Colorado's Speed Management Action Plan

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Technical Report Documentation Page

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10. Abstract This plan outlines recommendations and countermeasures to improve three speed-related focus crash types, including roadway departure, intersections, and non-motorized users. The plan documents a step-by-step approach for applying systemic data analysis to the identified focus crash types and summarizes actions that Colorado DOT and its partners can take to address the statewide speed management program.	

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Executive Summary

Speed-related crashes on Colorado roadways accounted for 31 percent of all traffic fatalities in the State in 2015. Without a speed-related emphasis in the State's strategic highway safety plan, this speed management plan can help guide Colorado's activities and coordination with stakeholders on speed-related safety discussions, plans, and projects to reduce the frequency and severity of speed-related crashes.

Through data analysis, a study of Colorado DOT's policies and guidance documents, and stakeholder discussions, this plan outlines recommendations and countermeasures to improve three speed-related focus crash types, including roadway departure, intersections, and non-motorized users. The plan documents a step-by-step approach for applying systemic data analysis to the identified focus crash types and summarizes actions that CDOT and its partners can take to address the statewide speed management program.

Recommendations are supplemented with current State practices that CDOT can use to model its own speed management program and countermeasure implementation activities. This plan encourages Colorado DOT and local agencies to take a broad look at existing policies and programs to identify opportunities for fully integrating speed management throughout their organizations. This document also recommends strategies for revising or enhancing existing speed management practices and shaping new practices.

1 Introduction and Background

Reductions in traffic fatalities and crashes are no accident; advancing transportation safety requires a strategic vision for cost-effectively advancing approaches that ultimately lead to safer infrastructure and wiser road users. While Colorado establishes goals for reductions in overall traffic fatalities and serious injuries in its 2014-2019 Strategic Highway Safety Plan (SHSP), the plan does not include speeding-related crashes as one of its emphasis areas.

Colorado's Speed Management Action Plan describes specific activities and actions CDOT and speed management stakeholders can take to meet these goals and to integrate speed management concepts through guidance and training, stakeholder coordination, enforcement and adjudication, and countermeasure implementation.

The purpose of this Plan is to provide suggestions and a framework for improving Colorado's roadway safety by significantly reducing speeding. The plan addresses two main components: updating speeding-related policies and programs and improving the process for identifying speeding-related crash locations. The general outline of the plan is as follows:

- Chapter 1: Introduction, Background, and Organization emphasizes the importance of maintaining a Speed Management Action Plan and introduces the sources of information from which this plan was developed.
- Chapter 2: Identifying and Resolving Policy and Program-level Speeding-related Issues identifies speeding-related issues that were cited during the data analysis and literature review and confirmed during the workshop. In addition, this section outlines solutions and recommendations to address these issues and provides examples of agencies employing similar strategies.
- Chapter 3: Identify Speeding-related Problem Locations and Countermeasures using Systemic Data Analysis details a systemic approach to crash data analysis using CDOT's crash, roadway, and traffic data.
- Chapter 4: Conclusions and Next Steps summarizes the partners for success and next steps for CDOT.

1.1 Importance of Speed Management

In 2015, Colorado reported 168 speeding-related fatalities, accounting for 31 percent of the total traffic fatalities in the State, compared with 27 percent nationwide.[1] Speeding-related fatal (K) and serious injury (A)[2] crashes accounted for 21 percent of all K+A crashes Colorado. Speeding is a complex issue for transportation agencies to address because it can involve multiple safety areas. The speed at which

[1] National Center for Statistics and Analysis. (2017, July) Speeding: 2015 data (Traffic Safety Facts. Report No. DOT HS 812 409). Washington, DC; National Highway Traffic Safety Administration.
[2] The KABCO scale is a five point indexing system that consists of: fatal injury (K), incapacitating injury (A), non-incapacitating injury (B), possible injury (C), and no injury/property damage only (O).

drivers choose to travel is impacted by public attitudes, roadway design, appropriate speed limits, traffic calming, and enforcement strategies, to name a few.

Since speeding-related crashes occur across other SHSP focus areas, many of the countermeasures applicable to crashes within these focus areas also apply to speeding-related crashes. With speed as a crosscutting issue, the Federal Highway Administration (FHWA) encourages States to take a broad look at their speeding-related policies, safety plans, and programs to identify opportunities for integrating speed management throughout these business processes.

1.2 Plan Development

The project team developed this plan based on a three-pronged approach that included a review of relevant Colorado Department of Transportation (CDOT) literature, data analysis to identify factors and trends that contribute to speeding-related crashes, and an interactive workshop with Colorado's key safety and speed management stakeholders.

1.2.1 Policy, Guidance, and Practice Review

The project team conducted a literature review of CDOT's current state of the practice, speeding-related policies and guidance, and other safety plans to learn how Colorado is currently integrating speed management. Areas of improvement identified while reviewing these documents helped to shape the recommendations and strategies presented in this plan.

The project team reviewed the following resources:

- State of Colorado's Traffic Accident Reporting Manual (July 2006)
- CDOT Methodology for Evaluating and Setting Speed Limits (March 2012)
- CDOT Methods for Setting Speed Limits
- CDOT Draft Variable Speed Limits Protocol and State of Practice
- CDOT Authorization and Declaration of Temporary Speed Limits (August 2003)
- CDOT Safety Assessment Manual (December 2003, Revised February 2009)

1.2.2 High-Level Preliminary Data Findings

The number of crashes in Colorado has risen consistently since 2011 as shown in Figure 1. Speeding-related crashes that result in fatal or serious injuries (FSI) account for approximately 20 percent of total FSI crashes in Colorado. Speeding-related fatalities over the analysis period had decreased until 2013 and then started to climb, with a 42 percent increase from 2013 to 2015, represented in Figure 2.

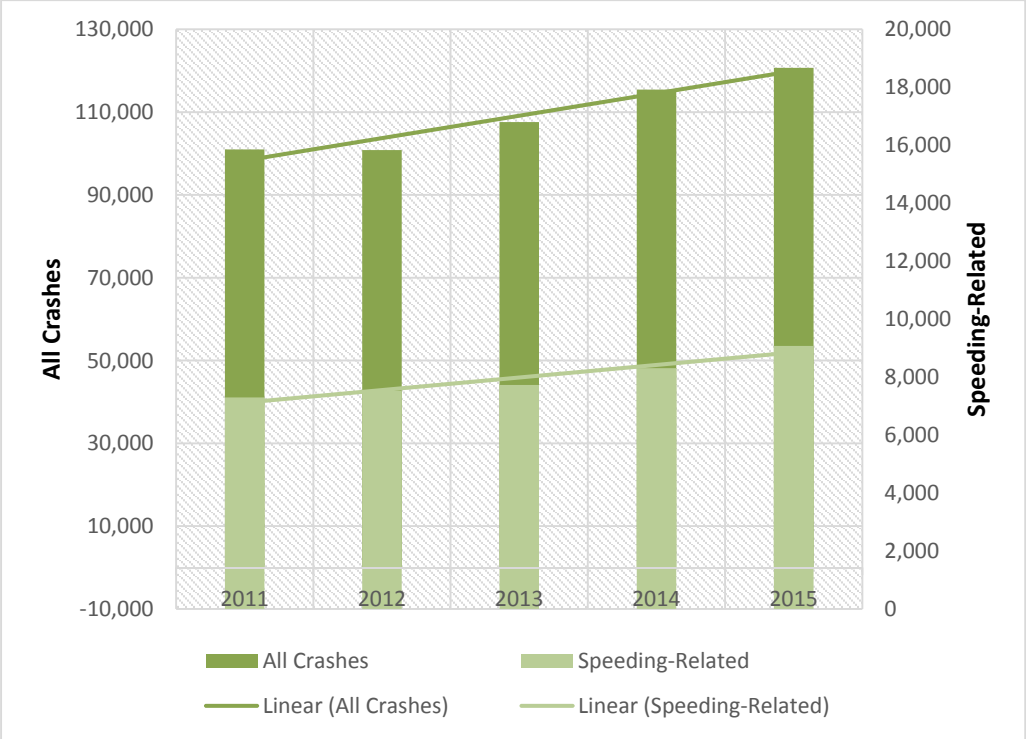

Figure 1. All Crashes and Speeding-related Crashes in Colorado from 2011-2015

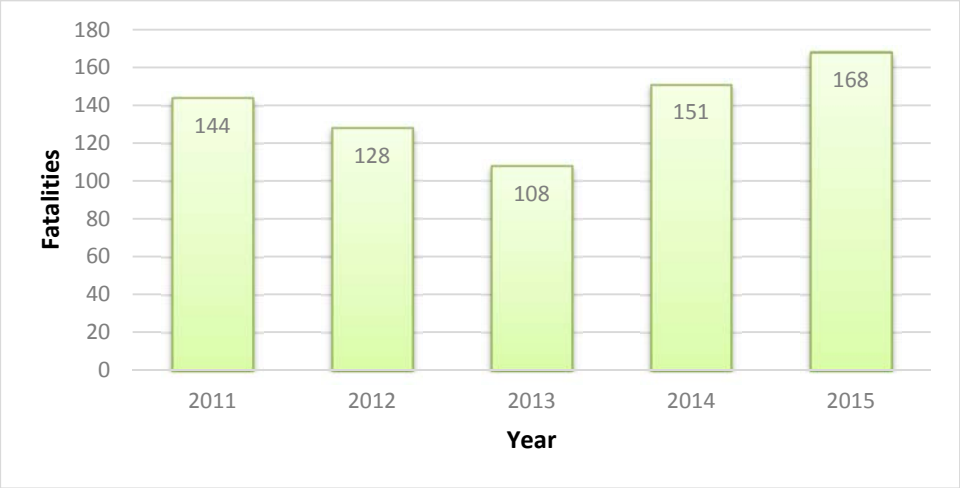

Figure 2. Speeding-related Fatalities in Colorado from 2011-2015

While the majority of speeding-related crashes occur in urban areas, the most severe crashes of this type occur in rural areas. **Error! Reference source not found.** shows that 54 percent of speeding-related fatal and serious injury crashes and 69 percent of all speeding-related crashes occur on the urban system, while 62 percent of fatalities occur on rural roads.

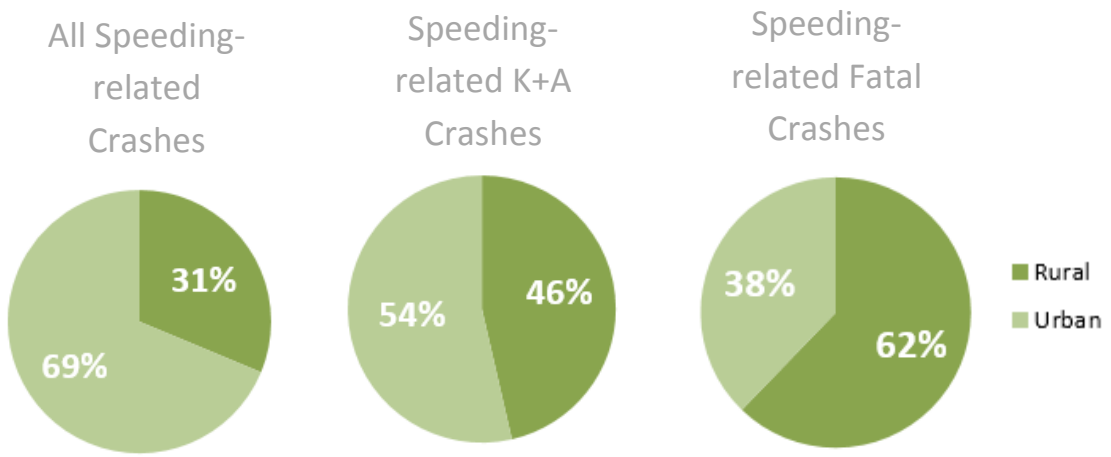

Figure 3. Urban and Rural Split of All Speeding-related Crashes, Fatal and Serious Injury Crashes (K&A), and Fatalities

Figure 4 indicates the degree to which speeding-related crashes occur by posted speed limit. In Colorado, the ratio of speeding-related crashes to all crashes decreases significantly along with the posted speed limit.

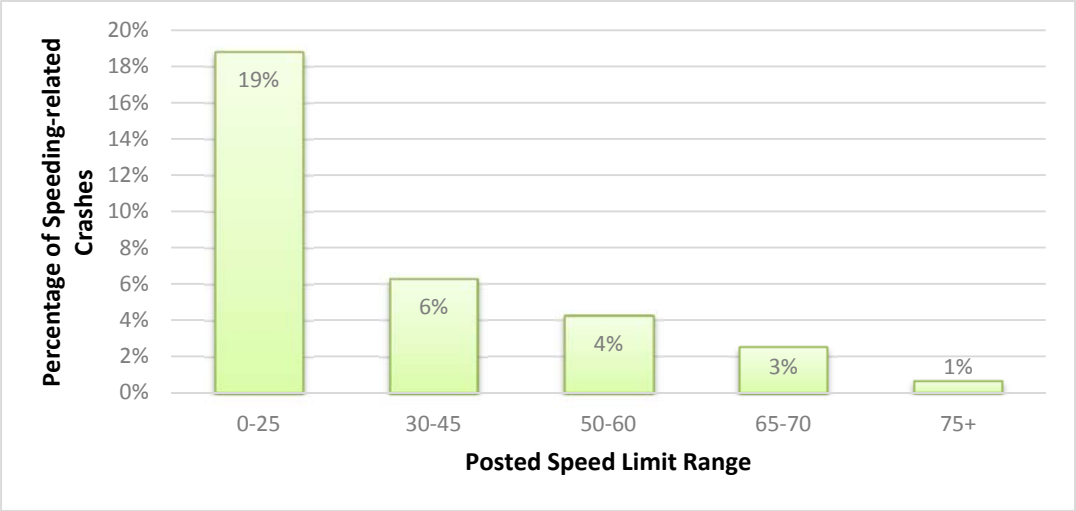

Figure 4. Colorado's Ratio of Speeding-related Crashes by Posted Speed Limit

1.2.3 Stakeholder Input

The Federal Highway Administration (FHWA) project team and Colorado's safety stakeholders participated in a Speed Management workshop on May 4, 2017, at CDOT Headquarters in Denver.

Attendees specialized in a variety of disciplines and included participants from CDOT, local agencies, and law enforcement.

The workshop agenda included discussions surrounding the following topics:

- Data Collection and Analysis.
- Speed-setting policies.
- Roadway Design Policies and Speed.
- Communication, Collaboration, and Outreach Policies.
- Countermeasures.
    - Roadway Departure.
    - Intersection.
    - Pedestrian and Bicycle.
- Plan Development.

The attendee list and workshop agenda can be found in Appendix A.

During the workshop, attendees shared practices related to various aspects of speed management such as: practices for setting speed limits, policies and guidance, collaboration between agencies and disciplines, speed enforcement, countermeasures, and data analysis. Throughout the workshop, key themes surfaced during stakeholder discussions that were deemed important to the development of and inclusion in Colorado's Speed Management Action Plan, including:

- Guidance and support.
- Countermeasure implementation.
- Stakeholder coordination.
- Systemic data analysis and countermeasure selection.

The discussions that took place, the shared feedback, and the information exchanged during the workshop were integral to shaping this plan.

1.3 A Living Document

Colorado views the coordination of speed management topics as imperative to integrating the plan with other roadway safety plans. This effort can build a unified, statewide approach to improving highway safety, including addressing speed management. Reducing fatalities and serious injuries on the transportation system is directly impacted by an agency's efforts to manage roadway speeds and to implement effective speed management strategies.

As new technologies and techniques emerge and innovative strategies come to light, Colorado should re-examine the practices, statewide guidance, and tools used to assess whether current speed management practices continue to align with long-term safety goals through collaborative efforts with safety stakeholders.

2 Identifying and Resolving Policy and Program-level Speeding-related Issues

This chapter provides suggestions and a framework for updating speeding-related policies and programs. (Suggestions for improving the process for identifying speeding-related crash locations will be discussed in Chapter 3.) This chapter is organized by the key themes that stakeholders identified during the speed management workshop:

1. Guidance and support
2. Countermeasure implementation
3. Stakeholder coordination

Under each section (or key theme), the primary challenge(s) are listed, along with recommendation(s) to address each challenge (see Figure 5), and implementation guidance.

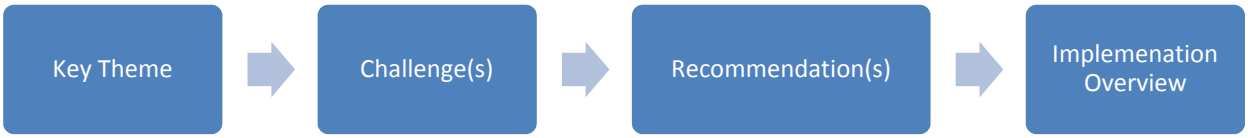

Figure 5. Example Relationship of the Overarching Key Theme, Specific Identified Challenges, and Corresponding Recommendations.

2.1 Guidance and Support

The following challenges and recommendations relate to the common key theme of guidance and support. To address the lack of documented processes and criteria for a variety of speeding-related topics, Colorado may consider developing the recommended policies and practices that have the shortest return-on-investment cycle.

CHALLENGE #1: Lack of a unified and consistent process or criteria for establishing speed limits, including those within special areas or zones (e.g., schools, work zones).

CDOT's speed-setting practice starts with the 85th percentile speed, but accounts for other factors, including crash history, roadway curvature, and other factors.

Colorado has different speed-setting methods for State and local agencies. Law enforcement indicated it is difficult to explain inconsistent posted speed limits to drivers who experience a 5 mph posted speed disparity when transitioning from one jurisdiction to another within a short roadway segment.

For work zones, CDOT generally tries to maintain non-work zone speed limits to reduce impacts to drivers. This results in little to no change in speed differentials—a significant crash risk—among vehicles within the zone, especially when workers are not present. CDOT does, however, reduce speed limits within work zones in instances where drivers or workers are at risk, such as where positive protection measures are not able to be used. CDOT continues to review and update its

work zone speed limit setting protocols and practices.

CDOT does not currently consider the amount of bicycle and pedestrian activity when determining speed limits.

RECOMMENDATION #1: Establish consistent and appropriate speed limits through statewide policy; communicate the policy statewide, both internally and with local agencies.

Support: Developing a documented speed-setting procedure and instituting it into policy will improve the consistency with which speed limits are established statewide, including suggested criteria for local roads and ensuring that criteria are examined and detailed for special use areas, such as schools and work zones, and are inclusive of bicyclists and pedestrians. Having a documented, repeatable process can make it easier and faster for staff to evaluate existing speed limits and establish new ones. Such a process will also eliminate stark differences in signed speed limits on routes as they cross district or regional lines. In addition, a documented, institutionalized, and vetted process can lend weight in political disputes, harmonize adjudication, and expedite and improve the reliability of determining posted speeds.

Utilizing USLIMITS2, an online tool developed by FHWA to support engineering studies, is also an effective strategy to help assess and establish safe, reasonable, and consistent speed limits. FHWA promotes USLIMITS2 as one of its most recent proven safety countermeasures.

Another suggested recommendation is to convene a focus group to develop CDOT's speed limit setting policy. Once the speed-limit setting process is finalized, consider rolling out the information to districts or regions through a short training course or during internal conferences or meetings.

For local agencies, CDOT should consider documenting the speed setting evaluation process and criteria and making it publically available to all agencies in the State. The document should fully detail the speed limit approval process and relevant stakeholders. CDOT should also consider conducting training with local agencies on speed setting process, possibly in conjunction with safety, planning, and other topics.

Examples of speed limit setting policies in other States:

- California Manual for Setting Speed Limits
- Massachusetts Department of Transportation's Procedures for Speed Zoning
- Missouri Department of Transportation's Engineering Policy Guide, 949.2 Speed Limit Guidelines
- Wisconsin Statewide Speed Management Guidelines

USLIMITS2 resources:

- Web link to the USLIMITS2 tool
- Free USLIMITS2 training webinar/workshop upon request for public agencies. Contact: help@uslimits.org.
- USLIMITS2 Proven Safety Countermeasure flyer
- Georgia Department of Transportation Setting Speed Limits with Help from USLIMITS2 case study

CHALLENGE #2: Limited formal guidelines or criteria for determining when State and local engineers should reassess and update speed limits.

Land development and rezoning can dramatically change a corridor's use, traffic volumes, transportation modes, and mean speeds in just 5 to 10 years. Often speed limits that were appropriate 10 years ago are no long appropriate due to changing environmental factors (e.g., more residential housing, shopping, pedestrian and bicycle use). CDOT believes there are areas where speed studies have never been performed due to political and public pressure. Updating speed limits has become highly politicized at the local level.

RECOMMENDATION #2a: Determine when State and local engineers should reassess and update speed limits and incorporate this criteria into the procedure for setting speed limits.

Support: Given that parts of Colorado may have faster land-development rates than other areas, a procedure for setting speed limits will need to address when or what criteria trigger a need to re-examine speed limits to ensure that posted speeds are appropriate.

Using the same focus group that developed the procedure for setting speed limits, continue to expand on it by developing criteria on when to reassess existing speed limits. Research other States' criteria for reassessing speed limits to help with drafting Colorado's guidelines.

Example:

California Manual for Setting Speed Limits

North Dakota Department of Transportation Speed Limit Guidelines

RECOMMENDATION #2b: Educate local agencies on the speed limit re-evaluation process.

Support: Local agencies have emphasized the importance of constant communication and a strong relationship with CDOT when evaluating and addressing speed limits on State-owned roadways that appear to be local roads. Although CDOT owns these roads, local agencies field public complaints. As such, it is imperative that local agencies understand the logic behind the speed study evaluations and decisions.

CHALLENGE #3: Alignment of design speed with future posted speed limits.

Road geometry can influence a driver's speed. CDOT's Roadway Design Guide, Chapter 7 details the factors that designers use to establish design speeds, which are largely specific roadway characteristics and design elements. Conversely, CDOT's practice for establishing posted speeds considers driver behavior (e.g., 85th percentile speed), roadway environment and context (e.g., rural versus urban, number of access points, etc.), visual roadway elements, and the frequency of bicyclists and pedestrians.

CDOT also believes that, while past roadway designs have accommodated road users, many corridors and locations are now "out of date."

RECOMMENDATION #3a: Review and update existing design manuals and guidance, as needed, to ensure designers and planners align design speed with future posted speed limits; educate

internal staff.

Support: Studies have shown that certain roadway design features encourage motorists to more closely adhere to posted speeds. When posted speed limits are significantly lower than a road's design speed, drivers may feel they can safely drive faster. This is reflected in crash severity levels among pedestrians and bicyclists, since crash severity within these modes readily parallels increasing vehicle speeds.

To begin the process, CDOT's Traffic and Safety Section may consider engaging the Project Development Unit and Pedestrian and Bicycle Unit to better understand and influence the process for selecting design speeds during the project development process. CDOT's Project Development Unit plays a major role in roadway design features that impact travel speeds and associated speed limits. CDOT's Pedestrian and Bicycle Unit expressed its desire for design speeds to address the presence of bicyclists and pedestrians coupled with freight movements and roadway context/environment (e.g., downtown business areas) to be considered.

These units, and other members of a multidisciplinary team, including local agencies and affected businesses and residents, can discuss not only current roadway uses but also future planned uses and incorporate countermeasures (e.g., Road Diets) that both address speed and accommodate future travel modes, such as pedestrians.

When the results or refinements are finalized, consider developing a short course for roadway designers, planners, project managers, and traffic engineering staff. (This may even be coupled with the recommended course on how to determine speed limits.)

Example:

FHWA Speed Concepts: Informational Guide presents information to help engineers, planners, and elected officials better understand design speed and its implications in achieving desired operating speeds and setting rational speed limits.

Technical Memorandum from FHWA on the Relationship between Design Speed and Posted Speed clarifies that the selection of a posted speed is an operational decision for which the owner and operator of the facility is responsible. Anticipated operating speeds as well as posted speeds should be considered in the selection of the design speed, but there is no regulation establishing a more direct relationship.

NHI Courses that may be beneficial for staff:

- NHI Course 380116 – Speed Management
- NHI Course 380095 – Geometric Designs: Applying Flexibility and Risk Management

New Jersey Department of Transportation's Roadway Design Manual presents effective guidance for designers and planners on the importance of properly selecting the target operating speed and design criteria to result in users driving the roads at a safe and appropriate speed. The introductory section of the NJDOT manual is devoted to this concept.

Guidelines for Employers to Reduce Motor Vehicle Crashes. This document represents a joint effort by NETS, NHTSA and OSHA to reduce motor vehicle-related deaths and injuries in the Nation's workforce.

Michigan DOT: Evaluating the Impacts of Speed Limit Policy Alternatives. Michigan is one of the States with a differential speed limit for rural and urban environments. This study involved a comprehensive state-of-the-art review of prior research on the relationships between traffic

speed, safety, and crash risk. A survey was conducted of state agency practices with respect to speed limit establishment and another survey was conducted to obtain feedback on proposed changes from the trucking industry.

Illinois Center for Transportation: Speed Harmonization—Design Speed vs. Operating Speed. When the actual operating speed on the roads exceeds the design speed, which is common on rural highways, the roadway design may become problematic from a safety point of view. This report presents a new methodology that summarizes the relationship between design speed and operating speed as well as the safety impacts of various geometric elements.

Designing Roads That Guide Drivers to Choose Safer Speeds. The findings in this study show that it is possible to influence traffic speeds through careful selection of roadway and roadside design elements.

RECOMMENDATION #3b: Capitalize on reconstruction opportunities to align design and posted speeds.

Support: If CDOT does not plan to incorporate non-roadway characteristics into the process for establishing design speeds, it should aim to re-evaluate design speeds when corridors are being redesigned, reconstructed, or resurfaced to address context sensitive needs, which impact design and posted speeds.

Example: For example, local agencies in Colorado stated they have implemented traffic calming measures by altering roadway geometry and design elements (e.g., 1-ft. reduction in lane width, addition of raised medians) and successfully decreased 85th percentile speeds by 5 mph.

CHALLENGE #4: CDOT believes the *Estimated Vehicle Speed* field of the crash report is only marginally reliable. Inaccurate speeding-related data may lead to ineffective use of funding.

RECOMMENDATION #4: Review and redefine speeding-related data fields in crash reports.

Support: The City of Castle Rock is working with CDOT to conduct more advanced crash analysis. The metropolitan planning organization (MPO) geocodes local crashes within the region using State database. CDOT may consider expanding the working group to include law enforcement such that the data collected from the report fields can be useful for CDOT's purposes and effective in the adjudication process.

Depending on the results of potential revisions, the State may consider exploring a new definition for "speeding-related crash" based on the Model Minimum Uniform Crash Criteria Guideline (MMUCC) and with assistance from law enforcement and adjudication representatives. In addition, CDOT may consider collaboratively developing statewide guidance and training to deploy to officers across the State to further promote accuracy and consistency in field data collection.

Example:

Refer to Model Minimum Uniform Crash Criteria (MMUCC) Guideline. The MMUCC 5th Edition Guideline is available for download at: https://www.nhtsa.gov/about-mmucc.

2.2 Countermeasure Implementation

During the workshop, attendees discussed perceived challenges with specific speeding-related countermeasures and implementation strategies. This section highlights those challenges and provides recommendations for improvement. Countermeasures related to the three focus areas (i.e., roadway departure, intersections, and pedestrians/bicyclists) are discussed in Chapter 3: Identify Speeding-related Problem Locations and Countermeasures using Systemic Data Analysis.

CHALLENGE #5: Communication among CDOT's Maintenance Division, CDOT's traffic operations center, law enforcement, and the snow patrol during winter weather; and communication from these groups to road users.

Rapid response to improve or maintain road conditions during severe winter weather events can proactively improve loss-of-friction crashes but can also embolden drivers to proceed at speeds too fast for conditions, when specific speeding-related guidance is not given. Depending on the nature of the event and CDOT's response, road conditions may change quickly and drastically.

RECOMMENDATION #5: Explore various weather responsive traffic management (WRTM) strategies that can be implemented to help prevent speeding-related crashes during inclement weather.

Support:

To address communications among CDOT staff:

1. Determine a regular interval for winter weather responders to communicate current road conditions for their areas to CDOT's traffic operations center no less than hourly and every 15 to 30 minutes during extreme weather events.
2. Develop protocols for determining recommended winter-weather posted speeds and related messages to road users. Update no less than hourly, with more frequent revisions during extreme events.

To address communications to road users:

1. Install road weather sensors to detect road conditions that require drivers to alter their operating speeds from the posted speed limit. Communicate downstream road weather conditions and upstream weather-related recommended speed limits via dynamic message signs and variable speed limit (VSL) systems, respectively.
2. Use traffic management sensors to detect vehicle operating speeds during winter weather and communicate weather-related recommended speed limits via dynamic message signs and VSL systems.

Additional strategies include:

- Using weather-responsive traffic signal timing, which alters the timing of signals during adverse weather, adjusting the yellow clearance interval, all-red intervals, pedestrian intervals, etc. This technology also accounts for travel speeds and reduced pavement friction.
- Employing automatic de-icing sensors and equipment at locations that may freeze or become slick quickly and/or frequently. This strategy could prevent inclement weather crashes where motorists are going too fast for conditions and are unaware of icy or slick conditions.

Resources:

For more information on weather responsive traffic management strategies, visit FHWA's Road Weather Management website.

FHWA's Guidelines for the Use of Variable Speed Limit Systems in Wet Weather provides guidelines for the design, installation, operation, maintenance, and enforcement of wet weather VSL systems.

Utah DOT Weather Responsive Traffic Signal Timing, FHWA-JPO-12-088. The report contains the system design, operation, evaluation approach, findings, and lessons learned from the implementation of weather responsive traffic signal management by Utah DOT.

CHALLENGE #6: Practices for reducing speeds in "special use areas" are not effective.

For school zones, workshop attendees noted that static school zone speed limit signs are not an effective means to garner adherence.

In work zones, CDOT has seen that typical work zone signing packages or double-fining are not enough to slow vehicles. As a result, CDOT is careful to reduce speed limits only when either road users or workers are at a special risk due to the proximity of activities near the travel way.

RECOMMENDATION #6a: Consider interactive speed countermeasures and continue using automated enforcement in "special use areas."

Support: Within school zones, interactive speed warning systems can be used to dynamically alert drivers when their travel speeds are excessive. These systems can be timed to activate when school is in session, throughout the day, and as appropriate throughout the year. Coupled with random automated or static enforcement during school hours, interactive speed warning systems can be very effective.

For work zones, consider measures to reduce or eliminate work zone risks for road users and workers through positive protection and innovative traffic control staging in order to maximize opportunities for maintaining non-work zone speed limits through active work zones.

CDOT has used automated enforcement in both school and work zones with favorable results.

Resource:

Research shows that installing speed feedback signs, also called speed-activated warning or speed limit reminder signs, have been effective at reducing speeds up to 6 mph. FHWA's A Desktop Reference of Potential Effectiveness in Reducing Speed includes a compilation of study results on this countermeasure (and other speed countermeasures).

RECOMMENDATION #6b: Consider use of VSL in select work zones.

Support: Depending on the overall variance of traffic flows, it may be difficult to choose one static work zone speed limit that is appropriate for all conditions and is perceived by motorists to be reasonable at all times during the work zone activity. With VSL, motorists may respond better to realistic speed limits, which would result in higher compliance, lower speed variance, and increased safety.

Resources:

A Field Test and Evaluation of Variable Speed Limits in Work Zones. This report describes a field operational test of a VSL system in a work zone in Michigan and evaluates the extent to which speed limit compliance is affected, the credibility of the speed limits is increased, safety is improved, and traffic flow is improved.

Evaluation of Variable Advisory Speed Limits in Congested Work Zones. Researchers at the University of Missouri found that using variable speed limits in construction zones may ease congestion, reduce crashes, and make work zones safer for both workers and travelers.

CHALLENGE #7: Local agencies believe they have little opportunity to change operating speeds or posted speed limits.

In general, local agencies are hesitant to assess current operating speeds on roads where posted speeds need to be reviewed due to concerns that operating speeds will have risen, in turn potentially causing posted speeds to rise also. Due to the involvement of elected officials in determining posted speed limits on local roads, local agencies have little influence and input for designating reasonable, site-specific posted speed limits using criteria and a process similar to CDOT's.

RECOMMENDATION #7a: Consider empowering local agencies with opportunities to install traffic calming measures and provide appropriate guidance.

Support: Local agency owned roads, with generally lower posted speed limits compared to the State system, experience 50 percent of all speeding-related fatalities, 59 percent of speeding-related fatal and serious injury crashes, and 70 percent of all speeding-related crashes in Colorado. These statistics are substantial considering that non-state roads only carry 39 percent of vehicle miles traveled within the State.[3]

Several larger municipalities in Colorado have some form of traffic calming programs, including Colorado Springs, Centennial, Lakewood, and El Paso County. In Loveland, it appears that proposed traffic calming measures are required to be approved by the city or county, placing engineering and behavioral responsibilities in the hands of elected officials.[4]

To provide and promote consistency when implementing traffic calming solutions, CDOT could develop statewide traffic calming guidelines that communicate the process for assessing when traffic calming measures are appropriate, the process for seeking funding, descriptions of traffic calming countermeasures, construction specifications, and additional resources.

Example: South Carolina DOT's Traffic Calming Guidelines (2006) detail specific criteria for determining when measures might be suitable for implementation and denote steps that local agencies may follow for implementation.

RECOMMENDATION #7b: Proactively identify corridors where traffic calming measures may be

[3] CDOT 2015 Daily Vehicle Miles Traveled

[4] Per http://www.reporterherald.com/news/loveland-local-news/ci_30891213/loveland-city-council-could-reconsider-downtown-traffic-calming

suitable and coordinate with local agencies to apply the guidance.

Support: CDOT has an opportunity to dedicate staff and resources to proactively identify corridors where one or more traffic calming measures may be effective. This can be accomplished by performing data analyses using the eligibility criteria identified in traffic calming guidance developed under the previous recommendation. This approach removes the responsibility from local agencies, which may not have access to criteria data or data analysis resources. Once CDOT develops a list of potentially suitable locations for speed management countermeasures, the local agency can further examine the list and take the lead in implementation appropriate countermeasures.

During location list development, it may be helpful to coordinate with law enforcement (and other partners) to narrow and refine the list. Law enforcement often has insights into locations that could benefit from traffic calming measures.

Example of conducting feasibility studies across the entire road network: To determine the feasibility of converting four-lane roads to three lanes (Road Diets), many state and local agencies in the United States have completed assessments of their road networks to determine potential conversion sites. This can be a proactive and effective way of supporting traffic calming and addressing speeding-related issues. Genesee County (Michigan) Metropolitan Planning Commission's (GCMPC) Complete Streets Program used a systemic approach to assess four-lane roads within GCMPC's jurisdiction to determine suitability for four-to-three lane conversions. Iowa DOT and Kansas City, Missouri, have also completed similar assessments. For more information on Road Diets, visit FHWA's Road Diet website.

Oregon DOT coordinates a program called All Roads Transportation Safety (ARTS) that addresses safety programs for all public roads in Oregon. While this is all-encompassing for safety-related projects, CDOT could adopt similar steps to assist local agencies in identifying corridors or locations where traffic calming measures may be most needed. Oregon DOT develops an initial data-driven list of both systemic and hot-spot locations for the regions/stakeholders to review and refine. For more information, http://www.oregon.gov/ODOT/Engineering/Pages/ARTS.aspx.

2.3 Stakeholder Coordination

Stakeholder communication among those who develop and implement policy, enforce and reinforce speeding-related offenses, educate about and influence driver behaviors, and determine infrastructure solutions can dramatically alter the effectiveness of a State's speed management program.

CHALLENGE #8: Stakeholder collaboration and coordination is not being conducted to its full potential.

There is room for CDOT to improve its communication internally and externally with its law enforcement, local agency, and other stakeholder partners. Currently, stakeholders in Colorado have very limited platforms to meet, discuss, elaborate, and improve speed-management practices.

RECOMMENDATION #8a: Capitalize on existing stakeholder meetings or develop a speed management task force.

Support: Colorado should consider assembling a Speed Management team that focus on safety,

operations, and trade-offs between the two and that brings together State and local representatives, members from the "4E's" (engineering, enforcement, education, and EMS), communications staff, and elected officials. This group may comprise local agencies, metropolitan planning organizations, AAA, law enforcement, and businesses, in addition to CDOT.

Example: The Maryland Strategic Highway Safety Plan (SHSP) contains six emphasis areas (EAs), many of which could include speeding-related topics. Each EA team is comprised of members from the "4E's" and gathers together quarterly to discuss progress on SHSP action steps and brainstorm solutions. These group meetings are an ideal platform for engineers, law enforcement, educators, and EMS representatives to share ideas on how to reduce speeding-related crashes and tackle other safety challenges.

RECOMMENDATION #8b: Expand current partnerships and build new ones.

Support: Fully explore speed management issues and challenges by brokering information with new stakeholders. Consider stakeholders that may be able to help with specific expertise, research, communications and outreach, or ones that simply share the same goals and objectives. These may include partnering with the following groups, for example:

- Maintenance staff during the design process to improve future roadway maintenance and safety.
- Law enforcement, public health, or medical providers to improve data collection methods.
- Marketing/communication staff to conduct outreach to public.
- Government relations staff to conduct outreach to elected officials.
- Schools, hospitals, businesses, sports/recreational organizations, etc.

Examples of unique partnerships:

During an automated speed enforcement (ASE) demonstration project in Arizona, NHTSA partnered with a major regional employer, Raytheon, to expand marketing and outreach. Raytheon sponsored local traffic reports via radio and TV, carrying the ASE safety message. By tying its name to the message, Raytheon gained positive visibility and associated its brand with the message's excellence and high standards. The additional marketing boosted visibility while the introduction of a new voice in the conversation helped build credibility for an important safety initiative that had received significant local pushback.

In Connecticut, the Connecticut Transportation Safety Research Center (CTSRC) recently hired an epidemiologist to work with the Highway Safety Office on research related to injury prevention, analysis of risk-taking behavior, and implementing effective countermeasures to advance public safety. The CTSRC also has a behavior analyst on staff who conducts research on motor vehicle crashes to determine the driver behavior and psychology that may lead to crashes.

RECOMMENDATION #8c: Promote a safe speed culture.

Support: This recommendation goes beyond CDOT and traditional safety stakeholders and into the public and non-traditional partners.

Have conversations with elected officials to instill a greater understanding of the impacts of a safer transportation network throughout the community. One message could connect how safer roads improve business for local retailers.

Include and engage local agencies, MPOs, municipalities, cities, and counties on speed management topics, and ensure they understand the potential safety and non-safety impacts of

good speed management practices.

Example: The Missouri Department of Transportation (MoDOT) has recently developed the "hOUR" program, which encourages businesses to adopt traffic safety policies within their organization. MoDOT safety officials are working to convince businesses that encouraging safe driving behaviors before, during, and after work is beneficial to their business and employees, similar to providing vaccinations and allowances for well-checks, etc. The agency is encouraging businesses to spend a small amount of time with employees discussing the importance of traffic safety and adopting a traffic safety policy. For more information on this program, https://savemolives.com/templates/interior_page/132.

2.4 Implementation Overview

Table 1 below summarizes the estimated implementation time, cost, and impact of each recommendation discussed in this chapter and indicates the lead agency responsible for initiating the response. This table serves as a resource for CDOT and other stakeholders to prioritize their next steps for improving CDOT's overall speed management program and reduce speeding-related crashes as they consider budget and staffing resources.

The definitions below describe the implementation time, cost, and impacts as they relate to Table 1.

Implementation time

- **Immediate –** Near term; up to 3 months.
- **Short-term –** Up to one year.
- **Long-term –** 1+ years.

Cost

- **Low** – May require labor hours but no monetary investment.
- **Midrange** – May involve significant labor hours and/or investment of up to $100,000.
- **High** – Monetary investments over $100,000.

Impact

- **High** – Ability to address speed management issues statewide and/or significantly reduce crashes.
- **Midrange** – Ability to address speed management issues on a regional or local scale and/or moderately reduce crashes.
- **Project Specific** – Ability to address speed management issues and reduce crashes on a specific project.

Table 1. Recommendations, Implementation Timeframe, Relative Cost, and Relative Impact

Lead Agency	Recommendations	Implementation Time			Cost			Impact		
		Immediate	Short Term	Long Term	Low	Midrange	High	High	Midrange	Project Specific
	Guidance and Support									
CDOT	#1 - Establish consistent and appropriate speed limits through statewide policy.		√		√				√	
CDOT	#2a - Determine when speed limits are to be reassessed and updated.		√		√				√	
CDOT	#2a - Educate local agencies on the re-evaluation process		√		√				√	
CDOT	#3a – Review and update design manuals relating to design speed and future posted speed limits; educate internal staff			√	√				√	
CDOT	#3b – Capitalize on reconstruction opportunities to align design and posted speeds.		√		√				√	
CDOT/DPS	#4 - Review and redefine speeding-related data fields in crash reports.		√			√			√	
	Countermeasure Implementation									
CDOT	#5 - Explore various weather responsive traffic management (WRTM) strategies that can be implemented to help prevent speeding-related crashes during inclement weather.			√			√	√		
CDOT/DPS	#6a - Consider interactive speed countermeasures and continue using automated enforcement in “special use areas.”		√			√		√		
CDOT	#6b – Consider use of variable speed limits in select work zones.		√			√				√
CDOT	#7a - Consider empowering local agencies with opportunities to install traffic calming measures, and provide guidance.		√		√				√	
CDOT	#7b - Proactively identify corridors where traffic calming measures may be suitable and coordinate with local agencies to apply the guidance.		√		√			√		
	Coordination									
CDOT	#8a - Capitalize on existing stakeholder meetings or develop a speed management task force.	√			√				√	
CDOT	#8b - Expand current partnerships and build new ones.		√		√				√	
CDOT	#8c - Promote a safe speed culture.			√		√		√		

3 Identify Speeding-related Problem Locations and Countermeasures using Systemic Data Analysis

The previous chapter provided suggestions and a framework for updating speeding-related policies and programs. This chapter outlines the process for identifying speeding-related crash locations through the use of systemic analysis. CDOT relies heavily on traditional crash analysis methods, which identify improvement sites based on the number of severe crashes, but is starting to conduct more systemic safety analysis.

CHALLENGE: CDOT lacks a documented process for identifying and improving high-risk locations. Crash data can be unreliable.

RECOMMENDATION: Use a systemic approach to safety data analysis that is not solely dependent upon crash data.

Support: As a proactive means of addressing speeding-related crashes, CDOT can conduct systemic safety data analyses to determine risk-based roadway and traffic features that contribute to speeding. The systemic safety approach predicts roadway and traffic characteristics that are most likely to contribute to or be involved in fatal and serious injury crashes. Widespread implementation of low-cost countermeasures complements the analysis component by reducing all crash severity levels.

This recommendation has two parts: (1) encourage use of systemic safety data analysis to identify locations and (2) determine low-cost countermeasures that can be systemically implemented to address the risk factors.

1) **Train staff on how to conduct systemic safety data analysis to identify locations and encourage the use of the approach.** FHWA provides training on how to apply the systemic safety approach and offers technical assistance to help agencies understand and use it effectively. Visit FHWA's Systemic Approach to Safety website to access systemic analysis tools and free training: https://safety.fhwa.dot.gov/systemic/.

   Additionally, FHWA's *Development of a Speeding-related Crash Typology* gives insights into the road conditions and vehicle, driver, and crash characteristics by which speeding-related crashes most often occur.

2) **Determine low-cost countermeasures to implement systemically.** Using systemic data analyses performed using CDOT crash, roadway, and traffic data, a discussion of risk factors and complementary speeding-related countermeasures are provided within this chapter.

The remainder of this chapter presents a systemic approach to crash data analysis using CDOT's crash, roadway, and traffic data, based on the process outlined in FHWA's *Systemic Safety Project Selection Tool.*[5] The process includes:

1. Identifying focus crash types.
2. Identifying focus facilities.
3. Identifying and evaluating risk factors based on fatal crash locations in the focus group.
4. Applying risk factors to the entire focus group population in order to identify a ranked list of sites that exhibit the greatest number of risk factors.
5. Selecting the appropriate countermeasure(s).

Risk factors are characteristics present at fatal and serious injury crash locations that may have contributed to either the occurrence of the crash or its severity. Risk factors may be the degree of curvature, the posted speed limit, or other elements.

3.1 Identify Focus Crash Types

The project team analyzed Colorado's crash data to determine the extent of speeding-related crashes in the State, the severity of those crashes, and other crash characteristics. CDOT provided 5 years (2011-2015) of crash data from the State database for analysis. This set of data included information about all crashes on all roads.

FHWA has determined that integrating speed management into roadway departure, intersection, and pedestrian and bicycle safety focus areas has great potential to reduce fatalities and help States reach safety goals. Therefore, CDOT and the project team selected the following three speeding-related crash types to analyze within this plan:

- Roadway departure crashes on horizontal curves and tangent segments (separately)
- Intersection crashes
- Pedestrian and bicycle crashes

The following sections describe how the project team defined and queried CDOT crash and roadway dataset for each of these focus crash types.

3.1.1.1 Defining Speeding-related Crashes

Based on the discussion during the workshop at CDOT with agency and stakeholders, the team defined speeding-related crashes using the crash report's estimated vehicle speed fields, entitled [speed_1], [speed_2], and [speed_3], and the posted speed limit field, entitled [limit1], as follows:

[5] H. Preston, R. Storm, J. D. Bennett, B. Wemple. July 2013. "Systemic Safety Project Selection Tool." Federal Highway Administration. FHWA-SA-13-019. Washington DC. Accessible at: https://safety.fhwa.dot.gov/systemic/resources.cfm

- For roads where the posted speed limit is 35 mph or lower, crashes are coded as speeding-related if the estimated vehicle speed at the time of the crash is 5 mph or more over the speed limit; or,
- For roads where the posted speed limit is greater than 35 mph, crashes are coded as speeding-related if the estimated vehicle speed at the time of the crash is 10 mph or more over the speed limit.

3.1.1.2 Defining Roadway Departure Crashes

The project team defined roadway departure crashes as those in the crash database that meet the following criteria:

- All non-pedestrian, non-bicycle crashes that:
    - Do not include intersection crashes.
    - Do not include any other pedestrian or pedalcycle-related crashes.

The project team used the field [road_desc], and to exclude intersection crashes, we selected the crashes within this field coded as "Non-Intersection." Then, to determine roadway departure crashes, the team used fields [acctype] and [event_1] and selected crashes within the fields coded as any of the below:

- Barricade/Traffic Barrier
- Bridge Rail
- Cable Rail
- Concrete Barrier
- Crash Cushion
- Culvert/Headwall
- Curb/Raised Median
- Delineator Post
- Embankment Cut/Fill Slope
- Fence
- Guard Rail
- Head-On
- Involving Other Object
- Large Boulders Or Rocks
- Light/Utility Pole
- Mailbox
- Other Fixed Object
- Overturning
- Sideswipe Opposite Direction
- Sign
- Traffic Signal Pole
- Tree/Shrubbery
- Wall/Building

The project team combined this query criteria with that described under *Defining Speeding-related Crashes* to generate all roadway departure crashes involving speeding.

3.1.1.3 Defining Roadway Departure Crashes at Horizontal Curves

The project team defined crashes at horizontal curves as those in the crash database that were coded as "Curve On-Grade" or "Curve On-Level" in [contour] field.

The project team combined this query criteria with that described under *Defining Speeding-related Crashes* and *Defining Roadway Departure Crashes* to generate all roadway departure crashes at horizontal curves involving speeding.

3.1.1.4 Defining Roadway Departure Crashes at Segments

The project team defined crashes at segments as those in the crash database that that were coded as "Straight On-Grade" or "Straight On-Level" in [contour] field.

The project team combined this query criteria with that described under *Defining Speeding-related Crashes* and *Defining Roadway Departure Crashes* to generate all roadway departure crashes at segments involving speeding.

3.1.1.5 Defining Intersection Crashes

The project team defined crashes at intersection as those in the crash database that were coded in the [road_desc] field as one of the below:

- At Driveway Access
- At Intersection
- In Alley
- Intersection-related
- Roundabout

The project team combined this query criteria with that described under *Defining Speeding-related Crashes* to generate all intersection crashes involving speeding.

3.1.1.6 Defining Pedestrian and Bicycle crashes

The project team defined pedestrian and bicycle (or pedalcycle) crashes using the [acctype] and [event_1] fields. If "Bicycle" or "Pedestrian" was indicated in either field, then the crash was assumed to involve a pedestrian or bicycle crash.

The project team combined this query criteria with that described under *Defining Speeding-related Crashes* to generate all pedestrian and bicycle crashes involving speeding.

3.2 Identify Focus Facilities

The goal of establishing a focus facility type is to take a very broad crash type (e.g., horizontal curves) and break it down into smaller groups based on location types that exhibit similar risk characteristics. It is sometimes easiest to represent this “narrowing down” as a crash tree diagram that graphically breaks down crashes into progressively more detailed categories.

The highest level of the crash tree begins with the total number of fatal crashes in the focus crash type. Each subsequent level separates fatal crashes by intrinsic roadway characteristics. The roadway characteristics with the greatest number of fatal crashes are carried forward into the next level of the crash tree diagram. Depending on the data set and the scope of the analysis, each subsequent level may differentiate:

- Segment versus intersection
- Number of lanes
- Divided versus undivided roadways
- Intersection control type, including signalized, unsignalized, and uncontrolled (typical intersection divisions)
- Tangent sections versus horizontal curves
- High-speed versus low-speed
- Presence of street lighting
- District or region

The focus facility type is determined using this method for each focus crash type.

3.2.1 Focus Facility: Roadway Departure

Roadway departure crashes are broken down into crashes at horizontal curves and at segments.

3.2.1.1 Focus Facility: Roadway Departure at Horizontal Curve

Horizontal curve crashes account for 26 percent of all speeding-related fatalities, 19 percent of K+A crashes, and 12 percent of total crashes, even though horizontal curves comprise a small proportion of Colorado's roadway network.

This crash type was broken down by:

- Rural vs. urban
- Undivided vs. divided
- Number of lanes
- Posted speed limit

For each level of the crash tree, the largest group is identified and broken down into the next level.

The resulting focus facility type represents 30 percent of all roadway departure horizontal curve speeding-related fatal crashes.

Roadway Departure at Horizontal Curves Focus Facility: Rural *two-lane undivided horizontal curves with posted speeds between 40-50 mph.*

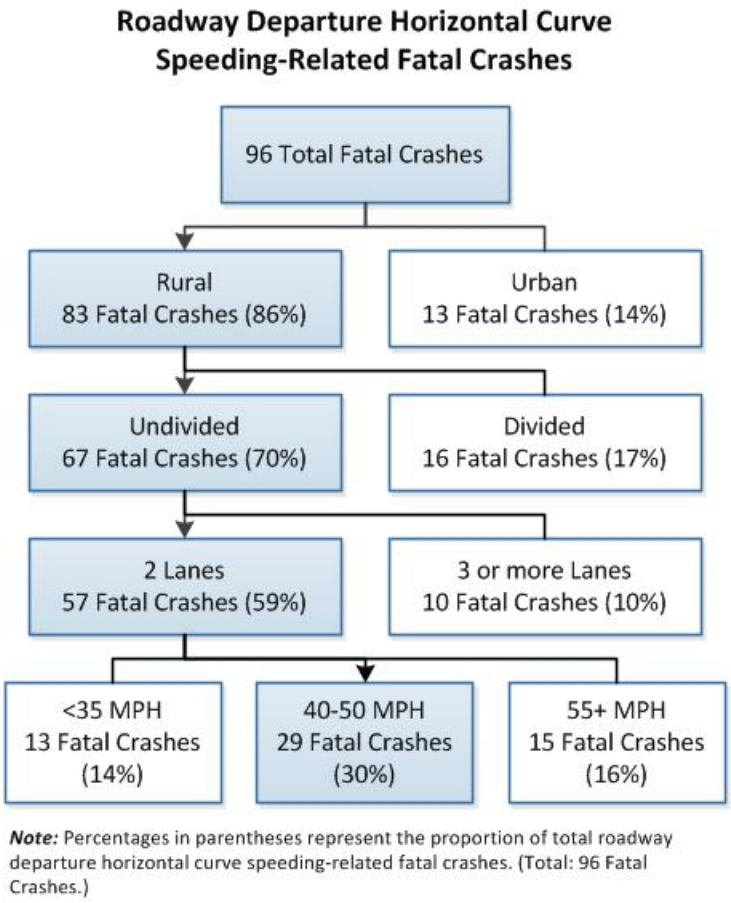

Figure 6. Roadway Departure Horizontal Curve Speed-related Fatal Crashes.

3.2.1.2 Focus Facility: Roadway Departure at Tangent Segments

Roadway departure tangent segment crashes account for 29 percent of all speeding-related fatalities, 26 percent of K+A crashes, and 17 percent of total crashes.

This crash type was broken down by:

- Rural vs. urban
- Undivided vs. divided
- Number of lanes
- Posted speed limit
- ADT

For each level of the crash tree, the largest group is identified and broken down into the next level.

The resulting focus facility type represents 17 percent of all roadway departure speeding-related fatal crashes on straight segments.

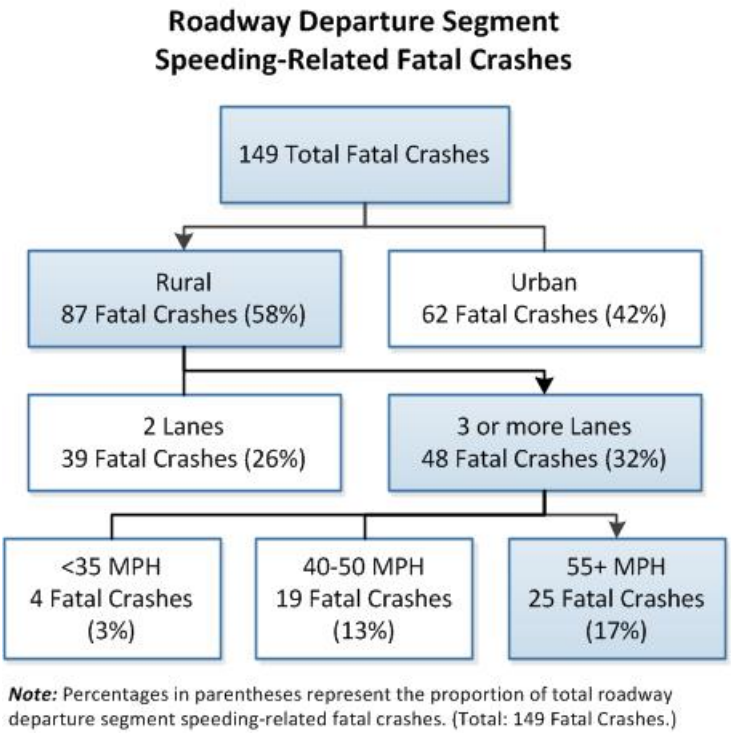

Figure 7. Roadway Departure Segment Speeding-related Fatal Crashes

Roadway Departure at Tangent Segments Focus Facility: *Rural two-lane undivided tangent segments with posted speeds of 55 mph or greater and with an ADT of 2,000 or more.*

3.2.2 Focus Facility: Intersections

Intersection crashes account for account for 32 percent of all speeding-related fatal crashes, 41 percent of K+A crashes, and 48 percent of total crashes.

This crash type was broken down by:

- Rural vs. urban
- Signalized vs. unsignalized vs. roundabout
- Number of lanes

For each level of the crash tree, the largest group is identified and broken down into the next level.

The resulting focus facility type represents 25percent of all intersection speeding-related fatal crashes.

Intersection Focus Facility: *Rural two-lane unsignalized intersections.*

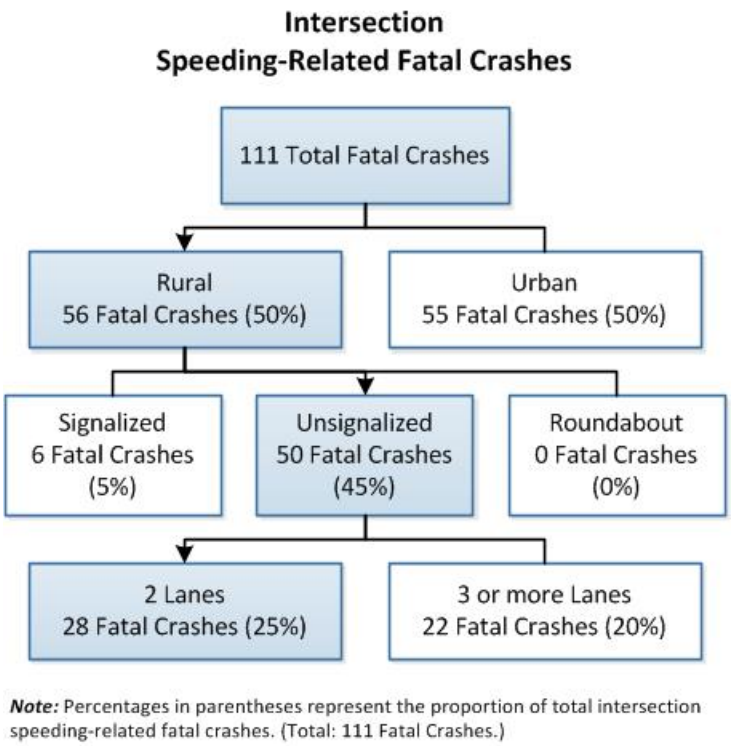

Figure 9. Intersection Speeding-related Fatal Crashes

3.2.3 Focus Facilities: Pedestrian and Bicycles

Pedestrian and bicycle crashes account for 4 percent of all speeding-related fatal crashes, 5 percent of K+A crashes, and 1 percent of total crashes.

This crash type was broken down by:

- Rural vs. urban
- Undivided vs. divided
- Speed limit

For each level of the crash tree, the largest group is identified and broken down into the next level.

The resulting focus facility type represents 38percent of all pedestrian and bicycle speeding-related fatal crashes.

Pedestrian and Bicycle Focus Facility: *Divided urban roadways with speed limits of 35 mph or less.*

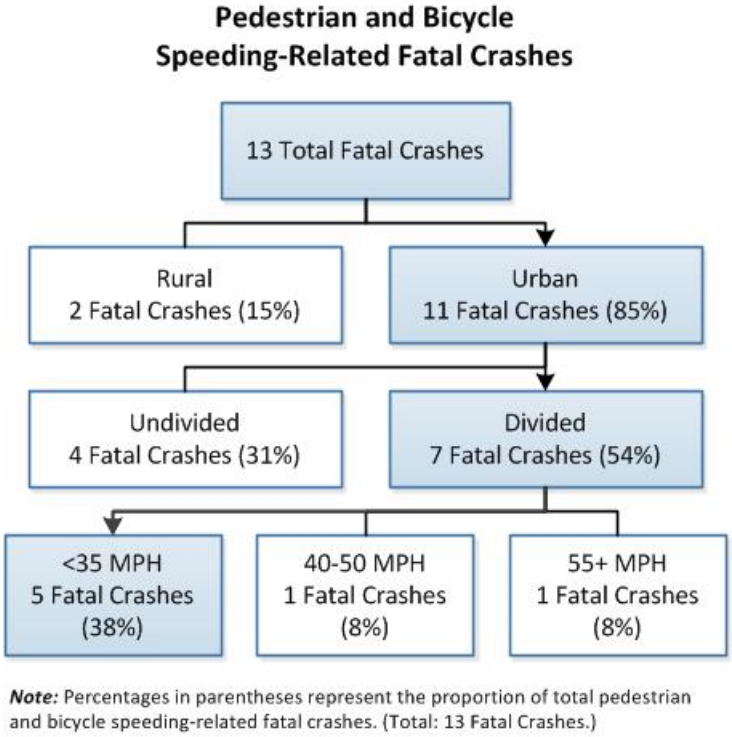

Figure 9. Pedestrian and Bicycle Speeding-related Fatal Crashes

3.2.4 Focus Facility Summary

The previous section used fatal crashes to identify focus crash types and focus facility types. These are summarized below. Each focus facility comprises a sizeable proportion of the focus crash type and represents the types of roadways where SCDOT can realize the largest safety improvement for the investment.

Roadway Departure at Horizontal Curve Focus Facility: Rural two-lane undivided horizontal curves with posted speeds between 40-50 mph. This focus facility type makes up 30 percent of all horizontal curve fatal crashes.

Roadway Departure at Tangent Segments Focus Facility: Rural two-lane undivided horizontal curves with posted speeds of 55 mph or greater and with an ADT of 2,000 or more. This focus facility type makes up 17 percent of all fixed object fatal crashes.

Intersections Focus Facility: Rural two-lane unsignalized intersections. This focus facility type makes up 25 percent of all horizontal curve fatal crashes during inclement weather.

Pedestrian and Bicycle Focus Facility: Divided urban roadways with speed limits of 35 mph or less. This focus facility type makes up 38 percent of all intersection fatal crashes during inclement weather.

The next step is to identify risk factors inherent to these focus facilities. In later steps, these risk factors will enable SCDOT to identify potentially dangerous locations that may not have experienced a fatal crash or serious injury crash yet, but may experience one in the future. Through this systemic process, crashes can be prevented before they occur.

3.3 Identifying, Evaluating, and Applying Risk Factors

The next step is to define, document, and assess the most common roadway characteristics, or risk factors, associated with the focus crash type and focus facility type. Risk factors are roadway characteristics that are present in severe crash locations and have been shown to increase the likelihood of a crash. This section discusses how to identify, evaluate, and apply risk factors within the systemic safety analysis process.

Note that a roadway feature itself is not the risk factor. It is the degree of the characteristic that causes the characteristic to be unsafe. For example, 10-ft. lane widths would be a greater risk factor than 11-ft. wide lanes, since the degree of variance from a standard 12-ft. lane is more when lane width is 10 ft.

CDOT should select risk factors that they can apply to the entire facility.

Potential risk factors

- Number of lanes
- Lane width
- Shoulder width
- Clear zone width
- Roadside hazard rating
- Absence of center or edge lines
- Curve radius
- Grade
- Superelevation
- Pavement friction
- Sight distance
- Number of roadside obstacles per mile

More examples can be found in the resources shown at left.

3.3.1 Identify Risk Factors

Identifying risk factors can largely come from engineering judgment and experience, but it can also come from documented resources. Below are several sources CDOT might use to identify risk factors for their focus facility types:

FHWA's Potential Risk Factors list.[6] FHWA provides a list of potential risk factors for curves, segments, and intersections that is classified into three categories: *Roadway & Intersection Features, Traffic Volume,* and *Other Features*.

***Highway Safety Manual* (HSM).**[7] Each chapter in Parts C and D of the HSM focuses on a facility type and organizes crash modification factors (CMF) by roadway characteristic (e.g., lane width, shoulder width, roadside hazard rating). These roadway characteristics can be used as risk factors.

Field Visits to Several Sites. Visiting several locations within the focus facility type will help identify common risk factors that may be present at other locations within the same facility type.

Transportation Personnel. Talking with pavement and maintenance staff can yield otherwise unforeseen risk factors. EMS providers and law enforcement may also have an opinion of risk factors that contribute to crashes on the focus facility type.

[6] Federal Highway Administration (FHWA). *Potential Risk Factors*. Washington, D.C. Accessible at: http://safety.fhwa.dot.gov/systemic/pdf/FHWA_SystemicApproach_PotentialRiskFactors.pdf

[7] American Association of State Highway and Transportation Officials (AASHTO). *Highway Safety Manual*. 2010. 444 N Capitol St. NW - Suite 249 - Washington, DC 20001.

3.3.2 Collecting Data for Risk Factor Analysis

In order to determine if a roadway characteristic is a risk factor, the roadway characteristic must be quantified at each fatal/serious injury crash location within the focus facility type. Agencies often select 5 – 10 roadway characteristics to evaluate for risk factors. The selection is based on engineering judgement of the underlying causes of the fatal/serious injury crashes and availability of roadway and intersection data. An agency does not necessarily need a robust dataset to identify locations that can benefit from a safety improvement. Below are several methods CDOT could use to quantify roadway and intersection characteristics for risk factor evaluation.

Roadway and intersection inventories can provide most of the data needed to identify risk factors and prioritize locations based on the number and severity of risk factors present.

Online aerial imagery (e.g., Google Earth Pro, Bing maps) allows practitioners to view many roadway data attributes from their desk and estimate the number of risk factors present at a given location. For example:

- **Lane width and shoulder width** can be estimated using Google Earth Pro's *Ruler Line* tool.
- **Clear zone width and presence of obstacles** can be detected by using the *Street View* feature.
- **Side slope** can be estimated using a combination of Google Earth Pro's *Ruler Line* tool and *Elevation* tool.
- **Curve radius** can be estimated using Google Earth Pro's *Ruler Circle* tool.

Photo and video logs captured and retained by many agencies can be used similarly to Google Earth to estimate many roadway data attributes including lane width, shoulder width, segment length, roadside hazard rating, and curve density.

Field visits enable precise measurement of all roadway and intersection characteristics of interest. They can also provide valuable insight to the "sense" of the crash site that cannot be captured through aerial photos or roadway and intersection inventories.

> Building a more comprehensive roadway and traffic inventory database will enhance CDOT's ability to perform systemic safety analyses.

CDOT's roadway and traffic inventory databases currently contain lane and shoulder width values, number of lanes, posted speed limits, and ADT, which together provide a good start for performing systemic analyses. If additional risk factors resulting in more nuanced analyses capabilities are desired, CDOT will need to obtain these manually through field visits, roadway video footage, or aerial map software. CDOT should work towards building an even more comprehensive roadway inventory database, which will allow for more robust systemic safety analysis.

3.3.3 Evaluating Risk Factors

The next step is to determine the degree to which risk factors decrease safety. Small differences from the base condition, or "ideal" roadway configuration, may not have a noticeable impact on safety. CDOT should select the threshold at which deviations from the base condition noticeably affect safety. This

threshold (e.g., lane widths of 10 ft. or less) is the risk factor used in the next section to prioritize locations for countermeasure selection and treatment. Risk factor thresholds can be determined in several different ways:

HSM and CMF Clearinghouse. Practitioners can use the HSM and the CMF Clearinghouse[8] to estimate the degree to which each risk factor contributes to the overall reduced level of safety within the facility type. CDOT can select one of the following approaches:

1. Use the CMF values in the HSM and CMF Clearinghouse to individually predict the increased number of crashes over the base condition for each site. (Sites are prioritized based on predicted number of crashes.)
2. Set a threshold value (e.g., lane widths of 10 ft. or less) for which every site that meets or exceeds this threshold is flagged. (Sites are prioritized based on those exhibiting the greatest number of flagged risk factors.)

Qualitative Assessment. Based on experience, engineering judgment, and engineering guidance, CDOT may choose to quantify levels of risk factors as *Low*, *Medium*, or *High,* especially where exact data may be missing. Using the same example, a lane width of 11 ft. to 11.5 ft. may be classified as *Low*, 10.5 ft. to 11 ft. as *Medium*, and below 10 ft. as *High* risk for potential crashes.

Crash Data. CDOT can use crash data to determine the threshold values for risk factors. For example, agency staff may compare fatality and serious injury crashes on roads with lane widths of 9.5 ft., 10 ft., 10.5 ft., and 11 ft. and find that a significant decrease in safety occurs on roads with lane widths of 10 ft. or less. The agency would then use lane widths of 10 ft. or less as one of their risk factors.

3.3.4 Apply Risk Factors / Screen and Prioritize Candidate Locations

Once CDOT identifies risk factors and their threshold values for each focus facility, the next step is to expand the vetting process from the fatal/serious injury crash locations used to determine the focus facility to locations experiencing all crash severity levels within the focus facility type. This can be accomplished by using roadway and intersection data collected from a roadway or intersection inventory, online aerial imagery, photo or video logs, or field visits through a similar process as *Section 3.3.1 Collecting Data for Risk Factor Analysis*.

For each crash location, determine the number of risk factors it exhibits. Rank locations based on the number of risk factors present. Systemic analysis approaches might weigh risk factors equally, which simply means the more risk factors present, the higher the location's priority. However, risk factors also can be given relative weights. In this case, particular risk factors—if found to have a stronger association with locations where severe focus crashes occurred—can be given larger weights.

Through this method, fatal crash locations will be ranked near the top of the list along with non-fatal crash locations.

[8] Federal Highway Administration (FHWA). *CMF Clearinghouse User Guide*. Washington, D.C. Accessible at: http://www.cmfclearinghouse.org/userguide.cfm.

1.1.1.1 Example: Using the HSM to Determine and Apply Risk Factors

An agency is applying systemic safety analysis to the below crash type and focus facility type.

Crash Type: Horizontal Curves

Focus Facility Type: Two-lane, rural, horizontal curves with posted speeds of 55 mph or greater and an ADT of 2,000 or above.

The agency chooses lane width, shoulder width, curve radius, and roadside hazard rating as its risk factors, because these can be queried from its roadway inventory database and through manual investigation using Google Earth Pro. For its focus facility type, the agency finds that lane width varies between 9 ft. and 14 ft., shoulder width between 0 ft. and 8 ft., curve radius between 400 ft. and 1,500 ft., and roadside hazard rating between 2 and 7.

The agency chooses to consult the HSM to determine threshold risk values. They assume an average curve length of 2,000 ft. in order to simplify curve radius calculations. The resulting CMFs are as follows:

Lane Width	CMF
12 ft.	1.00
11 ft.	1.05
10 ft.	1.30
9 ft.	1.50
Source: HSM p. 10-24	

Shoulder Width	CMF
6 ft.	1.00
4 ft.	1.15
2 ft.	1.30
0 ft.	1.50
Source: HSM p. 10-26	

Curve Radius	CMF
1100ft	1.14
900ft	1.17
700ft	1.20
500ft	1.23
Source: HSM p. 10-27	

Roadside Hazard Rating	CMF
4	1.07
5	1.14
6	1.22
7	1.31
Source: HSM p. 10-30	

The agency chooses to focus on risk factors that cause a 20-percent increase in crash likelihood over the HSM-defined base conditions. As a result, the agency selects the following risk factors, which have a CMF of 1.2 or greater, for this scenario.

Risk Factors:

Lane Width = 10 ft. or less
Shoulder Width = 2 ft. or less
Curve Radius = 700 ft. or less (assuming an average curve width of 2,000 ft.)
Roadside Hazard rating = 6 or greater

The agency vets all roadways in the focus facility type (regardless of crash frequency or severity) by these risk factors. Roadways that have all four risk factors are prioritized for countermeasure selection. Since this is only a small number of locations, the agency also considers locations that have three risk factors for countermeasure implementation, as funding allows.

3.4 Selecting Speeding-related Countermeasures

Countermeasure selection will be largely based on the risk factors identified. For example, if narrow clear zone is a risk factor, then a countermeasure may be expanding clear zone widths. Not all risk factors need to be directly correctable. For example, if a horizontal curve has narrow lanes, a small radius, and no shoulders or clear zone, then an appropriate countermeasure may be enhanced roadside delineation. Directly addressing a risk factor by widening the road or straightening out a curve is probably not cost effective. Once risk factors are identified, the benefit-cost ratio should be considered when selecting appropriate countermeasures.

The following sections propose and describe countermeasures that could be used to reduce speeding-related crashes at the focus facility types identified previously (horizontal curves and tangent sections (roadway departure), intersections, and pedestrian and bicycle).

3.4.1 Roadway Departure Countermeasures

This section lists countermeasures that could be used to reduce speeding-related roadway departure crashes and includes various resource links.

Remove, shield, or delineate fixed objects within curves. Remove trees, brush, and other obstacles within a designated distance from the edge of travel way along the outside of curves as appropriate. Shield or delineate any fixed objects that cannot feasibly be removed along the outside of the curve; all fixed objects including trees, utility poles, culverts/bridge abutments, mailboxes, and guardrail should be considered.

Enhanced curve signing and delineation. Install oversized signs, florescent sheeting, full post delineation, and center and edge line striping at curves with high rates of speeding-related roadway departure crashes.

Sequential dynamic curve warning system. This warning device contains a series of blinking chevron signs installed along a curve that flashes sequentially through the curve to alert speeding drivers of both the presence of the curve and the location of the edge of the roadway during low-light conditions. Consider this strategy if enhanced curve signing and delineation has been previously installed and the area is still experiencing high rates of speeding-related crashes.

ITS solutions. Speed feedback signs, also called speed-activated warning or speed limit reminder signs, remind drivers of their speed. Research shows these types of signs have been effective at reducing speeds by 5 mph.

Rumble strips. Rumble strips are milled or raised elements on the pavement that, when traversed by a tire, alert drivers through vibration and sound that their vehicles have left the travel lane. They are designed to address crashes caused by distracted, drowsy, or otherwise inattentive drivers who drift from their lane (which often occurs in horizontal curves). They are most effective when deployed in a systemic application, since driver error may occur on all roads.

High-friction surface treatments (HFST). HFST uses a thin layer of durable, high friction calcined bauxite aggregate as a topping on resins or polymers—usually urethane, silicon, or epoxy—with a

binder. These aggregate systems provide long-lasting skid resistance and make the overlay much more resistant to wear and polishing than standard pavements. The increased friction enables shorter stopping distances and provides speeding drivers a better opportunity to recover from their mistakes.

Transverse or optical speed bars. This pavement measure creates a visual effect that encourages motorists to slow down. Bar placement can be designed to minimize wear from wheel tracking. Studies show reductions in 85th percentile speeds up to 5 mph. This treatment is used when there is a need for a sudden decrease in speed (e.g., at sharp curves).

Targeted enforcement, outreach, and education. Determine specific corridors with a high speeding-related roadway departure crash history and conduct high-visibility enforcement and education efforts. Data shows males are more likely to be involved in speeding-related crashes, and that motorcyclists are at high risk of involvement in this type of crash.

RESOURCES

FHWA, Integrating Speed Management within Roadway Departure, Intersections, and Pedestrian and Bicyclist Safety Focus Areas. Speeding contributes to nearly one-third of all roadway fatalities, and this proportion has remained largely unchanged for the past decade. Since roadway departure, intersection, and pedestrian and bicycle crashes have been identified by the FHWA as three areas with great potential to reduce fatalities, States are being encouraged to integrate speed management into these three safety focus areas.

FHWA's Horizontal Curve Safety website provides resources and links relating to curve-related safety countermeasures. FHWA also offers a Pavement Friction website that provides information on both traditional and high-friction surface treatments as well as case studies, noteworthy practices, and other resources.

FHWA has recently announced two new proven safety countermeasures that are focused on curve safety but are also applicable to speed management: Enhanced Delineation and Friction for Horizontal Curves Flyer and Roadside Design Improvements at Curves Flyer.

Visit FHWA's Clear Zone website for many resources and guidance relating to appropriate clear zones, tree and landscaping considerations, and utility and roadside safety.

For information on appropriate roadside barriers, check out FHWA's Countermeasures that Reduce Crash Severity website, which provides links to hardware eligibility letters, guidance and policies, and other resources.

3.4.2 Intersection Countermeasures

This section lists countermeasures that could be used to reduce speeding-related intersection crashes and includes resource links.

Improve visibility or conspicuity of intersections. Ensure sight distance is adequate, clear sight distance triangles, install advance signing, and enhance striping. Installation of lighting may also be beneficial if there are patterns of nighttime speeding-related crashes.

Reduce left-turn conflicts at intersections. Convert protected-permitted left turn signal phasing to protected-only. Consider alternative intersection designs to limit or eliminate the left-turning conflict movements, such as the restricted crossing U-turn or the median U-turn.

ITS solutions. Install intersection conflict warning system (or dynamic advance intersection warning system) that notify the side street or major street vehicle of an approaching vehicle.

Smooth lane narrowing. For intersections located on higher-speed roadways, narrow the lanes leading up to the intersection using pavement markings or medians to create visual cues to drivers that the roadway is changing and there is a need to slow.

Transverse rumble strips. Install transverse rumble strips prior to the intersection on the stop-controlled approach.

Targeted enforcement, outreach, and education. Determine specific corridors with a high speeding-related intersection crash histories and conduct high visibility enforcement and education efforts.

RESOURCES

FHWA's Intersection Safety website provides strategies and resources to make intersections safer.

Review FHWA's Intersection Safety Strategy brochure for concise information on intersection countermeasures.

FHWA has recently announced two new Proven Safety Countermeasures that are focused on intersection safety: Systemic Application of Multiple Low Cost Countermeasures at Stop-Controlled Intersections and Reduced Left-Turn Conflict Intersections.

3.4.3 Pedestrian and Bicycle Countermeasures

This section lists countermeasures that could be used to reduce speeding-related pedestrian and bicycle crashes and includes resource links.

Road Diets. Review existing candidate roads for reconfiguring lanes. Studies show that Road Diets, when implemented in appropriate contexts, can lower speeds and reduce the number of motorists speeding excessively, improving the overall safety of pedestrians and bicyclists. Additional space created can be used to build sidewalks, pedestrian refuge islands, bicycle lanes, landscaping, and other features.

Evaluate sidewalk and bicycle lane gaps. Since pedestrian and bicycle crash data is limited, gauge crash risk to these vulnerable users by inventorying gaps in sidewalks and bicycle lanes. Having this framework, comparing it to crash data, traffic counts, etc., can be a starting point to then prioritize pedestrian and bicycle safety projects.

Appropriate speed limits. Balance multimodal interests within the context of the facility, considering the different users and uses when setting speed limits.

Pedestrian refuge islands and curb extensions. Pedestrian refuge islands allow pedestrians to cross in two stages, simplifying the crossing task. Refuge islands or median islands also provide visual friction to reduce the speed of motorists. Curb extensions provide safety benefits to pedestrians by reducing their crossing distance and improving the visibility of pedestrians by aligning them with the parking lane.

Speed feedback signs. In areas of high pedestrian and bicycle activity, where speeding is a concern, install speed feedback signs, which display a driver's current speed.

Pedestrian hybrid beacon. The pedestrian hybrid beacon (PHB) or HAWK signal is a traffic control device designed to help pedestrians safely cross busy or higher-speed roadways at midblock crossings and uncontrolled intersections.

Targeted enforcement, education and outreach. Enforce speed limits at speeding-related crash locations where there is increased risk of pedestrian or bicyclist involvement, such as schools, busy urban areas, etc. Conduct education and outreach on pedestrian and bicyclist safety, from all viewpoints; i.e., teaching the pedestrian, bicyclist, and driver important safety tips and rules.

RESOURCES

FHWA's Pedestrian and Bicycle Safety website provides strategies and resources for pedestrian and bicycle safety.

FHWA's Road Diet website presents guidance, resources, and case studies relating to Road Diets.

3.4.4 Speeding-related Countermeasure Cost and CMF Matrix

The relative cost and CMF values for the countermeasures in this section are summarized in the table below. The CMF Clearinghouse and other published resources should be used to learn more about the expected safety benefits and what types of crashes are addressed. The definitions below describe the implementation cost as they relate to Table 2.

Cost

- **Low** – Under $5,000 at a single implementation site.
- **Midrange** – Over $5,000 and up to $100,000 at a single implementation site.
- **High** – Investments over $100,000 at a single implementation site.

Site conditions and crash types should be examined before determining the suitability of these speed-related countermeasures. Where several countermeasures may be deemed suitable, CDOT should consider prioritizing implementations on a lowest cost, most effective CMF, or highest benefit-cost basis.

3.4.5 Implementation Considerations

Countermeasures can be implemented through systemic and stand-alone projects. Opportunities to incorporate countermeasures into planned projects should be evaluated for feasibility. Some countermeasures can be implemented as a result of a change in policy; for example, installation of oversized signs, florescent sheeting, and full post delineation on all roadways meeting a certain criteria.

Speed-related countermeasures often have synergies with treatments designated for roadway departure, intersections, bicycles and pedestrians, and other crash types. CDOT should cross reference all countermeasures outlined in this plan with the Colorado Strategic Highway Safety Plan (SHSP), the Colorado Highway Safety Improvement Plan (HSIP), roadway departure and intersection safety implementation plans, and others as appropriate.

Speed-related countermeasures where a safety benefit can be shown are eligible for HSIP funding and can also be incorporated into the State's transportation improvement program through individual or systemic projects.

Table 2. Speeding-related Countermeasure Cost and CMF Matrix

Countermeasure	Impact Area			Cost			CMF
	RwD	Intersections	Ped/Bike	Low	Mid	High	
Enhanced curve signing and delineation	X			X			0.671 – 0.741
Sequential dynamic curve warning system	X				X		0.438 – 0.627
Signing or dynamic signing addressing speed	X	X	X		X		0.87 – 0.95
Transverse or optical speed bars.	X			X			0.68
Remove or delineate fixed objects within curves	X			X			0.5 - 0.9
Rumble strips	X		X	X			0.6 – 0.85
High friction surface treatments (HFST)	X				X		0.522 – 0.607
Improve visibility or conspicuity of intersections		X		X			Unknown
Reduced left-turn conflicts at intersections (Note: relative cost varies depending on design/project)		X			X	X	0.5 - 0.7
Smooth lane narrowing		X		X			Unknown
Transverse rumble strips		X		X			0.36 – 1.4
Road Diet (Note: relative cost varies depending on design/project)			X	X	X		0.59 – 1.0
Pedestrian refuge islands and curb extensions			X		X		0.54 – 1.94
Pedestrian hybrid beacon			X		X		0.30 - 0.85

4 Conclusions and Next Steps

Colorado experiences significant speeding-related fatalities and serious injuries associated with roadway departure crashes on horizontal curves and segments, intersection crashes, and pedestrian and bicycle crashes. As such, this plan encourages Colorado to integrate speed management into these safety focus areas by providing strategies and countermeasures for improving safety in all areas.

In addition, the State and local agencies should take a broad look at the existing policies and programs to identify opportunities for fully integrating speed management throughout their organizations. This document recommends strategies for revising or enhancing existing speed management practices or shaping new practices.

4.1 Partners for Success

This plan's success depends not only on efforts put forth by CDOT, but also local jurisdictions throughout the State and other potential safety partners, such as:

- AAA Colorado - Traffic Safety department
- Bicycle and pedestrian advocacy groups
- Businesses
- Colorado Associated General Contractors
- Emergency services
- Metropolitan planning organizations
- Regional sports teams and other venues for marketing
- Colorado City and County Management Association
- Colorado Department of Motor Vehicles
- Colorado State Patrol and local enforcement agencies
- Colorado Police Chiefs Association
- Colorado Trucking Association
- Work Zone Safety Industry/Groups
- Universities and schools

4.2 Next Steps

When fully implemented, recommendations and strategies identified in this plan can significantly influence the reduction of severe speeding-related crashes in Colorado. Working with its partners, CDOT can extend the speed management topic into practices and policies that encompass the standards by which roadways are designed, constructed, and operated, including the enforcement and adjudication of speeding-related offenses.

CDOT should consider and prioritize the recommendations outlined in Chapter 2: Identifying and Resolving Policy and Program-level Speeding-related Issues and complete the systemic data analyses

described in Chapter 3: Identify Speeding-related Problem Locations and Countermeasures using Systemic Data Analysis in addition to implementing speeding-related countermeasures in Chapter 3.

5 Appendix A – Workshop Attendee List and Agenda

COLORADO
Department of Transportation
Transportation Systems Management & Operations

Speed Management Workshop

Class Dates: May 4, 2017
Class Location: CDOT HQ – Denver, CO

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Colorado Speed Management Action Plan Workshop Agenda

Thursday, May 4, 2017

9:00-9:30	**Welcome and Introductions** Includes a review of workshop goals, objectives and outcomes
9:30-10:30	**Problem Identification** Data Analysis Results High Crash Locations vs. Systemic Approach
10:30-10:45	**Break**
10:45-11:30	**Colorado Speed Management Policies** Speed Limit Setting Existing Safety Plans and Policies
11:30-12:00	**Roadway Departure Crashes** Engineering Countermeasures Behavioral Countermeasures
12:00-1:00	**Lunch**
1:00-1:30	**Intersection Crashes** Engineering Countermeasures Behavioral Countermeasures
1:30-2:30	**Pedestrian and Bicyclist Crashes** Engineering Countermeasures Behavioral Countermeasures
2:30-2:45	**Break**
2:45-3:45	**Developing a Speed Management Action Plan** Key topics/issues to cover in the plan. Challenges to implementation and possible solutions.
3:45-4:00	**Wrap Up** Feedback Next Steps