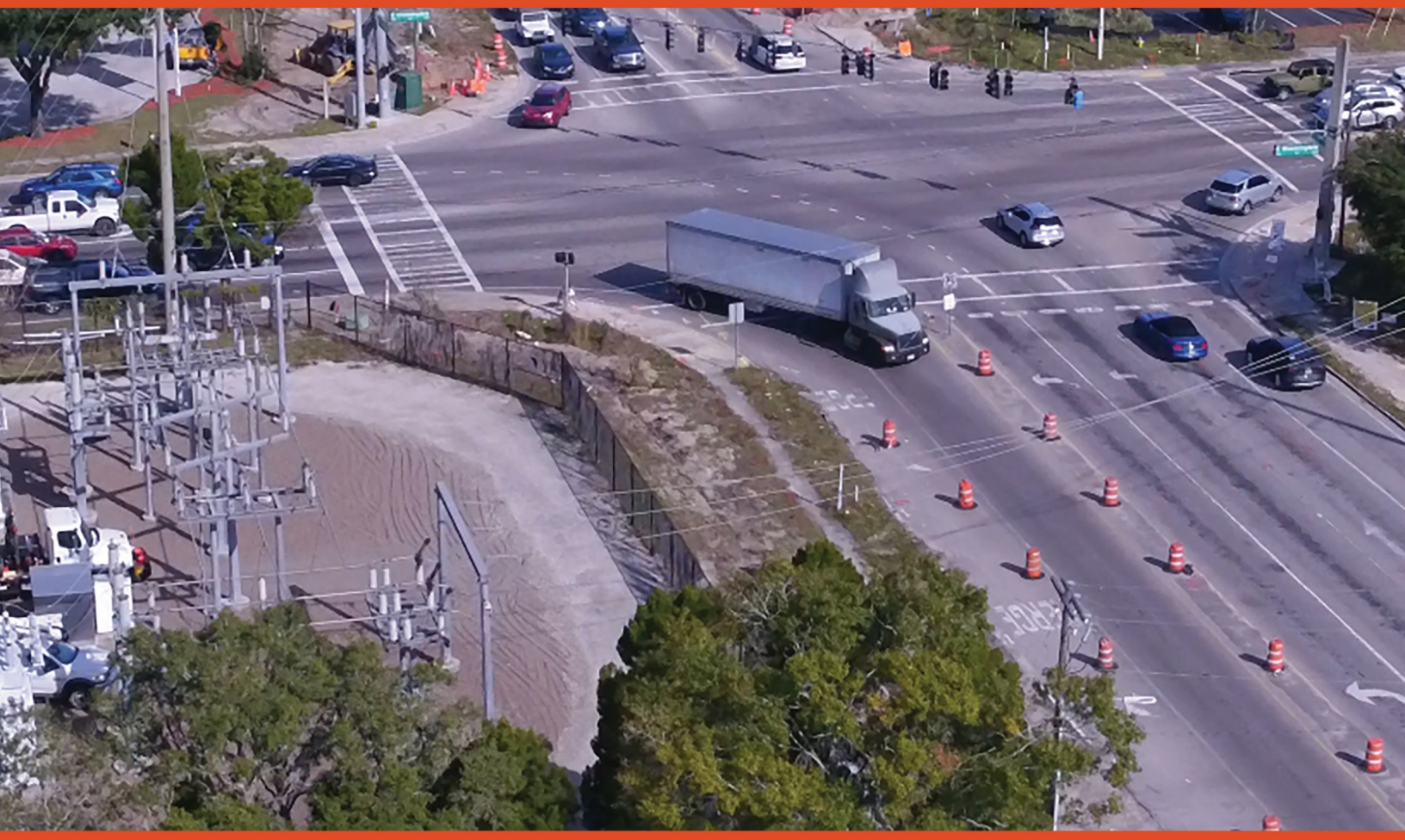
Commercial Motor Vehicle Safety in Work Zones



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16. Abstract

This document provides a comprehensive overview of commercial motor vehicle (CMV) safety challenges in work zones and outlines practical mitigation strategies rooted in the Safe System Approach. It synthesizes engineering interventions, enforcement tactics, and educational programs tailored to CMVs, emphasizing proactive crash prevention and stakeholder collaboration. By integrating advanced technologies, robust transportation management plans (TMPs), and targeted outreach, the publication offers actionable steps for reducing CMV-involved work zone crashes and enhancing overall roadway safety.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS

AAA	American Automobile Association
AASHTO	American Association of State Highway and Transportation Officials
ATSSA	American Traffic Safety Services Association
AFAD	automated flagger assistance device
AI	artificial intelligence
CAV	connected and automated vehicle
CFR	Code of Federal Regulations
CMV	commercial motor vehicle
C-V2X	Cellular Vehicle-to-Everything
CVO	commercial vehicle operations
ELD	electronic logging device
FARS	Fatality Analysis Reporting System
FDOT	Florida Department of Transportation
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
HOS	hours of service
HVE	high-visibility enforcement
ITS	Intelligent Transportation Systems
MDODE	Managing Disruptions to Operations Data Exchange
MUTCD	Manual on Uniform Traffic Control Devices
NHTSA	National Highway Traffic Safety Administration
PIO	public information and outreach
PSA	public service announcement
SSA	Safe System Approach
SSC	speed safety camera
SWZ	smart work zone
TMA	truck-mounted attenuator
TMC	traffic management center
TMP	transportation management plan
TTC	temporary traffic control
TTCP	temporary traffic control plan
USDOT	U.S. Department of Transportation
VSL	variable speed limit
WZRSA	work zone road safety audit
WSDOT	Washington State Department of Transportation
WZDI	Work Zone Data Initiative

CHAPTER 1. INTRODUCTION AND DOCUMENT OBJECTIVES

OVERVIEW OF WORK ZONES AND COMMERCIAL MOTOR VEHICLE SIGNIFICANCE

Work zones are key for maintaining, rehabilitating, and upgrading our Nation's road networks. These areas, marked by construction, maintenance, or utility activities, often incorporate temporary traffic control (TTC) zones. TTC zones may involve narrower lanes, lane shifts, closures, or shoulder reductions, among other differences to the permanent condition of the roadway; these factors can create challenges for motorists.[1]

While all road users encounter these challenges, commercial motor vehicles (CMVs), including large trucks and buses, tend to experience unique and more pronounced risks. Their larger sizes, extended braking distances, and more limited maneuvering capabilities can increase the likelihood and severity of crashes, especially under rapidly changing or constrained roadway conditions. In recognition of these challenges, Federal agencies such as the Federal Highway Administration (FHWA) have emphasized the urgent need to address CMV safety in work zones.

For the purposes of this document, CMVs refer to large trucks and buses with a gross vehicle weight or gross combination weight of 10,001 pounds or more.[2]

CMVs frequently traverse long distances, carry heavy loads, and often operate on tight schedules, all factors that can significantly affect their performance in and around work zones.[3] Passenger vehicle drivers in these areas may also underestimate the blind spots, turning radii, or stopping distances that large trucks and buses need, leading to potential conflicts. Furthermore, work zones can introduce increased interactions between CMVs, construction equipment, and other users within or near the work zone.

OBJECTIVES OF THE DOCUMENT

This document addresses CMV safety in work zones by providing practical information for planners, designers, engineers of record, agencies, and anyone who may review, design, and implement work zones. Topics covered include:

- CMV Considerations in Work Zones: Demonstrate why CMVs could receive focused attention during the development of the transportation management plans (TMPs).

- Safe System Approach Principles and the Safe System Roadway Design Hierarchy: Show how these safety frameworks can be applied specifically to counter CMV involved work zone crashes.

- Comprehensive Strategies: Present a range of engineering, enforcement, and educational strategies tailored to CMVs, drawing on FHWA's Proven Safety Countermeasures where applicable and other evidence-based and noteworthy practices.

- Collaborative Stakeholder Involvement: Emphasize cross-agency and industry partnerships—encompassing traffic engineers, law enforcement, motor carrier associations, technology providers, and local communities—to develop robust and enduring safety solutions.

- TMP checklist in Chapter 7 for agencies and practitioners to apply from project inception through completion.

CHAPTER 2. UNDERSTANDING CMV INVOLVEMENT IN WORK ZONE CRASHES

NATIONAL STATISTICS AND TRENDS

Between 2019 and 2023, CMVs have been disproportionately involved in fatal work zone crashes across the United States. According to data from FHWA's Commercial Motor Vehicle Safety in Work Zones Targeted Action Plan and the National Work Zone Safety Information Clearinghouse, CMVs were involved in approximately 27 percent to 34 percent of all fatal work zone crashes during this period, as shown in Table 1. This is notably higher than their involvement in fatal non-work zone crashes, which has remained steady at around 10 percent to 13 percent.[4,5] All crash data presented in this chapter is sourced from the National Work Zone Safety Information Clearinghouse[5] or the National Highway Traffic Safety Administration (NHTSA) Fatality Analysis Reporting System (FARS).[6]

Table 1. Commercial motor vehicle representation in fatal work zone crashes

Year	2019	2020	2021	2022	2023
Truck-Involved Fatal Work Zone Crashes	249	207	292	246	252
Bus-Involved Fatal Work Zone Crashes	3	4	3	6	6
% CMV Involvement in Fatal Work Zone Crashes	32.9%	27.1%	33.5%	30.3%	31.5%

Source: *National Work Zone Safety Information Clearinghouse, 2025*
https://workzonesafety.org/work-zone-data/work-zone-fatal-crashes-and-fatalities/

According to the National Work Zone Safety Information Clearinghouse data from 2019 to 2023, large trucks were involved in 98 percent of all CMV-related fatal work zone crashes, while buses accounted for 2 percent. Figure 1 illustrates the total number of work zone fatalities and the total work zone CMV-involved fatalities, including a breakdown of the percentage of involvement for trucks and buses.

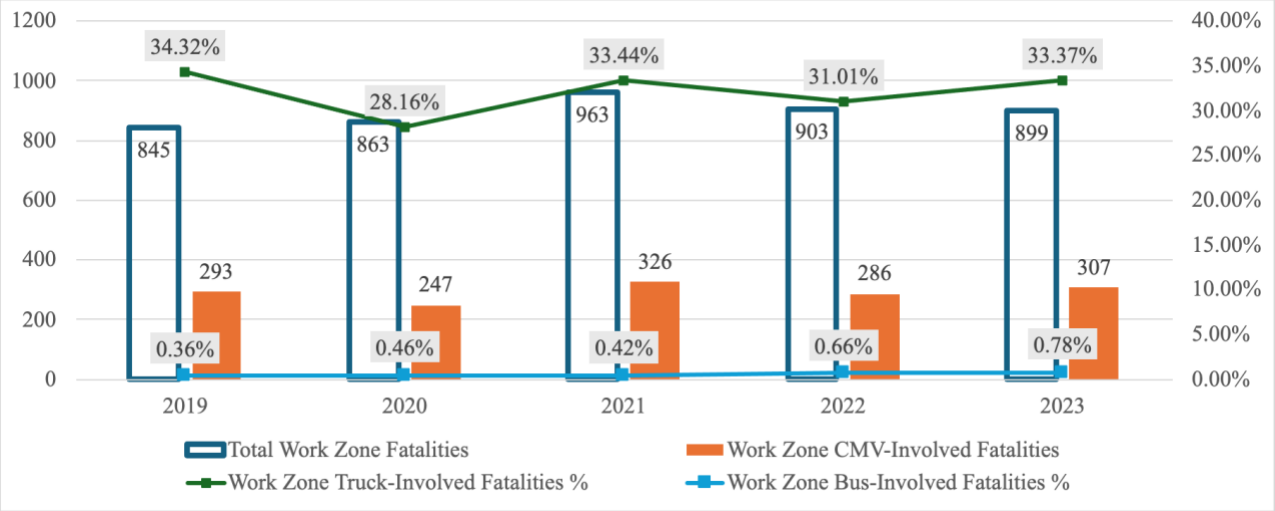

Figure 1. Graph. Overview of work zone fatalities and CMV involvement

Source: *National Work Zone Safety Information Clearinghouse, 2025*
https://workzonesafety.org/work-zone-data/work-zone-fatal-crashes-and-fatalities/

CRASH CHARACTERISTICS

- Roadway Types:
    - Urban Interstates: CMVs are involved in more than 30 percent of fatal work zone crashes.[5]
    - Rural Interstates: CMVs are involved in more than 50 percent of fatal work zone crashes.[5]
- Classification of crash types involving CMVs in work zones:[6]
    - Rear-End Collisions: From 2019 to 2023, around 44 percent of CMV-involved work zone crashes involved rear-end impacts, either by CMVs into other vehicles or other vehicles into CMVs.
    - Fixed Object and Non-Motorized Traffic Crashes: Around 27 percent of the CMV involved work zone crashes in the analysis period belong to this category.
    - Angle and Head-On Crashes: 13 percent and 8 percent of CMV involved work zone crashes in the analysis period belong to these categories, respectively.
    - Sideswipe Crashes: During the analysis period, sideswipe crashes made up approximately 7 percent of all work zone crashes involving CMVs.

- Examination of common factors.
    - CMV-involved work zone crash fatalities were most often occupants of non-CMVs (71 percent).
    - The front and back of the CMV were the initial point of contact in 47 percent and 38 percent of all CMV-involved fatal work zone crashes, respectively.

These crash characteristics warrant close attention as they guide the selection of strategies presented in subsequent chapters. For instance, the predominance of rear-end crashes can be attributed to sudden stops in work zones and the longer stopping distances necessary for CMVs, among other factors. This highlights the importance of strategies such as speed management and dynamic queue-warning systems. Similarly, the frequency of sideswipe and fixed-object crashes illustrates the need for maintaining adequate lane widths and positive-protection measures. These considerations are discussed in Chapter 4. Finally, the elevated CMV involvement on rural interstates emphasizes the value of strategies such as dedicated truck lanes and alternate routing, alongside targeted enforcement to reduce traffic violations in critical work areas.

By aligning recommended countermeasures with frequently observed crash types, this document ensures that engineering, enforcement, and outreach interventions focus on the conditions most often associated with fatal and severe work zone incidents. However, it is also important to note that it is unclear from the available data whether this overrepresentation of CMV involvement in fatal work zone crashes stems from:

- More work zones being located on roadways with higher CMV volumes.
- Increased activity of construction trucks delivering and removing materials and equipment.
- The inherently greater difficulty CMV drivers face in negotiating work zone conditions.
- Driver distraction or inattention resulting in more frequent rear-end collisions by CMVs and into the rear of CMVs by non-CMVs.

CHAPTER 3. THE SAFE SYSTEM APPROACH TO WORK ZONE MANAGEMENT

The Safe System Approach (SSA) is a foundational framework adopted by the U.S. Department of Transportation (USDOT). Its central goal is to prevent fatalities and serious injuries by designing roads, vehicles, and operations to anticipate human mistakes and limit crash forces to survivable levels.[7,8]

Within the Safe System Approach, six guiding principles shape all safety efforts:

1. Death or Serious Injury Is Unacceptable – All road users can be protected from crashes that can cause fatalities or life-altering injuries.

2. Humans Make Mistakes – Because perfect driver behavior cannot be assumed, roads and work zones must be designed for error tolerance.

3. Humans Are Vulnerable – People have physical limits to injury tolerance, speed, and impact angle influence crash severity.

4. Safety Is Proactive – Agencies can anticipate problems and address risky conditions before crashes occur.

5. Responsibility Is Shared – Planners, designers, enforcement, industry, and individual road users each play a role in ensuring safety.

6. Redundancy Is Crucial – Layered protective measures (from infrastructure design to user awareness) create failsafe conditions when one measure is insufficient.

As shown in Figure 2, the SSA also includes five key elements:

1. Safe Road Users – Encouraging responsible behavior among all users (e.g., commercial drivers, passenger vehicle drivers, non-motorized road users).

2. Safe Roads – Designing infrastructure to reduce crash severity (through geometry, barriers, clear zones, etc.).

3. Safe Vehicles – Promoting advanced vehicle safety features (e.g., collision avoidance systems) for both passenger cars and CMVs.

4. Safe Speeds – Adopting speed management strategies so that if a crash occurs, the resulting forces are less likely to produce severe injuries.

5. Post-Crash Care – Ensuring quick, effective emergency response and medical treatment.

Figure 2. Graphic. Overview of the Safe System Approach

Source: *Federal Highway Administration*

SAFE SYSTEM ROADWAY DESIGN HIERARCHY

FHWA's publication *The Safe System Roadway Design Hierarchy*[9], published January 2024, provides a structured framework to prevent fatalities and serious injuries by categorizing engineering and infrastructure-based countermeasures according to their alignment with the Safe System Approach. While not specific to work zones, this framework can be applied to work zones to identify infrastructure-based countermeasures.

The Safe System Roadway Design Hierarchy organizes countermeasures into four tiers, ranked from those most aligned with Safe System Approach principles to those that primarily rely on user compliance. These tiers inform transportation agencies in selecting engineering and infrastructure-based interventions to address safety challenges effectively.

- **Tier 1: Remove Severe Conflicts**
  Focuses on eliminating specific high-risk conditions, and therefore the possibility of fatal or serious injuries from certain conflicts. Examples include creating dedicated truck-only lanes or using physical barriers to separate work areas from active traffic lanes.

- **Tier 2: Reduce Vehicle Speeds**
  Aims to lower crash energy by reducing travel speeds through the implementation of narrower lanes, dynamic speed limits, and other traffic-calming measures.

- **Tier 3: Manage Conflicts in Time**
  Controls movements that occupy the same physical space. Traffic signals, flagging operations, and alternating one-lane TTC zones help separate movements in time.

- **Tier 4: Increase Attentiveness and Awareness**
  Involves alerting users to potential conflicts, providing necessary information for safe navigation, and raising conspicuity of such cues. Changeable message signs and advanced warning signs are key examples.

The Safe System Roadway Design Hierarchy sets the foundation for managing work zone safety in a structured, proactive way. By first striving to remove severe conflict points (Tier 1), then reduce speed (Tier 2), carefully manage the times and places where conflicts occur (Tier 3), and finally increase driver awareness (Tier 4), practitioners can layer multiple strategies to protect all roadway users. Please refer to Figure 3.

The next chapter examines how these tiers translate into practical, on-the-ground solutions. It also discusses the various factors that contribute to CMV crashes in work zones and identifies targeted engineering measures to address those challenges effectively.

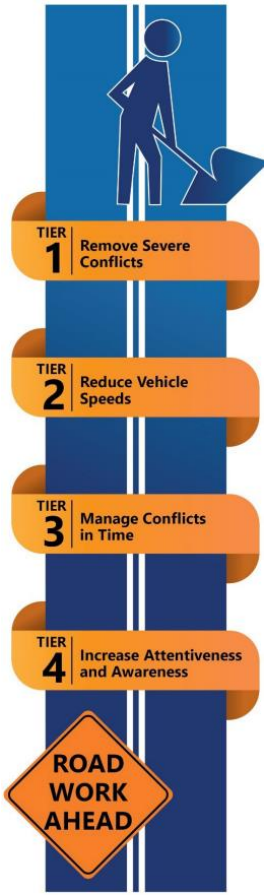

Figure 3. Graphic. Safe System Roadway Design Hierarchy

Source: *Federal Highway Administration*

CHAPTER 4. CONTRIBUTING FACTORS AND ENGINEERING SOLUTIONS

This chapter expands on the Safe System Approach concepts introduced in Chapter 3, focusing on CMV challenges in work zones. After examining the underlying factors associated with CMV crash risk in work zones, the chapter outlines the components and importance of a project-specific transportation management plan (TMP) and provides targeted engineering solutions that agencies can deploy to improve safety and operations.

A checklist has been provided in Chapter 7 of this document. Agencies can consult this checklist during TMP development and throughout the project timeline.

CONTRIBUTING FACTORS AFFECTING CMV SAFETY IN WORK ZONES

CMVs face increased crash risks in work zones for several reasons. Before discussing the components of a TMP and how they are applied, it is important to understand the factors that contribute to these risks, including physical challenges, the impact of severe weather conditions, and scheduling factors related to CMV traffic.

Terrain and Regional Challenges

- Mountainous or Rolling Corridors:
  CMVs already face reduced speeds on steep upgrades and need longer braking distances on downgrades. Additionally, rolling corridors increase the risk of brake failures for CMVs. Narrowed or shifting lanes during construction worsen these risks.

- Preserving Existing Safety Features:
  Where truck escape ramps (see Figure 4) or wide shoulders typically exist, removing or limiting these features can place CMVs at higher risk of brake failure or rollover.

- Seasonal Weather:
  Snow, ice, and fog can compound risks on winding roads or steep grades. Nighttime or off-peak work, common in mountainous regions, further reduces visibility.

Physical Constraints

- Lane Widths:
  Most work zones reduce the existing roadway cross-section, forcing CMVs to navigate narrower lanes or tight lateral clearances.

- Taper Lengths:
  Short tapers can cause abrupt merges, which are especially difficult for large trucks with extended stopping distances.

- Shoulder Restrictions:
  Shoulders converted into travel lanes eliminate safe recovery zones for CMVs that drift or experience mechanical issues. Shoulder restrictions limit safe areas for effectively enforcing the work zone speed limit or addressing reckless driving.

Figure 4. Photo. Runaway truck ramp

Source: *UTAH Department of Transportation (UDOT)*

- Median Crossovers:
  Work zones on divided highways sometimes require temporary median crossovers to maintain traffic flow by routing vehicles onto the opposing roadway (see Figure 5). These crossovers typically involve an S-curve alignment.

  Navigating shorter reverse curves can be challenging for CMVs, especially when elevation differences exist between the two roadways. If a crossover is placed on a sag or crest vertical curve, the combination of horizontal and vertical curvature may cause trailer sway or off-tracking, increasing the difficulty of maintaining CMVs in their lane.[11]

Figure 5. Photo. Box trucks navigating a work zone median crossover

Source: *Federal Highway Administration*

Urban Bus Operations

- Loss of Curbside Boarding Areas:
  Work zone storage, barrier placement, or material staging can block existing bus stops, forcing passengers to board or alight in live traffic and thereby increasing the risk of potential conflicts.

- Interrupted ADA-Compliant Access:
  Sidewalk closures, uneven temporary surfaces, or missing curb ramps sever the accessible path between bus doors and pedestrian facilities, limiting service for riders with mobility devices.

- Reduced Schedule Reliability:
  Lane closures, queue formation, and signal re-timing cause unpredictable delays, negatively impacting on-time performance and discouraging transit ridership. Unscheduled stop relocations and detours create confusion for riders about where to board, resulting in unsafe crossings or riders lingering near construction zones.

- Constrained Maneuvering Space for Buses:
  Narrowed lanes and removed bus bays restrict buses from merging, stopping flush to the curb, and re-entering traffic, increasing crash risks.

Scheduling and Funding Considerations

- Construction Restricted to Night Work:
  Although working at night can reduce daytime congestion, limited lighting and fatigued drivers can heighten CMV crash risk. In rural work zones, where lighting is typically limited, CMVs and road workers are at a heightened risk level due to the maneuverability constraints of larger vehicles.

- Project Funding for Temporary Alignments:
  Wider temporary lanes, improvements along temporary pathways, and transitions, or devices added to improve safety, increase upfront costs associated with projects, and must be considered throughout the project timeline.[12,13]

- Coordination Across Multiple Projects:
  Overlapping work zones or concurrent closures can compound detour complexity, which is particularly detrimental to freight movement.

Traffic Management and Driver Behavior

- Queuing and Speed Variance:
  When sudden slowdowns occur, CMVs are more prone to rear-end crashes. Drivers often struggle with repeated decelerations in stop-and-go patterns.

- Driver Distraction and Fatigue:
  Interacting with personal electronics, route-finding apps, and exceeding their hours of service could reduce CMV driver alertness in traffic.

- Inconsistent Enforcement or Communication:
  Infrequent speed control, unclear signing, or sudden lane closures can leave truck drivers unprepared for rapid changes. Outdated roadside message signs and work zone warning signs without active work reduce the effectiveness of these messages when needed.

TRANSPORTATION MANAGEMENT PLAN COMPONENTS

A Transportation Management Plan (TMP) is necessary to minimize work zone delays and crashes. Each project's TMP varies in scope depending on its anticipated impacts. Under Title 23 of the Code of Federal Regulations (CFR), Part 630 Subpart J, § 630.1010 defines "significant projects" as those expected to have substantial impacts on work zone safety and mobility. For these significant projects, § 630.1012 specifies that the TMP must include a temporary traffic control plan (TTCP) and must address both Transportation Operations (TO) and public information and outreach (PIO) components. For projects or classes of projects determined by State DOTs to have less than significant work zone impacts, the TMP may consist solely of a TTCP, though states are encouraged to also consider TO and PIO components.[12]

State DOTs operationalize and often exceed these Federal requirements through standardized documentation procedures. For example, Florida's Department of Transportation (FDOT) Design Manual Chapter 240 implements these Federal rules and requires completion of Form 240 for all projects regardless of their significance. This form ensures documentation of all TMP components, including the TTCP, TO, and PIO. It provides a consistent structure to demonstrate compliance with Federal and State regulations.14

For significant projects, agencies often form a multi-disciplinary team (including FHWA, local government, businesses, and other stakeholders) to plan, coordinate, implement, monitor, and evaluate these components.[12]

Below, each TMP component is explored in relation to the contributing factors cited earlier in this chapter, and engineering and operational strategies are examined as part of these components.

Temporary Traffic Control Plan

The TTCP is central to any TMP. In the context of CMVs, the TTCP defines how traffic will be routed through or around a work zone and directly addresses the unique operational needs of large trucks and buses in a project-specific context. Each TTCP element can integrate effective practices for CMV safety to ensure alignment with the Safe System Roadway Design Hierarchy by removing severe conflicts, reducing speeds, managing conflicts in time, and finally increasing driver attentiveness and awareness.[9]

Below are key considerations and strategies that can be considered for incorporation into the TTCP, compiled from various sources, mainly FHWA publications, manuals, standards, and State DOT publications. For more detailed information, consult the following references: 1, 4, 10, 11, 12, 13, 15, and 16.

Transportation Operations Considerations and Strategies

Geometry, Lane Widths, and *Tapers*

- Maintaining Safe Lane Widths (Tier 3)
  Provide at least one 11–12 foot lane in high-volume truck corridors when possible. Wider lanes reduce the likelihood of encroachments onto adjacent lanes, especially where CMVs are prevalent (See Figure 6).[1,15]

- Truck Run-Off Areas (Tier 1)
  Retain or replicate existing truck escape or runaway ramps in mountainous or rolling terrain. If closure is unavoidable, clearly sign the closure in advance.[4,9]

- Vertical and Horizontal Structure Clearances (Tier 1)
  Ensure updated signing and adequate bridge vertical clearances where lane shifts move trucks onto a shoulder or median under a structure.[2,10]

- Access / Egress Points (Tiers 1 - 3)
  Incorporate a dedicated lane or area for construction vehicles to decelerate and accelerate or use spotters/temporary signals for trucks delivering materials. Minimizing sudden slowdowns in the mainline traffic flow reduces rear-end crashes. Work zone access points can be clearly outlined and included in the TTCP.[4,16]

  It is critical that the crossover design provides sufficient curvature radii, transition length (intermediate tangents), and appropriate superelevation to accommodate CMVs. Adequate lane width and clear signing (such as advisory speeds or "Stay In Your Lane" signing) should be provided to guide trucks safely through the temporary alignment.[11,15]

  Use construction vehicle notification systems where construction vehicles may have more difficulty merging with through traffic.

  Use warning signs on the back of construction vehicles delivering materials to discourage drivers from following construction vehicles into the work zone.

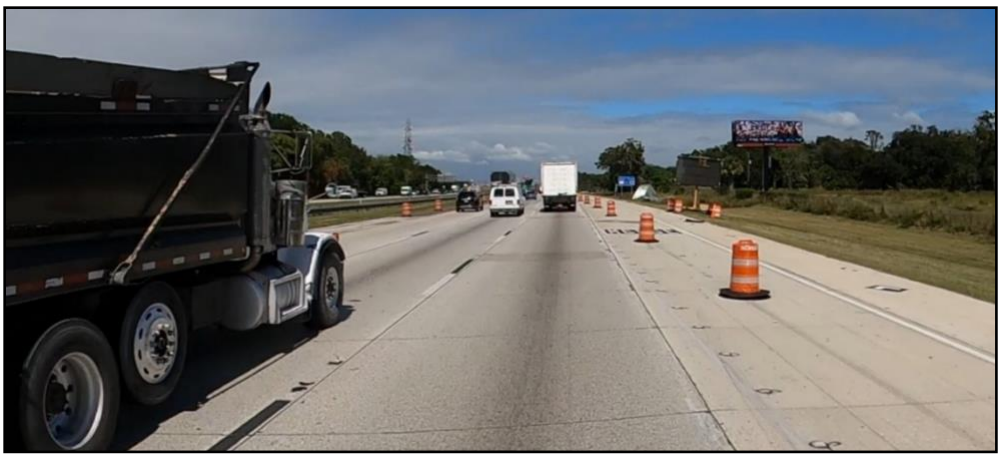

Figure 6. Photo. Commercial motor vehicles navigating through a work zone lane closure

Source: *Federal Highway Administration*

Shoulders, Refuge Areas, and Positive Protection

- Preserving Shoulders or Providing Pull-Off Areas (Tier 1)
  If shoulders are to be used as temporary travel lanes, incorporate periodic refuge areas for breakdowns. Figure 7 shows a CMV navigating a work zone with narrowed lanes and restricted shoulders.[15,17]

- Median Barriers for Opposing Flows (Tier 1)
  Where two-way traffic on separated alignments or with substantial separation is temporarily forced onto the same alignment or a roadway without crashworthy or significant separation, portable concrete barriers can prevent head-on collisions. These barriers may also serve as positive protection for workers or other non-motorized traffic.

- Work Zone Clear Zones and Buffer Spaces (Tier 1)
  Work zone design should maintain adequate lateral clear zones and longitudinal buffer spaces wherever feasible, keeping traffic at a safe distance from workers and equipment. Even when positive protection such as concrete barriers are used, a buffer space is needed to accommodate the barrier's deflection distance if struck by a heavy vehicle. This ensures that if a CMV impacts a barrier, there is no secondary collision involving work crews or equipment behind the barrier.[17]

  Published guidance on work zone clear zones indicates that areas adjacent to the travel lanes should be kept free of equipment, materials, and personnel whenever possible. Designers should tailor the size of clear zones and buffer spaces to the work zone speed and roadway conditions, and never position workers immediately behind a barrier without allowance for barrier deflection. Adhering to these clear zone and deflection distance practices significantly reduces the risk of errant CMVs and any other vehicles intruding into the work zone.[17,18]

- Wider Edge Lines (Tier 4)
  High-visibility edge lines (6 to 8 inches wide) help trucks maintain lane position in narrowed or shifting sections. They can reduce lane departure crashes by giving drivers clearer visual information. Raised pavement markers help with delineation during lane closures and transition tapers.[10,15]

- Safety Edge or Pavement Edge Treatments (Tier 1)
  Where drop-offs occur (e.g., staged construction, overlays), a 30-degree pavement edge slope prevents abrupt tire scrubbing, allowing CMVs to re-enter the travel lane safely.[15]

- Automated Flagger Assistance Devices (AFAD) (Tiers 1 and 3)
  AFADs are useful on two-lane, two-way roads where flaggers typically manage alternating traffic. AFADs can keep workers out of active lanes of traffic and visually reinforce the need to stop or slow.

  Field evaluations of the Missouri DOT's Automated Flagger Assistance Device showed that vehicles approached the AFAD at speeds on average 4.2 mph slower than under human flagger control, stopped 11.4 ft farther back, and were released 1.3 s faster, demonstrating that AFADs can measurably slow drivers and improve work-zone safety.[19]

Figure 7. Photo. Commercial motor vehicle traveling through narrowed work zone lanes

Source: *Federal Highway Administration*

Managing Speeds and Enforcement

- Use Appropriate Speed Limits (Tier 2)
  If narrow lanes, lane shifts, or close worker proximity justify lower speeds, set work zone speed limits that reflect actual conditions. Per Chapter 6 of the MUTCD, *"Reduced speed zoning (lowering the regulatory speed limit) should be avoided as much as practical because drivers will reduce their speeds only if they clearly perceive a need to do so."* Avoid arbitrary blanket reductions, document the rationale, and consider the non-vehicular context (e.g., workers without positive protection).[1,10]

- Variable Speed Limits (VSLs) (Tier 2)
  VSLs adjust automatically based on traffic volumes, queue buildup, or weather conditions. By harmonizing speeds, VSLs reduce abrupt braking and speed variance in congested zones. The installation of VSL requires compliance with State or local laws and regulations, Figure 8 shows a VSL sign.[10,13]

- Speed Safety Cameras (SSCs) (Tier 2)
  Mobile or point-to-point (P2P) speed cameras can deter excessive speeding, especially where geometry or lack of safe shoulders make human enforcement difficult. Studies show up to a 25 percent reduction in work zone fatal crashes and a 17 percent reduction in operating speeds, though legal limitations hinder widespread implementation.[20] Refer to the *Automated Enforcement Tools* section in Chapter 5 for a discussion on the legality of these systems.

  In partnership with the Washington State Patrol and the Washington Traffic Safety Commission, the Washington State Department of Transportation (WSDOT) began field testing two average speed P2P camera installations on State highways in April 2024. This is among the first U.S. pilots of P2P enforcement on higher-speed facilities. In P2P enforcement, cameras are placed at multiple points along a segment and are time-synchronized to calculate a vehicle's average speed over the corridor. The pilot will run through at least June 2025 and is specifically designed to evaluate the technology's effectiveness in reducing speeds and crashes on limited access highways.[20,21,22]

Figure 8. Photo. Variable speed limit sign

Source: *Federal Highway Administration*

Dynamic Merging and Queue Management

- Dynamic Lane Merge Systems (Tier 4)
  Automated or sensor-based signing instructs drivers, CMVs included, when to merge to prevent late cut-ins, reducing crash risk.[13,23]

- Advanced Queue Warning (Tier 4)
  Advanced queue warning systems are primarily designed to reduce end-of-queue rear-end collisions. By detecting slowing or stopped traffic and activating portable message signs upstream, they give CMV drivers, who require longer stopping distances, early alerts to decelerate safely, minimizing the risk of losing control at the tail of a queue.[13,23]

- Speed Management Strategies (Tier 2)
  Pair queue warnings with VSLs or SSCs to encourage consistent deceleration.[20]

Urban Bus Operations and Temporary Bus Stop Management

- Temporary Accessible Boarding Pads (Tier 1)
  Provide a 96 inch by 60 inch firm, slip-resistant boarding pad with detectable warning domes, flush transitions, and channelizer or tubular-marker separation from travel lanes to maintain ADA compliance and minimize live-traffic exposure.[10]

- Continuous ADA-Compliant Pedestrian Path (Tier 1)
  Maintain a minimum 48-inch clear width, with a smooth pedestrian path linking temporary stops to existing sidewalks or transit hubs. Provide 60 inch by 60 inch passing spaces every 200 feet. Protect the path with pedestrian channelizing devices.[10, 24, 25]

- Temporary Stop Advance Warning Signage (Tier 4)
  Install "Transit Stop Ahead" warning signs and supplemental "TEMPORARY BUS STOP" per MUTCD advance-warning requirements, at 500 feet and 250 feet upstream of relocated stops to alert motorists and riders.[10]

- Modify Allowable Work Hours to Avoid Peak Boarding Times (Tier 3)
  Schedule lane closures and major work outside of peak boarding periods or use short-duration operations to preserve schedule reliability and rider safety.

  Designate a certified TTC inspector to supervise temporary stop arrangements, deploy transit-specific flaggers during peak hours, and modify device placement in real time to guarantee safe boarding and reduce delays.

Detours, Diversions, and Alternate Routes

- Selecting Appropriate Detour Facilities (Tier 1)
  Confirm that detour routes can handle heavy loads, large turning radii, and overhead clearances. Coordinate with local agencies to obtain agreements for the use of their facilities. Identify the need for improvements in detour facilities to promote safety.[26]

- Separate Truck vs. Passenger Vehicle Detours (Tier 1)
  Routing cars onto narrower or lower-capacity local roads while leaving trucks on the main corridor can reduce speed differences and weaving conflicts.[27]

- Routing of Oversized Loads (Tier 1)
  Ensure that permits issued for oversized loads provide routing instructions to avoid work zones if possible. In addition, TMP development should proactively consider how oversize overweight (OSOW) freight will be accommodated throughout the project.[12]

  Any detour or diversion planned in the TMP must be evaluated for adequacy in handling extra-large vehicles' dimensions and weights. For example, alternate routes should be examined for sufficient pavement strength and width, overhead clearance, turning radii at intersections, where geometric constraints could impede OSOW vehicles. Early coordination with the State OSOW permits offices is advisable to communicate planned

work zones and develop appropriate OSOW routing strategies (such as timed crossings or escorted detours).[26]

The University of Wisconsin publication Oversize/Overweight Vehicle Accommodation in Work Zones provides detailed strategies for integrating OSOW needs into work zone planning. See Chapters 5 and 6 of that document for detailed information on OSOW considerations during the development of a TMP.[26]

- Advance Warning Signs (Tier 4)
  Advance warning signs are critical for alerting drivers, especially CMV operators, of upcoming work zone conditions. The TTCP typically includes an advance warning diagram showing staged warning signs along each approach to the work area. The FHWA's Manual on Uniform Traffic Control Devices (MUTCD) includes typical diagrams showing minimum requirements, while some State DOTs impose standards with more specific or stringent guidelines. Static signs should be positioned at appropriate intervals based on approach speeds, with higher-speed highways requiring earlier placement distances.[1,10]

  Whether portable or overhead, changeable message signs effectively convey real-time information such as lane closures, reduced speed limits, or queue warnings. By providing timely, clear warnings, agencies give CMV drivers additional reaction time to brake gradually and make necessary lane changes, mitigating the risk of abrupt maneuvers. Enhanced conspicuity measures like flashing beacons on advanced warning signs or speed feedback signs can further attract the attention of truck drivers who may be fatigued or focused on navigating the work zone. Figure 9 shows an overhead changeable message sign displaying work zone alerts.

- Crash Cushions / Impact Attenuators (Tier 1)
  These are placed in front of temporary barrier ends or near lane tapers to mitigate the severity of collisions with errant trucks.[9,18]

Figure 9. Photo. Changeable overhead message sign showing work zone travel alert

Source: *Federal Highway Administration*

Intelligent Transportation Systems and Smart Work Zone Technologies

Although the following are often seen as the Transportation Operation (TO) strategies, they are also budgeted and provisioned within the TTCP:

- Traffic Monitoring & Management (Tiers 2 and 4)
  Deploy portable sensors or cameras to monitor speeds, queue lengths, and volumes. Feeds can be linked to a traffic management center (TMC) for proactive decision-making.[13,28]

- Automated or Temporary Signals (Tier 1 and 3)
  Consider portable traffic signals instead of flaggers for one-lane, two-way work zones. These can be timed or sensor-based to handle CMV platoons or varying volumes. In cases of non-compliance, these might increase the risk of head-on collisions. Some State DOTs supplement temporary signalization with worksite traffic supervisors or traffic control officers.[10,12]

- In-Cab Warnings & Truck Telematics (Tier 4)
  Connected vehicle platforms link roadside units and geofencing to push "Work Zone Ahead" or "Lane Closure" alerts directly to CMV in-cab devices (ELDs or telematics apps, see Figure 10). As a vehicle crosses successive upstream geofences, it receives a low-fidelity "inform" message, then "advise," "alert," and finally a high-fidelity "warn" prompt as it nears the active work area. This approach ensures drivers get progressively stronger, distance-based warnings. Field deployments in Maricopa County demonstrated that this graduated messaging notably improves driver compliance and reaction times.[29,30,43]

  The Federal Motor Carrier Safety Administration's Tech-Celerate Now Phase I Final Report documents voluntary adoption levels of key ADAS technologies, lane departure warning (LDW), and forward collision warning/automatic emergency braking (FCW/AEB), across Class 8 fleets, and notes that OEMs typically bundle these features as factory-installed packages on new trucks.

- Warning Systems for Vehicles Entering/Exiting the Workspace (Tier 4)
  Use the Work Zone ITS Technology Supplement's recommended dynamic warning system, which combines radar, microwave, or video sensors directly connected via wired or wireless links to activate flashing lights on static warning signs or messages on portable changeable message signs when a construction truck is about to enter or exit the workspace. This approach addresses the credibility issues of static "truck entrance" signage by alerting motorists only when a slow-moving vehicle is present, thereby improving driver response. Sensor location and aiming must ensure detection exclusively at the access point to avoid false activations. Warning signs should be placed adequately upstream, based on operating speeds, following positive guidance principles.[31]

Figure 10. Photo. Commercial motor vehicle operator utilizing an electronic logging device

Source: *CRST*

Novel or Specialized Measures

Some strategies go beyond standard practice, but can yield significant safety benefits in certain work zones:

- Direct Speed Limiters for CMVs in Work Zones (Tier 2)
  In partnership with major carriers, fleets can temporarily cap truck speeds in designated corridors. This approach complements SSCs and has shown success in pilot programs.[13,20]

- Truck-Mounted Attenuators (TMAs) & Moveable Barrier Systems (Tiers 1 and 2)
  These allow dynamic reconfiguration of lanes to match peak direction flow. TMAs protect short-duration tasks from unexpected truck encroachments.[18,23]

- Smart Work Zone Deployments (Tier 4)
  Smart Work Zone (SWZ) solutions may combine portable sensors, queue detection, dynamic merges, in-cab warnings, and real-time traveler information to create a cohesive system for truck drivers.[13,28]

- Staged Lane Reductions & Dynamic Closures (Tier 1)
  In certain high-volume corridors, scheduling lane closures in real-time (overnight or during lulls) can reduce truck backup risk.[13,32]

Public Information and Outreach (PIO)

Effective traveler information for commercial vehicle operations (CVO) hinges on accurate, real-time data dissemination and robust public outreach. Recent research underscores how proactive, user-centric communication not only helps CMV drivers plan better routes but also protects infrastructure and enhances overall safety. Below are key recommendations and strategies for strong PIO tailored to CVO, applicable to agencies of any size or region:

- Leverage a Dedicated CVO Information Hub

  Consolidate Key Data: Merge work zone alerts, route restrictions from incidents, weather and other disruptive events, temporary bus stop locations, truck parking, and real-time traffic conditions into a single portal that is clearly labeled and easy to access. Leverage data standards such as Connected Work Zones (CWZ) and Work Zone Data Exchange (WZDx) feeds (*see Resources*) to enable third-party access to this real-time information.[29,33]

  Highlight Accuracy and Timeliness: Emphasize that all data (e.g., bridge restrictions, construction schedules) reflect up-to-the-minute field updates to build trust with carriers.

- Strengthen Carrier-Focused Outreach

  Engage Large and Small Fleets: Recognize that smaller operators may lack advanced routing tools. Provide straightforward pre-trip planning resources (e.g., integrated route-restriction maps, single-click route checks) and distribute them via trucking associations, motor carrier newsletters, and industry meetings.

  Promote CVO Resources: Many CMV stakeholders remain unaware of official data. Feature these tools in dispatch offices, weigh stations, and driver training schools to expand reach and encourage safe route planning.[3,29]

- Push Real-Time Traveler Information

  Automated Alerts: Collaborate with private-sector telematics and navigation app providers to deliver geofenced notifications (e.g., lane closures, detours, restrictions) directly to in-cab devices and smartphones.

  Pilot Innovative Systems: Studies have highlighted the value of integrated "Trapped Traveler" or standstill-queue messaging for communicating with drivers caught in extended backups.[13,30]

- Collaborate with Private Data Providers

  Invite robust partnerships so real-time agency data (closures, weather advisories, parking availability) flows into commercial platforms such as major ELD dashboards and driver routing apps.[29,30]

  A proven model is USDOT's Freight Logistics Optimization Works (FLOW) program, in which beneficial cargo owners, ocean carriers, ports, terminals, railroads, and third-party logistics firms share individual logistics data with the Bureau of Transportation Statistics. BTS then anonymizes regional segments and aggregates the inputs, returning participants a holistic, actionable view of supply-chain conditions. This approach ensures no proprietary details are exposed.[34]

- Coordinate Regionally and Across Agencies

  Neighboring Regions: For corridors that cross multiple jurisdictions, ensure consistent alerts and route restriction updates, minimizing confusion for interstate carriers.[29]

- Conduct Ongoing Evaluations and Solicit User Feedback

  Driver Surveys and Focus Groups: Periodically measure how well outreach resonates with various fleet sizes. Adapt tactics based on driver input about new technologies or missing data.

  Performance Metrics: Track indicators such as reduced CMV-involved incidents or improved trucking-site hits on the PIO webpage to gauge effectiveness and inform of changes.

Chapter Summary

When TTC provisions and TO strategies merge, supported by a PIO process that keeps stakeholders informed, work zones can be designed to meaningfully reduce crash risks for CMVs. The strategies discussed in this chapter cover all levels of the Safe System Roadway Design Hierarchy.

Overall, a well-structured TMP, backed by strong public involvement and advanced intelligent transportation system (ITS) capabilities, can significantly enhance the safe passage of CMVs through work zones, preserving the efficiency of freight operations and protecting all roadway users.

CHAPTER 5. ENFORCEMENT, EDUCATION, AND COLLABORATIVE STRATEGIES

This chapter outlines enforcement strategies and educational efforts that complement the engineering solutions presented in Chapter 4. It also highlights the importance of collaboration among agencies, industry representatives, and other stakeholders to foster a comprehensive, Safe System–based approach to CMV safety in work zones.

ENFORCEMENT AND REGULATORY MEASURES

Enforcement plays a key role in reinforcing safe driving behaviors and ensuring compliance with traffic regulations. While robust engineering designs can reduce crash likelihood and severity, consistent law enforcement presence and effective regulatory frameworks further mitigate CMV-involved collisions in work zones.

1. High-Visibility Enforcement (HVE)

   Positioning: Marked patrol cars could be prominently visible to oncoming drivers, particularly upstream of lane closures or near known crash hot spots.

   Targeted Patrols: Focus on enforcement during peak construction hours or when traffic queues typically form, deterring tailgating, speeding, or improper lane changes by both CMVs and passenger vehicles.

   Studies of marked patrol vehicles in interstate work zones show mean speed reductions of 4.2 to 8.4 mph and decreases in speed-limit violations of 14 to 32 percent. In moderate-speeding zones, circulating police patrols reduced mean free-flow speeds by 6.1 to 8.4 mph, while in high-speeding sites all enforcement treatments (including patrols alone) yielded 4.2 to 6.9 mph reductions and cut non-compliance to 11–16 percent.[35]

2. Specialized CMV Enforcement

   Truck Lane Restrictions: On corridors with high truck volumes, enforce temporary lane-use restrictions so that large vehicles remain in designated lanes, reducing weaving and abrupt merges.

   Weight and Equipment Checks: When feasible, coordinate with State and Federal motor carrier enforcement (weigh station checks) near major work zones to identify fatigued drivers, unsafe equipment conditions, or carriers out of compliance.

3. Automated Enforcement Tools

   Implementation of automated enforcement systems in work zones requires legal review before deployment. State statutes differ significantly in whether and how they authorize speed safety cameras (SSCs). Some expressly ban it on public highways without legislative enabling language, while others permit only limited pilot programs subject to strict conditions.

   Agencies must question whether they have clear statutory authority, assess potential challenges related to photographic evidence collection, and ensure that due process requirements are met through advance notification, signing, and compliance with other requirements. Additionally, compliance with administrative procedure acts governing rulemaking, calibration protocols that satisfy evidentiary standards, and relevant case law on the admissibility of electronic speed measurements must all be confirmed to withstand scrutiny.

   Work Zone Speed Safety Cameras: Deploy SSCs or portable radar units in high-risk or long-term work zones to capture violators.

   Point-to-Point (P2P) Speed Enforcement: This valuable approach, though less common in the United States, calculates average speeds over a defined corridor, discouraging drivers, especially trucks, from accelerating after passing a single enforcement location.

   SSCs, including fixed, mobile, and P2P units, employ speed measurement devices and photographic or video evidence to detect and deter speeding in work zones. Fixed SSCs on urban principal arterials have demonstrated crash reductions up to 54 percent for all crashes and 48 percent for injury crashes; point-to-point systems yield up to a 37 percent reduction in fatal and injury crashes; and mobile units report up to a 20 percent decrease in urban arterial crash rates. SSC deployments generate upstream and downstream spillover safety benefits beyond the immediate enforcement site.[22,37]

4. Regulatory Coordination

   FMCSA Partnerships: Partner with FMCSA staff to address persistent carrier violations and to share data on hours of service (HOS) infractions, ensuring that the most at-risk drivers and/or carriers receive heightened scrutiny.

   State-Level Policies: Stay informed about any newly enacted legislation (e.g., higher fines for work zone speeding, stricter penalties for handheld device use) and include these in signing or public information campaigns.

Together, these enforcement, regulatory, and educational strategies advance the principles of the Safe System Approach, most notably shared responsibility and system redundancy, by directly fostering driver attentiveness and safe behaviors. Engineering countermeasures shape the physical work-zone environment to reduce exposure and severity. At the same time, complementary actions targeting human factors ensure that motorists remain vigilant, aware of changing conditions, and responsive to temporary traffic controls. In this way, non-engineering measures support and amplify the benefits of infrastructure-based solutions without altering the intent or scope of the Hierarchy Framework.

DRIVER EDUCATION

While physical design changes and robust enforcement have significant impacts, proactive education helps drivers, both CMV operators and the general motoring public, adapt to work zones' unique and changing conditions.

CMV-Focused Training

1. Company Safety Programs

   Major trucking companies often conduct periodic in-house training on new regulations, fatigue management, and defensive driving. Incorporating work zone–specific modules (e.g., strategies for navigating narrow lanes and anticipating sudden slowdowns) can help reduce crash risk.

2. Continuing Education Credits

   Industry associations (e.g., State trucking associations or American Trucking Associations) can offer continuing education credits on topics like safe merging, speed control, and blind spot management in work zones.

3. Use of Simulators

   Driving simulators that replicate real-world work zone challenges, such as lane shifts, nighttime operations, or unexpected queues, can improve driver preparedness without putting them (or other motorists) at risk.

Non-CMV Outreach

1. Public Service Announcements (PSAs)

   Simple PSAs via radio, TV spots, or social media can remind passenger vehicle drivers about the stopping distances of large trucks and the importance of avoiding last-second merges near CMVs in work zones.

2. Work Zone Safety Driver Education Programs

   Free, online, self-paced work zone safety courses for new teen drivers are available via https://www.workzonesafe.com/. Oklahoma and Wisconsin teens are required to complete the "Work Zone Safe" course before obtaining their intermediate license, and Pennsylvania's new drivers are recommended to include the same curriculum. The course modules teach work-zone signage recognition, merging strategies, and first-responder awareness.

   FMSCA's Work Zone Safety Tips provide additional shareable and printable materials encouraging drivers to research their route and plan ahead, be attentive and drive slower in work areas, move into the open lanes of traffic, maintain a safe distance from the vehicle in front, and never cut off a truck or bus.[39]

3. Motor Club and Fleet Partnerships

   Collaborate with organizations like the American Automobile Association (AAA) or large delivery fleets to spread key safety messages: avoid tailgating CMVs, do not cut them off in a merge zone, and stay clear of truck blind spots.

4. Work Zone Awareness Campaigns

   Leverage nationwide events such as National Work Zone Awareness Week or local work zone safety campaigns. Emphasize that the majority of serious injuries in CMV-involved crashes often befall occupants of passenger vehicles.

These education efforts support the Safe System Approach element of Safe Road Users, reinforcing responsible driving behaviors and heightened vigilance in dynamic work-zone environments.[38]

COLLABORATIVE APPROACHES

A Safe System thrives when multiple stakeholders coordinate their efforts, pooling insights and resources to improve outcomes for CMV safety in work zones.

Work Zone Road Safety Audits (WZ RSAs)

The WZ RSA is a formal proactive examination of TTCP and field conditions by an independent multidisciplinary team distinct from a simple design compliance review to identify safety concerns and recommend countermeasures before crashes occur. Agencies are encouraged to apply WZ RSAs on projects with elevated risk factors, complex traffic configurations, or significant CMV volumes to ensure proactive safety management. WZ RSAs follow an eight-step process.[40]

1. Identify candidate work zones.
2. Select an audit team.
3. Conduct a start-up meeting.
4. Perform field review.
5. Analyze and report findings.
6. Present findings to the road owner.
7. Prepare a formal response.
8. Incorporate findings into final plans and future standards.

Pre-construction RSAs occur at two stages: the preliminary stage, when TTCP concepts remain flexible, and the detailed stage, once elements such as tapers, channelizing devices, barriers, and signing are finalized. A multidisciplinary team reviews the TTCP to identify potential design deficiencies, such as insufficient taper lengths, narrow lane widths, or missing positive protection, and to verify that MUTCD and other State or agency-specific standards and preferences have been applied correctly and are sufficient to address identified risks.[40,41]

Construction-phase WZ RSAs confirm that field installations conform to the approved TTCP by checking device placement, barrier performance, and sign visibility under live traffic and flagging any deviations for immediate correction.[40,41]

Post-construction RSAs, or after-action reviews, analyze safety and operational metrics to determine whether corridors that met all requirements still exhibit elevated crash rates and to recommend refinements to TTCP details, training curricula, and interagency procedures.[40,41]

Multi-Agency Task Forces

Regional Coordination: In corridors that cross jurisdictional boundaries, a multi-agency task force (including the State DOT, local agencies, highway patrol, and FMCSA) could synchronize enforcement and messaging and coordinate cohesive detour plans. In addition, it could establish protocols for routinely sharing upcoming work-zone schedules, locations, lane configurations, and expected durations.

Data and Planning Information Sharing: Beyond exchanging crash data, traffic volumes, and enforcement metrics, partners could circulate advance notifications of planned work-zone characteristics, such as geometric shifts, speed zone changes, and staffing levels, to help all agencies anticipate operational needs and adjust enforcement, signing, and public outreach accordingly.

Carrier Engagement

Real-Time Information: Work with large trucking carriers and telematics providers to deliver in-cab alerts (e.g., queue warnings, ramp closures, alternate routing) via ELDs or dispatch messages.

Safety Feedback Loop: Encourage drivers and carriers to report near misses or confusing signing, so agencies can adapt swiftly (e.g., by adding or relocating portable message signs).

Community and Industry Partnerships

Local Businesses: In areas heavily dependent on trucking (e.g., near ports or distribution centers), coordinate with business owners to schedule large delivery windows outside of peak construction times.

Worker Unions and Contractors

Contractor staff and union representatives can offer on-the-ground perspectives. If work zone modifications are used to accommodate unexpected truck volumes, contractors can quickly adjust channelizing devices or staging areas.

Technical and Academic Collaboration

Universities: Partner with research centers on pilot projects (e.g., testing new queue detection equipment, analyzing the effectiveness of VSLs for CMV compliance).

Peer Exchanges: Host or attend workshops, site visits, and case-study forums where DOTs, local agencies, contractors, and university partners share engineering innovations like temporary barrier systems, channelizing device layouts, queue-detection technologies, and dynamic signing strategies, as well as operational lessons on enforcement and in-cab alerts. Highlight practical demonstrations of infrastructure-based countermeasures together with behavioral approaches to speed up the adoption of proven work-zone designs for CMV safety.

Agencies can maintain a holistic perspective that unites design, enforcement, and education by actively engaging these strategic stakeholders and partners. Cooperative approaches also encourage ongoing innovation, enabling continuous improvements to CMV safety in work zones.

CHAPTER 6. FUTURE DIRECTIONS, CONCLUSION, AND RECOMMENDATIONS

This final chapter highlights emerging trends, innovative technologies, and recommended next steps for agencies seeking to enhance CMV safety in work zones. It provides a summary of the Safe System Approach strategies covered in previous chapters and offers direction on how stakeholders can continue evolving their approaches.

FUTURE DIRECTIONS AND INNOVATIONS

1. Connected and Automated Vehicles (CAVs)

    - Enhanced In-Cab Alerts: As more CMVs adopt connected technology, fleets and agencies can leverage real-time data to push dynamic route information and queue warnings directly to drivers.

    - Platooning and Automation: Emerging automation features, such as truck platooning or advanced driver-assistance, could help maintain consistent speeds and reduce sudden braking events in work zones.

    - Automated and Cooperative Driving: Long-term, fully autonomous or cooperative vehicles may further minimize human errors, offering significant safety gains by negotiating work zones more predictably. For example, VISSIM-based research on cooperative adaptive cruise control (CACC) truck platooning in freeway work zones shows measurable safety improvements under simulated high-volume, constrained environments.[42]

2. Scalable Pilot Projects

    - Smart Work Zones: Sensor-based portable traffic signals, Artificial Intelligence (AI)-driven queue detection, and real-time traveler information can be piloted on smaller corridors before wider deployment. In recent years, many manufacturers have incorporated SWZ technologies into their TTC devices, increasing the availability of devices for SWZ applications and pilot projects.

    - Moveable Barrier Systems: These systems involve rigid-wall trailers towed by semi-tractors, creating protected environments for crews. They can be quickly deployed, repositioned, and removed, minimizing worker exposure and maximizing work time during lane closures. These barriers provide continuous separation from traffic, reducing distraction and glare, and eliminate the need for buffer lanes, keeping more lanes open. They may include truck-mounted attenuators, onboard storage, power, lighting, or signage. Proper coordination of routes, staging, and storage is essential, with optional rear-mounted cameras for precise placement. Research suggests flexible lane configurations can reduce CMV crash risks on busy interstates.[43]

3. Data-Driven Planning

    - Data Describing Non-Recurring Events: Federal initiatives, including Managing Disruptions to Operations Data Exchange (MDODE) and the Work Zone Data Initiative (WZDI), encourage real-time identification of work zones and other disruptive non-recurring events, and data exchange standards to describe these events and communicate this information between organizations and systems. Broad accessibility to this type of data can assist in proactive route planning, hazard notification and avoidance, and linkage with telematics or crash records for predictive analytics and proactive interventions.

    - Big Data Integration: Agencies increasingly tap crowd-sourced speed data to identify real-time slowdowns, distributing that information through traveler information systems and ELDs.

4. Continual Workforce Development

    - Training and Certifications: State DOT staff, consultants, and contractors implementing these measures can benefit from ongoing professional development on the latest in SWZ technologies, connected vehicle standards, and CMV effective practices.

    - Collaborative Research: Further academic and private-sector collaborations can drive innovation, fostering new devices or strategies and evaluating existing practices to serve CMVs in constrained environments more effectively.

ACTIONABLE RECOMMENDATIONS

The following recommendations translate the preceding chapters into tangible steps for each major stakeholder group. While many of these strategies overlap, organizing them by audience helps clarify responsibilities and encourages integrated solutions.

For Planners and Project Scoping Teams

1. Apply Early Safety and Mobility Screening

    - 23 CFR § 630.1006(b) requires that each State "identify safety and mobility performance measures that will be used to manage work-zone performance." Select candidate projects for enhanced CMV and transit mitigation by tracking delay, queue length, speed loss, and crash frequency against agency thresholds.

    - Flag projects likely to exceed thresholds for development of complete TMP and conduct an RSA before preliminary engineering solutions are examined. Document anticipated conflicts with transit routes and facilities and gather input from affected transit agencies throughout TMP development and construction.

- Engage bus operators during TMP scoping to identify critical routes, peak dwell times, and necessary stop amenities; document agreed detours, stop relocations, and phases in the TO plan.

2. Corridor Sequencing & Freight Assessment

    - Map planned lane closures, detours, and night work across overlapping projects to ensure at least one high-capacity route remains open for CMVs, including any bus routes.

    - Run regional travel-demand or dynamic-traffic-assignment models to estimate CMV queue length, travel-time loss, and exposure hours for each staging option.

    - Adjust phasing, detour geometry, or contract incentives when modelling shows cumulative delay beyond reasonable limits.

3. Early Documentation of Mitigation Commitments

    - Record truck-only detours, interim bus-stop relocations, and time-of-day lane-closure restrictions in the draft TMP so design and construction teams can plan resources and budget.

    - Convene an interdisciplinary planning workshop with freight shippers, motor-carrier representatives, and transit agencies to validate these commitments and identify seasonal freight surges or fixed-route constraints. Conduct pilot programs and evaluate data.

    - Tie the agreed-upon measures to project performance goals and include them in project public information and outreach plans.

For Engineers and Designers

1. Integrate CMV Considerations into Work Zone Planning

    - Accommodate the size and operational characteristics of CMVs (wider lanes and sufficient vertical clearance along all project routes and detours).

    - Incorporate SWZ tools like queue warning systems, variable speed limits, and real-time data feeds.

2. Enhance Visibility and Signing

    - Use high-performance retroreflective materials on signs and channelizing devices.

    - Ensure signing is visible from higher CMV cabs and keep it clear of obstructions.

3. Leverage Emerging Technologies

    - Stay informed about autonomous and connected vehicle developments that can affect work zone design (like C-V2X-based "work zone ahead" alerts).

    - Pilot or adopt driver assistance systems (e.g., lane-keeping assist) in agency fleets to evaluate how they operate in TTC areas.

4. Conduct Pilot Programs and Evaluate Data

    - Implement new strategies (e.g., mobile barrier systems, truck-only lanes) on a trial basis to gather before-and-after safety metrics.

    - Document successes and challenges so that lessons learned can be applied to future projects.

For Agencies and Organizations

1. Promote Interagency Collaboration

    - Foster cooperation between State DOTs, FHWA, FMCSA, local jurisdictions, law enforcement, and Trucking and Bus associations to coordinate enforcement, share resources, and streamline detour planning.

    - Form regular task forces or working groups that review ongoing work zones and discuss near-miss incidents. See the Collaborative Approaches segment in Chapter 5 for more information.

2. Consider Investment in Enforcement Initiatives and Driver Education

    - Expand enforcement in high-risk corridors (e.g., SSCs, P2P enforcement) where permitted by law.

    - Develop or fund driver education campaigns, emphasizing the risks of distracted driving and speeding in work zones.

3. Regularly Update Standards and Manuals

    - Consistently revise design manuals to train design and field staff on new work zone layouts. Evaluate past results and review finalized RSA documentation (see Chapter 5 for more information), as well as the historical safety performance of work zones to pinpoint areas where standards and manuals can be enhanced.

    - Incorporate advanced driver assistance systems (ADAS) considerations into operational procedures, ensuring new technologies work seamlessly in TTC zones.

4. Identify Data Gaps for Ongoing Research

    - Collect and analyze crash and operational data to pinpoint recurring CMV safety issues.

    - Collaborate with academic institutions to study emerging hazards or evaluate novel technologies (e.g., truck platooning in long-term work zones).

For CMV Operators and Drivers

1. Adhere to Safe Driving Practices

    - Maintain adequate following distances and respect posted speed limits, especially in areas with reduced lane widths or abrupt merges.

    - Consult FMCSA's Driver Resource Hub, which includes safety guidance and additional information for CMV operators. (*see Resources*). Stay alert for changing conditions; anticipate the need for early braking to avoid rear-end collisions.

2. Embrace Connected and Automated Features

    - Where available, enable in-cab warning systems or telematics apps that provide real-time updates on lane closures, detours, or incident locations.

    - Offer feedback to technology providers or agencies if alerts are unclear, redundant, or slow to update.

3. Collaborate with Stakeholders

    - Report confusing signing or near-miss incidents to dispatchers or local authorities, helping them refine TTC plans.

    - Participate in pilot programs (e.g., testing partial automation or speed limiters) and share on-the-ground insights.

For Passenger Vehicle Drivers

1. Integrate CMV-Focused Training into Licensing Requirements

    - State-Mandated Module: Consider requiring all new and renewing license applicants to complete a concise, interactive training module on sharing the road with CMVs in work zones. Cover blind spot awareness, safe passing distances, and safe merging procedures when adjacent to large trucks or buses.

    - Interactive Scenarios: Use video simulations or web-based scenarios illustrating common work-zone conflicts (like cutting off a CMV in a narrowing lane). Leverage

FHWA-developed outreach materials and State DMV testing platforms to host short video scenarios with embedded knowledge checks to reinforce correct responses.

- Partnerships: Collaborate with State DMVs, third-party testing centers, and motor-vehicle associations to develop standardized e-learning content that can be updated as best practices evolve.

- Public Accountability: Display completion rates and post-module survey results on State DMV websites to build public trust and drive continuous improvement of the training content.

2. Increase Awareness of CMV Operational Challenges

    - Understand that CMVs often have extensive blind spots and need greater stopping distances.

    - Give CMVs space when merging or changing lanes to minimize conflicts in areas where lanes shift frequently.

3. Follow Work Zone Instructions and Drive Cautiously

    - Obey reduced speed limits and heed signing, especially where lane closures or flagging operations are active.

    - Minimize distractions (texting, eating, speaking with passengers) and remain alert to sudden slowdowns common in work zones.

4. Support a Safer Driving Environment

    - If you observe hazardous behaviors (such as severe tailgating around CMVs), consider reporting them through appropriate channels.

    - Share safe driving tips within your community or workplace, emphasizing that most fatalities in CMV-involved crashes are occupants of smaller vehicles.

CLOSING NOTE

Enhancing CMV safety in work zones demands a multifaceted approach that addresses engineering and design, enforcement, driver education, and innovative policy. By adopting these actionable recommendations and remaining vigilant about emerging technologies and data-driven improvements, stakeholders across the transportation ecosystem can significantly reduce CMV-related crash risks and ensure safer passage for all road users.

CHAPTER 7. CMV SAFETY IN WORK ZONES CHECKLIST

PLANNING AND SCOPING PHASE

1. Preliminary Data Collection & Crash Review
   - ☐ Gather existing CMV crash data and identify any corridors or segments with high freight traffic
   - ☐ Examine the project area's pre-work zone crash history (focusing on rear-end collisions, lane-departure incidents, hard-braking events, etc.) to help inform early decisions
   - ☐ Incorporate a review of available data-driven tools and resources such as State DOT "Top Concern Locations" lists, GIS dashboards showing operational speeds and crash metrics, non-motorized traffic dashboards, and real-time data exchanges on safety performance
   - ☐ Collect transit data: map existing bus routes, stop locations, ridership volumes, and any crash history at stops to identify high-risk locations

2. Stakeholder Identification
   - ☐ Identify relevant parties (e.g., FMCSA, law enforcement, maintenance staff, local agencies, motor carrier representatives) who can offer insights on CMV operations
   - ☐ Initiate lines of communication for data sharing and potential collaboration
   - ☐ Engage transit stakeholders: include local transit agencies, bus operators (and paratransit providers), and ADA coordinators to capture bus stop and service-reliability concerns

3. Early Freight and CMV Considerations
   - ☐ Screen for large-truck access needs (e.g., overhead clearances, turning radii, high freight volume)
   - ☐ Decide if CMV detours or specialized corridors may be involved, especially on projects that cross multiple jurisdictions
   - ☐ Identify potential stop relocations: plan for temporary bus stops with ADA-compliant boarding and continuous pedestrian paths

4. Initial Risk Assessment
   - ☐ Determine if terrain (steep grades, winding segments) or unique site conditions (limited shoulders, narrow bridges) could elevate CMV crash risk
   - ☐ Identify any ongoing or upcoming projects that might overlap or create complex detours or lane limitations for freight traffic
   - ☐ Review project location and review TTCP plans as part of the initial RSA.

5. CMV-Focused Planning Constraints
   - ☐ Explore possible funding avenues or special programs (e.g., grants for SWZ deployments) if advanced freight strategies are anticipated

- Outline high-level project goals that address CMV safety (e.g., reduce rear-end collisions by X percent, provide safe passage for pedestrians, micromobility users, and other non-motorized traffic)
- Add transit reliability targets: set goals to maintain on-time performance for affected bus routes and minimize passenger delays

6. Early Public Information and Outreach Strategy
   - Determine how CMV operators and the public will be informed about upcoming lane restrictions or changes (e.g., State DOT social media, project website, newsletters)
   - Discuss potential partnerships with telematics providers to implement in-cab alerts once design details are set
   - Coordinate rider communications: work with transit agencies to notify passengers of stop relocations, schedule adjustments, and safe temporary boarding locations

DESIGN PHASE

1. Apply Safe System Roadway Design Hierarchy Tier 1 Strategies: Remove or Separate Conflict
   - Provide robust physical separation between travel lanes and the work area, using portable concrete or steel barriers
   - For project areas with significant CMV traffic, evaluate the need for dedicated CMV lanes for traversing through the work area and separated detours to accommodate CMVs

2. Apply Safe System Roadway Design Hierarchy Tier 2 Strategies: Reduce Vehicle Speeds
   - Set Appropriate Speed Limits
     - Select realistic, context-based speed limits for each stage of construction, referencing data from the Planning & Scoping Phase
   - Incorporate Speed Management Strategies
     - Plan for Incorporation of speed management tools such as SSCs, P2P if permitted by law
     - Plan for speed adjustments in real time if traffic volumes or queue lengths fluctuate significantly, if allowed per State laws

3. Apply Safe System Roadway Design Hierarchy Tier 3 Strategies: Manage Conflicts in Time
   - Signal or Flagging Needs
     - Determine if alternating one-lane TTC zones will be involved, and specify timing for heavy trucks (e.g., longer green intervals)
   - Night vs. Day Work
     - If phasing construction occurs at night, confirm adequate lighting and consider truck traffic peaks to reduce conflict

4. Apply Safe System Roadway Design Hierarchy Tier 4 Strategies: Increase Attentiveness and Awareness
   - Signing Plans
     - Map out permanent and temporary signs, focusing on earlier warnings for CMVs that need extra braking distance
   - Driver Alert Features
     - Incorporate rumble strips, changeable message signs, and queue warnings upstream of potential slowdowns[45].

5. Prepare Plans, Specifications & Estimate (PS&E) Package
   - Identify and quantify pay items for all temporary traffic control elements (barriers, signs, channelizing devices, detours, ITS tools, and any temporary bus-stop accommodations) and include them in the PS&E package.

6. Work Zone Access/Egress
   - Safe Entry/Exit Points
     - Define where construction vehicles (including large trucks) will enter or exit, with attention to turning radii and sight distance (signing for each entrance/exit may be beneficial for subcontractors)
     - Provide sufficient vertical clearance along work zone access/egress points.
   - Acceleration/Deceleration Lanes
     - If geometry allows, include paved acceleration/deceleration lanes to reduce abrupt merging into mainline traffic

7. Include Smart & CMV-Focused Countermeasures
   - Review CMV Safety Countermeasures
     - Reference applicable proven strategies such as speed feedback signs and movable barriers in design documents
   - Budgeting for Technology
     - Factor in costs for potential in-cab telematics partnerships, queue detection systems, or truck-aimed message signs

CONSTRUCTION PHASE

1. Speed & Queue Management
   - Implement Speed Controls
     - Use speed feedback trailers or SSCs if allowable by State law
   - Monitor Queues
     - Deploy sensors or cameras to detect backups; trigger “SLOW TRAFFIC AHEAD” messages or similar context-appropriate messaging to alert CMVs and other drivers early to the work area conditions

2. Smart Work Zone Activation
   - Dynamic Merge Systems
     - If specified in the design, activate sensor-based signing guiding drivers when to merge
   - In-Cab Alerts
     - If a data-sharing agreement exists, feed real-time traffic conditions to CMV telematics solutions

3. Frequent Lane Condition Checks
   - Striping & Channelizing Devices
     - Inspect after every phase shift or for longer projects at predetermined intervals to confirm adequate lane width for CMVs
   - Barrier & Pavement Maintenance
     - Ensure reflectivity of pavement markers and barrier retroreflective strips. Ensure transition areas are safe and without drop-offs

4. Enforcement Collaboration
   - Law Enforcement Coordination
     - Schedule targeted patrols for times of day with peak truck volumes or frequent conflicts
   - Work Zone Safety Citations
     - Record speeding or lane violation trends, adjusting enforcement presence as needed

5. Public & CMV Outreach
   - Real-Time Updates
     - Keep websites, social media, or phone hotlines updated with new closures or detours that affect CMVs
   - Truck Stop Notices
     - Post signs at nearby rest areas or weigh stations to inform drivers of unexpected lane closures or major shifts

6. Ongoing Data Collection
   - Speed & Crash Metrics
     - Track average speeds for both CMVs and passenger vehicles, plus near-miss or crash events
   - Queue Length Measurements
     - Note how often traffic backups exceed thresholds that might endanger CMVs (e.g., segments with limited sight distance)

7. Performance Assessments
   - Identify Persistent Problems
     - If rear-end crashes continue, add more signing, monitor queue, review posted speed limit thresholds, or introduce additional enforcement

- Conduct work zone RSA to identify any shortcomings early in the project timeline after the work zone layout is completed and periodically or after phase changes for complex work zones.
- Adapt Work Zone Layout
  - Adjust lane closures, shift barrier locations, or modify lane widths if data indicate safety improvements are involved.

8. Stakeholder Communication
   - Weekly/Monthly Calls
     - Invite trucking and bus industry representatives, local DOT staff, EMS, project workers, CMV drivers and law enforcement to provide feedback.
   - Mid-Project Adjustments
     - Implement changes (e.g., adjusting signing or adding rumble strips) swiftly if stakeholder feedback flags significant safety risks.

PROJECT CLOSE-OUT

1. Document Lessons Learned
   - Successes & Challenges
     - Summarize which strategies reduced crash severity or frequency or improved CMV flow
   - Data & Outcomes Sharing
     - Provide references (e.g., crash rates, queue statistics) for use in future corridor designs or pilot programs

2. Compare to Baseline
   - Pre- vs. During-Construction Analysis
     - Examine CMV crash involvement frequency, speed variance, and other safety metrics
   - Note Long-Term Adjustments
     - Evaluate the effectiveness of short-term measures such as VSL and enhanced signing and if they prove effective, consider whether to include them as permanent features

3. Post-Project Dissemination
   - Regional/National Exchanges
     - Present key insights at conferences or share within State DOT peer networks
   - Pursue Grants or Safety Awards
     - Evaluate If the project led to a significant drop in CMV-involved crashes. Consider applying for grants that could expand these approaches to be more broadly applied
     - Document effective countermeasures by significance and associated cost to help with standardization and incorporation into future projects

APPENDIX A. RESOURCES

1. Commercial Motor Vehicle Safety
   Clearinghouse topic page offering data, trends, case studies, and actionable guidance specifically on CMV safety in work zones
   URL: https://workzonesafety.org/topics-of-interest/large-truck-safety/

2. Commercial Motor Vehicle Safety in Work Zones Targeted Action Plan
   FHWA's targeted action plan presenting crash statistics, noteworthy State DOT practices, and best-practice guidance to improve CMV safety and mobility in work zones
   URL: https://ops.fhwa.dot.gov/wz/cmv_safety/index.htm

3. Safe System Roadway Design Hierarchy
   FHWA framework document that categorizes engineering and infrastructure-based countermeasures into tiers aligned with Safe System Approach principles.
   URL: https://highways.dot.gov/sites/fhwa.dot.gov/files/2024-01/Safe_System_Roadway_Design_Hierarchy.pdf

4. Connected Work Zone Implementation Guidance Standardization
   ITE's consensus-based standard defining the essential data elements, capabilities, and interfaces for connected work zones to ensure interoperability and enhance safety.
   URL: https://www.ite.org/technical-resources/standards/cwz/

5. Work Zone Data Exchange (WZDx)
   FHWA led open data specification that allows for harmonized, real-time sharing of work zone details, including smart device data and non-work zone restrictions, to enhance safety, mobility, and automated vehicle navigation.
   URL: https://ops.fhwa.dot.gov/wz/wzdx/

6. Transportation Management Plans (TMPs)
   Clearinghouse resource detailing coordinated strategies, State-specific templates, and guidelines for developing and implementing TMPs to effectively manage work-zone impacts.
   URL: https://workzonesafety.org/topics-of-interest/transportation-management-plans/

7. Implementing the Proven Safety Countermeasures in Work Zones
   FHWA guide describing application of Proven Safety Countermeasures, including RSA integration, under the Safe System Approach.
   URL: https://highways.dot.gov/sites/fhwa.dot.gov/files/2024-10/PSCs_Work%20Zone%20Informational%20Guide_508.pdf

8. Manual on Uniform Traffic Control Devices (MUTCD) 11th Edition
   National standard for all traffic control devices. Published January 2024, with sign design updates in March 2025
   URL: https://mutcd.fhwa.dot.gov/

9. NHTSA Fatality Analysis Reporting System (FARS)
Data system providing detailed fatal crash statistics, including CMV involvement in work zones, used extensively in FHWA analyses.
URL: https://www.nhtsa.gov/crash-data-systems/fatality-analysis-reporting-system

10. Commercial Motor Vehicle Safety in Work Zones Targeted Action Plan (PDF) Detailed action plan report (FHWA-HOP-20027).
URL: https://ops.fhwa.dot.gov/publications/fhwahop20027/fhwahop20027.pdf

11. U.S. Department of Transportation, Federal Motor Carrier Safety Administration. Driver Resource Hub. 2025. Centralized portal aggregating FMCSA tools and guidance for commercial motor vehicle drivers on licensing, training, safety compliance, and regulatory updates.
URL: https://www.fmcsa.dot.gov/driver-resources

APPENDIX B. REFERENCES

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