CHAPTER 20
SAFETY AND TRAFFIC ENGINEERING

20.0 INTRODUCTION

The mission of CDOT's Safety and Traffic Engineering Branch is to reduce the incidence and severity of motor vehicle crashes and the associated human and economic loss. This chapter addresses most, but not all, important design issues related to providing a safer transportation system.

20.1 ROADWAY SAFETY

Major factors affecting highway safety are the roadway and roadside features, driver ability and awareness, environmental factors, and vehicle characteristics. Highway safety is greatly influenced by variations among drivers (human factors). The drivers' knowledge and driving performance in a given environment or roadway condition are the primary determinants of safety. However, there are other factors such as highway design that also have a tangible impact on safety.

Design consistency in terms of geometry, cross section, and hazard shielding and mitigation should be maintained for entire corridors to minimize unexpected conditions. Advance warnings of changing conditions should be provided.

The designer should request from the Safety and Traffic Engineering Branch a detailed safety assessment report or a traffic operations analysis. The report or analysis will make recommendations for safety improvements based upon factors that include accident history, hazard severity, and cost. The designer should document decisions to apply or not to apply any given safety feature in accordance with CDOT Policy Directive 548.0, *Safety Considerations on 3R Projects* **(1)** and Design Bulletin 2005-1 **(2)**.

Primary references for safer designs are the AASHTO *Highway Safety Design and Operations Guide* **(3)**, and the AASHTO *Roadside Design Guide* **(4)**.

20.1.1 Bicycle and Pedestrian Safety

Bicyclists and pedestrians should be considered when scoping all projects. Bicycle and pedestrian traffic, shoulder width, and shoulder rumble strips should be addressed during the scoping stage of any project, including resurfacing projects.

See Chapter 14 of this Guide, “Bicycle and Pedestrian Facilities.”

20.1.2 Railroad-Highway Grade Crossings

Railroad-highway grade crossings involve two distinct modes of transportation with different operating authorities and operating characteristics. Roadway and railway may intersect at-grade, or may be grade-separated by a structure that carries the roadway over or under the railroad. The majority of the nation’s railroad-highway grade crossings remain at-grade. A railroad-highway grade crossing is typified by continuous vehicular traffic, interrupted periodically by a train’s passage. The intermittent nature of train operations may dull a driver’s awareness to a train’s possible approach. Some drivers are tempted to disregard warnings and try to beat a train through the crossing. Except in unusual circumstances, trains have the right-of-way due to their huge mass, which often results in very long stopping distances. Safety at railroad-highway grade crossings is of utmost importance. The designer should include appropriate features to discourage risky driver behaviors, to provide sufficient advance notice of the grade crossing and of a train’s approach or presence, and, as appropriate, to physically prohibit vehicles from entering the crossing.

Strategies for improving railroad-highway grade crossing safety include upgrading warning devices and improving the geometry, sight distance, and ride quality of the crossing. Active grade crossings contain train-activated devices that warn drivers of the approach or presence of a train. When new devices such as gate supports are installed, they may become roadside hazards and warrant shielding from errant vehicles.

Passive grade crossings lack such warning devices and rely on signs and pavement markings to identify the crossing location. Passive grade crossings have a higher risk for crashes because there is less direct control over driver actions. Where passive grade crossings remain in place, enhanced sign systems may increase driver awareness and responsiveness.

Active railroad-highway grade crossings that are located adjacent to a signalized roadway intersection increase the complexity of signing and signals. Drivers may receive conflicting information from such closely spaced signals, or traffic stopped at the adjacent signalized intersection may queue back onto the grade crossing. Consideration should be given to interconnecting the traffic control signal with the active control system of the railroad crossing and providing a "pre-emption" sequence. With pre-emption, the approach of a train causes the traffic signals to enter a special mode to control traffic movements in coordination with the train's passage through the crossing. Traffic control signals near rail-highway grade crossings shall conform to Section 8.07 of the *Manual on Uniform Traffic Control Devices for Streets and Highways (MUTCD)* **(5)**; and pre-emption shall conform to Part 4D.13 of the *MUTCD*.

When a railroad-highway grade crossing is located within the limits of a rehabilitation project, the crossing, along with any existing devices, should be relocated or reconfigured as necessary to be compatible with changes to the highway. A safety assessment of the existing crossing should also be made and, to the extent feasible, the project should include any appropriate crossing safety improvements.

In 1991, the Federal Railroad Administrator established a goal of closing 25 percent of all railroad-highway grade crossings in the country. Closing unnecessary grade crossings improves safety by eliminating the potential for vehicle-train crashes and by concentrating limited safety funds on the remaining crossings. Guidance for eliminating and consolidating railroad-highway grade crossings is provided in "AASHTO Highway-Rail Crossing Elimination and Consolidation" **(6)**.

The transportation bill, SAFETEA-LU **(7)**, has funding provisions in Section 148 for the elimination of hazards and the installation of protective devices at railroad-highway grade crossings. Projects are identified and prioritized based on a hazard analysis and benefit/cost ratio. All projects involving work on railroad property or adjustments to railroad facilities require a written contract among CDOT, the railroad, and any involved local agencies. Any changes to a grade crossing's operating characteristics should also be coordinated with the Colorado Public Utilities Commission (PUC). The CDOT Safety and Traffic Engineering Branch Utilities Unit administers the highway-rail grade crossing program and is the Department's point of contact with the railroad, the PUC, and local agencies on all CDOT railroad contracts.

For additional guidance on railroad-highway grade crossing components, safety assessment, safety measures, project development, and traffic control, see:

- *FHWA Railroad-Highway Grade Crossing Handbook* **(8)**.

- *FHWA Guidance on Traffic Control Devices at Highway-Rail Grade Crossings* **(9)**.
- *Manual on Uniform Traffic Control Devices (MUTCD)* Part 8 **(5)**.
- *CDOT Railroad Manual* **(10)**

20.1.3 Roadway Geometry Considerations

Horizontal curves typically have crash rates from 1.5 to 4 times higher than tangent sections. Crash rates tend to increase with the reduced sight distance associated with either a reduced curve radius or an increased deflection angle. Therefore, it is usually beneficial to maximize curve radii and minimize deflection angles when designing alignments. The use of spiral curves can help to mitigate some of the safety problems associated with horizontal curves by:

- Providing a safer path for the driver from a tangent position to a curve position
- Providing a location for the required length of transition from normal crown to full superelevation.

The attributes of spiral curves are explained in section 3.2.2.2 and the *PGDHS* **(11)**.

Vertical curves can also lead to higher crash rates due to the reduced sight distance imposed by the crest of a vertical curve. Accordingly the designer should minimize the severity of vertical curvatures in the alignment design. Intersections located on or near vertical curves should be investigated thoroughly and avoided when practical alternatives can be found.

20.1.4 Intersections

Intersections are the major points of conflict in roadways. Safety measures that can reduce conflict, particularly from left turns, include medians, protected left-turn phasing of signals, and auxiliary lanes. Left-turn lanes should be designed with an offset toprovide for proper sight distance to oncoming traffic when a vehicle is in the opposing left-turn lane. Safer methods for accommodating pedestrian and bicycle traffic movements through the intersection should also be considered (see Chapter 14). All-way stops or roundabouts may sometimes be desirable alternatives to traffic signals. Criteria for all-way stops are found in Section 2B of the *Manual on Uniform Traffic Control Devices (MUTCD)* **(5)**. Further information on roundabout design is found in Chapter 19 of this Guide and FHWA's *Roundabouts: An Informational Guide* **(12)**.

"Stop Ahead" warning signs should be placed ahead of intersections where the driver may not anticipate the required stop or where sight distance is obstructed. For additional emphasis, a yellow beacon above the “Stop Ahead” sign, a red beacon above the “Stop” sign, or both can be considered.

The designer must consider to corner radii and sight distances at intersections. A large corner radius can increase the roadway crossing width, making it difficult for pedestrian crossing, and will allow for increased vehicle speed around intersection corners. Conversely, too small a radius can cause maneuverablity problems for large vehicles.

As part of a project, traffic signals should be rebuilt or modified to comply with current standards and to meet design traffic demands.

It is essential to have proper application of traffic control devices to designate right of way and safe movement of all traffic, including pedestrians and bicyclists. Follow the standards published in the latest edition of the *MUTCD* **(5)**.

20.1.5 Interchanges

Interchanges usually do not have the direct conflicts of intersections, but the vehicle merge areas often show a high frequency of crashes.

A large portion of truck crashes occurs at interchanges. The potential for overturning of high profile vehicles increases on circular ramps. Adequate signing, careful attention to merging patterns, and ramp geometrics can mitigate these problems. These concepts are detailed in the *Highway Capacity Manual* **(13)**. See chapter 10 for interchange design.

20.1.6 Context Sensitive Solutions

Safety is a challenge to be addressed on every project. It may not be the primary driver for a given project, but it should be a consideration in the development and evaluation. Context Sensitive Solutions (CSS) equally address safety, mobility, and the preservation of scenic, aesthetic, historic, environmental, and other community values. To balance these values the design process should be flexible in adherence to standards and criteria. A successful context-sensitive solution produces transportation solutions that are both safe and feasible. CSS maintains safety and mobility as priorities, yet recognizes that these are achieved in varying degrees with alternative solutions. Utilizing the CSS philosophy, CDOT design professionals determine which safe solution best fits, given the site's conditions and context. CSS is about making good engineering decisions.

NCHRP Report 480, *A Guide to Best Practices for Achieving Context Sensitive Solutions (CSS)* **(14)** discusses two types of safety: nominal safety and substantive safety. "Nominal safety" equates adherence to standards or design policy with achieving safety, and considers substandard designs to be unsafe. Under the nominal safety concept, a roadway designed to current or modern criteria would be characterized as 'safe'. However, engineers should also consider substantive safety in the design process. Substantive safety refers to the actual (or expected) crash frequency and severity for a highway or roadway.

These two types of safety should be considered when addressing a safety problem. The solution should balance cost, environment, and other stakeholder values. High-accident locations with substandard design features should be priorities for improvement. Locations that are nominally safe, but substantively less safe also should be considered.

For every project, the setting and character of the location, the values of the community, and the needs of highway users should be balanced.

Consider the following:

- Flexibility provided within the standards.
- Design exceptions where there are environmental concerns.
- Opportunities to re-evaluate decisions made in the planning phase.
- Design speed.
- Preservation of existing horizontal and vertical geometry, cross section, and design for resurfacing, restoration, and rehabilitation (3R) improvements where it is known that safety problems do not exist.
- Alternative standards for a corridor or scenic route.
- Safety and operational impact of various design features and modifications.

These concepts are discussed in detail in NCHRP Report 480, *A Guide to Best Practices for Achieving Context Sensitive Solutions (CSS)* **(14)** and *Flexibility in Highway Design* **(15)**. Additional information on context-sensitive solutions can be found in the following references:

- NCHRP Report 480, *A Guide to Best Practices for Achieving Context Sensitive Solutions***(14)**
- NCHRP Report 374, *Effect of Highway Standards on Highway Safety* **(16)**
- NCHRP Project 430, *Improved Safety Information to Support Highway Design* **(17)**
- NCHRP Report 362, *Roadway Widths for Low-Traffic-Volume Roads* **(18)**

- IHSDM: *Interactive Highway Safety Design Model* **(19)**
- FHWA-RD-99-207, *Prediction of the Expected Safety Performance of Rural Two-Lane Highways* **(20)**
- CDOT Chief Engineer's Policy Memo 26, *Context Sensitive Solutions (CSS) Vision for CDOT* **(21)**

20.1.7 Work Zone Safety

Proper traffic control, delineation, and channelization are critical to achieving safety in work zones. A work zone can pose additional hazards to the motorist and cause risk to workers. All traffic control devices must meet the guidelines in *NCHRP Report 350, Recommended Procedures for the Safety Performance Evaluation of Highway Features* **(22)** and the *MUTCD* **(5)**. See also section 20.5.1.

20.1.8 Roadway Shoulders

Refer to CDOT Policy Directive 902.0, *Shoulder Policy* **(23)**.

20.2 REDUCING RUN-OFF-THE-ROAD CRASHES

Apply the following improvements where appropriate to reduce the frequency and severity of run-off-the-road crashes:

- Removing obstacles from the roadside
- Redesigning the obstacle
- Relocating obstacles from the clear zone
- Installing breakaway devices that reduce impact severity [NCHRP Report 350 **(22)**]
- Shielding obstacles with guardrail
- Improving delineation
- Upgrading guardrail
- Using rumble strips
- Applying Textured shoulder treatment
- Eliminating shoulder drop-offs, using safety edge technology
- Correcting superelevation
- Improving the pavement condition
- Improving the roadway geometry
- Flattening slopes

- Maintaining the clear zone

20.2.1 Rumble Strips

Studies have shown that rumble strips can reduce the frequency of run-off-the-road crashes. Rumble strips alert drivers when their vehicles stray onto the shoulder or over the centerline of the roadway. Rumble strips can also provide protection for pedestrians and bicyclists on the shoulder by discouraging motorists from straying onto the shoulder. Improperly installed rumble strips can force the bicyclist into the travel lane causing conflict with the motorists.

20.2.1.1 General Criteria

See Standard Plan M-614-1 **(24)** for rumble strip details.

To maximize a smooth shoulder surface suitable for bicycle use, rumble strips should be installed immediately adjacent to the edge of the travel lane. AASHTO considers a 4-foot width on the shoulder beyond the rumble strip to be the minimum for safe bicycling. See AASHTO's *Guide for the Development of Bicycle Facilities* **(25)**.

Rumble strips should be used on rural highways at locations where run-off-the-road type crashes are most likely to occur. These locations should include:

- On long tangents.
- At approach ends of isolated horizontal curves.
- Along steep fill slopes.
- At approaches to narrow bridges.
- At documented high-crash locations.

Rumble strips should not be used where guardrail is installed on shoulders that are less than 6 feet wide. When rumble strips are discontinued for guardrail or narrow shoulders, the rumble strip should end at least 250 feet prior to the end section of the guardrail or the narrowing of the shoulder. This will allow bicyclists room to reposition their bikes on the shoulder.

Rumble strips are not normally used in urban areas because of the noise they cause and the frequent use of the roadway shoulder for turning or parking.

When warranted by accident history, centerline rumble strips may be used to mitigate head-on, sideswipe, and opposite side run-off-the-road crashes in areas with a history of these types of crashes, mountainous areas, or areas where sight distance is constrained. When used, centerline rumble strips should be installed in "no passing" zones, but may continue into "passing" zones.

Shoulder rumble strips are somewhat less effective in mountainous areas or on roadways with a high-frequency of horizontal curves where drivers are already more attentive. Rumble strips may be omitted on steep, downhill sections to provide bicyclists with more maneuvering room, particularly where run-off-the-road accident history is low.

20.2.1.2 Installation on Interstate Highways

Rumble strips should be installed on the inside (left) shoulders of all rural Interstate highways as shown on Standard Plan M-614-1 **(24)** and may be continuous as determined by the designer. They should be installed on the outside (right) shoulders providing the shoulder width is 6 feet or greater.

20.2.1.3 Installation on Narrow Shoulders

Where the system-wide evaluation indicates a significant history of run-off-the-road crashes, rumble strips may be considered if bicycle traffic can still be accommodated. Consider applying rumble strips only in high-crash locations rather than over the entire length of the roadway.

Before installing rumble strips on narrow shoulders, the designer should weigh the benefits to motorists, versus the reduction in usable bicycle riding width. Installation of rumble strips on shoulders which are 4 feet wide or narrower will provide bicycles with less than the AASHTO recommended 4-foot clear bike path and will have a negative impact on bicycle travel.

For further information on rumble strips, refer to the FHWA Rumble Strip web site **(26)** and to NCHRP Synthesis 191 *Use of Rumble Strips to Enhance Safety* **(27)**.

20.3 ROADSIDE SAFETY

Roadside safety is improved by reducing the likelihood of a vehicle leaving the roadway and by reducing the hazards faced by an errant vehicle that leaves the roadway. This section discusses the methods and tools used to improve roadside safety. Additional strategies can be found at the joint AASHTO-NCHRP web site for implementing the Strategic Highway Safety Plan **(28)**.

CDOT has adopted the AASHTO *Roadside Design Guide* **(4)** for use in determining barrier warrants, length of needed barrier, and overall roadside design considerations. Some of the items that are covered are:

- Barrier types and characteristics.
- Methods for mitigation of obstacles.
- Clear zone concept.
- Embankments and cut slopes.
- Fixed objects.
- Shoulder drop-offs.

CDOT’s *Standard Plans - M & S Standards* **(24)** contain design and typical installation details for guardrail, end treatments and transitions. The guardrail details on the *Standard Plans* do not fit all situations. A new item or design adaptation not covered by CDOT's *Standard Plans - M & S Standards* **(24)** is not necessarily precluded from use. Consult the *Roadside Design Guide* **(4)** or contact the Standards and Specifications Unit in Project Development for additional information.

See the *Crash Cushion and End Treatment Selection Guide* **(29)** which is on the CDOT web site and contact the Standards Engineer to determine the acceptability of any alternative design.

20.3.1 Unique Hazards

Special situations may occur where protection is desirable even though not required; for example, where there is a potential obstacle that is not within the clear zone, or where there are objects with historic, environmental or economic significance.

20.3.2 Guardrail

Guardrail should be installed only at specific locations where roadside hazards warrant, and after all other possible mitigation measures have been considered. CDOT uses two primary types of guardrail: strong-post W-Beam (Type 3) and F-shaped concrete barrier (Type 7). Modified Thrie-Beam (Type 6), 3- and 4-strand cable guardrail, and other types are also used in special situations. A fully functional guardrail installation will consist of a transition (if changing rail rigidities), a run of computed length of need, and an end treatment.

Refer to section 4.9 for further information on guardrail.

20.3.2.1 Review of Accident History

For 3R projects, guardrail may be warranted in locations where there is a history of frequent run-off-the-road crashes. When available, three years of accident data should be analyzed to determine if the accident history indicates the need for guardrail.

20.3.2.2 Maintaining Continuity

Driver expectation is often a key component in determining guardrail placement. Consider how the placement of guardrail will affect the driver's perception of both the area where the guardrail is placed and the surrounding areas. Maintaining continuity of roadside characteristics is important and can affect the designer's guardrail decisions in many ways. Guardrail choices made for the first section of a corridor will affect the options available for guardrail in the subsequent sections. A decision should be made early in the scoping process on how the corridor will be designed to create a consistent type of roadway.

If a proposed guardrail installation is only marginally warranted, but the rest of the section has guardrail, then installing the guardrail may be appropriate. Placing guardrail, widening shoulders, or straightening horizontal curves may not be advisable for short sections of roadway when it will likely cause a motorist to exceed the safe operating conditions of adjacent segments yet to be improved. Improving safety in a corridor should sometimes be done in short sections, but the overall corridor safety should be maintained during the process. If isolated segments of a corridor are upgraded, a letter outlining the decision should be included in the project file.

20.3.2.3 Determination of Length

The procedure for determining the length of need for guardrail is contained in the *Roadside Design Guide* **(4)**.

20.3.2.4 Offset

Standard Plans M-606-1 and M-606-12 **(24)** list recommended offsets. As a general rule, if the shoulder width is 6 feet or less, the guardrail should be offset an additional 2 feet from the edge of shoulder. If the shoulder width is 8 feet or greater, no additional offset is required. The 2-foot offset is intended to provide additional width for opening the door of a parked or stranded vehicle.

In most cases, new guardrail should not be installed on the z-slope or side slope unless the slope is 10:1 or flatter. Where necessary, installations may be made on slopes as steep as 6:1, but only if they are located so that the errant vehicle is in its normal attitude at the moment of impact.

In general, the placement recommendations shown in the AASHTO *Roadside Design Guide* **(4)**, Table 5.5, should be followed.

20.3.2.5 Access Treatments

Short gaps between guardrail sections should always be avoided. Such gaps may allow vehicles to pass behind the rail or strike end treatments, which will cause greater damage than impacting the rail.

Short gaps should be addressed when designing access treatments. Some rules to follow include:

- Move accesses, if possible, to avoid gaps in guardrail.
- Remove obstacles around accesses (flatten slopes, relocate mailboxes, etc.).
- Install Type 3J End Anchorage and 3K Terminal, provided obstacles are cleared behind the rail (see details in the *Standard Plans - M & S Standards* **(24)**.
- Install standard Type 3 guardrail with appropriate end treatments.
- Install Type 3 guardrail with reduced post spacing (see detail in *Standard Plans - M & S Standards*) **(24)**.

20.4 TRAFFIC ENGINEERING PLANS

Traffic control plans should include a “Schedule of Construction Traffic Control Devices,” construction traffic control plans, detour routes, temporary as well as permanent signing, striping, pavement markings, and signal plans.

20.4.1 Source Documents

Many documents and manuals govern the manner in which a set of traffic plans is prepared.

While the list below includes the main sources of information for the traffic engineer, it is not all-inclusive. Traffic control and operations is an ever changing field of engineering and the use of the latest state-of-the-art techniques is encouraged. See also the references at the end of this chapter.

- AASHTO *Highway Safety Design and Operations Guide* **(3)**.
- AASHTO *Roadside Design Guide* **(4)**.
- CDOT *Standard Plans* ("S" Standards, which are a part of the *M & S Standards*) **(24)**.
- *Colorado Supplement* to the *Standard Highways Signs* **(30)**.
- *Manual on Uniform Traffic Control Devices for Streets and Highways* **(5)**.
- CDOT *Recommended Pavement Marking Practices* **(31)** Copies of this guideline are available from the Safety and Traffic Engineering Section.
- FHWA *Standard Highway Signs Standard Alphabets* **(32)**.
- FHWA *Standard Highway Signs* **(33)**.
- CDOT *Standard Specifications* **(34)**.
- AASHTO *Standard Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals* **(35)**.
- *Colorado Supplement* to the *MUTCD.* Sets forth additions, deletions or changes to the *MUTCD* required by the peculiarities of Colorado State Law **(36)**.
- ITE *Traffic Control Devices Handbook* **(37)**.
- ITE *Traffic Engineering Handbook* **(38)**.
- ITE *Transportation Planning Handbook* **(39)**

20.5 CONSTRUCTION TRAFFIC CONTROL

20.5.1 Construction Traffic Control Plan

The Construction Traffic Control Plan (TCP) is a strategy for safely moving traffic through a work zone. The Safety and Traffic Engineering Branch provides standards to be used for developing the TCP.

The components of a typical TCP are:

- Schedule of Construction Traffic Control Devices/Tabulation of Traffic Engineering items.
- Construction Signing Plan.

- Detour Routes.
- Tabulation of Signs.
- Permanent/Existing Signing Plan.
- Cross sections at Class III and overhead sign locations.
- Standard Overhead Sign Bridges/Standard Overhead Sign Cantilever/Standard Overhead Sign Butterfly.
- Tabulation of Pavement Markings.
- Pavement Marking Plan
- Signal Plan.
- List of Standard Special Provisions.
- List of Project Special Provisions.
- Detailed Sign Layouts.

Information contained in a TCP typically includes:

- Placement and maintenance of traffic control devices.
- Methods and devices for delineation and channelization.
- Construction scheduling.
- Application and removal of pavement markings.
- Roadway construction lighting requirements.
- Traffic regulations.
- Uniformed traffic control (surveillance).
- Inspection activities.

The TCP should be developed during the initial planning stages of any scheduled activity and should be considered in all decisions related to the activity. The Region Traffic Engineering Section will work closely with the Project Manager to develop a sound TCP for all construction activities. The TCP is included in the Contract Plan Package along with the specifications for the project.

The *MUTCD* **(5)** and CDOT's *Standard Plans – M & S Standards* **(24)** provide a framework to develop a sound and effective TCP for all construction projects. See section 20.3 of this guide and section 3.10 "Construction Traffic Control Plans" of the *CDOT Project Development Manual* **(40)**.

20.5.2 Construction Signing and Striping

Construction signing is an essential and integral part of any highway construction project. Part VI of the *MUTCD* **(5)** and the CDOT "S" Standards **(24)** provide examples of typical construction signing, methods of erection and signing placement to handle a variety of typical construction activities. Construction signs are typically placed on the roadway for a short period of time, therefore avoiding the need for standard durable panel material. Section 630 of the CDOT *Standard Specifications* **(34)** governs the choice of construction sign panel material.

The typical construction signing placement presented in the *MUTCD* **(5)** and Standard Plan S-630-1 **(24)** and typical striping layout presented in Standard Plan S-627-1 **(24),** are designed to assist those involved with construction traffic control, but are not intended to replace sound engineering judgment or the experience of a qualified traffic engineer.

20.5.3 Temporary Pavement Markings

Proper temporary striping is a key component of highway projects, particularly for delineation of passing and no-passing zones. Temporary pavement markings are used to supplement drums or traffic cones in a construction work zone or as provisional markings on a roadway. Temporary markings may be categorized as "Full-Compliance," "Interim" or "Control Points." Full Compliance markings are those meeting all the requirements of Part III of the *MUTCD* **(5)**. When appropriate, interim markings, such as paint or removable pressure sensitive tape, are used until full-compliance markings are installed. Control points are placed for the purpose of guiding the installation of interim or full–compliance pavement markings.

In work zones where traffic is redirected for more than one day, temporary pavement markings are typically placed along tapers and tangents, but may be placed elsewhere in the project if the need arises. Temporary pavement markings may be white or yellow depending on the type of marking (i.e., edge line, lane line or channelizing line) they replace. When construction is completed, temporary pavement markings should be easy to remove without damaging or scarring the roadway surface. In most cases, temporary pavement markings shall be removed and full-compliance markings installed within 14 days of completion of the project.

Estimates for temporary pavement marking quantities, whether they are paint or removable tape, are itemized on the Tabulation of Traffic Engineering Items plan sheet.

20.5.4 Channelizing Devices

Channelizing devices are designed to warn and alert drivers of potential obstacles created by construction or maintenance operations on or near the traveled way, to protect workers in the work zone, and to guide and direct drivers and pedestrians safely past potential obstacles. These devices may be used to provide a smooth and gradual transition in moving traffic from one lane to another, onto a bypass or detour or in reducing the width of a lane. Channelizing devices should always be preceded by a system of warning devices adequate in size, number, and placement for the roadway. Channelizing devices should be designed in a way that minimizes damage to vehicles that inadvertently strike them.

Taper design is one of the most important elements within the system of construction traffic control devices. A poorly designed taper will almost always produce undesirable traffic operations, congestion, or possible crashes. Tapers may be necessary in both the upstream and downstream directions of traffic depending on the construction activity. Tapers are classified as merging tapers, shifting tapers, shoulder tapers and two-way traffic tapers. Examples of tapers and formulas for calculating their minimum desirable lengths are found in the Standard Plan S-630-1 **(24)**.

A variety of channelizing devices have been approved by CDOT for use in construction projects. These channelizing devices include:

- Traffic cones
- Tubular markers
- Vertical panels
- Drums
- Barricades
- Concrete barriers
- Water-filled barriers

Traffic cones are typically reserved for lane closures and other construction activities during daylight hours. Traffic cones with retroreflective bands are also allowed for nighttime use, but only during working hours. The remaining channelizing devices listed above have been approved for both day and nighttime construction activities. Details regarding the placement of channelizing devices can be found in the *MUTCD* **(5)** and in the *Standard Plans – M & S Standards* **(24)**.

Quantities for all channelizing devices required on a construction project are tabulated in the Schedule of Construction Traffic Control Devices.

20.5.5 Special Devices

Other special traffic control devices may include variable message signs and arrow panels. Requirements for the use of these devices are addressed in Part VI of the *MUTCD* **(5)**.

20.5.6 Construction Staging/Phasing

Most highway construction projects require the maintenance of traffic throughout the work zone. The Region Traffic Engineering Section will work closely with the design and construction engineers to develop a construction staging concept that can expeditiously complete the project while safely and efficiently conveying traffic through the work zone. Construction signing plans should detail the construction signing schemes for all the planned phases of the project.

When appropriate, consider full road closures for construction projects to expedite construction and eliminate construction and traffic conflicts.

20.5.7 Construction at or Near Railroad-Highway Grade Crossings

Highway construction at or near railroad-highway grade crossings may require special traffic control measures to preserve highway and traffic safety, protect workers, and provide for the safe passage of trains through the project work zone. Construction traffic control activities involving railroads may occur on:

- Section 148 **(7)** railroad-highway grade crossing safety projects.
- Other projects requiring work on or near railroad tracks or property.
- Railroad-highway grade separation structure projects.

Refer to the MUTCD Section 6G.19 **(5)** for standard guidance for work in the vicinity of railroad-highway grade crossings; and MUTCD Figure 6H-46 for typical application of construction traffic control devices at railroad-highway grade crossings. It is necessary to prevent vehicles from stopping on tracks, and to prevent the queuing of stopped vehicles across the tracks.

Section 148 **(7)** safety projects are constructed by railroad forces on a “Force Account” basis. If the crossing is on a State highway, CDOT maintenance forces will be responsible to furnish construction traffic control. If the crossing is on a local road or street, the involved local agency is responsible for traffic control. The local agency involvement is to conserve limited federal Section 148 **(7)** funds so that the moneys will be spent on actual safety devices. The project plans will include a tabulation of construction traffic control devices as a planning aid for the responsible party; traffic control will be coordinated with the designated CDOT Resident Engineer who is responsible for project oversight.

Highway projects involving work on or near railroad tracks or crossings may, in addition to necessary traffic control measures at grade crossings, also require the use of railroad flaggers. Railroad flaggers are railroad employees who are authorized to stop or direct train traffic on the affected tracks. Whenever the highway work may pose a danger to trains or interfere with normal train movements (construction equipment near tracks, bridge demolition work, etc.), the railroad company will require a railroad flagger to be stationed at the project site. The flagger will monitor site conditions and exert positive control over trains passing through the project. Railroad flagging requirements, if any, will be set forth in the project special provisions, and flaggers will be paid out of project funds in accordance with the special provisions. Railroad flagging rates (daily or hourly) will be specified by the railroad company.

Highway construction on railroad overpass structures may also require the use of railroad flaggers to guard against hazards to trains such as falling debris, bridge falsework, or construction equipment.

The required contract (see section 20.1.2) among CDOT, the railroad, and involved local agencies will set forth traffic control responsibilities, coordination requirements, and railroad flagging requirements. The designer should request a contract from Safety and Traffic Engineering Branch well in advance of planned construction to allow sufficient time for contract development and execution. CDOT field construction personnel should closely coordinate traffic control with railroad and local agency representatives.

20.6 PERMANENT SIGNING

20.6.1 Uniform Standard Regulatory and Warning Signs

CDOT has adopted the *MUTCD* **(5)** guidelines for the placement of permanent regulatory and warning signs on the State highways. Signing shall be in conformance with the *MUTCD* Parts II and III **(5)**. Proper installation and consistency of signs provide guidance and information to safely travel a section of roadway. Signs should be clear and positioned for adequate response time, particularly on high-speed roadways. Detailed layouts and standard sizes for these signs can be found in the FHWA *Standard Highway Signs* **(33).** For further details including ground sign placement, consult the *MUTCD* **(5)** and Standard Plan S-614-1 **(24)**. All signs must meet NCHRP 350 requirements for crashworthiness. See applicable CDOT S Standards **(24)** and CDOT Specifications for currently accepted sign designs.

The Tabulation of Signs sheet provided for permanent signing on the project lists the panel sizes, post lengths, sign locations and color, *MUTCD* code, foundation requirements, and quantities required on a construction project.

Signs should be replaced on a project when damaged, faded or no longer retroreflective. For most new construction or reconstruction projects, signs should be updated or replaced. The designer should check with the Region Maintenance or Traffic Engineering Section for the replacement schedule. For overlay projects, the designer should examine the condition of existing signs to determine if replacement is needed. Signs that are more than ten years old will usually require replacement.

Signing is used for a wide range of purposes. The designer will follow the CDOT “S” Standards **(24)** and the *MUTCD* **(5)** when determining the signing requirements for a project.

20.6.2 Special Signs

Special signs are those not designated with a sign code in the *MUTCD* **(5)**. These signs may include construction signs indicating detours or hours of operations or permanent signs such as guide signs, specific information signs, or other special interest signs. The Region Traffic Section will provide detailed sign layouts for all special signs. Legends shall consist of either upper or lowercase characters provided in the *Standard Highway Signs Standard Alphabets* **(32)**, with letter sizes following the guidelines in Part II of the *MUTCD* **(5)**.

Special signs are tabulated on the Schedule of Construction Traffic Control Devices or the Tabulation of Signs provided in each contract plan package.

Only symbols that have been approved by FHWA may be used on special signs.

20.6.3 Sign Classifications

Permanent sign panels placed on the State highway system are classified as Class I, II or III.

Class I sign panels are single-sheet aluminum with a minimum thickness of 0.080 inches. Class I panels are flush mounted directly to wooden, U-2 steel, or tubular steel posts, as directed in Standard Plan S-614-2.

Class II sign panels are also single-sheet aluminum with minimum thicknesses of 0.100 inches mounted on wooden, U-2 steel, or tubular steel posts, however, Class II signs are mounted with one or two aluminum backing zees as outlined in Standard Plan S-614-3 **(24)**.

Class III signs are guide or informational signs constructed of 0.125-inch minimum thickness sheet aluminum and mounted with backing zees. Class III signs may be located either on overhead sign structures according to the Standards for Overhead Sign Structures or on the ground using wooden, tubular steel, or W-beam shaped steel posts.

20.6.4 Ground Sign Supports and Foundations (Class III)

Determining the requirements for Class III ground sign supports and foundations is the responsibility of the designer. Standard Plan S-614-6 **(24)** provides data for determining sign supports and concrete footing sizes for all Class III ground sign installations. Class III panels may require either wooden, tubular steel, or W–beam shaped steel supports depending on the panel size and the applied moment due to wind loads. CDOT Standards use a design wind speed of 90 mph for wind loading in most locations. Breakaway sign support requirements are found in Standard Plan S-614-5 **(24)** for both wood and steel sign supports.

Material quantities for sign supports and concrete footings are detailed on the Tabulation of Signs provided in the plans for any permanent signing project done by the Safety and Traffic Engineering Branch.

20.6.5 Overhead Sign Structures

Overhead sign structures used on the State highway system are classified into three categories:

- Sign bridges
- Cantilever sign structures
- Butterfly sign structures

The type of overhead sign structure required for a project is covered in Standard Plan S-614-50

(24), and depends on the location and the number of sign panels needed. Once the panel sizes and span lengths are known, the structural and foundational requirements of the structure are determined using the Standard Plans **(24)** developed by Staff Bridge Branch.

Standard Plan S-614-50 **(24)** should be included in all plans that require overhead sign structures. Plan sheets for overhead sign structures not found in the *Standard Plans – M & S Standards* **(24)**, including cantilevers and butterfly sign structures, can be obtained from the Staff Bridge Branch.

20.6.6 Cross Sections at Class III and Overhead Sign Structure Locations

Cross sections are required for Class III and larger sign installations using appropriate stationing. Cross sections should extend 50 to 100 feet beyond the edge-of-traveled way, depending on the lateral placement of the sign. All features such as curb and gutter, guardrail, ditches, fences, right of way lines, bikeways, and roadways should be indicated. Class III panels should be detailed on the cross sections and placed the appropriate lateral distance from the edge-of-traveled way. The bottom of the panel shall be located in accordance with Standard Plan S-614-1 **(24)**.

For sign bridge structures, a cross section from the median centerline to 41 feet beyond the edge-of-traveled way should be obtained.

20.7 SPECIFICATIONS

20.7.1 Standard Specifications

All standard specifications for traffic control devices related to construction are found in the CDOT *Standard Specifications for Road and Bridge Construction* **(34)**.

20.7.2 Standard Special Provisions

Traffic Standard Special Provisions are additions and revisions to the *Standard Specifications* initiated by Safety and Traffic Engineering and approved by the Joint CCA/CDOT Specifications Committee. These provisions are unique to a selected group of projects or are intended for temporary use. Standard Special Provisions to be used on construction projects can be accessed on the Construction Specifications web site **(41)**.

20.7.3 Traffic Project Special Provisions

Traffic Project Special Provisions are additions and revisions to the *Standard Specifications* unique to a particular project. They are available for use on a project-by-project basis and are posted on the Safety and Traffic Engineering web site **(42)**.

20.8 SIGNALS

20.8.1 Signal Plans

Traffic signals play an important role in the safe and steady flow of traffic. The *MUTCD Part IV* **(5)** provides the criteria for the design and installation of traffic signals. The traffic signal plan sheets provided by the Region Traffic Section will show the placement of the signal poles, heads, conduit, pull boxes and all other related signal equipment. Standard Plans S-614-40 and S-614-40A **(24)** provide details of the signal equipment required by CDOT.

When designing sidewalks and channelization islands, consideration of *Americans With Disabilities Act* standards and the needs of able-bodied pedestrians should be taken into account. Poles, boxes and other related equipment should be placed so that pedestrians have unobstructed walkways.

20.8.2 Warrant Studies

Properly designed traffic signals make intersections safer and more efficient by improving traffic flow. However, signals are not cure-alls for improving traffic flow and reducing crashes at all intersections. Traffic signals should be warranted before they can be installed. Specific criteria are given in Part IV of the *MUTCD* **(5)** for the installation of traffic signals. Even if an intersection meets the criteria, careful consideration should be given to other traffic control devices before a signal is decided upon.

20.9 PAVEMENT MARKINGS

20.9.1 Permanent

Adequate pavement markings have been a cost-effective means of enhancing both traffic safety and mobility. The Department requires centerline, edge line, auxiliary lane, crosswalk and other pavement markings on all roads under its jurisdiction. CDOT requires durable pavement markings on all mainline Interstate projects and on other selected roadways where traffic volumes are high or non-durable markings have not been cost-effective. "Durable" pavement marking materials are those materials capable of providing a longer service life than conventional paint.

General guidelines for the selection of pavement marking materials for roadway projects may be found in an agreement between CDOT and the FHWA titled, "Recommended Pavement Marking Practices" **(31).** Copies of this guideline are available from the Safety and Traffic Engineering Section.

Other considerations in the selection process may include the desire to use materials that are lead-free, materials that contain lower levels of volatile organic compounds, or materials that do both. The *MUTCD* **(5)** and Standard Plan S-627-1 outline the details and requirements for the proper selection and installation of all pavement markings. Refer to Standard Specifications Section 627 **(33)**.

Tabulation of Pavement Marking quantities will be included in the plan sheets provided by the designers and reviewed by the Region Traffic Engineering Section for most construction projects.

20.9.2 Temporary

See section 20.5.3.

20.10 RESEARCH

The Safety and Traffic Engineering Branch in cooperation with the Division of Transportation Development Research Branch and the Materials and Geotechnical Branch is constantly evaluating new traffic engineering products available from the private industry. For information regarding research projects on State highways, contact the Safety and Traffic Engineering Branch or the Region Traffic Engineer.

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