Boulder County

APPENDIX F

COUNTERMEASURE TOOLKIT

TOOLKIT OF COUNTERMEASURES: SYSTEMWIDE APPROACH TO CRASH REDUCTION

This countermeasure toolkit supports a systemwide approach to crash reduction in Boulder County. It largely focuses on the five common crash types that result in serious injuries and fatalities and also provides speed-related countermeasures and other countermeasures to comprehensively reduce severe crashes.

These top five crash types account for ***77%*** of fatal and serious injury crashes in Boulder County:

- **Single-Vehicle Crashes,** including departing from the road, colliding with fixed objects, collisions with animals, and overturning vehicles
- **Bicycle Crashes**
- **Head-On Crashes**
- **Broadside Crashes**
- **Left-Turn Crashes**

Each crash type and commonly contributing behaviors and characteristics are described in more detail on the subsequent pages. Potential solutions are also identified and should be deployed first at locations with known crash history (higher priority), then at areas with similar characteristics (lower priority).

Planning Level Cost for Identified Solutions:

Costs are estimated in 2025 dollars, with the levels as follows:	
$	Under $50,000
$$	$50,001 - $100,000
$$$	$100,001 – $500,000
$$$$	$500,001 - $1,000,000
$$$$$	Over $1,000,000

SINGLE-VEHICLE CRASHES

Single-vehicle crashes result in ***36%*** of the serious injury and fatal crashes in Boulder County. Examples of single-vehicle crashes include departing from the road, colliding with fixed objects, and overturning vehicles. Some common behaviors and related conditions that most frequently contribute to these types of crashes include:

1. **Departing from the road and colliding with fixed objects.**
    a. Inadequate warning signs, lack of clear lane markings, and lack of roadway shoulders particularly in areas of sharp curves or elevation changes.
    b. Impaired, distracted, and aggressive driving contribute to off-road crashes as they prohibit the driver's ability to focus, react approriately, and maintain control of the vehicle. It may include behaviors such as driving under the influence, speeding, tailgating, and aggressive maneuvers.
2. **Overturning vehicles.**
    a. Impaired, distracted, and aggressive driving contribute to off-road crashes as they prohibit the driver's ability to focus, react approriately, and maintain control of the vehicle. It may include behaviors such as driving under the influence, speeding, tailgating, and aggressive maneuvers.

Potential Solutions

Systemwide Solution & Strategy for Implementation	Cost Considerations	Where to Consider Implementation
Install rumble strips on the shoulder or centerline. Milled or raised elements on the pavement intended to alert drivers through noise and vibration that their vehicle has left the travel lane and they are crossing the centerline. If implemented, to minimize noise impacts, rumble strips should not be installed within 300 feet of residences or businesses.	**$$**	Locations with cross over crashes or off-right crashes; locations with sharp curves.
Install roadside barriers. Safety features along the edge of roads to prevent vehicles from leaving the roadway and to restrict drivers from striking off-road fixed objects, steep embankments, or hazardous terrain. These barriers, which can include guardrails, concrete barriers, or cable barriers, absorb impact and reduce the severity of crashes.	**$$$-$$$$**	Locations with high traffic volumes, sharp curves, or areas with significant roadside hazards.

SINGLE-VEHICLE CRASHES

Potential Solutions (cont.)

Systemwide Solution & Strategy for Implementation	Cost Considerations	Where to Consider Implementation
Install high friction pavement. Produces vibration and sound to prevent roadway departure and alert drivers to slow down.	**$$**	Locations such as sharp curves, intersections, areas with significant slowing/stopping, or steep grades.
Enhance lighting. Improves nighttime visibility at intersections, crosswalks, and along roadways. Installing brighter and more strategically placed lighting helps drivers detect hazards, pedestrians/bicyclists, and roadway features more easily.	**$$-$$$**	Unsignalized or signalized, unlit intersections with patterns of nighttime crashes; unlight roadway segments with patterns of nighttime crashes.
Enhance delineation along horizontal curves. Warn drivers of a change in roadway direction that can be implemented in advance of or within curves, such as chevrons or retroreflective signs.	**$**	Locations with horizontal curves.
SafetyEdge^{SM} technology. Shapes the edge of the pavement at approximately 30 degrees from the pavement cross slope during the paving process. This safety practice eliminates the potential for vertical drop-off at the pavement edge, has minimal effect on project cost, and can improve pavement durability by reducing edge raveling of asphalt.	**$$$**	Locations that are planned for re-paving and have a history of off-right crashes.
Median barrier. Longitudinal barriers that separate opposing traffic on divided highways to reduce cross median crashes. Could include concrete, metal-beam, or cable rail.	**$$$-$$$$$**	Undivided highways with a crossover crash history.
Refer to speeding strategies (below).	**N/A**	N/A

SINGLE-VEHICLE CRASHES

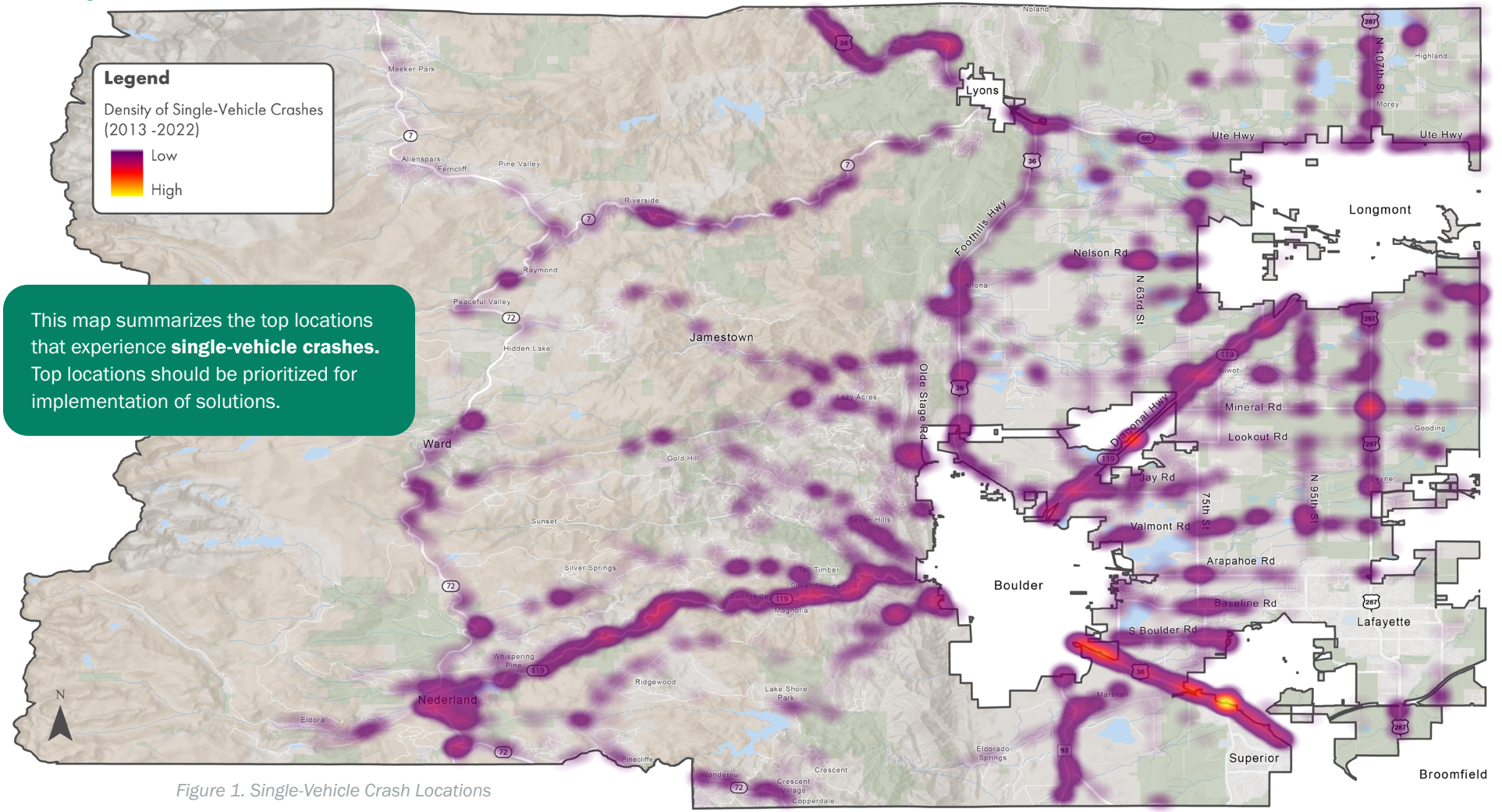

Figure 1. Single-Vehicle Crash Locations

BICYCLE CRASHES

Bicycle crashes result in ***12%*** of the serious injury and fatal crashes in Boulder County. Some common behaviors and related conditions that most frequently contribute to these types of crashes include:

1. **Vehicle failing to yield right-of-way to a bicyclist at an intersection.**
   a. A driver turns right in front of a bicyclist traveling parallel to the vehicle while the bicyclist is crossing the intersection in the street (travel lane or bicycle lane) or in the crosswalk. May involve lack of visibility of bicyclist.
   b. A driver turns left and does not yield to a bicyclist crossing the intersection in the street (travel lane or bicycle lane) or in the crosswalk. May involve lack of visibility of bicyclist.
2. **Vehicle failing to yield to a bicyclist at a non-intersection location.**
   a. Inadequate bicycle facilities where a lack of dedicated bicycle lanes, bike paths, or other bicycle-specific infrastructure forces bicyclists to share lanes with motor vehicles, increasing the risk of vehicles leaving their lane and striking a bicyclist.
   b. Low visibility due to lack of lighting, reflective gear, or improper clothing makes it difficult for drivers to see bicyclists, particularly at night or in low-light conditions.
   c. Impaired, distracted, and aggressive driving contributes to crashes where vehicles depart from their lane or fail to yield the required space for bicyclists and strike a bicyclist traveling along the roadway.
3. **Bicyclist at fault.**
   a. Bicycle fails to obey traffic laws including actions such as running stop signs or red lights, crossing against a traffic signal, failing to signal turns, making sudden lane changes, or riding against the flow of traffic.
   b. Bicyclists riding too fast for conditions and losing control of their bicycle resulting in single-bicycle crash or collision with a vehicle.

Potential Solutions

Systemwide Solution & Strategy for Implementation	Cost Considerations	Where to Consider Implementation
Bicycle or buffered bicycle lanes. Provide dedicated, on-road space for bicycling with additional marked space between vehicles and cyclists.	**$$-$$$**	Roads with lower speeds and volumes.
Separated bicycle lanes. On road space for bicyclists that includes a separated bicycle lane delineated with flexible posts or other barriers to physically separate vehicles and bicyclists.	**$$$-$$$$**	Roads with higher speeds and volumes.

BICYCLE CRASHES

Potential Solutions (cont.)

Systemwide Solution & Strategy for Implementation	Cost Considerations	Where to Consider Implementation
Improvements at intersections. These may include installing bicycle conflict markings (green paint or chevrons) to dedicate space and raise visual awareness to bicyclists through the intersection or installing bike boxes to allow bicyclists to position themselves ahead of vehicles to improve visibility at traffic signals.	$$	Major or minor signalized or unsignalized intersections; high-conflict driveways.
Protect vehicle turning movements in traffic signal phasing. Separate right or left-turn movements from the bicycle movement in the traffic signal phasing at intersections to eliminate conflicts between vehicles and bicyclists. This is particularly effective when there are a high number of left-turning or right-turning vehicles to eliminate conflicts.	$$	Signalized intersections with a high volume bicycle movements and high number of left-turning or right-turning vehicles.
Leading pedestrian interval. Gives a bicyclist (and pedestrian) crossing in the crosswalk a three to seven second head start when entering an intersection with a corresponding green signal in the same direction.	$	Signalized intersections.

BICYCLE CRASHES

This map summarizes the top locations that experience **bicycle crashes.** Top locations should be prioritized for implementation of solutions.

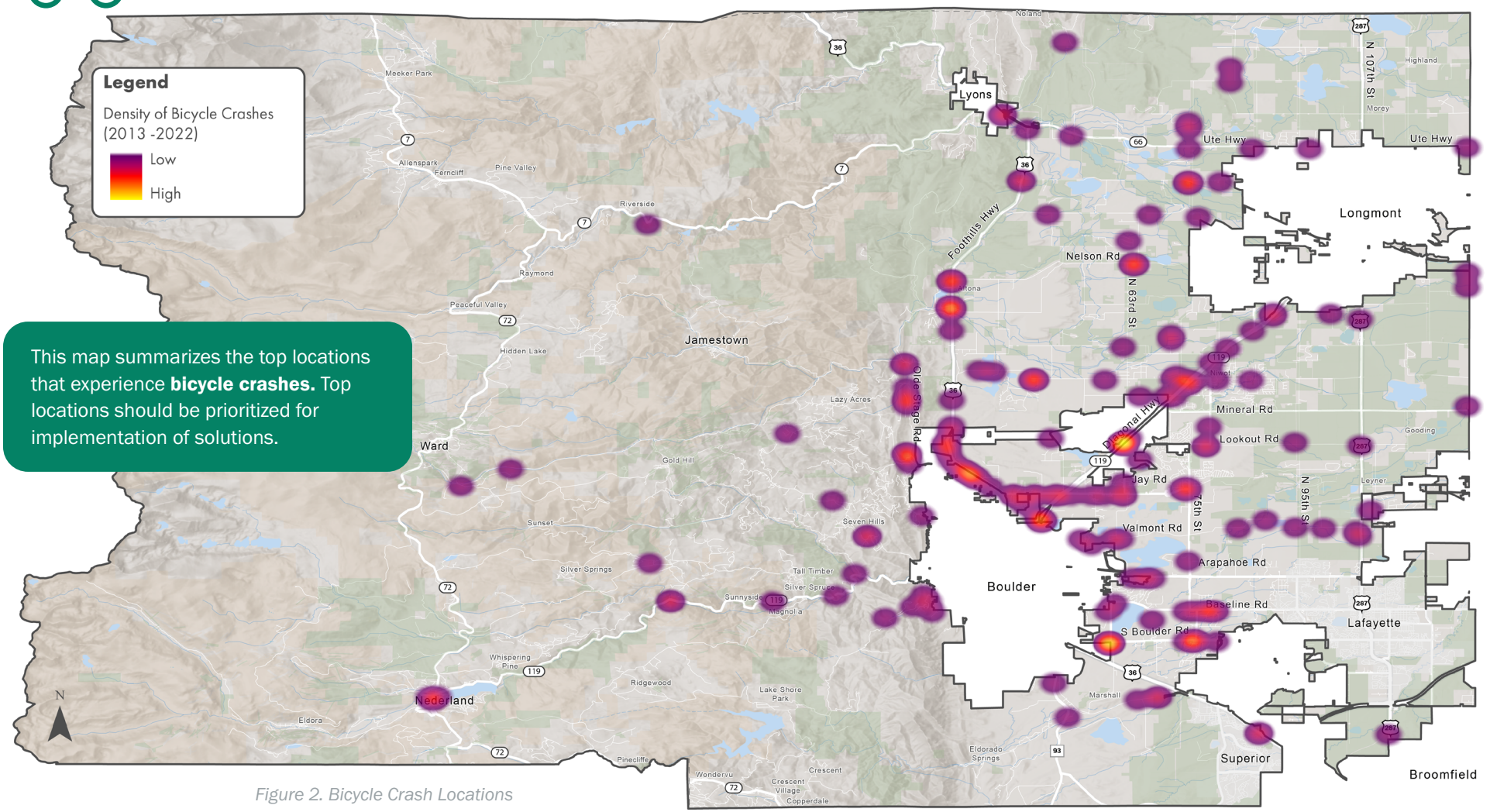

Figure 2. Bicycle Crash Locations

HEAD-ON CRASHES

Head-on crashes result in ***11%*** of the serious injury and fatal crashes in Boulder County. Some common behaviors and related conditions that most frequently contribute to these types of crashes include:

1. **Crossing over the centerline on undivided highways and curved roadways.**
    a. High speeds with lack of a median barrier on undivided highways to restrict vehicles from crossing into opposing traffic.
    b. Often weather conditions, risky passing maneuvers, and distracted, impaired, or aggressive driving can contribute to these crashes on these types of roadways.
    c. Limited sight distance or warning signage which could increase the likelihood of vehicles crossing into opposing traffic.
2. **Departing from the travel lane on rural roadways.**
    a. Narrow vehicle lanes and lack of separation between opposing traffic.
    b. Inadequate warning signs, lack of clear lane markings, and inadequate sight distance for passing.

Potential Solutions

Systemwide Solution & Strategy for Implementation	Cost Considerations	Where to Consider Implementation
Install a center median barrier. Longitudinal barriers that separate opposing traffic on a divided highway to reduce cross median crashes. Could include installation of a metal guard rail, concrete, or cable barrier.	**$$-$$$**	Undivided highways with a crossover crash trend.
Enhance delineation along horizontal curves. Warn drivers of a change in roadway direction that can be implemented in advance of or within curves, such as chevrons or retroreflective signs.	**$$-$$$**	Locations with horizontal curves.
Install centerline rumble strips. Milled or raised elements on the pavement centerline intended to alert drivers through noise and vibration that their vehicle has left the travel lane and they are crossing the centerline. If implemented, to minimize noise impacts, rumble strips should not be installed within 300 feet of residences or businesses.	**$$-$$$**	Rural roads with a crossover crash trend
Refer to speeding strategies (below).	**N/A**	N/A

HEAD-ON CRASHES

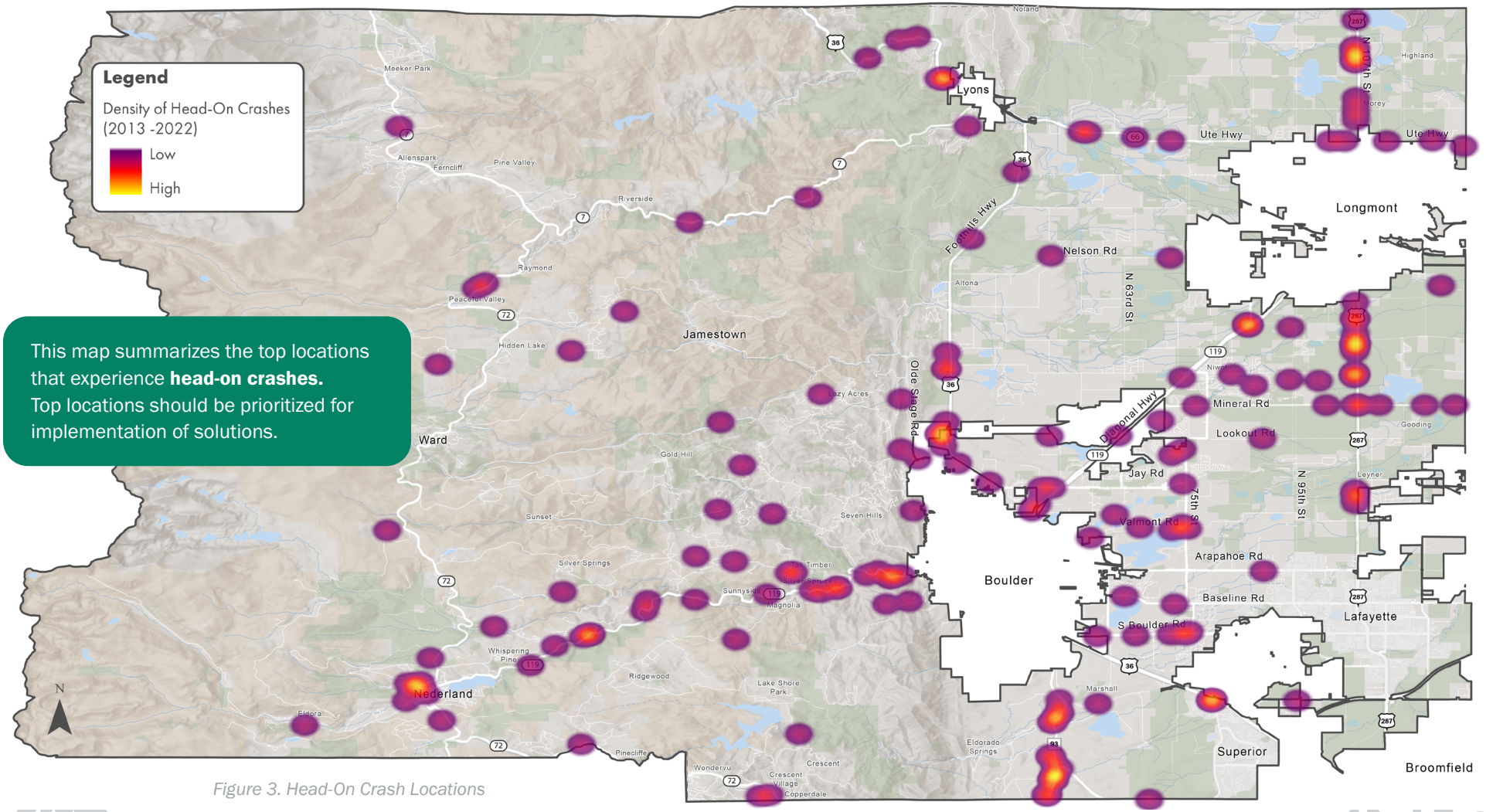

Figure 3. Head-On Crash Locations

BROADSIDE CRASHES

Broadside crashes result in **9%** of the serious injury and fatal crashes in Boulder County. Some common behaviors and related conditions that most frequently contribute to these types of crashes include:

1. **Red-light running.**
   a. Insufficient signal size, too few signal heads per lane, and missing signal backplates can contribute to poor signal visibility, which can contribute to these types of crashes.
   b. Yellow clearance and all-red times are non-optimal which may cause drivers to not be able to stop in time or can contribute to more aggressive driving behaviors.
2. **Failing to yield at unsignalized location.**
   a. Poor visibility of the stop sign or oncoming traffic.
   b. Congestion on the main street causing drivers from the side street to become impatient and make a riskier turning movement.

Potential Solutions

Systemwide Solution & Strategy for Implementation	Cost Considerations	Where to Consider Implementation
Improve traffic signal head visibility. Upgrade traffic signal heads with retroreflective backplates, add new signal heads to have one traffic signal head over each travel lane, and/or install near-side signal heads where visibility is limited.	**$-$$$** *Generally a low cost; however, the cost is sometimes higher in cases where mast arms need to be replaced to extend the mast arm length or the additional signal equipment may exceed the structural capacity of the signal poles in mast arms.*	Undivided highways with a crossover crash trend.
Update yellow & red intervals. Evaluate the yellow and red clearance intervals to determine if the interval is adequate for vehicles to react and stop at a traffic signal based on speed and grade approaching the intersection.	**$**	Locations with horizontal curves.

BROADSIDE CRASHES

Potential Solutions (cont.)

Systemwide Solution & Strategy for Implementation	Cost Considerations	Where to Consider Implementation
Increase enforcement. Install Red-Light Running Cameras or coordinate with emergency response to increase enforcement locations.	$$	Signalized locations with the greatest history of red-light running crashes.
Improve stop sign visibility. Implement tubular reflectors to sign posts and stop signs.	$	Two-way stop controlled and all-way stop-controlled intersections.
Install roundabout or other traffic control device. Evaluate unsignalized and signalized intersections to see if changes in traffic control are warranted.	$$$$-$$$$$	Unsignalized intersections with a broadside crash history, evaluate for roundabout, traffic signal, or restricting turning movement access. At signalized locations, evaluate for a roundabout.

BROADSIDE CRASHES

This map summarizes the top locations that experience **broadside crashes.** Top locations should be prioritized for implementation of solutions.

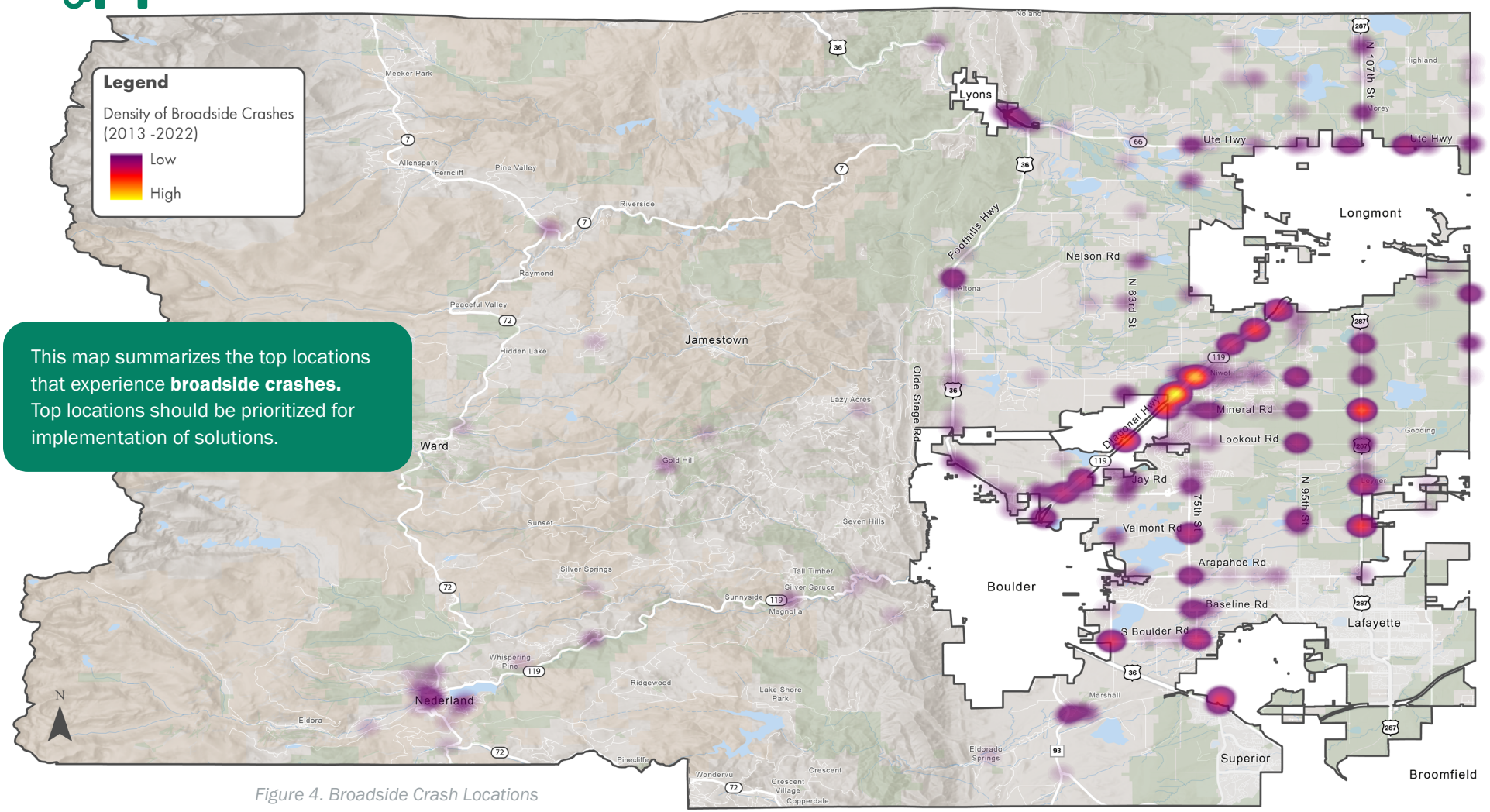

Figure 4. Broadside Crash Locations

LEFT-TURN CRASHES

Left-turn crashes result in **9%** of the serious injury and fatal crashes in Boulder County. Some common behaviors and related conditions that most frequently contribute to these types of crashes include:

1. **Failing to yield at a signalized intersection.**
   a. A driver turns left on a permitted left-turn signal operation and does not yield to an oncoming vehicle.
2. **Failing to yield at an unsignalized intersection.**
   a. A driver turns left and does not yield to an oncoming vehicle.
   b. A driver turns left and does not yield to a perpendicular through vehicle.

Potential Solutions

Systemwide Solution & Strategy for Implementation	Cost Considerations	Where to Consider Implementation
Upgrade left-turn operations. Upgrade left-turn signal phasing to permitted-protected or protected-only to eliminate/reduce left-turn conflicts. Protected-only phasing provides a separate phase for left-turning traffic and allowing left-turns to be made only on a green left arrow signal indication. Permitted-protected phasing allows left-turning drivers to turn either during a separate phase or during a regular green light when gaps in opposing traffic allow for a safe turn. Separate left-turn motor vehicle movements prevent turning vehicles from overlapping with the pedestrian walk phase or conflicting with oncoming vehicles.	**$**	Signalized intersection with left-turn crash trend.
Improve visibility with positive left-turn offset. Shifts left-turn lanes laterally to provide the left-turning motorist a line of sight to opposing through vehicles. Instead of attempting to look around opposing left-turning vehicles, the motorist can clearly see oncoming traffic to make safer gap decisions.	**$$-$$$$**	Unsignalized locations; Signalized locations with permitted left-turn movements.

LEFT-TURN CRASHES

Potential Solutions (cont.)

Systemwide Solution & Strategy for Implementation	Cost Considerations	Where to Consider Implementation
Partial closure to prohibit left-turn movements. Restricts specific left-turn movements at intersections to reduce conflict points, often implemented through physical barriers, signage, or traffic signal modifications.	$$-$$$$	Unsignalized intersection or driveway access with left-turn crash trend; signalized locations that cannot operationally support protected left-turn operations or have geometry restricting left-turns.
Install roundabout or other traffic control device. Evaluate unsignalized and signalized intersections to see if changes in traffic control are warranted.	$$$$-$$$$$	Evaluate for a roundabout, traffic signal, or restricting turning movement access at unsignalized locations. Evaluate for a roundabout at signalized locations.

LEFT-TURN CRASHES

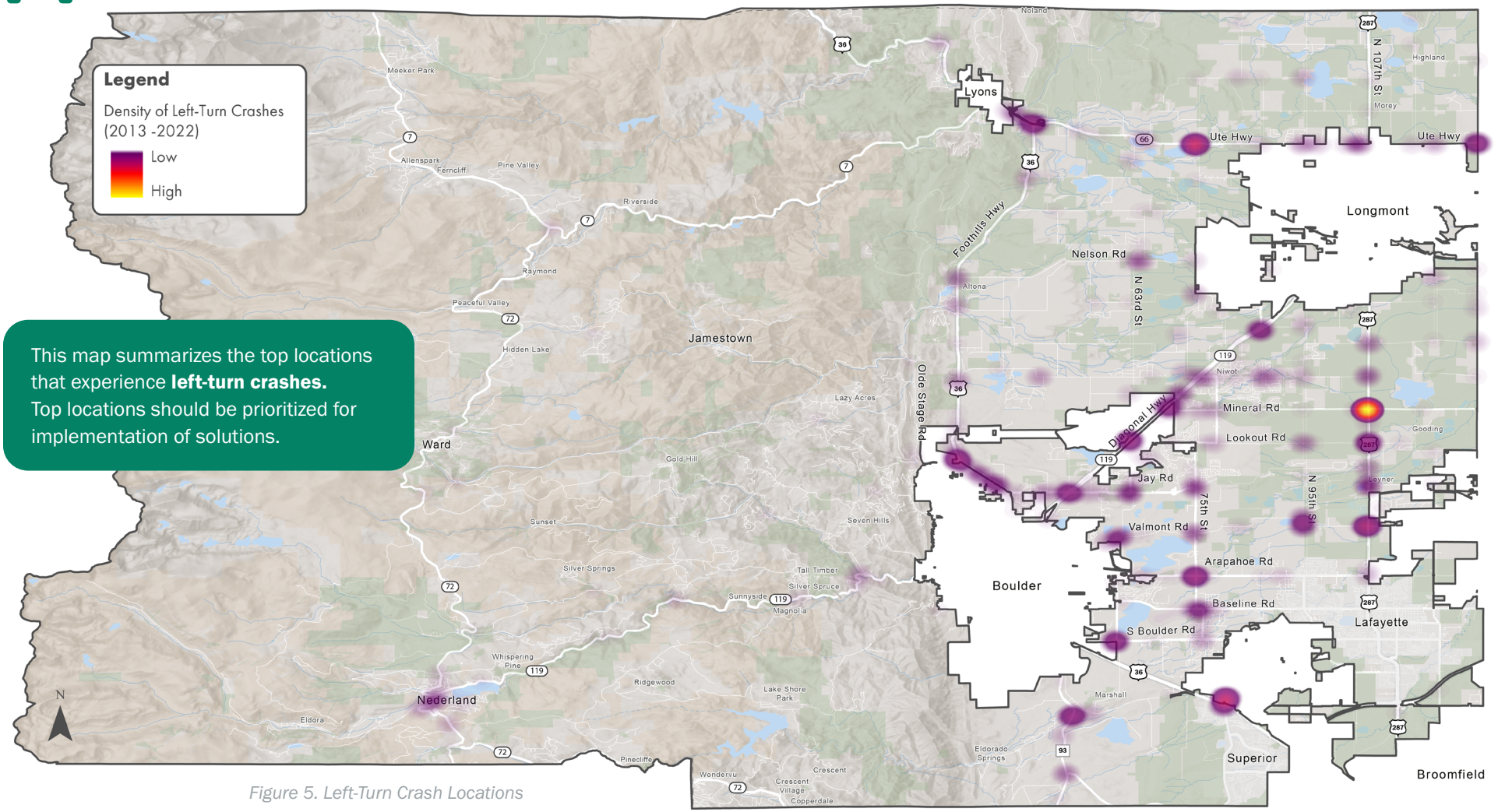

Figure 5. Left-Turn Crash Locations

OTHER COUNTERMEASURES IN THE TOOLBOX

Speed-related Countermeasures

Vehicle speeds have a substantial influence on traffic crashes. For example, at higher speeds a driver is more likely to lose control of their vehicle and/or take longer to stop. In addition, a crash at a higher speed can make the impact more severe, posing a greater risk of injury to all road users. Speeding (i.e., traveling faster than the posted speed limit) is a common contributing factor in the occurrence of traffic crashes.

Systemwide Solution & Strategy for Implementation	Cost Considerations	Where to Consider Implementation
Increase enforcement. Install speed cameras or coordinate with emergency response to increase enforcement locations.	$$	Locations include high-speed roads and school zones.
Vary speed limits. Variable speed limits use current roadway conditions like traffic speed, volumes, weather, and road surface conditions to determine appropriate speeds and display them to drivers in real time.	$$	Locations where there are known weather related crashes or high levels of congestion.
Evaluate/adjust the speed limit.	$	Locations where there are inconsistent speed limits along the corridor or known speeding related crash history.
Traffic calming elements. Design and engineering strategies implemented to slow down vehicle speeds and improve safety for all road users- particularly pedestrians and bicyclists. These measures introduce physical changes to the roadway (such as speed humps, chicanes, curb extensions/ bulbouts, raised crosswalks, or road narrowing).	$-$$$	Locations with residential streets or other low-speed, lower-volume roads.
Speed feedback signs. Interactive signs that display vehicles current speed to remind driver to slow down and obey the posted speed limit.	$	Locations include residential areas, school zones, curves, work zones, and rural roads.

Speed-related Countermeasures (cont.)

Systemwide Solution & Strategy for Implementation	Cost Considerations	Where to Consider Implementation
Road diets. Reallocating roadway space, typically reducing the number of travel lanes to calm traffic and enhance safety for all users. Creates space for features like bike lanes, wider sidewalks, or center turn lanes. Road diets are particularly effective on streets with moderate traffic volumes, improving safety for pedestrians, cyclists, and motorists while maintaining efficient traffic flow.	**$$$-$$$$$**	Locations where there are more lanes than vehicular capacity needed. Examples include roadways with two-way center turn lanes or roads with 3 or more travel lanes.
Roundabouts. Reduce conflict points, lower vehicle speeds, and virtually eliminate angle crashes common at traditional intersections. Their circular design promotes continuous traffic flow, minimizing delays while improving efficiency for all users.	**$$$$-$$$$$**	Unsignalized or signalized intersections.

Miscellaneous Countermeasures

Education, enforcement, and policy updates work in conjunction with engineering improvements to influence road user behavior and to help establish long-term systemic changes that create safer transportation systems. Together, these countermeasures work to reduce crashes, improve compliance, and foster a culture of safety on the roads.

Systemwide Solution & Strategy for Implementation	Cost Considerations	Where to Consider Implementation
Education. Plays a vital role in traffic safety by raising awareness, promoting safe behaviors, and informing road users about traffic laws and best practices. Through public outreach, school programs, and media campaigns, education helps reduce risky behaviors such as speeding, impaired driving, and distracted driving.	**Varies**	County or regionwide
Enforcement. Partnering with law enforcement ensures compliance with laws designed to reduce crashes and improve roadway safety. Targeted enforcement of speeding, impaired driving, seat belt use, and other violations help deter dangerous behaviors and reinforces safe driving habits.	**Varies**	County or regionwide
Policy updates. May include lowering speed limits, enhancing penalties for dangerous driving behaviors, or updating design standards and guidelines for safer roadway designs.	**Varies**	County or regionwide