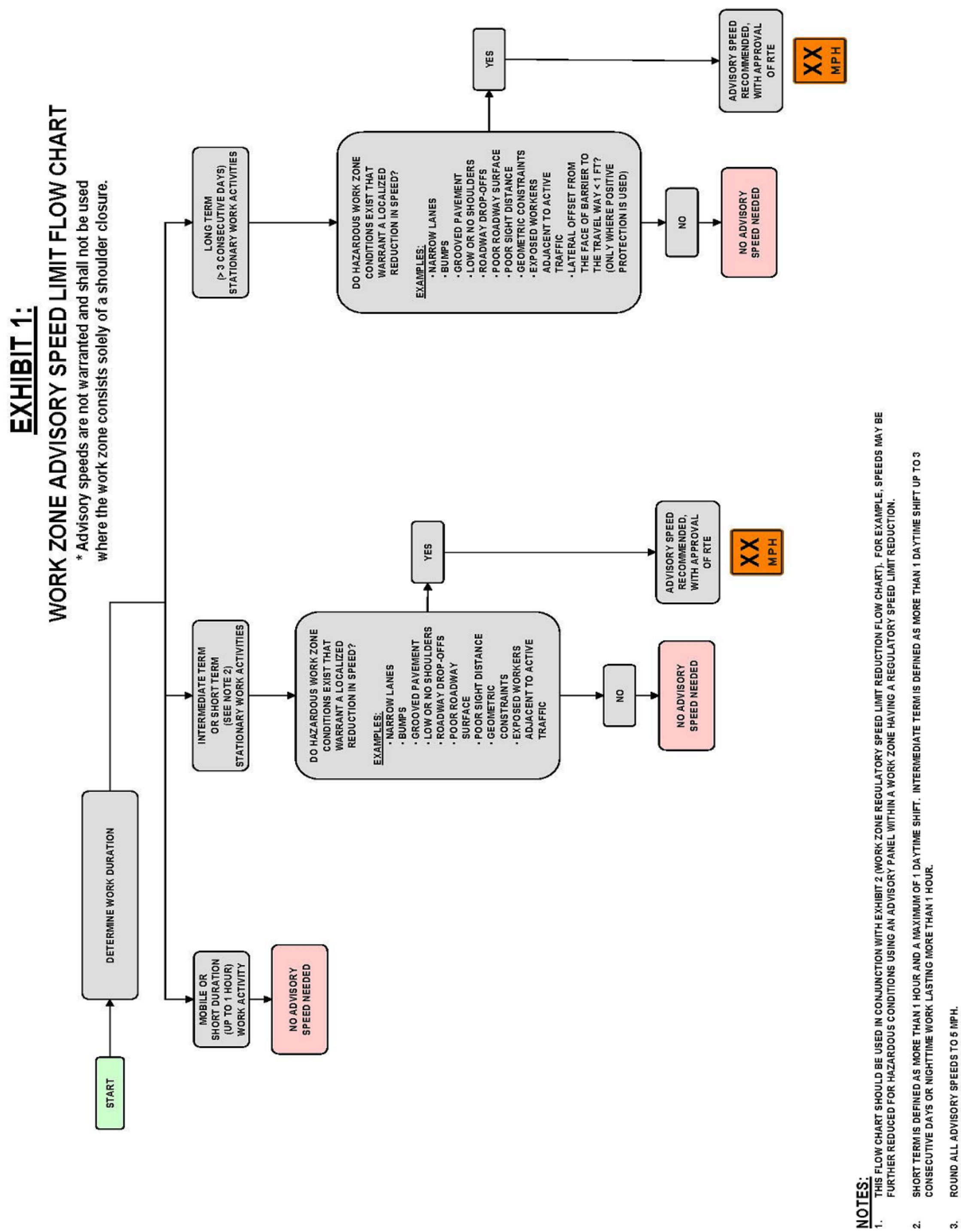
Step #6 Develop Detailed TTC Plans

Select the alternatives that meet the objectives of the overall plan. Add details such as:

- Detour/transition geometrics and locations.
- If lane closures are needed, use the lane closure technique discussed in Section 10.12.7 to determine period for closures.
- Advanced signing scheme and locations, revisions needed to existing signs including guide signs, and proposed signs for all work activities lane closures, detours, etc., on mainline, side roads, crossroads and ramps.
- Need for portable traffic signals, changeable message signs, and barriers. 5. How existing operations will be maintained side streets, businesses, residents, bicycles, pedestrians, buses bus stops, etc.
- Revisions to signal phasing and/or timing during each TTC plan phase.
- Regulatory speed desired for each phase.
- All pay items and quantities needed for TTC plan.
- How existing auxiliary lanes will be used and any restriction necessary during construction.
- Typical sections for each phase.
- Outline key strategies to be used, such as Service patrol, law enforcement, public service announcements, night work, and Motorist Awareness System.
- Need for alternate route improvements.

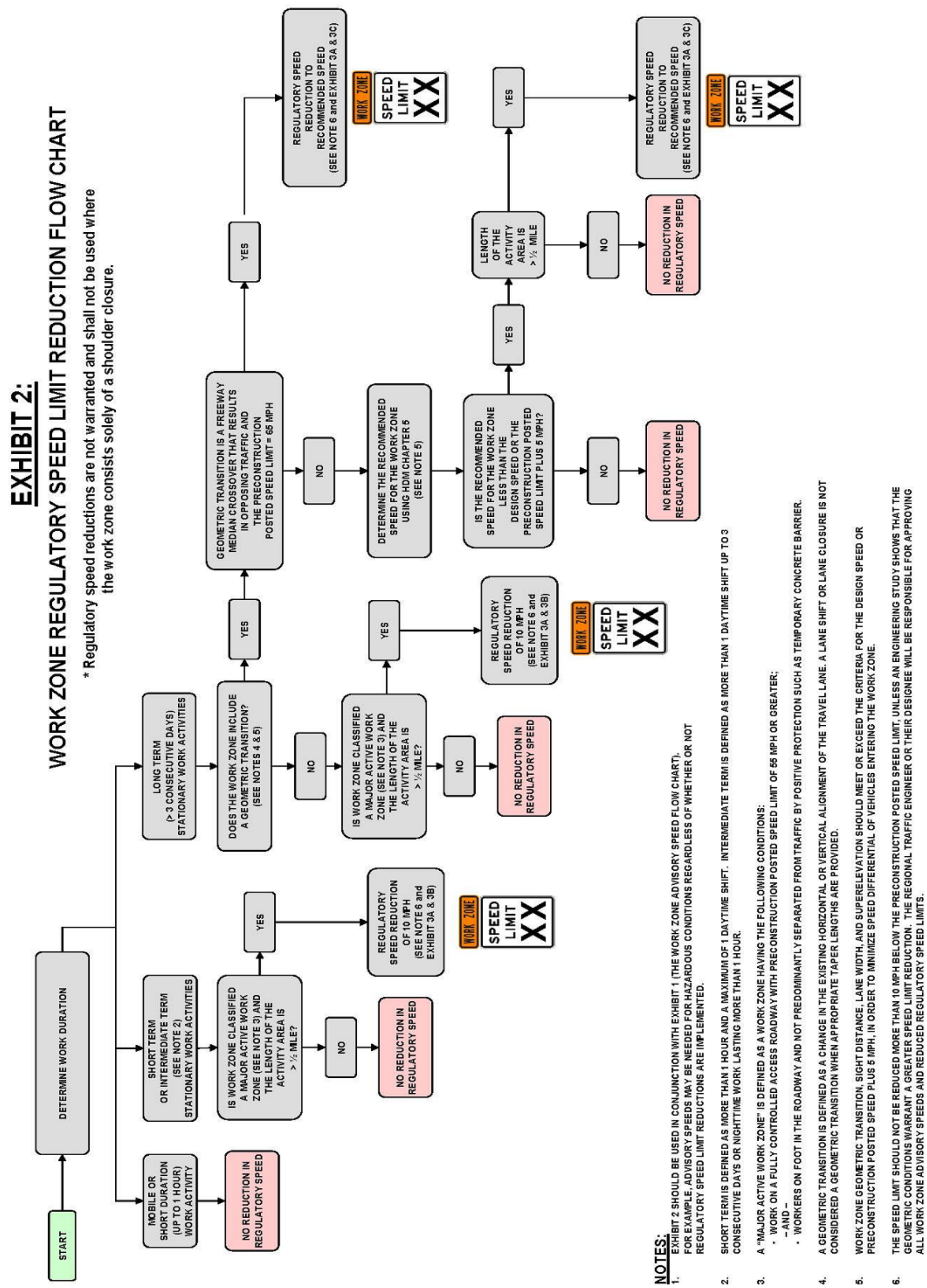
Source: Florida DOT Plans Preparation Manual
Chapter 10 Transportation Management Plan 10.3.1.1.1

Appendix D: New York DOT Work Zone Advisory Speed Limit Flow Chart



Source: New York DOT Design Manual- Engineering Instruction EI 08-030 Exhibit 1

Appendix E: New York Work Zone Regulatory Speed Limit Reduction Flow Chart



Source: New York DOT Design Manual Engineering Instruction EI 08-030 Exhibit 2

Appendix F: Types and Effectiveness of Work Zone Enforcement Efforts

Method	Description	Reductions in Average Speed in Work Zones
Circulating (mobile) Patrols	Marked enforcement vehicles circulate in within and/or upstream of the work zone (this method could also be performed covertly in unmarked vehicles).	2-5 mph
Stationary Patrols	Marked enforcement vehicles are parked next to the roadway either within or upstream of the work zone (this method could also be done covertly by using unmarked vehicles or by parking the vehicle in a hidden location to monitor traffic).	3-13 mph
Police Traffic Controllers	Enforcement personnel are positioned outside of their vehicle next to roadway (speed control), or in travel lane (for intersection or other right-of-way control activities).	3-14 mph
Camouflaged Enforcement	Enforcement personnel wear vests and hardhats and stand on or near equipment to monitor speeds; violators are identified via radio for downstream apprehension by other officers. Typically, this method is supplemented with advance warning signs and media notification about the enforcement operation, making it an overt activity.	NA (likely similar to automated speed enforcement effects)
Aerial Speed Enforcement	Enforcement personnel track travel times between marked points, notify ground patrols of violators for apprehension. Traditionally, this method has been performed covertly (although static signs are typically posted to warn drivers of its use).	NA
Automated Speed Enforcement	Speed measuring devices and digital camera capture license plate of speed violator; ticket is sent to vehicle owner. This method is usually supplemented with advance warning signs and media notification about the enforcement location and/or operation.	3-8 mph

NA = data not available

Source: NCHRP Web-Only Document 194
Traffic Law Enforcement in Work Zones: Phase II Research

Appendix G: Benefits and Implementation Factors for Various Exposure Control Measures

Measure	Benefits	Implementation Factors to Consider
Full road closures	• Contractor has full access to roadway • Multiple tasks can be completed simultaneously • Can reduce total project time	• Availability of adequate alternative routes • Coordination with local agencies and other stakeholders • Adequate advance notification of all affected parties • Improvement costs on detour or nearby local roads to handle additional traffic during closure
Diversions	• Traffic flow is maintained within roadway right-of-way • Limited effect on nearby roadways	• Diversion roadway costs (temporary pavement, channelization modifications, lighting, etc.)
Median crossovers	• Traffic flow is maintained within roadway right-of-way	• Adequate capacity on temporary two-way operation roadway • Ramp access to and from two-way roadway • Adequate protection of newly-created roadside hazards (i.e., previously downstream ends of bridges or culverts, creation of two-way traffic operation, etc.) • Use of adequate design speed for temporary crossover • Costs of temporary crossover
Ramp closures	• Encourages drivers to seek out alternative routes • Can eliminate the need for complex traffic control to accommodate traffic entering and exiting the facility • Can be restricted to HOVs only and provide an incentive for carpooling /vanpooling and transit use through the work zone	• Adequate advance notification of local residents and businesses • Adequate capacity on local street system • Potential for providing an access incentive to high-occupancy vehicles (HOVs) • Effects of ramp closure on upstream and downstream ramps and cross-street intersections
Rolling roadblocks	• Effective for very short-duration work tasks that require a full closure • Can be used for traffic control set up and removal activities if desired	• Adequate advance notification of rolling roadblock operation • Adequate advance signing of slow traffic ahead • Sequence of enforcement or work vehicles onto and off of the roadway • Adequate rolling roadblock distance to create adequate gap in traffic
Working at night	• Traffic congestion is lower than if the work were conducted during the day • Total crash costs are reduced • Fewer driver complaints	• Adequate advance notification and signing • Adequate lighting of work operation and flagger stations • Avoidance of glare issues for approaching motorists (in both directions) • Provision of adequate rest time for workers and supervisors/inspectors
Accelerated construction	• Project duration can be significantly reduced • Construction innovation is encouraged and rewarded • Reduced exposure • Less inconvenience for drivers	• Adequate balance between dollar values for incentives and penalties • Ability to accurately estimate a reasonable completion date for project or critical milestone • Steps needed to ensure that safety is not compromised by increased production pressure

Source: FHWA Guidelines on Use of Exposure Control Measures
Developed by The Roadway Safety Consortium, under Grant Agreement DTFH61-06-G-00007.

Appendix H: New York DOT Night Time Operation Considerations

Traffic-Related		
	Positive Aspect	Negative Aspect
Congestion	Significantly reduces or avoids traffic congestion and motorist delays.	
Safety	Lower traffic demand at night lead to reduced overall crashes. Some workers may be more aware of the dangers and more conscious of safety practices.	Risk of crashes may increase due to low visibility. Some workers and drivers may be less alert at night. Lighting glare can impair driver's vision. Average speed may be higher if volumes are lower.
Traffic Control	Increased flexibility in work zone due to less traffic interference and improved level of service.	Need enhanced traffic control for vehicles and pedestrians which can increase project cost and duration. Set up and removal are complex and can make night operations unfeasible if they cannot be removed by day time. Potentially lower levels of speed limit enforcement in work zones.
Construction-Related		
	Positive Aspect	Negative Aspect
Quality	Quality can be enhanced when sufficient level of lighting is provided. Cooler temperatures can enhance the quality of the concrete set at night.	Work quality may be affected negatively if lighting is insufficient. In some cases, work products were less aesthetically pleasing than products done during the day. Cooler temperatures may preclude asphalt concrete paving at night.
Productivity	Less traffic interference and longer work shifts can enhance productivity and efficiency. Allows more lanes to be temporarily closed to accommodate work activities.	Reduced visibility may lead to lower productivity levels. Longer set up and removal time of traffic control and lighting. Greater difficulty communicating with supervisor and technical support staff.
Equipment Repair	Breakdown of equipment can be mitigated through the use of contingency plans.	Equipment repair may be hampered during night time.
Work Operations	Possibility of decreased completion time through double shift work.	Personnel scheduling may be more difficult. Local ordinance may restrict work at night. Restrictions may also be imposed by unions, material suppliers on night time work.

Source: New York DOT Design Manual Chapter 16
Maintenance and Protection of Traffic in Highway Work Zones, Exhibit 16-24.

Appendix H (continued)

Social		
	Positive Aspect	Negative Aspect
Driver Condition	Driver anger and frustration as a result of traffic delays may be reduced.	Concerns over driver fatigue, drowsiness, confusion and effects of alcohol increase at night.
Worker Health	Health of workers can be affected positively by less exposure to automotive emissions caused by decreased congestion.	Concerns over biological clock factors, and various physiological and mental stresses that can result from lack of sleep. Workers often perceive that their level of safety decreases at night and that speeds are higher. Employee morale may be negatively affected. Normal social and family life of workers may be disrupted.
Economic		
	Positive Aspect	Negative Aspect
Business Cost	Losses incurred by surrounding business as a result of operations may go down as a result of eliminating work during day time.	Trucking and shipping industries which rely extensively on night time operations may be impacted.
Driver Cost	Driver costs will decrease because of lower vehicle operating cost and time savings	
Construction Cost	Reduced traffic interference and enhanced flexibility can drive down the cost of nighttime operations compared to daytime operations.	Costs of delivering materials may be slightly higher for night time than day time. Night operations may be more expensive because of overtime, night premium pay, lighting expense and enhanced traffic control costs.
Environmental		
	Positive Aspect	Negative Aspect
Light Pollution	Excessive lighting can be controlled by using new technologies.	Light pollution can be caused by excessive lighting of the work zone.
Noise	Disturbances can be mitigated by using the latest technologies, and proper planning and administration of work zone.	Can cause noise, vibration, light and otherdisturbances to neighboring communities.
Fuel Consumption/Energy Use	Less fuel is burned through idling cars in congested work zones. New lighting technologies consume less energy.	Energy consumed to provide lighting.
Air quality	Pollution from automotive exhaust emissions decreases from reduced congestion levels.	

Source: New York DOT Design Manual Chapter 16
Maintenance and Protection of Traffic in Highway Work Zones, Exhibit 16-24.

Appendix H (continued)

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Appendix H (continued)

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Source: New York DOT Design Manual Chapter 16
Maintenance and Protection of Traffic in Highway Work Zones, Exhibit 16-24.

Appendix I: Indiana DOT Process for Constructability Review Checklist

Note: only a portion of the checklist most pertinent to traffic control plans is in included.

Rev. 05-05-14

INDIANA DEPARTMENT OF TRANSPORTATION

LEVEL 1

PROJECT CONSTRUCTABILITY REVIEW 3

STAGE 3 PLAN REVIEW SUBMISSION

PROJECT MANAGER/CONSTRUCTION MANAGER/MAINTENANCE MANAGER

PRIMARY DES NO. ____________________ CONTRACT NO. ____________________

ROUTE ____________________ DISTRICT ____________________

WORK TYPE____________________ RFC DATE ____________________

PROJECT LOCATION ____

____

PROJECT DESCRIPTION ____

____

COUNTY/CITY/TOWN ____________ DESIGNER ____________________

PROJECT MANAGER ____________________

CONSTRUCTION MANAGER ________________ DATE ____________________

EVALUATION OF PROJECT CONSTRUCTABILITY QUALITY

	EVALUATION CRITERIA	Y	N	N/A	NOTE	FLAG
	I. CONSTRUCTION PHASING					
*	1. ARE WORK ZONE WIDTHS ADEQUATE FOR CONSTRUCTION EQUIPMENT NEEDS?					
*	2. ARE THERE GRADE CHANGES BETWEEN PHASES THAT WON'T ALLOW ACCESS TO ADJACENT PROPERTIES?					
*	3. IS THERE ENOUGH HORIZONTAL CLEARANCE FOR BARRIERS, SHORING, AND CONSTRUCTION ACCESS?					
*	4. ARE THERE AREAS WITH RESTRICTED ACCESS?					
*	5. ARE WORK ZONE WIDTHS ADEQUATE FOR CONSTRUCTION EQUIPMENT NEEDS?					
*	6. ARE TRAVEL LANES ADEQUATE?					
*	7. PROJECT PHASING CONSIDERED DRAINAGE CONSTRUCTION?					
*	8. DOES STAGING CAUSE SPECIAL CONDITIONS (I.E. STRUCTURAL ADEQUACY/STABILITY)? IF SHOULDERS ARE REQUIRED TO CARRY TRAFFIC DURING STAGE CONSTRUCTION, ARE THEY STRUCTURALLY ADEQUATE OR SHOULD RECONSTRUCTION BE REQUIRED?					

Source: Indiana DOT Central Office - Project Management Constructability Review Process

Appendix I (continued)

*	9. Are there grade changes between phases that won't allow access to adjacent properties?					
*	10. Do the utility relocation plans work for all phases of construction?					
*	11. Are comments from previous review adequately addressed?					
*	12. Any subdivisions or commercial/industrial areas not indicated? Conflicts with adjacent projects, if any?					
*	13. Was the designer conservative in locating phase lines (horizontally) to allow the contractor greater flexibility during construction?					

J. Traffic Maintenance & Traffic Management Plans						
*	1. Are lane closures reasonable for traffic volumes?					
*	2. "Drop offs" due to construction phasing addressed to safely maintain traffic lanes.					
*	3. Pedestrian, bicycle, ADA needs considered?					
*	4. Are location of traffic control signs, warning devices, and barricades encroaching on lanes?					
*	5. Are exits and entrances to work zones adequate and safe?					
*	6. Are lanes on which traffic is to be maintained compatible with local conditions?					
*	7. Is special access required to adjacent property?					
*	8. Is safe pedestrian access and access to business/residences provided throughout the project duration?					
*	9. Has consideration been given to depth of total pavement section (including sub-grade treatment and profile changes) for safety and access?					
*	10. Design adequate for averting delays/congestion?					

Source: Indiana DOT Central Office - Project Management
Constructability Review Process

Appendix I (continued)

	Evaluation Criteria	Y	N	N/A	Note	Flag
*	11. Is detour necessary for averting delays/congestion?					
*	12. Permits for overlength loads to the job feasible?					
*	13. Check out haul routes through metropolitan areas – restrictions?					
*	14. Is there adequate structure vertical clearance over entire project travelway?					
*	15. Can overloads/widths be hauled through job?					
*	16. Are truck turnaround areas available?					
*	17. Can Bridge large or heavy members be transported legally without limitations on existing roads, bridges, or hauling equipment?					
*	18. Determine if there are any other projects that may be in construction along the detour route.					
*	19. Are there any RR crossings located in the proposed detour?					
*	20. Adequate turn lanes provided to avoid traffic backups?					
*	21. Does the TMP adequately address site conditions and traffic volumes?					
*	22. Does the MOT plan address adequate work area for construction operations?					
*	23. Are conflicts with other work in area of project being addressed?					
*	24. Can emergency vehicles travel through zones without delays?					
*	25. Is there adequate vertical clearance in all phases of the MOT?					
*	26. Are approach and driveway grade appropriate and has construction phasing and property owner access been considered?					

Project Constructability Review (Stage 3)

* - Item related to consultant designer evaluation

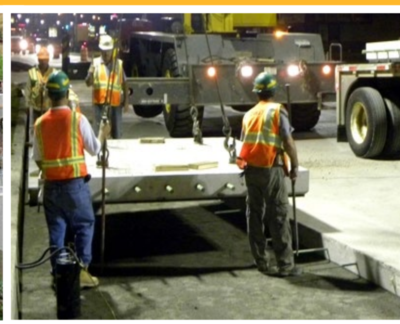
Y - Yes, **N** - No, **NA** - Not Applicable, **Note** - See note number, **Flag** - Item requires priority attention

Source: Indiana DOT Central Office - Project Management Constructability Review Process

Developed by:
Traffic Operations and Safety Laboratory
University of Wisconsin
www.topslab.wisc.edu

DEPARTMENT OF
Civil and
Environmental Engineering
UNIVERSITY OF WISCONSIN–MADISON



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Federal Highway Administration

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