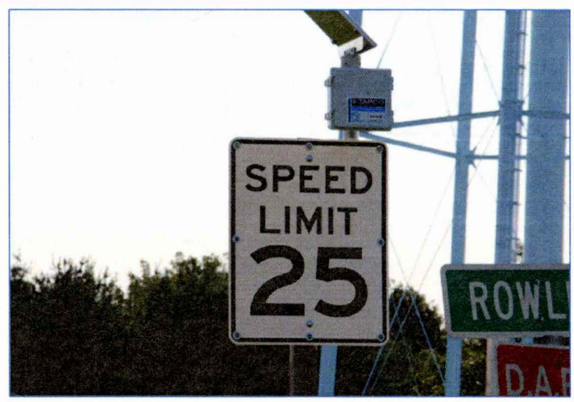
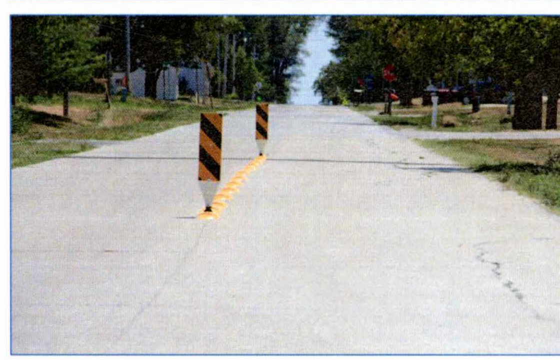
Speed Management Toolbox for Rural Communities

MTC
MIDWEST TRANSPORTATION CONSORTIUM

Final Report
December 2012





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16. Abstract

The primary objective of this toolbox is to summarize various known traffic-calming treatments and their effectiveness. This toolbox focuses on roadway-based treatments for speed management, particularly for rural communities with transition zones. Education, enforcement, and policy strategies should also be considered, but are not the focus of this toolbox.

The research team identified treatments based on their own research, a review of the literature, and discussion with other professionals. This toolbox describes each treatment and summarizes placement, advantages, disadvantages, effectiveness, appropriateness, and cost for each treatment.

The categories of treatments covered in this toolbox are as follows: horizontal physical displacement, vertical physical displacement, narrowing, surroundings, pavement markings, traffic control signs, and other strategies.

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Overview

The primary objective of this toolbox is to summarize the effectiveness of various known traffic-calming treatments. The toolbox focuses on roadway-based treatments. Education, enforcement, and policy countermeasures should also be considered, but are not the focus of this toolbox. Furthermore, the focus of this toolbox is on strategies for rural communities with transition zones.

The research team identified treatments based on their own research, through a review of the literature, and through discussion with other professionals. This list is not necessarily comprehensive. Each treatment that the team was aware of is summarized using the format outlined in Table 1.

Table 1: Outline of information provided for treatments in this toolbox

Subsection	Summarizes
Description	Treatment or countermeasure
Placement	How the treatment or countermeasure has been applied, where it is most effective, and so forth
Advantages	Treatment advantages
Disadvantages	Main treatment disadvantages
Effectiveness	Studies showing whether the treatment is effective, information about crash reductions, and speed changes, with the assumption that speed change can be used as a crash surrogate
Appropriateness	What situations the treatment can be used in
Cost	Price to install the treatment

The purpose of traffic-calming treatments in rural communities is to notify drivers that they are entering a community and must adjust their speeds accordingly. This speed reduction is used as a surrogate measure for safety.

A variety of strategies can be applied to the roadway to slow down drivers physically or psychologically. The different types of treatments are laid out into separate strategies. Different strategies may be more beneficial in other locations and must be considered when selecting the treatment. The strategies presented in this toolbox are summarized in Table 2.

Table 2: Outline of strategies in this toolbox

Strategy	Effect
Horizontal Physical Displacement	A form of displacement that requires drivers to move horizontally left or right to require them to slow down
Vertical Physical Displacement	A form of displacement that moves drivers vertically, giving them an unpleasant feeling to slow down
Narrowing	Used to psychologically make drivers adjust their speeds because they cannot go the desired speed with a narrowed lane
Surroundings	A treatment that is placed off the roadway to alert drivers that they are entering a community
Pavement Markings	Markings on pavements to alert drivers a speed change occurs or to give drivers a sense of feeling they are speeding up
Traffic Control Signs	Types of signs that can draw more attention to slow down
Other	Other treatments that did not fit into the above strategies

This toolbox does not recommend design solutions. In addition, be sure to note the following:

- The effectiveness of various treatments are estimates only and will vary based on roadway, environmental, and operational conditions.
- Treatments that place a device within the roadway clear zone should follow the *Manual on Uniform Traffic Devices* (MUTCD) and national guidelines for crash worthiness.
- Treatments that include pavement marking or roadway surface treatments should meet skid-resistance requirements.
- The MUTCD and state and local guidelines should be consulted before selecting treatments.
- Use of treatments when not warranted or overuse of treatments may result in driver disregard. When not effective, the treatments can also require long-term maintenance costs, which are not warranted. As a result, agencies should judiciously select and apply treatments.
- Many of the devices listed are considered supplementary in that they supplement and do not replace traditional traffic control.

Manual on Uniform Traffic Control Devices Guidance

This toolbox provides information about traffic-calming treatments. The MUTCD (2009) covers some of the treatments. The MUTCD should be considered the main source of information about selecting and applying traffic control devices. Information from the MUTCD supersedes any information provided in this toolbox.

In some cases, the treatments discussed in this toolbox are considered experimental and require MUTCD approval. Users should consult the MUTCD and their own state and local guidance before application of treatments. Many of the devices listed in this toolbox are considered supplementary in that they supplement and do not replace traditional traffic control. For instance, placing on-pavement speed signing is supplemental to posted speed limit signs.

Accordingly, selected treatments should be placed so that they enhance rather than detract from regular traffic control. In addition, caution should be used so they do not appear to be sending different messages from regular traffic control, which could cause confusion.

Crash Modification Factors

Crash reduction factors (CRFs) or crash modification factors (CMFs) have been developed for various roadway countermeasures.

A CRF is the expected percentage change in crashes due to a particular treatment. A CRF of 20, for instance, indicates that a 20 percent reduction in crashes might be expected with use of the treatment. CRFs can be negative indicating an expected increase in crashes.

A CMF is a multiplicative factor to compute the expected number of crashes at a site after implementing a given countermeasure. A CMF of 0.80 indicates that the expected number of crashes after the treatment would decrease by 20 percent.

CMFs are presented in this toolbox and were identified through a review of existing studies. "A CRF [or CMF] should be regarded as a generic estimate of the effectiveness of a countermeasure. The estimate is a useful guide, but it remains necessary to apply engineering judgment and to consider site-specific environmental, traffic volume, traffic mix, geometric, and operational conditions, which will affect the safety impact of a countermeasure. The user must ensure that a countermeasure applies to the particular conditions being considered." (USDOT 2008)

We encourage users to consult the source documents and to access the Federal Highway Administration (FHWA) Crash Modifications Clearinghouse at www.cmfclearinghouse.org.

Treatments Covered in this Toolbox

This toolbox includes treatments, organized by the following categories, which can be used to slow drivers and improve safety as drivers enter rural communities:

- Horizontal physical displacement
- Vertical physical displacement
- Narrowing
- Surroundings
- Pavement markings
- Traffic control signs
- Other strategies

Acknowledgments

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- Iowa Department of Transportation (DOT)
- Iowa Highway Research Board (IHRB)
- Federal Highway Administration (FHWA) Accelerating Safety Activities Program (ASAP)
- Midwest Transportation Consortium (MTC)

Horizontal Physical Displacement

Physical displacement treatments involve moving drivers from the straight path on which they are driving, requiring them to slow down or evaluate their speed in the process. In this chapter, different treatments involving horizontal physical displacement are evaluated:

- Bulb-outs, neck-downs, chokers, or mid-block crossings
- Chicanes or serpentines
- Realigned intersections
- Roundabouts
- Mini-roundabouts
- Transverse rumble strips
- Woonerfs
- Bollards

Horizontal displacement treatments require drivers to move physically left or right, which should slow driver speeds. Drivers go much faster on a straight section of roadway because the conditions are conducive to that speed, but installing a curve or some other measure requiring drivers to stray from that straight roadway section lowers their speed in the process.

Bulb-Outs, Neck-Downs, Chokers, or Mid-Block Crossings

Description

Neck-downs, bulb-outs, chokers, and mid-block crossings are physical devices placed in the roadway to create horizontal deflections by narrowing points along the roadway. Drivers are forced to slow to negotiate the narrowed points on the roadway.

When applied on a two-lane road (each direction), these techniques can be used to narrow the lanes and slow traffic or to reduce the two lanes to one.

Narrowing of the main road section is referred to as a choke or mid-block crossing (when refuge and pavement markings are added). Narrowing at an intersection is referred to as a neck-down or bulb-out (Figure 1).

Figure 1: Bulb-outs (CWS, 2003)

Placement

Chokers and bulb-outs have been used in many locations:

- Local and collector streets
- Pedestrian crossings
- Main roads through small communities
- In conjunction with speed humps, speed tables, raised intersections, textured crosswalks, curb radius reductions, and raised median islands

One source indicated that, on facilities that are 30 mph or lower, chokers or bulb-outs should be at least 600 feet apart (Ewing, 1999).

Advantages

- Shorten pedestrian crossing distances
- Lead to tighter turning radii, forcing turning vehicles to slow

Disadvantages

- Interrupt drainage patterns at intersections and mid-block, which adds to the cost of implementation
- May be difficult for large or oversized vehicles, such as farm equipment, to negotiate

Effectiveness

An Institute of Transportation Engineers (ITE) study indicates that narrowing results in a 2.6 mph speed reduction (Ewing, 1999).

No crash modification factors were found relating to neck-downs, bulb-outs, chokers, or mid-block crossings.

Appropriateness

Devices used to narrow lanes physically should be used with caution for the types and amounts of traffic on primary roadways through small communities. Use of neck-downs, bulb-outs, chokers, and mid-block crossings may not be appropriate with heavy truck traffic and/or large farm equipment.

Cost

The uses of bulb-outs, neck-downs, chokers, and mid-block crossing have a very high cost if designing them into the roadway. A cheaper alternative is paint markings, which may have a lower effectiveness.

Chicanes or Serpentines

Description

Chicanes (Figure 2 and Figure 3) are short, horizontal displacements in the roadway that create a curvilinear alignment, which encourages slower speeds (Andrle et al., 2001).

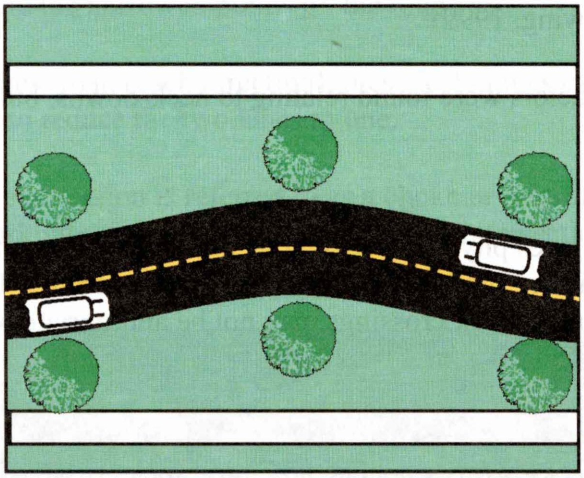

Figure 2: Aerial illustration of a chicane (Andrle et al., 2001)

Figure 3: Driver viewpoint of a chicane (CWS, 2003)

Chicanes are also called serpentines, as the physical constrictions at curbside create a 45 degree bend in a straight road, which forces drivers to negotiate the narrowed street in a snakelike fashion (Ewing, 1999). Traditional chicanes often require a change in the roadway alignment given they physically change the roadway.

A similar effect can be achieved by alternating on-street parking from one side of the street to the other. Alternate on-street parking can be accomplished by re-striping pavement markings for parking or by constructing islands for parking bays (Ewing, 1999).

The City of Nashville, Tennessee used zigzag pavement markings, which allowed for two full lanes, plus short stretches of parking on alternating sides of the street, to create a chicane pattern (Hamburg, 2005). The pattern and location are shown in Figure 4.

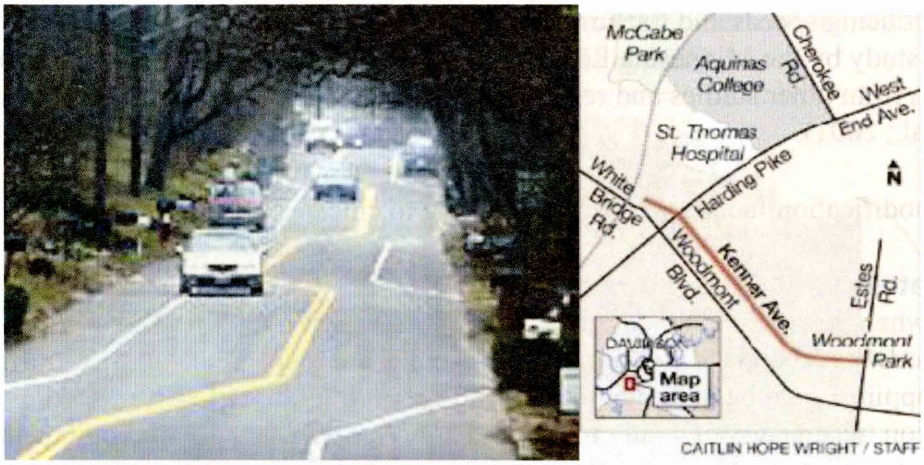

Figure 4: Use of pavement marking to create chicane (Hamburg, 2005)

The street was marked at 25 mph but had significant speeding problems. Other measures were tried but were not successful. The city felt that less intrusive measures should be tried before implementing more drastic devices, such as speed humps. No information on effectiveness was provided.

Placement

Chicanes should be placed 400 to 600 feet apart and the normal turning radii for design vehicles should be accommodated. Key considerations are visibility and provision of advance warning signs (Kastenhofer, 1997).

Alignment of the chicane should be shifted at least one lane-width and deflection angles should be at least 45 degrees. Center islands are also recommended, where appropriate, to prevent drivers from cutting across the centerline and continuing to speed.

Advantages

- Negotiating curves forces drivers to slow down
- Chicanes can be pleasing aesthetically

Disadvantages

- Potentially lead to high costs for curb realignment and landscaping
- Drainage problems (ponding) can occur
- Potential for head on collisions
- May be difficult for large trucks and farm equipment to negotiate if not designed properly
- Can have a negative impact on emergency response times

Effectiveness

Chicanes were evaluated on an arterial in Toronto. The roadway was 28 feet wide and chicanes were created using modular traffic-calming islands. The road was narrowed to 21 feet with chicanes. A reduction in the 85th percentile speed from 50 km/h to 45 km/h occurred (Macbeth, 1998).

The Seattle, Washington Engineering Department found that chicanes were an effective means of reducing speeds and traffic volumes under certain circumstances (FHWA, 1994). In addition, a study by the Minnesota Local Road Research Board (LRRB) summarized information from other studies and reported a 6 percent change in 85th percentile speeds (Corkle et al., 2001).

No crash modification factors were found relating to chicanes.

Appropriateness

Chicanes, when properly designed, may be appropriate for rural main streets. Special considerations must be given to geometrics if there is a high percentage truck traffic, because curb overtopping could be a problem if the shifts are too tight or closely spaced. Consideration must be given to alignment so that heavy trucks and farm equipment are able to negotiate the alignment.

Cost

One source indicated costs are $4,000 to $5,000 (Kastenhofer, 1997). Another source indicated $4,000 to $8,000, depending on the length of the roadway segment (CWS, 2003).

Temporary chicanes are also available. Use of pavement markings to create chicanes can be relatively inexpensive but, like bulb-outs, neck-downs, and chokers, effectiveness may be reduced.

Realigned Intersections

Description

Realigned intersections are changes in alignment that convert T-intersections with straight approaches into curving streets that meet at right angles (Figure 5).

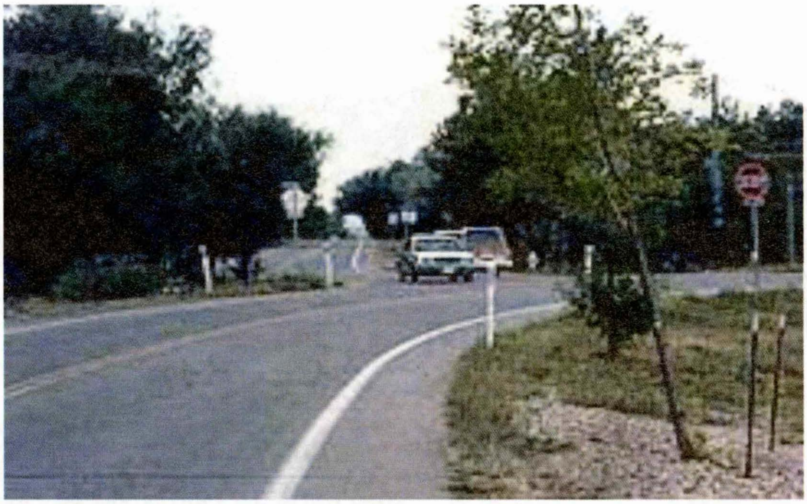

Figure 5: Realigned intersection in Boulder, Colorado (Ewing, 1999)

A former "straight-through" movement along the top of the T becomes a turning movement. While not commonly used, realigned intersections are one of the few traffic-calming measures for T-intersections because the straight top of the T makes deflection difficult to achieve.

Placement

Realigned intersections are typically only used where intersection approaches are not at right angles. This is a safety problem and can reduce accidents.

Advantages

- Can be effective reducing speeds and improving safety at a T-intersection

Disadvantages

- The curb realignment can be costly
- May require some additional right-of-way to cut the corner

Effectiveness

No data has been compiled on the effects of realigned intersections.

Appropriateness

The use of a realigned intersection is appropriate for any intersection that has an approach at an angle that has an effect on safety and sight distance.

Cost

Cost varies by curve radii and size of right-of-way acquisition, if required.

Roundabouts

Description

Roundabouts, by their very nature, manage traffic speeds (Figure 6).

Figure 6: Roundabout in Coralville, Iowa (Runge, 2005)

Roundabouts are designed to slow entering traffic to allow pedestrians and bicyclists to cross streets. Roundabouts also provide locations for gateway artwork and special landscaping (PSRC, 2003).

Rural roundabouts typically have high average approach speeds. These approach speeds require additional geometric and traffic control treatments to slow traffic before entering the roundabout. Supplemental features to slow traffic may include a raised splitter, or island, approaching the roundabout.

Use of roundabouts may increase delay on the main highway given all approaches are treated equally. Roundabouts can also require significant right-of-way, but can eliminate the need for long turn lanes.

Roundabouts have been used in Europe as gateway treatments that serve as part of the transition from rural highways to town centers. The center island could be used for a gateway or landscaping treatment (PSRC, 2003).

Placement

Roundabouts can be placed either at intersections or as part of transition areas entering communities.

Advantages

- Roundabouts physically force traffic to slow
- Evidence shows roundabouts reduce accidents
- Roundabouts can be used with landscaping

Disadvantages

- Significant costs associated with installing a roundabout
- Significant right-of-way requirements
- May be difficult for large farm equipment to negotiate

Effectiveness

Roundabouts are used typically only at intersections. However, roundabouts also force drivers, physically, to slow in the vicinity of the roundabout. The California DOT (Caltrans, 2002) suggests that, in the appropriate location, a roundabout can reduce the number and severity of collisions and improve traffic circulation, in addition to reducing speed.

The FHWA evaluated eight single-lane roundabouts in the US and reported a 51 percent reduction in crashes (Robinson et al., 2000).

While the use of roundabouts as gateway treatments is not well documented in the US, the Crash Modification Factors Clearinghouse provides CMFs for conversion from a traditional intersection to a roundabout as shown in Table 3.

Table 3: CMFs for roundabouts versus traditional intersections

Crash Severity/Type	CMF
Serious or minor injury	0.35
Property damage only	0.58
Vehicle/pedestrian	0.27

Appropriateness

Roundabouts are appropriate for the main street through rural communities if they can accommodate large farm vehicles that may be present.

Cost

Cost depends on a number of factors including size, acquisition of right-of-way, and so forth. The National Cooperative Highway Research Program (NCHRP) Synthesis 264 indicates the average construction cost for 14 US roundabouts was approximately $250,000 per intersection, not including purchase of additional right-of-way (Jacquemart, 1998).

Mini-Roundabouts

Description

Mini-roundabouts are one-way circular intersections similar to both full-scale, modern roundabouts and traffic circles. Both full-scale, modern roundabouts and traffic circles are used extensively in the US (with about 800 modern roundabouts now in the US) and elsewhere. Mini-roundabouts are a new development in the US, but they are already found in large numbers in the United Kingdom (UK) and France.

As the name implies, a mini-roundabout is a small and inexpensive roundabout that still has all of the standard features of a full-scale roundabout, including yield on entry, deflection, flare, and a low design speed. As of 2005, there was only one known mini-roundabout in the US, in Dimondale, Michigan, which is a small town near the state capital, Lansing, as shown in Figure 7.

Figure 7: Mini-roundabout in Michigan (Waddell and Albertson, 2005)

The image shows a splitter island with lighted bollard, yield pavement marking, and a small, slightly-raised, center island.

Placement

Mini-roundabouts can replace some signalized or stop-controlled intersections. Typically, no additional right-of-way is required to accommodate mini-roundabouts. An ideal location would be a four-way or three-way stop intersection in a small town.

Advantages

- The combination of deflection, flare, and curvature limit approach speeds at all entrances of the Dimondale mini-roundabout to between 15 and 25 mph, at which crash rate severity for vehicular and pedestrian crashes is usually reduced very significantly. A 10 mph or greater speed reduction can easily be achieved.

- Mini-roundabouts have much lower ongoing maintenance costs than traffic signals. The life cycle cost of a mini-roundabout will be significantly lower than that of a signalized intersection.
- Mini-roundabouts allow high traffic capacity but low traffic speed. Traffic is calmed without any loss of capacity.

Disadvantages

- Drivers must learn how to use them. This is only a disadvantage for a short time period.
- Mini-roundabouts may face resistance from the general public, adjacent small business owners, and local decision makers due to novelty. This resistance usually ends once the roundabout is installed and used for a few weeks. The benefits for traffic flow, traffic calming, and safety tend to become more evident to casual observers by then.

Effectiveness

Although experience with mini-roundabouts in the US and Canada is limited, they are very common in Europe, particularly France and the UK. Studies conducted there indicate that mini-roundabouts are very effective in terms of both traffic calming and safety. Mini-roundabouts are very compatible with pedestrian traffic, provided pedestrian crossings are located away from the central island (upstream and downstream from the splitter islands) and are clearly marked and signed.

No crash modification factors were found relating to mini-roundabouts.

Appropriateness

The most appropriate application for a mini-roundabout is as a replacement for a traffic signal or a four-way, stop-controlled intersection on an arterial street inside a small community. Without a significant amount of turning traffic at the intersection, some other, less-expensive traffic-calming treatment will be more appropriate.

Cost

Mini-roundabouts vary in cost from less than $10,000 up to $35,000. The cost of the Dimondale mini-roundabout was about $35,000, much of which paid for complete pavement resurfacing and new curbing. A low-end roundabout (a typical UK design) uses paint rather than raised curbing.

Transverse Rumble Strips

Description

Rumble strips are grooves placed in the roadway surface that transmit sound and vibration to alert drivers to changing conditions. Several agencies have used temporary rumble strips, which consist of strips of durable tape, rather than permanent installation.

Rumble strips are typically placed longitudinal to the roadway surface on the shoulder or edge of pavement to alert drivers they are leaving the roadway to reduce run-off-the-road crashes. Rumble strips have also been placed perpendicular to the direction of traffic and used to alert drivers of a change in upcoming conditions. Rumble strips have been used in advance of rural stop signs and prior to curves. In Iowa, transverse rumble strips are sometimes used on the approach to stop signs on rural roads. Typically, three sets of rumble strips are used to alert motorists approaching stop signs.

The City of Twin Lakes, Minnesota implemented rumble strips as a traffic-calming measure (Figure 8).

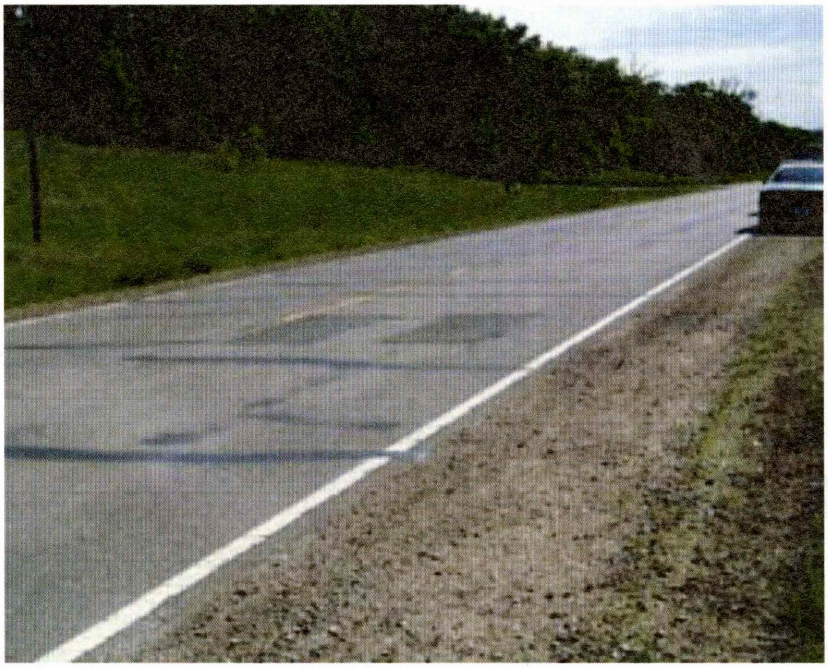

Figure 8: Rumble strips (Kamyab et al., 2002)

Twin Lakes installed a set of nine grooved rumble strips perpendicular to the vehicle path to remind motorists of upcoming speed reduction zones. Rumble strips were used in speed transition zones where posted speeds changed from 55 mph to 40 mph to 30 mph. The strips were placed on the highway before the 40 mph speed transition zone (Kamyab et al., 2002).

Placement

Meyer (2000) suggested that a series of rumble strips should be placed seven times the posted speed limit before the change for which drivers are being alerted. In a series of rumble strips, the spacing between each strip should be one foot for every 10 mph of the vehicle speed. For example, on a roadway posted at 45 mph, each strip would be 4.5 feet apart.

Advantages

- Do not affect emergency response services adversely
- Do not interfere with vehicle operation

Disadvantages

- Noisy
- May be a hazard to motorcyclists and bicyclists
- Require a high level of maintenance (CPVE, 2001)
- Drainage can cause water or ice to pond in the strips
- Vehicles may swerve around them to avoid them and, consequently, they should be used with caution on high-volume roads (Fontaine et al., 2000) or placed across the entire width of the road
- Effect on pavement wear is unknown when milled into the roadway surface

Effectiveness

A study by the Texas Technology Institute (TTI) evaluated the use of portable rumble strips in work zones to reduce vehicle speeds (Fontaine et al., 2000). Rumble strips consisted of 12 foot strips that were four inches wide and bright orange with adhesive backing. While the researchers did not find a reduction in passenger vehicle speeds, they did find a reduction in truck speeds of 3 to 5 mph.

The Crash Modification Factors Clearinghouse provides the CMFs shown in Table 4 for installing transverse rumble strips as a traffic-calming device in urban and suburban areas.

Table 4: CMFs for transverse rumble strip installation

Crash Severity	CMF
All	0.66
Serious or minor injury	0.64

Appropriateness

Rumble strips are appropriate for speed transition zones in rural traffic-calming areas to alert drivers of upcoming speed changes. Use of rumble strips in transition zones for rural areas are less likely to have an adverse noise impact than in urban areas given the transition area is likely to be located in a less-populated area. Rumble strips are also appropriate for crosswalks in high pedestrian areas.

Rumble strips are used frequently in Iowa in advance of stop signs on rural roadways. Note that their use in applications other than in advance of stop signs is strongly discouraged by the Iowa DOT and this information is included for consideration by areas outside of Iowa.

Cost

Portable rumble strips are available. Rumble strips can be milled into the roadway surface as well. Cost depends on which method is used.

Woonerfs

Description

The woonerf was first published in September 1976 by the Netherlands Ministry of Transport and Public Works (Schlabbach, 1997). The basic idea with a woonerf is to change streets from a traffic area to a more pedestrian area by giving pedestrians and cyclists a legal priority over vehicles.

Woonerfs are not all the same, using many different traffic-calming techniques to slow vehicles, which are then emphasized by the pedestrians having legal priority. The entrances to the woonerf are the main location for traffic calming, which can be seen in Figure 9.

Figure 9: Dutch woonerf (Schlabbach, 1997)

Some of the traffic-calming measures used for woonerfs are vertical deflections, narrowing by both physical and psychological means, and road geometry.

Placement

Schlabbach discusses the difficulty of establishing woonerfs on existing roads, suggesting they should be used more in new construction. Some areas that they could be used include schools, recreation areas, and offices.

Advantages

- Pedestrians have priority

Disadvantages

- Difficult to convert existing roads
- Meant for low volumes of traffic and low-speed roads
- Traffic could find another route and create the same problems on a different road

Effectiveness

With the priority on pedestrians, most tests are performed to determine the safety of pedestrians. A study by Rijswijk and Eindhoven examined safety and found an 80 percent reduction for injury accidents (Schlabbach, 1997). This reduction was also due to the amount of traffic being reduced by 16 to 25 percent and the average speed by 22 to 40 percent. Another study by Dutch municipalities found a reduction of 22 percent for injury accidents (Schlabbach, 1997).

Appropriateness

Woonerfs are appropriate in areas with high pedestrian traffic volumes, such as schools, shops, or other pedestrian-friendly areas. The construction of a woonerf decreases the amount of traffic, which may in turn change the ecological aspect of the area by decreasing noise and pollution (Schlabbach, 1997).

Because woonerfs are for high-pedestrian areas, they are not likely to be appropriate on rural roadways that provide access through communities.

Cost

As stated by Schlabbach, the cost to convert an existing road to a woonerf is very high, so a woonerf should typically be integrated into the design of a new residential road. No cost was found for new construction.

Bollards

Description

Bollards can be rigid or flexible posts that separate traffic to move drivers horizontally. There are a variety of uses for bollards including safety, traffic management, delineation, and traffic calming. In traffic calming, bollards are typically placed in a splitter island before a roundabout or center median. This placement requires drivers to alter their direction physically and directs drivers where they should be going (Transportation Alternatives, 2007) (Figure 10 and Figure 11).

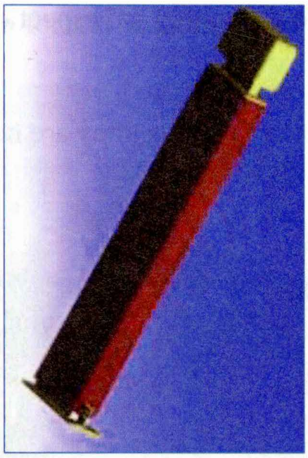

Figure 10: Flexible bollard (Transportation Alternatives, 2007)

Figure 11: Bell bollards (Transportation Alternatives, 2007)

Placement

Bollards are placed typically within a center island to reinforce moving over and to protect pedestrians. Bollards can also be placed at roundabouts or bulb-outs.

Advantages

- Can be used to direct traffic by displaying road signs
- Flexible bollards can withstand being hit and limit damage to vehicles
- Some bollards are removable for winter conditions
- Cost effective

Disadvantages

- Need to be placed so they do not impede traffic or pedestrian movements
- Excess use of bollards can reduce effectiveness
- Some bollards are expensive

Effectiveness

No studies have been done to test the effectiveness of bollards, but they have been used in a variety of situations to warn drivers of the need to move over.

No crash modification factors were found relating to bollards.

Appropriateness

Bollards have only been used typically on center islands or bulb-outs to convey to drivers that they need to move over. Bollards are only appropriate to use as a warning to obstacles that drivers need to see.

Devices should meet MUTCD guidelines and be crashworthy when necessary.

Cost

Bollards are a cost-effective way to delineate traffic around an island or other obstacle.

Vertical Physical Displacement

Vertical physical displacement is different from horizontal displacement due to the uncomfortable feeling that drivers get when traversing these treatments. While horizontal treatments are aimed at requiring drivers to lower their speeds to feel safe, vertical treatments are aimed at drivers slowing down to avoid the discomfort created from the treatment. This chapter discusses the following vertical physical displacement treatments:

- Raised intersections
- Speed humps and tables
- Speed lumps, slots, and cushions

Raised Intersections

Description
A raised intersection is a raised plateau, usually 3 to 6 inches above adjacent streets, used at an intersection (Dixon et al., 2008). A raised intersection is reached using slight ramps from the intersection approaches and motorists are forced to slow to negotiate it (CPVE 2001). A raised intersection slows drivers in a manner similar to a speed table, given drivers must slow to avoid physical discomfort.

Placement
Raised intersections are used only at intersections and are a good measure for high-pedestrian areas. Crosswalks should be on the raised section.

Advantages
- Can slow vehicles in critical problem areas (CPVE, 2001)
- Provide visual clues to drivers
- Attractive paving stones or bricks can be used to add to aesthetics (CPVE, 2001)

Disadvantages
- Require additional maintenance
- May have an impact on drainage
- May have an impact on turning movements (CPVE, 2001)
- Need to warn drivers about them

Effectiveness
Ewing (1999) indicated minimal speed reductions, given vehicles may already be slowing for the intersection. In other cases, raised intersections may have the same effectiveness as speed tables.

The Crash Modification Factors Clearinghouse provides a CMF of 1.05 for injury crashes for raised intersections.

Appropriateness
Raised intersections can be applied to rural main streets, particularly those with high pedestrian volumes. Raised intersections affect traffic operations, so large trucks and farm equipment should be considered.

Cost
Installation of raised intersections is a major investment.

Speed Humps and Tables

Description

Speed tables are asphalt or rubber mounds that cover the full width of the roadway. Speed tables are essentially speed humps that have been modified with a flat top, thus reducing the disruption to vehicle operations. The flat top is typically long enough for the entire wheelbase of a passenger car to rest on.

The ramps of speed tables are also sloped more gently than those of speed humps. Therefore, design speeds for speed tables are higher than those for speed humps. The most common type of speed table is the one designed by Seminole County, Florida. The Seminole profile is three to four inches high and 14 to 22 feet long (Ewing, 1999). An illustration of a typical speed table, compared to a typical speed hump, is shown in Figure 12.

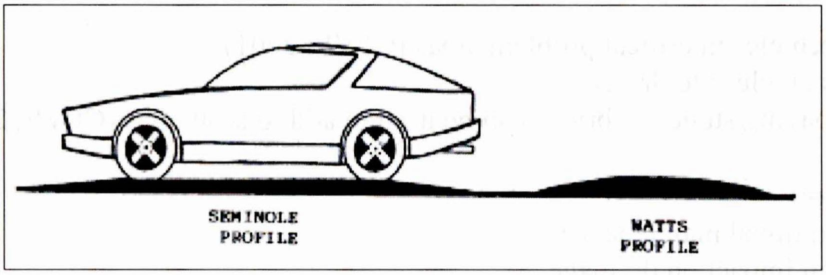

Figure 12: Seminole 22 foot speed table versus Watts 12 foot speed hump (Nicodemus, 1991)

Speed tables are being preferred commonly over speed humps. This preference is due in large part to emergency service vehicle delays given speed tables are less jarring and can allow larger emergency vehicles to cross with minimal disruption.

Like speed humps, speed tables are designed according to the desired target speed. The target speed can range up to 45 mph. For instance, the speed table in Figure 13 is designed with a 30 mph design speed.

Figure 13: 30 mph speed table in study for residential traffic calming in small Iowa communities

Placement

Speed humps or tables should not be placed near intersections. Several studies have indicated they are most effective when placed in a series.

The Delaware Department of Transportation (DelDOT, 2000) established a set of guidelines describing when particular treatments should be installed. DelDOT does not recommend using speed tables for interstates or principal arterials. However, they do recommend using speed tables on minor arterials, collectors, and local roads where the daily volume is less than 10,000 vehicles per day (vpd) and the posted speed limit is not greater than 35 mph.

Advantages

- Tables allow larger vehicles to cross with minimal disruption
- Tables allow vehicles to travel at a higher speed than speed bumps
- Slows down vehicles because of vertical displacement

Disadvantages

- Speed tables may delay emergency service vehicles
- May cause noise
- Speed tables may have an impact on drainage
- Drivers may swerve to avoid them, having an impact on pedestrians and other vehicles

Effectiveness

A study by the Minnesota Local Road Research Board (LRRB) summarized information from other studies, reporting a 28 percent change in 85th percentile speed, 15 percent change in average speed, and 28 percent decrease in auto collisions using speed tables (Corkle et al., 2001).

A previous study by the Center for Transportation Research and Education (CTRE) evaluated temporary speed humps and speed tables in three locations in rural Iowa communities. The speed hump and speed table were evaluated in the same location in each of three communities. Average and 85th percentile speeds decreased at the location of the device by up to 9 mph for the speed hump and 10 mph for the speed table (Figure 13) (Hallmark et al., 2002).

Temporary speed tables, in particular, can be designed to accommodate a range of desired speeds up to 45 mph (Recycled Technology, Inc., 2004). While it is not suggested that speed humps are appropriate for transitions from high-speed roadways, results of the research may be useful to small communities. (See Hallmark et al., 2002 for summary of results, effectiveness, and economic benefits evaluated.)

A speed table was used in Gilbert, Iowa as part of the researcher's traffic-calming study. The table was designed for 30 mph with a posted speed limit of 25 mph. The installation of the speed table resulted in an average speed reduction ranging from 2 to 4 mph and from 2 to 5 mph for the 85th percentile speed.

Ewing evaluated the effects of speed tables at 58 locations and reported that 22 foot speed tables can reduce 85th percentile speeds by about 18 percent (1999). They also noted that longer tables are less effective at reducing speeds; for longer tables, 85th percentile speeds can be reduced by about 9 percent.

Ewing also studied the number of collisions at 8 locations before and after introducing a speed table and found that collisions were reduced by 45 percent with the use of speed tables.

No crash modification factors were found relating to speed tables or speed humps.

Appropriateness

Speed tables and speed humps are appropriate when the design speed of the speed table or hump corresponds to the posted speed limit. Consideration should be given to farm vehicles and routes with a large number of heavy trucks.

Cost

Cost, according to one source, is $2,000 to $4,000 (Kastenhofer, 1997).

Speed Lumps, Slots, and Cushions

Description

Speed lumps, slots, and cushions perform in the same manner as speed humps by vertically displacing the vehicle, causing drivers to slow down beforehand. One major issue with speed humps and tables is that emergency vehicles must slow down when navigating them, like everyone else. This required slow down becomes problematic because it results in an increase in response time for emergencies.

Speed lumps, slots, and cushions are designed using multiple raised lumps with un-raised sections for emergency vehicle wheel paths. Figure 14 shows a common speed lump design in Sacramento and Diamond Bar, California (Gulden and Ewing, 2009).

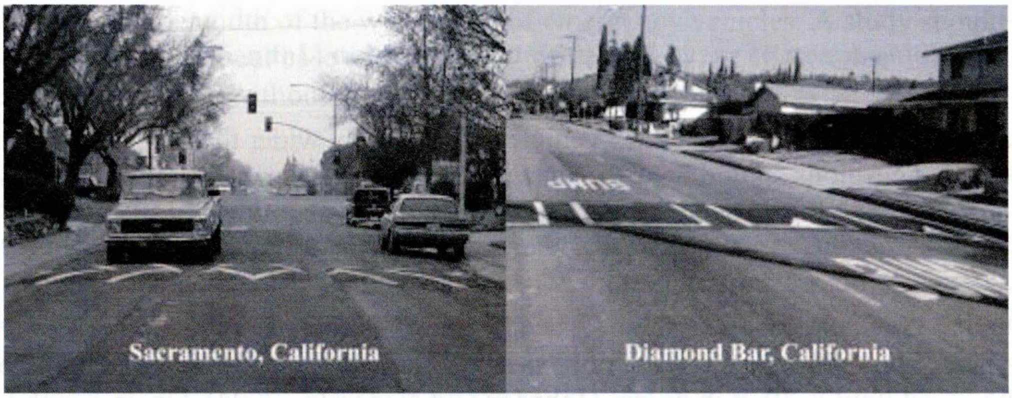

Figure 14: Typical asphalt speed lumps in California (Gulden and Ewing, 2009)

Un-raised sections allow emergency vehicles to continue at the same speed as they normally would. The reason this does not work for standard vehicles is because emergency vehicles typically have wider wheel bases than standard vehicles, so even if drivers decide to place one of their wheels in a wheel path, the other wheel will still hit part of the speed lump. The design is critical because, if not designed correctly, all vehicles (rather than only those with wider wheel bases) will be able to negotiate the speed lump without slowing down.

A concern with speed lumps and slots is that emergency vehicles must straddle the centerline, causing them to travel in both lanes of the roadway, which is another safety issue for emergency vehicles and oncoming vehicles. To remove this risk, speed cushions were developed, with the same intent as speed lumps and slots, but with wheel paths located centrally within both lanes.

Differences in speed humps, speed slots, and speed cushions are illustrated in Figure 15 (Johnson and Nedzesky, 2004).

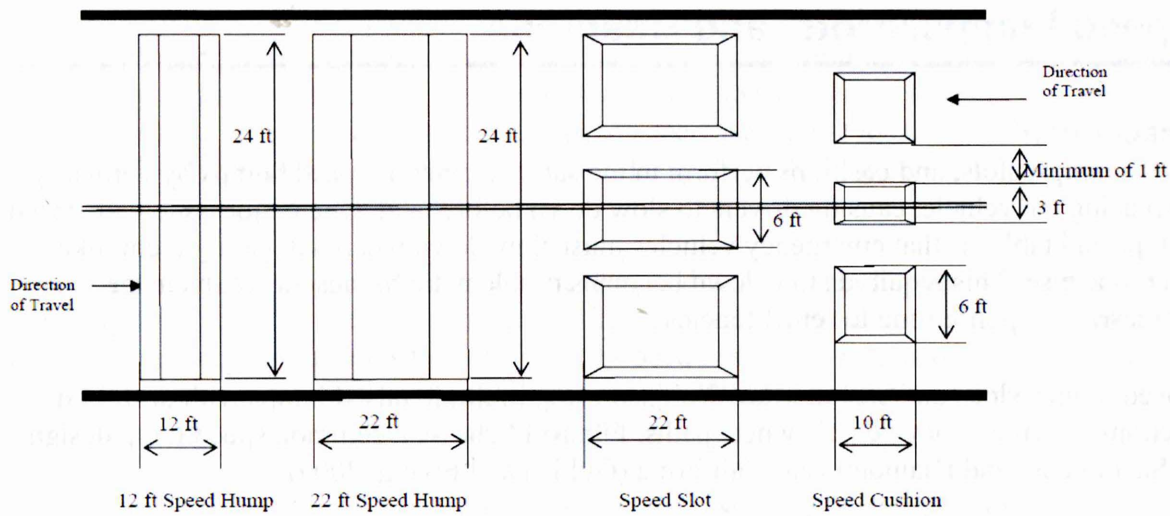

Figure 15: Comparison of speed hump, slot, and cushion (Johnson and Nedzesky, 2004)

Because the wheel bases of emergency vehicles are typically wider than those of typical vehicles, speed cushions should have the same effect as speed humps, lumps, and slots if designed correctly (Johnson and Nedzesky, 2004).

Placement

Speed lumps, slots, and cushions can be placed on local streets where speed reduction is desired. There should not be more than two travel lanes and the treatments should be placed where the speed limit is 30 mph or less (Johnson and Nedzesky, 2004). Contact with local emergency crews should verify wheel-base widths of emergency vehicles so that correct designs can be developed (Gulden and Ewing, 2009).

Advantages

- On-street parking and drainage are accommodated in the design of speed lumps like they are in speed humps (Gulden and Ewing, 2009)
- Emergency vehicles can negotiate speed lumps without having to reduce their speed
- Pre-fabricated rubber lumps can be installed easily by maintenance crews without needing additional skills
- Speed lumps are effective at reducing speeds on residential roadways while meeting the needs of emergency responders

Disadvantages

- Speed lumps should be placed as close as possible to existing street light to improve nighttime visibility of the devices
- Additional street lights may be necessary when speed lumps cannot be placed in front of existing street lights
- Speed lumps and slots require emergency vehicles to straddle centerlines and drive in both lanes of roadways (Johnson and Nedzesky, 2004)

Effectiveness

A study by Gulden and Ewing (2009) installed 50 speed lumps in the US and recorded before and after speeds. The study showed, on average, speed lumps were capable of reducing 85th percentile speeds by 9 mph or 25 percent. This study also showed little to no reduction in traffic volume, so the speed reduction is comparable to speed humps with typical volume reductions of 20 percent, which the speed lump improves on. This result shows that speed lumps are effective at reducing speed but are not an issue with most drivers so that they would decide to take an alternate path.

This study also found emergency vehicle speeds were "similar to normal operating speeds on the roadway," showing little to no delay with the speed lumps.

Appropriateness

Speed lumps are appropriate wherever speed humps may be used, but special consideration should be given to the width of the wheel base of emergency vehicles. A study should be done to verify that the wheel base of emergency vehicles will not allow other vehicles to traverse the speed lumps without vertical displacement as well.

Cost

When constructing speed lumps, a few options can affect cost. Some of these options include size of the lumps, width of the roadway, and whether using asphalt or rubber. A price approximated by Gulden and Ewing (2009) for rubber speed lumps is $3,000 to $4,000. The advantage of rubber speed lumps is that they can be pre-manufactured. Because there is not much difference between speed lumps and speed humps, the cost is relatively the same.

Narrowing

Narrowing is a traffic-calming measure similar to horizontal displacement. Drivers prefer wide lanes and open areas because of the safe feeling. Given this safe feeling, drivers then decide to travel at higher rates of speed because the conditions are conducive to this situation.

To take advantage of this driver preference, roadway narrowing can be used to slow drivers. Narrowing can be done by narrowing the lane physically or psychologically. In either case, narrowing gives drivers an uncomfortable feeling, reducing their speeds to feel safer. This chapter discusses both types of narrowing and the effectiveness of each measure:

- Center islands
- Vertical centerline treatments
- Shoulder widening to narrow travel lanes
- Four- to three-lane conversion
- Landscaping
- Hardscaping

Center Islands

Description

Lane narrowing reduces the width of the travel portion of a lane. The risk homeostasis theory (RHT) by Wilde (1982) explains that subjective risk remains the same while driving so, when a lane is narrowed, drivers will reduce their speed to sustain this constant level of subjective risk (Godley et al., 2004).

Lanes can be narrowed either physically or visually by increasing the marked width portion of a shoulder or median. Physical narrowing can be accomplished by using center islands, curb build-outs, or chicanes, but physical narrowing should be preceded by other traffic-calming devices to prevent accidents (Sustrans, 2005). Narrowing using a center island is shown in Figure 16.

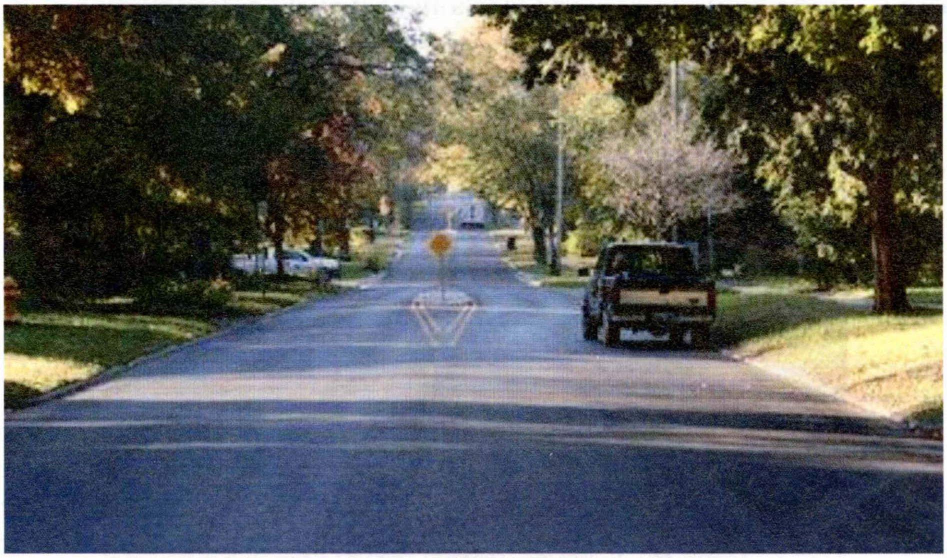

Figure 16: Use of a small, painted center island (Isebrands)

Center islands are usually raised islands, which are also called medians, within the roadway centerline. Center islands usually narrow the travel lane at that location and separate opposing traffic movements. When landscaped, center islands can improve the aesthetics of the corridor, and they can act as a gateway when placed at endpoints of a town.

Center islands are feasible without major roadway changes when the right-of-way is in excess of the minimum required street width. Center islands may also be painted areas, but these may be less effective than center islands with raised curbs and landscaping, given that vehicles can still traverse a painted island (CPVE, 2001).

The City of Drakesville in southern Iowa has a large center island widening along the main street as shown in Figure 17 through Figure 19.

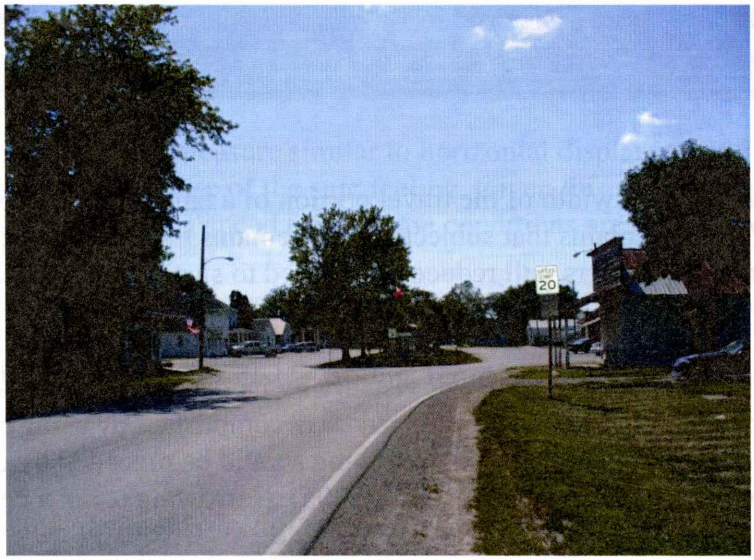

Figure 17: View of Drakesville center island as drivers enter main area of town

Figure 18: Close-up view of Drakesville center island

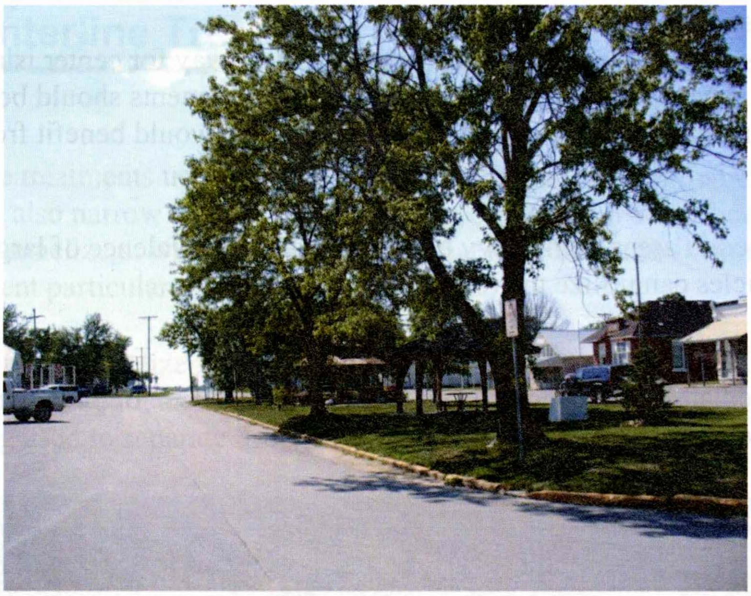

Figure 19: Side view of Drakesville center island showing gazebo and picnic area

The center island in Drakesville is surrounded by shops and forms a town square of sorts, with a gazebo and playground in the center. The island forces traffic to divert physically around it and has an aesthetically-pleasing appearance.

Placement

Median treatments can be continuous or placed in short sections.

Advantages

- Provide physical separation between travel lanes
- Create refuge areas for pedestrians
- May include landscaping that contributes to the pastoral nature of the area and is pleasing aesthetically
- May reduce head-on collisions

Disadvantages

- Depending on the roadway cross-section, separated lanes, in some cases, could lead to higher speeds, because drivers have less friction with on-coming vehicles
- Reduce access to businesses
- Require additional maintenance
- May have an impact on drainage

Effectiveness

Median treatments may be more effective when they provide a short interruption of traffic flow than when long center islands are used.

The Crash Modification Factors Clearinghouse provides CMFs of 0.56 for fatal and major injury crashes and 0.29 to 0.61 for all crashes for installation of a raised median.

Appropriateness

Rural main streets must have adequate additional right-of-way for center islands. If they do, center islands are especially appropriate when turning movements should be restricted or channelized downstream of an intersection, or in areas that would benefit from a pedestrian refuge.

Care should be used in areas with heavy truck volumes or prevalence of large farm vehicles so that larger vehicles can utilize the roadway.

Cost

Use of a raised median is a significant capital improvement. Use of pavement markings may be a fairly inexpensive alternative to raised medians.

Vertical Centerline Treatments

Description

Vertical centerline treatments use some type of vertical treatment to provide a sense of friction. They can also narrow the lane width. One type of vertical centerline treatment is use of longitudinal channelizers, which are delineators that have been used commonly to direct vehicles and prevent particular movements.

Depending on where channelizers are used, they may be between 18 and 36 inches tall, spaced about 32 inches apart, and may be yellow or orange in color. Figure 20 shows yellow channelizers being used to separate traffic movements.

Figure 20: Longitudinal channelizers

Channelizers have been used in work zones and high-occupancy vehicle (HOV) lanes, as well as on ramp exits. Special considerations must be taken when large trucks or farm equipment are present, because channelizers may restrict movements or even use of the road if they create a too narrow of roadway.

Other vertical centerline treatments include use of raised pavement markings or use of raised curbing.

Placement

Longitudinal channelizers and other vertical treatments should not be placed where they block a driveway or cross street. Most other placements are acceptable.

Advantages

- Separate traffic
- Able to withstand impact with a vehicle

Disadvantages

- May require maintenance with repeated impacts
- Wide vehicles and farm machinery have difficulty maneuvering (common in Iowa), so special consideration needed

Effectiveness

The ability of longitudinal channelizers to reduce speeds is not well documented. The majority of research regarding these devices pertains to their use at highway–railroad grade crossings.

The North Carolina DOT (NCDOT), for instance, placed the delineators along the centerline of the roadway extending about 100 feet from the railroad gates to dissuade drivers from going around the gates. Afterward, the NCDOT found the delineators reduced violations by 77 percent (ATSSA, 2006).

Longitudinal channelizers were used to create a center median as part of a rural traffic-calming project (Hallmark et al., 2007) as shown in Figure 21. Reductions of up to 3.0 mph in mean speed and 3 mph in 85th percentile speed were noted.

Figure 21: Creation of a center island with channelizers

No crash modification factors were found relating to longitudinal channelizers.

Hallmark et al. (2013) used temporary curbing to create a raised centerline treatment as a traffic-calming option. The treatment shown in Figure 22 was applied at north, south, and west community entrances in a small rural Iowa community.

Figure 22: Mountable curbing at south entrance to St. Charles, Iowa

The north/south main road through the community is a county road outside the community. The west community entrance is a state roadway outside the community. Sections of temporary curbing were placed 1 to 5 feet apart just after the regular posted speed limit within the community.

Speed data were collected before and 1 month after installation of the treatment. Speed decreased at two sites with decreases up to 2.2 mph in mean speed and decreases of up to 3 mph in 85th percentile speed. The fraction of vehicles traveling 5 or more mph over the posted speed limit decreased by 29 percent and the fraction of vehicles traveling 10 or more mph over the posted speed limit decreased by 29 to 46 percent. A large decrease (up to 71 percent) resulted for the fraction of vehicles traveling 15 or more mph over the posted speed limit. The fraction of vehicles traveling 20 or more mph over the speed limit decreased by 50 to 100 percent. At the third site, little change in any speed metrics occurred.

Appropriateness

Vertical centerline treatments are not appropriate for all situations but could be used to give drivers the perception of lane narrowing when entering town.

Cost

Longitudinal channelizers, raised pavement markings, and temporary curbing are low-cost options for narrowing lanes.

Shoulder Widening to Narrow Travel Lanes

Description

Lane narrowing reduces the width of the travel portion of a lane. Narrowed lanes provide a feeling of constraint and cause drivers to reduce their speed. Lanes can be narrowed either physically or visually by increasing the marked width portion of a shoulder or median.

Narrowing lanes visually is accomplished by re-painting shoulder and median markings to widen the shoulder or median and the decrease lane width. Reducing the width of lanes provides space for wider shoulders, bicycle lanes, left-turn lanes, etc.

Narrowing lanes may decrease speeds and smooth traffic flow. According to Caltrans (2002), lane narrowing is implemented normally as a highway transitions from rural to downtown and is suggested for main streets with average annual daily traffic (AADT) less than 10,000 vpd. However, reduction in level of service should also be considered.

Another option to give the appearance of lane narrowing is to provide shoulder surfaces that are different from the roadway surface, as shown in Figure 23.

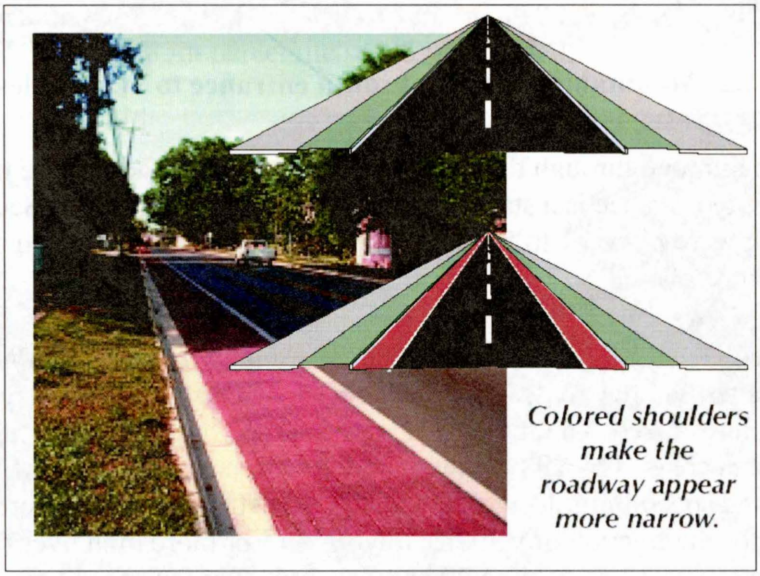

Figure 23: Colored shoulder (Oregon DOT, 1999)

Use of colored shoulders contrasts travel lanes with shoulders and can narrow the roadway visually. Colored shoulders typically last longer than markings on the roadway, due to lower vehicle traffic.

Another treatment actually constructs travel lanes out of one material and shoulders from another, such as concrete with asphalt, or uses different roadway material, such as cobblestones.

Shoulder widening was used in Roland, Iowa as part of the gateway traffic-calming treatment that was evaluated in that community as shown in Figure 24.

Figure 24: Use of shoulder widening in Roland, Iowa

Placement

Shoulder widening to narrow lanes is implemented along the length of the area selected for traffic calming. A transition should be provided in advance.

Advantages

- Provides additional space for shoulders, bike lanes, and sidewalks
- Low cost when implemented using pavement markings
- Can be implemented rapidly
- Does not lead to an increase in noise
- No impact to emergency vehicles
- Does not affect vehicle operation

Disadvantages

- Reduces separation between oncoming vehicles
- Pavement markings require maintenance

Effectiveness

Kamyab et al. (2002) reported on the use of lane narrowing as a traffic-calming measure in Twin Lakes, Minnesota. Lane width was reduced to 11 feet using pavement markings, creating 8 foot shoulders. Transverse stripes were also created on the shoulders, as shown in Figure 25.

Figure 25: Lane narrowing with transverse shoulder stripes

Hallmark et al. (2007) used lane narrowing as a rural traffic-calming measure in two rural Iowa communities. In one community, a center median was created using pavement markings as shown in Figure 16. Shoulder markings were also applied using pavement markings as shown in Figure 24. Both narrowed lanes. However, speeds did not appear to be affected by the painted lane-narrowing treatments.

No crash modification factors were found relating to lane narrowing.

Appropriateness

Narrowing lanes visually by re-painting lane edge lines is an acceptable strategy, particularly given it does not impede large vehicles or farm equipment.

Cost

The cost of initial pavement markings and subsequent maintenance are the costs associated with narrowing the roadway visually. One source indicated a cost of $0.15 to $1.00 per linear foot for painting and $1.00 to $5.00 per linear foot for plastic (CWS, 2003).

Four- to Three-Lane Conversions

Description
A four- to three-lane conversion is used to reduce an existing four-lane roadway to a 2+1 facility, in which the third lane acts as an alternating passing lane. Removal of two of the through lanes can narrow the roadway either physically or visually and may result in reduced speeds (Brewer et al., 2001). The lane conversion strategy is common in rural areas in Europe, with the middle lane serving as a passing lane with alternating right-of-way.

Placement
The treatment can be used along the length of a main road through a small community or for specific sections.

Advantages
- Provides a refuge area for vehicles entering and exiting the roadway
- Does not have an impact on drainage
- Does not affect emergency vehicles
- Can be implemented rapidly
- No increase in noise
- Does not affect vehicle operation negatively

Disadvantages
- Can increase queue delay on minor street intersections
- May reduce road capacity

Effectiveness
An earlier CTRE report on the use of four- to three-lane conversions showed moderate reductions in 85th percentile speeds up to 5 mph and a 60 to 70 percent reduction in the number of vehicles traveling more than 5 mph above the posted speed limit (Knapp and Giese 2001). Crash reductions from 17 to 62 percent were also documented.

Corkle et al. (2001) also evaluated a four- to three-lane conversion in Minnesota on a 35 mph minor arterial. The researchers reported reductions in both mean and 85th percentile speeds of up to 4 mph.

The Crash Modification Factors Clearinghouse provides CMFs of 0.47 to 0.63 for all crashes in converting a four-lane roadway to a three-lane roadway.

Appropriateness
Four- to three-lane conversions are especially applicable to areas where the highway has many access points along the through-town segment.

Cost
If four- to three-lane conversions are accomplished using pavement markings and the existing right-of -way, the treatment is relatively inexpensive.

Landscaping

Description

Landscaping is often used in conjunction with other traffic-calming treatments, such as raised medians or islands (Figure 26), chokers, roundabouts, traffic circles, and chicanes.

Figure 26: Median landscaping (www.springfield.il.us/green/News16.html)

Landscaping has two purposes: make traffic-calming treatments more attractive and further communicate to motorists that a slower speed is advisable.

An interesting question in the literature is whether landscaping alone can be employed as a traffic-calming device. The theory of using landscaping for traffic calming is that it can work in two ways:

- By planting alongside the road or street in such a way that the roadway appears narrower to the driver. The optical width of the road is narrowed as opposed to the physical width. A tunnel effect is created and the driver field of view is narrowed. This, in turn, should encourage drivers to slow down.

- By communicating a change in the character of the roadway from rural to urban. This is done by changing the nature of plantings alongside the roadway. For instance, in rural areas, trees are found in naturalistic clumps or groups while, in urban areas, trees are planted in formal rows and spaced at regular intervals.

Although the discussion in this section is specifically about landscaping, similar effects could also be achieved with "hardscaping," e.g., buildings and building setbacks, street cross-sections, on-street parking, and street fixtures. With these treatments, the goals would again be to narrow the optical width of the street and/or communicate the urban nature of the street.

However, hardscaping approaches will generally be much more expensive than landscaping solutions to traffic calming.

Placement

Landscaping should be placed along the entire length of the street where traffic calming is desired, on both sides of the street. It is particularly critical to place landscaping that narrows the optical width of the roadway and communicates that the road is changing from rural to urban in the transition zone where the largest decrease in speed is sought. Figure 27 from the National Forest Service shows how trees planted at fairly regular intervals communicate the message that the street is urban.

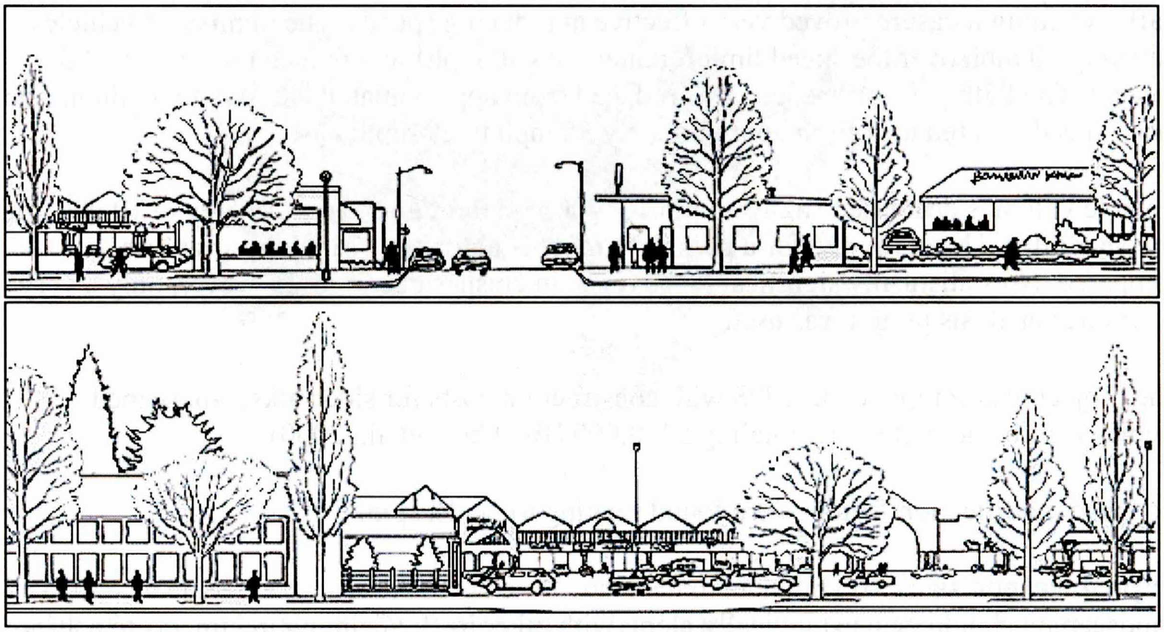

Figure 27: Regular spacing of trees (National Forest Service)

Trees will be the most effective form of landscaping generally in terms of traffic calming, due to the fact that they can grow large enough to provide the "optical narrowing" effect that should, in turn, reduce traffic speeds. Care should be taken in planting not to create additional driving hazards, such as blocking sight distance triangles at driveways and public road intersections. Clear zone issues should also be considered.

Advantages

Landscaping can serve multiple purposes, including community development and beautification and traffic calming.

Disadvantages

- Can be high-cost
- Maintenance is required
- Objects in clear zone can create traffic hazards if not designed properly

Effectiveness

The research literature is not clear on whether landscaping alone will be sufficiently effective to calm traffic in the absence of other traffic-calming treatments, including physical treatments and enforcement.

Lakewood, Colorado used a series of landscaped medians and curbside islands to create a narrow serpentine roadway alignment for traffic calming on a collector street. The alignment was 1,150 feet. The goal was to reduce speed but not volume, due to concerns that traffic would be diverted to other residential streets (Buchholz et al., 2000).

Vehicle speeds were compared before and one year after completion of the project. The traffic-calming measure proved very effective at reducing speeds. The number of vehicles traveling 10 mph over the speed limit (greater than 40 mph) was reduced from 35 to 2.5 percent. The 85th percentile speed was reduced from approximately 45 mph to 35 mph. The mean speed was reduced from approximately 36 mph to 29 mph.

Vehicle volumes decreased slightly from 11, 400 vpd through the project area to 10,900 vpd one year after. The crash rate for a period 31 months before to 17 months after was compared. No statistically significant difference in crashes occurred. However, only a very short after-analysis period was used.

The project was completed in 1998 with construction costs for sidewalks, landscaped medians, curb and gutter, etc. totaling $240,000 (Buchholz et al., 2000).

No crash modification factors were found relating to landscaping.

Appropriateness

Landscaping should be used logically along with other traffic-calming treatments to achieve the desired result. Landscaping should be part of a comprehensive traffic-calming plan for a community wishing to slow speeds and maintain traffic flow along an arterial roadway.

Cost

Cost varies depending on treatment.

Hardscaping

Description

Hardscaping can be thought of as the hard-surfaced complements to landscaping. Hardscaping is usually combined with landscaping, such as tree planting, to create a comprehensive streetscaping project, as shown in Figure 28.

Figure 28: Streetscape concept drawing for Niagara Falls, New York (www.usaniagara.com/projects_display.asp?id=8)

The complete cross section of the roadway is considered, including parking, sidewalks, and facades of adjacent buildings. Other elements of hardscaping may include pavement and crosswalk textures or colored pavements.

As is true with landscaping, streetscaping and hardscaping are thought to encourage calmer traffic in two main ways:

- By placing design elements, such as building facades, sidewalks, on-street parking, and street fixtures, close to the through lanes of the road or street in such a way that the roadway appears narrower to drivers (i.e., the optical width of the road is narrowed as opposed to the physical width). As described in the Landscaping section, with trees planted along a roadway, a tunnel effect is created and the driver field of view is narrowed. This, in turn, should encourage drivers to slow down.

- By communicating a change in the character of the roadway clearly from rural to urban in providing an overall design experience that simply looks relatively dense and urban. This provides a visual cue to drivers to slow down.

Placement

Streetscaping or hardscaping should be placed along the entire length of the street where traffic calming is desired, on both sides of the street. It is particularly critical to place features in such a way that they narrow the optical width of the roadway and communicate that the road is changing from "rural" to "urban" in the transition zone where the largest decrease in speed is sought.

Advantages

Like landscaping, enhanced hardscaping or streetscaping can serve multiple purposes, including community development and beautification and traffic calming.

Disadvantages

The research literature is not clear whether hardscaping or streetscaping alone will be sufficiently effective to calm traffic in the absence of other traffic-calming treatments, including physical treatments and enforcement.

Effectiveness

No information about the effectiveness was found.

Appropriateness

Hardscaping or streetscaping should be used logically along with other traffic-calming treatments to achieve the desired result. Hardscaping or streetscaping should be part of a comprehensive traffic-calming plan for a community wishing to slow speeds and maintain traffic flow along an arterial roadway.

Cost

Cost depends on the treatment but can entail a significant capital investment.

Surroundings

When drivers don't slow when entering a community, it is either because they choose not to slow down or do not realize they need to slow down. Very different characteristics exist between rural and urban areas, so surroundings can be used to notify drivers they are entering a community and must reduce their speeds.

The treatments in this chapter do not have an impact on drivers in any way except to let them know they need to lower their speeds because they are entering a community:

- Community gateways
- Banners

These treatments can be applied with multiple other traffic-calming treatments.

in such a way that they narrow the optical width of the roadway and communicate that the road is changing from "rural" to "urban" in the transition zone where the largest decrease in speed is sought.

Advantages

Like landscaping, enhanced hardscaping or streetscaping can serve multiple purposes, including community development and beautification and traffic calming.

Disadvantages

The research literature is not clear whether hardscaping or streetscaping alone will be sufficiently effective to calm traffic in the absence of other traffic-calming treatments, including physical treatments and enforcement.

Effectiveness

No information about the effectiveness was found.

Appropriateness

Hardscaping or streetscaping should be used logically along with other traffic-calming treatments to achieve the desired result. Hardscaping or streetscaping should be part of a comprehensive traffic-calming plan for a community wishing to slow speeds and maintain traffic flow along an arterial roadway.

Cost

Cost depends on the treatment but can entail a significant capital investment.

Surroundings

When drivers don't slow when entering a community, it is either because they choose not to slow down or do not realize they need to slow down. Very different characteristics exist between rural and urban areas, so surroundings can be used to notify drivers they are entering a community and must reduce their speeds.

The treatments in this chapter do not have an impact on drivers in any way except to let them know they need to lower their speeds because they are entering a community:

- Community gateways
- Banners

These treatments can be applied with multiple other traffic-calming treatments.

Community Gateways

Description

Community gateways are simply landscaped sign installations that announce to motorists that they are entering a community. Although installed often for community development and community pride purposes, effective community gateways will communicate to motorists that they are making a transition from a rural roadway to a city street.

Figure 29 through Figure 31 provide examples of community gateway signage used in rural Iowa.

Figure 29: Gateway sign in Tiffin, Iowa

Figure 30: Gateway sign in Rockwell City, Iowa

Figure 31: Gateway sign in Sioux Center, Iowa

Gateway signs provide an indication to motorists that they are leaving a rural area and entering a city or town where land use, pedestrian, and motor vehicle activities will be more intense. Motorists should, in turn, respond by slowing down.

Placement

A community gateway should be placed where a reduction in traffic speed is desired; it should be close to the boundary of the community. Gateways would best be placed in the speed transition zones where a gradual reduction of speed is desired. Community gateways are generally to be placed to the right of the roadway, although some are so large that they span the roadway. A large community gateway from Milwaukee, Wisconsin that completely spans the roadway is shown in Figure 32.

Figure 32: Gateway entrance in Milwaukee, Wisconsin

The gateway needs to be large enough to attract the attention of drivers and it also must be formal enough to communicate the message that the character of the roadway is changing from rural to municipal.

Advantages

A community gateway will probably not be installed for traffic-calming purposes alone. It will more likely be done for community development purposes, perhaps by a service or garden club. This can help keep installation and maintenance costs low for the community.

Other advantages include the following:

- Can be personalized to reflect community identity (CPVE, 2001)
- Aesthetically pleasing

Disadvantages

- Require considerable ongoing maintenance such as painting the sign and renewing and watering the vegetation
- May infringe on the clear zone

Effectiveness

The Department for Transport, UK, indicated that mean speed reductions of 3 to 13 mph, with an average of 5 mph, were achieved using gateways (Sustrans 2005). They also reported up to 15 mph speed reductions for the 85th percentile using gateways with other treatments (DETR, 2005).

The main purpose of a gateway entrance treatment is to remind drivers they are transitioning from a rural high-speed roadway to a community. Simple use of an entrance sign, however, may have limited effectiveness.

The Crash Modification Factors Clearinghouse provides a CMF of 0.98 for all crashes for construction of a gateway monument on state-owned roadways.

Appropriateness

The most appropriate application for a community gateway would be as an integral part of a more extensive community traffic-calming and corridor-beautification program. Given they do not infringe on the roadway, gateways are appropriate for use along major roads through small communities. Use of gateway entrance treatments should be consistent with clear-zone requirements, because they are often made of immovable material that presents a fixed object hazard.

Cost

A very elaborate community gateway may cost $10,000 including all materials and labor. An example of a $10,000 community gateway from Fort Dodge, Iowa is shown in Figure 33.

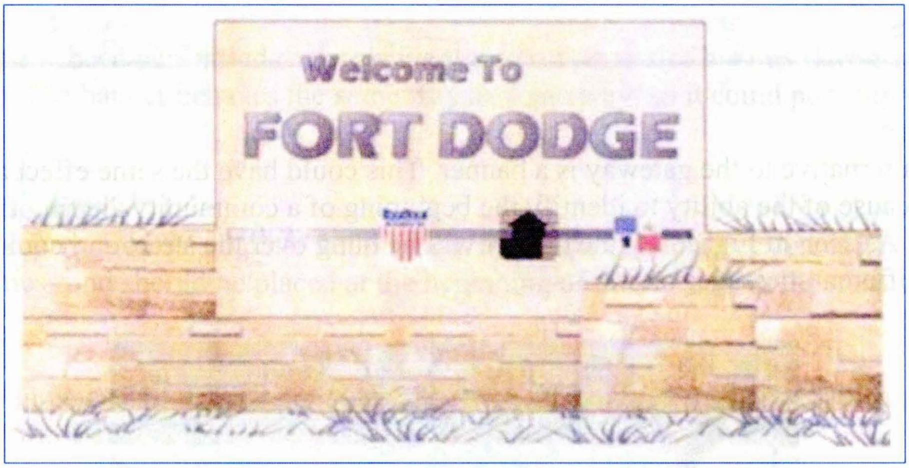

Figure 33: Fort Dodge, Iowa gateway treatment

It is masonry construction, which adds to the expense. Reductions in cost may be achieved through outside grants (e.g., the Keep Iowa Beautiful grant program), volunteer labor, donated materials, and use of less-expensive construction techniques.

Banners

Description

A cheaper alternative to the gateway is a banner. This could have the same effect as the gateway because of the ability to identify the beginning of a community alerting the driver to slow down. As seen in Figure 34, the banner will be hung over the street and could have a variety of different messages on it.

Figure 34: Banner over roadway (Dixon et al., 2008)

A problem with banners as rural traffic-calming treatments is that, if installed within the town, they don't allow drivers adequate time to slow down if they didn't already recognize the need to slow down entering the community.

Placement

Banners are usually placed within the town from buildings because that is typically the easiest place to hang them. Hanging the banner near the edge of the town or in the transition zone could be possible in some situations.

Advantages

- Cheaper alternative to the gateway
- Message can be changed easily given the cost of the banner is lower
- Same advantage as a gateway treatment

Disadvantages

- May not be as noticeable as a gateway treatment
- Typically hung from buildings, which removes the effect of alerting drivers that a community is being entered
- Maintenance or repair may be needed because of the material

Effectiveness

No studies have been performed to determine the effectiveness of banner placement (Dixon et al., 2008). The banner behaves the same way as a gateway, so it could possibly be as effective.

Appropriateness

It is not appropriate to use a banner within town for traffic calming because it will have lost its effectiveness and should be placed at the beginning of the town or in the transition zone.

Cost

Banners are inexpensive to create but may require installation of something to hang them outside of town. Banners are a much cheaper alternative to the gateway.

Pavement Markings

Pavement markings can be used in a variety of ways to slow drivers. The most noticeable features when driving can be the pavement markings because they are always within the sight of drivers as long as the pavement is clear (which is not always the case, particularly during winter months in Iowa).

Messages can be conveyed more easily with pavement markings because more attention can be drawn to them. This chapter discusses a variety of pavement markings that can be used to slow drivers:

- Transvers lane markings
- Surface treatments
- Pavement marking legends
- Wide edge lines

Transverse Lane Markings

Description

Transverse pavement markings usually consist of transverse bars or chevrons. The transverse bars are typically spaced to give drivers the perception that they are speeding up. This perception encourages drivers to be aware of their speeds and to slow down.

Lane markings can also be used as a way to alert drivers that they are entering a different area such as a community. Lane markings are a low-cost solution and have been used in work zones and along horizontal curves to slow speeds (Katz, 2004).

Pavement markings such as "dragon teeth" have been used in the UK to provide a visual change of the roadway and alert drivers that they are entering a rural community, as shown in Figure 35.

Figure 35: Dragon teeth (www.cornwall.gov.uk/transport/trafcalm/calmhome.htm)

Optical speed bars have been used at roundabouts in Great Britain (Meyer, 2001), in highway work zones, and on a four-lane undivided highway in Virginia (VTRC, 2006). Optical speed bars (shown in Figure 36) were used as a gateway treatment in Union, Iowa as part of a CTRE study (Hallmark et al., 2007).

Figure 36: Optical speed bars used in Union, Iowa

Converging chevrons have also been used to slow speeds. Converging chevrons were used as part of the gateway treatment in Roland, Iowa as shown in Figure 37.

Figure 37: Use of converging chevrons in Roland, Iowa

Placement

Transverse pavement markings should be spaced with decreasing space as drivers enter a transition zone. This spacing gives drivers the perception of going too fast or speeding up and encourages them to reduce their speeds.

Transverse pavement markings are appropriate for rural traffic calming, especially in transition zones, where drivers are being reminded of a change in roadway character.

Advantages

- Cost-effective
- Do not affect vehicle operation
- Do not have an impact on emergency vehicles
- Do not have an impact on drainage

Disadvantages

- Additional maintenance required to maintain, particularly with snow plows
- Less effective, particularly with adverse winter road conditions, when markings may not be visible

Effectiveness

A study in Minnesota used a converging chevron pattern in each travel lane as a traffic-calming measure (Corkle et al., 2001). The width of chevrons and spacing were decreased to give the illusion that vehicles were traveling faster than they actually were (Figure 38).

Figure 38: Aerial view of chevron lane markings in Eagan, Minnesota (Corkle et al., 2001)

The Minnesota project also placed 30 mph pavement markings and added high-visibility wind spinners on speed limit signs. The roadway was a community collector street with average daily traffic (ADT) of 4,000.

Data were collected before installation and one week after. Reductions of 5 and 3 mph in mean speeds (depending on the lane) were observed and 7 and 5 mph in 85th percentile speeds. Speeds were also collected 28 weeks after installation. The highest speeds recorded were reduced from 58 to 44 mph and 53 to 45 mph one week after installation and 58 to 48 mph and 53 to 48 mph at 28 weeks after installation.

The markings were re-painted after four years, because the researchers felt that the fading paint had an impact on the results. After re-painting, the researchers found similar speed-reduction results as those conducted one week after initial installation (Corkle et al., 2001).

The previous CTRE study on rural traffic-calming treatments evaluated two different on-pavement markings (Hallmark et al., 2007). Peripheral transverse pavement markings were used to slow incoming traffic at the community entrances in a small rural Iowa community as shown in Figure 36.

The markings were placed so they terminated at the first speed limit sign entering the community, which marked the speed zone that was continued throughout the community for that section of roadway. Decreases up to 2 mph in mean and 85th percentile speeds were noted.

A converging chevron pattern was used at the community entrances in another small rural Iowa community as shown in Figure 39. Mean speeds decreased by up to 3.0 mph and 85th percentile speeds decreased by up to 4 mph.

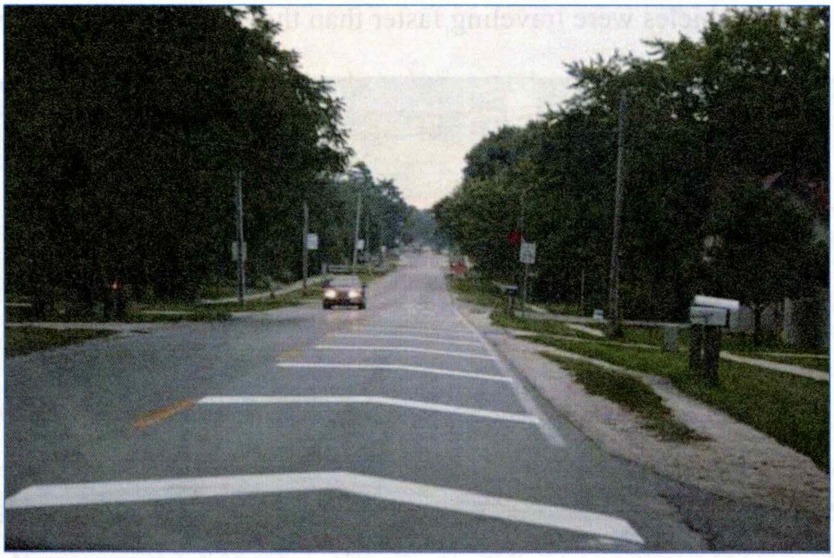

Figure 39: Use of converging chevrons on County Road E-18 in Iowa

Transverse pavement markings, which are low cost, do not present the safety hazards associated with horizontal or vertical deflections. Transverse pavement markings can also accommodate all types of vehicles without interfering with vehicle operation and do not change the characteristic of the roadway physically.

Hallmark et al. (2013) used transverse speed bars at three locations within two small rural Iowa communities. The proposed treatment consists of a series of triple bars as shown in Figure 40. The bars were spaced at intervals so that drivers are able to position their vehicles within the wheel paths.

Figure 40: Transverse bar treatments

Speed decreased at two sites with decreases 1 mph in mean and 85th percentile speed. The fraction of vehicles traveling 5 or more mph over the posted speed limit decreased by around 8 percent and the fraction of vehicles traveling 10 or more mph over the posted speed limit decreased by 12 percent for both sites. A large decrease resulted for the fraction of vehicles traveling 15 or more mph over the posted speed limit (25 and 17 percent) and for those traveling 20 or more mph over (40 and 25 percent).

At the third site, mean and 85th percentile speed increased slightly. The fraction of vehicles traveling over the posted speed limit increased, as well, with an 8 percent increase for vehicles traveling 5 mph over the posted speed limit, a 24 percent increase for vehicles traveling 10 mph over, a 36 percent increase for vehicles traveling 15 mph over, and a 100 percent increase for vehicles traveling 20 or more mph over the posted speed limit.

Cost

Transverse markings are low cost with the initial cost to lay markings and cost of subsequent maintenance.

Surface Treatments

Description

Colored surface dressings or textured surfaces are common traffic-calming treatments in Europe and are often used in conjunction with gateways or other traffic-calming measures to emphasize the presence of traffic-calming features. Surface treatments are usually implemented on the full width of roadway and can be done with pavement markings (Figure 41 and Figure 42) or textured pavement (Figure 43).

Figure 41: Red pavement markings with posted speed limit signs (DETR, 2005)

Figure 42: Pavement markings used as entrance treatment (DETR, 2005)

Figure 43: Textured surface treatment (CWS, 2003)

Surface treatments draw attention to the fact that something about the roadway is changing and provide visual clues and, in the case of textured pavement, an auditory clue to drivers that they have entered a different area.

A colored surface treatment was used as an entrance treatment in Dexter, Iowa as part of previous CTRE traffic-calming research, as shown in Figure 44 (Hallmark et al., 2007).

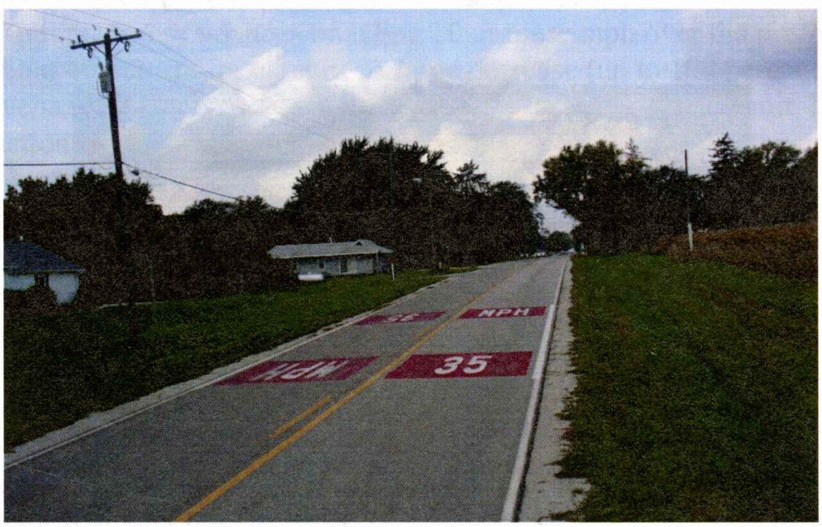

Figure 44: Colored pavement markings in Dexter, Iowa

Placement

Textured surfaces are placed typically in the transition zones before entering towns and are used often in conjunction with other techniques, such as landscaping. Colored surface markings should be skid resistant and should be placed across both lanes so that drivers aren't tempted to change lanes to avoid the treatments.

Surface treatments that cover a significant portion of a lane should meet state or local skid resistance requirements.

Advantages

- Can be aesthetically pleasing
- Do not affect vehicle operation
- Do not have an impact on emergency vehicles
- Do not have an impact on drainage
- In the case of surface coloring, does not have noise impacts

Disadvantages

- Require regular maintenance
- May be less effective in winter and under other adverse weather conditions when markings are not visible
- Textured surfaces, like cobblestones or bricks, can be difficult for bicyclists and pedestrians to negotiate
- Textured surfaces have increased noise

Effectiveness

An initial reduction in speed often occurs after installation. Surface treatments are considered most effective in combination with other techniques. Colored surfaces may be less effective particularly during winter months due to snow or ice cover.

One study in Shropshire, UK reported on the use of colored surface treatments in conjunction with speed limit signs (DETR 2005). The study reports on use of red patches 8 meters long across the full width of the roadway, along with speed limit signs placed for each direction as shown in Figure 45.

Figure 45: Treatment used in Shropshire, UK (DETR, 2005)

This configuration was repeated at 10 locations throughout the city and was used along with other traffic-calming measures. Reductions in both mean and 85th percentile speeds decreased, although the study did not provide the exact numbers for this treatment.

Colored pavement markings were applied outside of a small rural community in Iowa in an initial study as shown in Figure 46.

Figure 46: Colored pavement marking treatment for rural traffic calming in Iowa

The markings were very effective with reductions in mean speeds up to 7.4 mph and in 85th percentile speeds up to 9 mph.

In a follow-up study, CTRE evaluated a similar treatment at three community entrances in two rural Iowa cities (Hallmark et al., 2013). Speed decreased at three sites with decreases up to 2.3 mph in mean speed. All sites had a decrease in 85th percentile speed of 2 mph. The fraction of vehicles traveling 5 or more mph over the posted speed limit decreased by 30 to 44 percent and the fraction of vehicles traveling 10 or more mph over the posted speed limit decreased by about 40 percent for all sites. A large decrease (up to 100 percent) resulted for the fraction of vehicles traveling 15 or more mph over the posted speed limit. No change was noted in the fraction of vehicles traveling 20 or more mph over the posted speed limit.

No crash modification factors were found for colored pavement markings.

Appropriateness

Surface treatments are appropriate for traffic calming along major roadways in rural communities, especially in transition zones where drivers are being reminded of a change in roadway character.

Surface treatments are low cost and do not present the safety hazards associated with horizontal or vertical deflections.

Textured surfaces, such as cobblestones or other materials, may not be appropriate with heavy loadings that may occur on major rural roads.

Cost

Use of painted roadway surfaces is generally low cost and entails the initial cost to paint the roadway and subsequent costs to maintain. Paint must be skid resistant.

Other roadway surface treatments, such as use of different textures or incorporating dyes into the roadway or shoulder pavement, are more expensive.

Pavement Marking Legends

Description

Some communities have painted the speed limit on the roadway to remind drivers of the speed limit or to indicate a transition zone as shown in Figure 47.

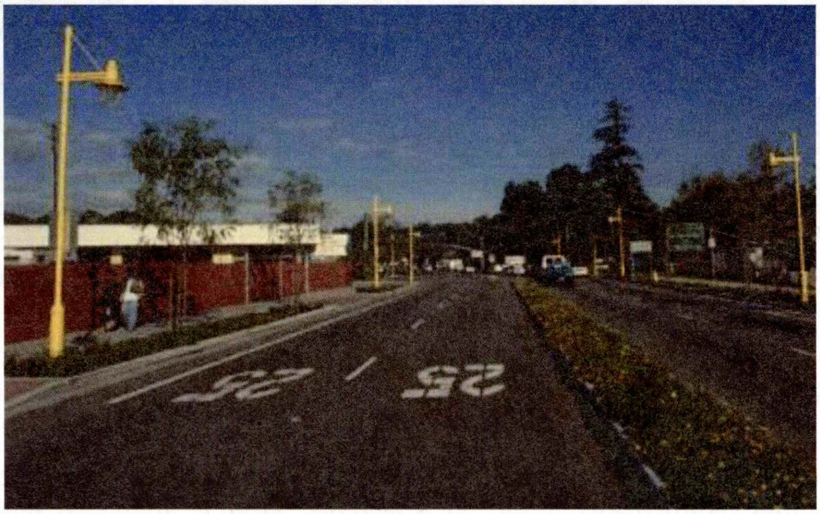

Figure 47: Speed limit pavement markings (CWS, 2003)

In other cases, use of the word SLOW or SCHOOL is used. Use of the wording on the pavement surface is more dramatic than only using signing, which can get lost in the clutter of a streetscape.

On-pavement speed markings were used as part of the gateway treatment in Roland, Iowa, as shown in Figure 49, as part of a previous CTRE traffic-calming research project (Hallmark et al., 2007).

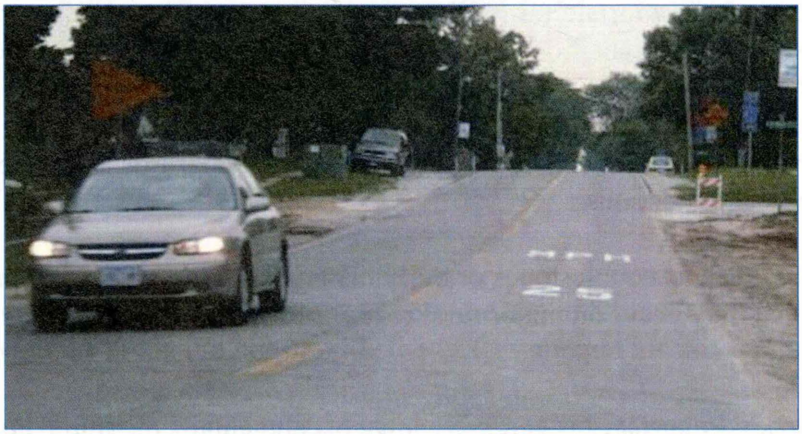

Figure 48: Use of on-pavement speed marking in Roland, Iowa

Use of the wording SLOW was utilized as part of the research project, as well, along one section of roadway in the vicinity of areas where pedestrians cross a state road, through the community of Slater, Iowa, as shown in Figure 49.

Figure 49: Use of on-pavement SLOW marking in Slater, Iowa

Placement

No guidance was found on exactly where on-pavement markings should be placed. However, it is assumed that speed-limit legends would be placed on the pavement in the same locations as speed limit signs.

Advantages

- Inexpensive
- Can be implemented rapidly
- No increase in noise
- No impact to emergency vehicles
- No adverse effect on vehicle operation

Disadvantages

- Increased maintenance costs
- Not necessarily visible when snow or ice on the roadway

Effectiveness

The study by Hallmark et al. (2007) showed that the use of SLOW pavement markings did not appear to be effective.

Appropriateness

Use of pavement markings does not affect vehicle operation and is appropriate for use along major roads through small communities.

Cost

CWS (2003) indicated a cost of $25 to $50 per letter or number and $100 to $200 per symbol.

Wide Edge Lines

Description
Edge lines are used to guide users where to drive on roadways. By having wider edge lines, drivers may feel they need to drive closer to the centerline because of the narrower feeling. Mixing this narrower feeling and the fact that drivers are closer to oncoming traffic should slow drivers. The idea that the wide edge line is different than standard could give this effect.

Placement
There have not been any studies of using wide edge lines for traffic calming, but they have been used on rural two-lane roads (Cottrell, 1986). Wider edge lines can be placed in any location that currently has edge lines.

Advantages
- User drives closer to the center of the lane
- Increased alertness to road conditions from perceived narrowing

Disadvantages
- Increased chance of encroaching on opposing lane

Effectiveness
The use of wide edge lines has been ineffective when tested. A study by Cottrell (1986) looked into no edge lines, 4 inch edge lines, and 8 inch edge lines. In the testing, the lateral placements were emphasized, as this was the motivation of slowing down vehicles. After the study, lateral placement was lower but it was so small that it was practically insignificant. These data also showed no significant difference in encroachment of the mean speeds.

The Crash Modification Factors Clearinghouse provides CMFs of 0.57 to 1.05 for severe crashes for installation of wider markings without resurfacing.

Appropriateness
Wider edge lines are appropriate in areas that need increased guidance from the edge lines. Edge lines can provide warning and guidance to drivers without requiring drivers to remove their attention from the roadway (Cottrell, 1986).

Cost
Wide edge lines could double the cost of edge lines because of the wider width.

Traffic Control Signs

Like pavement markings, traffic control signs are used as a way to notify drivers that speeds need to be reduced. Signs are very easy for drivers to miss or ignore, so different signs are being used to draw more attention and better notify drivers. The signs in this chapter are not standardly used in all situations, but they provide ways to attract more attention from drivers:

- Dynamic speed displays and vehicle-actuated signs
- Photo-radar reinforcement
- Light-emitting diodes (LEDs) in pavements markings or signs

Dynamic Speed Displays and Vehicle-Actuated Signs

Description

Dynamic speed signs and displays are usually radar-activated signs that display approaching speeds dynamically for individual vehicles and/or display messages, such as YOUR SPEED, SLOW DOWN, or REDUCE SPEED, particularly when an approaching vehicle exceeds a certain speed (Figure 50 and Figure 51).

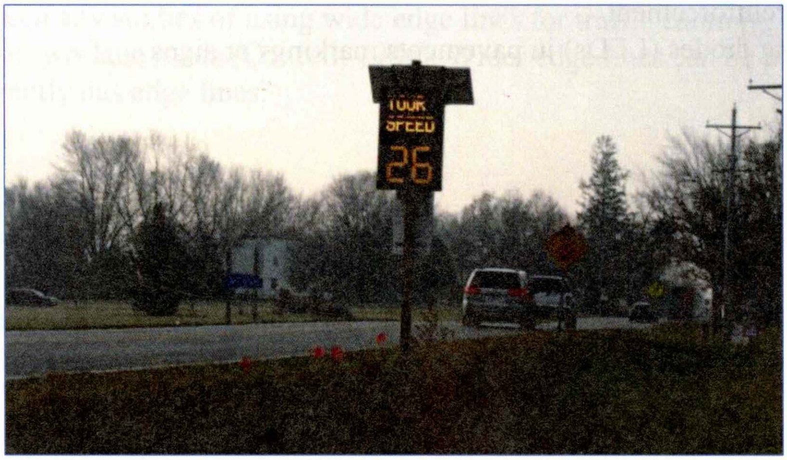

Figure 50: Dynamic radar speed sign

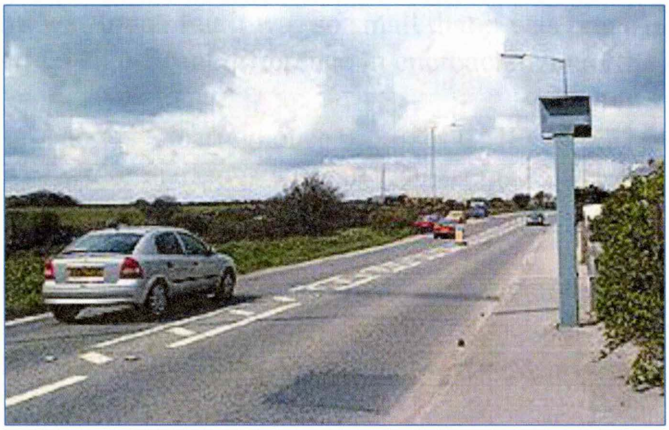

Figure 51: Speed camera (www.cornwall.gov/transport/trafcalm/calmhome.htm)

These devices can be portable or permanent. They alert drivers that they are speeding and create a sense of being monitored. These devices may also slow drivers who have radar detectors.

Placement

Devices are placed in the location where a reduction in speed is desired. They may also be used in transition zones to slow traffic in advance of lower speed areas.

Advantages

- Do not affect vehicle operation
- Do not have an impact on emergency vehicles
- Do not have an impact on drainage
- Can be moved and used at different locations when portable
- Less expensive than enforcement in the long term (CWS, 2003)
- May be implemented immediately

Disadvantages

- High initial cost
- Require regular maintenance and a power source
- Motorists may speed up to see how fast they can go (which can be addressed by only posting speeds in a certain range)
- Drivers may become immune to them if overused and no perception of further enforcement
- Possibly effective for only one direction of travel

Effectiveness

The Texas Transportation Institute (TTI) evaluated the use of portable speed display trailers in work zones (Fontaine et al., 2000). The researchers found that passenger vehicle speeds were reduced by 7 to 9 mph at one site and 2 to 3 mph at another. Truck speeds were reduced 3 to 10 mph at both sites.

The Department of Transport, UK found that average speeds can be reduced by 1 to 7 mph using dynamic speed signs. The researchers also suggest that signs are more effective on a mobile basis, given drivers may become immune when the signs are installed on a permanent basis (Sustrans, 2005).

Chang et al. (2004) tested the use of radar speed signs in reducing speeds and found that the devices were effective and had a sustained effect in maintaining lower 85th percentile and average speeds.

Two different dynamic speed feedback signs were evaluated as part of the earlier traffic-calming research project by Hallmark (2007). One sign technology that displayed current driver speed in Union, Iowa was effective at reducing driver speeds significantly. Another sign that was capable of providing different messages to drivers, in addition to their current speed, was evaluated in Slater, Iowa. This sign reduced average speeds by 5 mph and 85th percentile speeds by 7 mph.

In another study by CTRE, two different dynamic speed feedback signs were evaluated in two different rural Iowa cities (Hallmark et al., 2013). The first was a speed limit sign that has radar-actuated LEDs embedded around the outside of the sign as shown in Figure 52.

Figure 52: Speed limit sign with radar-actuated LEDs around the border

One radar-actuated LED speed limit sign was placed at the east community entrance along Iowa Highway 251 (West Main Street) in St. Charles, Iowa. The second was placed at the west community entrance on County Road (CR) D-47 in Rowley, Iowa. A sign that shows vehicle speed was also evaluated at the east entrance to Rowley along CR D-47.

Speeds decreased at both sites with the LED signs. Only a minor decrease occurred at the St. Charles site with a 0.4 mph decrease in mean speed and no change in 85th percentile speed. Decreases of about 10 percent in the fraction of vehicles traveling 5 or 10 mph over the posted speed limit resulted for that site with no statistically significant changes for vehicles traveling 15 or 20 mph over the posted speed limit.

The second LED sign, located in Rowley, had large decreases in mean and 85th percentile speeds (decreases of 6 and 7 mph, respectively). Large decreases were also noted for vehicles traveling over the speed limit as follows: 25 decrease in the fraction of vehicles traveling 5 mph over the posted speed limit, 40 percent for vehicles traveling 10 mph over, 53 percent for vehicles traveling 15 mph over, and 65 percent for vehicles traveling 20 or more mph over.

The speed display sign had similar large decreases with reductions of 8 and 9 mph in mean and 85th percentile speeds, respectively. The fraction of vehicles traveling 5 or more mph over the posted speed limit decreased by about 45 percent and the fraction of vehicles traveling 10 or more mph over decreased by 73 percent. A decrease of about 80 percent resulted in both the fraction of vehicles traveling 15 or more mph over the posted speed limit and 20 or more mph over.

Appropriateness

Dynamic speed signs are appropriate for rural main streets.

Cost

Dynamic speed signs cost from $2,000 to $11,000 per display.

Photo-Radar Reinforcement

Description

Photo-radar reinforcement uses radar to measure vehicle speeds passing a section of roadway and takes photographs of vehicles exceeding the speed limit. With vehicle photographs, license plate numbers can be used to issue citations to the vehicle owners. Some states require that citations be issued to drivers and treated as moving violations with points assessed against drivers' licenses.

This type of measure is similar to enforcement but does not require an officer to be there at all times. Portable units are also available to change where the reinforcement is needed.

Placement

Photo-radar reinforcement can be used in most situations using permanent or portable units. Portable units can be moved constantly to help keep drivers from slowing down in specific locations only.

Advantages

- Can be portable allowing for different roadways to be monitored daily
- Using turnkey contracting is a less expensive alternative than commissioned police officers (Ewing, 1999)
- Revenue generated from citations

Disadvantages

- Higher initial investment
- Not perceived positively by the public
- Fixed units do not typically reflect speed reductions downstream (Dixon et al., 2008)
- Not authorized in all states

Effectiveness

Because of the high expenses involved with photo-radar reinforcement, high-volume roads are the most effective locations for placement. San Jose, California implemented photo-radar reinforcement using a fixed camera on 20 local streets. Thirteen of the streets saw speeds fall during the peak hours (Ewing, 1999).

Appropriateness

Not all states allow for photo-radar enforcement.

Cost

Photo-radar reinforcement typically comes with a contracted turnkey option. This avoids the high initial cost by leasing the equipment and giving the provider a portion of the fine. The typical cost for this option was $4,000 per month for the lease of the equipment, $3,000 for program operation, and $20 per citation issued. In addition to these costs are the annual cost of a police officer to review and issue the citations (Ewing, 1999).

Purchase of photo-radar equipment can have an initial cost of $85,000. The benefits of both of these methods are the revenue that is generated from the citations (Ewing, 1999).

LEDs in Pavement Markings or Signs

Description

Linear strips of LEDs that have been coated in plastic have been used in pavement and on signs as dynamic road markings. A developer of these linear strips of LEDs is LEDline.

The LEDs use induction power connections that allow them to be used in a variety of ways. Figure 53 shows the LEDline in the pavement with the advisory speed limit for a curve.

Figure 53: Speed limit in pavement at night (Hutchins and Hutchins, 2009)

The LEDline is not limited to only dark conditions because it can be seen easily in daylight as well. Unlike the traffic-calming pavement marking that displays only SLOW or the speed limit, for example, the LEDs can behave like a vehicle-actuated sign, but in the pavement, which can draw more attention from drivers.

When using these LED markings in pavements, skid resistance is not an issue because the LED strips are typically about 1 inch wide, making them much narrower than a tire. Another benefit from these treatments is that the LEDs can melt snow, increasing their visibility in winter conditions, and, when embedded in the pavement, they will not be impacted by snowplows. This treatment, therefore, behaves like a pavement marking but accounts for some typical pavement marking disadvantages. These LED markings can be used in virtually any environmental condition (Hutchins and Hutchins 2009).

Another use for the LEDline product can be seen in Figure 54 on traffic signs or barriers.

Figure 54: LEDline on chevrons (Hutchins and Hutchins, 2009)

The LEDs could be able to draw attention to signs better or have a sequence to make drivers perceive that they are driving faster than they should be. Either could help drivers better detect the need to slow down earlier.

Placement

The LEDs would be placed in the same situations as other surface treatments. They could also be used in similar situations as vehicle-actuated signs.

Advantages

- Earlier detection of traffic calming/the need to slow down
- Can be seen in many adverse weather conditions and during daylight
- No impact to skid resistance

Disadvantages

- Use during the day should be further investigated to determine if additional surface treatments needed

Effectiveness

It is not known whether LEDs in the pavement or on signs have been used for traffic calming, but they have been used by the Texas DOT (TxDOT) on a dangerous rural bend with success in reducing crashes (Hutchins and Hutchins, 2009).

Appropriateness

LEDline is approved by the FHWA as a Raised Pavement Marker by meeting MUTCD section 3B, 11-14, so it can be used in most cases, but should be approved further.

Cost

Installation of the LEDs is fairly simple by saw-cutting a groove that houses the LED and an induction connection system. This eliminates having to hardwire the LEDline to a power line, reducing cost. The induction system also provides for lower operating cost and allows a long life span with 50,000+ hours (Hutchins and Hutchins, 2009).

Other Strategies

Traffic-calming strategies that do not fit into the other treatment categories are discussed in this chapter:

- Enforcement
- Transition zones
- Self-explaining roads
- Pace car program

Enforcement

Description
Enforcement is typically a police presence to monitor speeds and issue citations for violations (Figure 55).

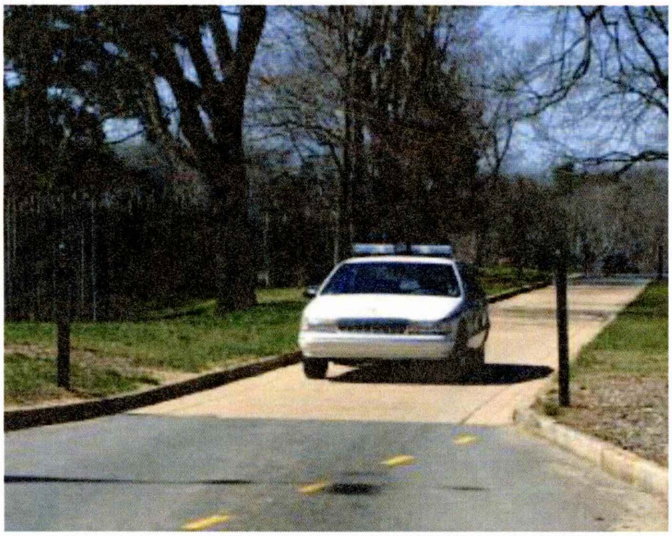

Figure 55: Use of enforcement to slow speeds (CWS, 2003)

Enforcement is used often with other traffic-calming devices to regulate behavior. Enforcement may also be used by itself to reduce speeds to the appropriate speed range.

Placement
Enforcement should occur in the area where reductions in speed are desired.

Advantages
- Effective in getting driver attention
- Does not affect vehicle operation
- Does not have an impact on emergency vehicles
- Does not have an impact on drainage
- Can be moved and targeted at different locations
- May include secondary benefits of reduced crime and increased sense of security (CWS 2003)

Disadvantages
- Expensive (one source indicated that additional revenue for tickets does not pay for officer work time)
- Requires a regular presence

Effectiveness
Enforcement is effective when used regularly.

Appropriateness

Police enforcement is already used to maintain speed limits in several small Iowa communities. Photo-enforcement can be used as well.

Cost

The cost depends on the amount of officer time used to monitor a location.

Transition Zones

Description

Transitional speed zones are used to allow drivers time to slow their speeds when traveling, typically between a rural and urban area. Transition zones involve having a distance to slow the vehicle from the rural speed limit, typically 55 mph or greater, to the urban speed limit, which can vary between 45 mph and 25 mph.

The problem in most communities is that they are not designed adequately. Some communities will have a transition zone either too short in length or a drastic drop in speed of 55 mph to 25 mph. Designing the speed transition correctly should allow for drivers to slow down more over a period of time.

Placement

The placement of a transition zone is typically a set distance before the start of the reduced speed limit for the urban area. Texas, for example, requires 0.2 miles to slow down for a 15 mph reduction. This means the transition area begins 0.2 miles before the urban speed limit starts. Maine has the same types of policies, but they require 0.3 miles (Hildebrand et al., 2004). Therefore, the placement of transition zones occurs typically when there are reductions of speeds greater than 10 mph going into an urban area.

Advantages

- Gives drivers more time to slow their vehicles

Disadvantages

- Increased amount of signs
- Must begin transition outside of the city, typically, which may require approval
- Possibility of speed dispersion

Effectiveness

The study by Hildebrand et al. in the *ITE Journal* (October 2004) concluded no significant reductions in speed from the transitional zone to the non-transitional zone. This also supported a reference the authors had to Thornton and Lyles that said there was no effect. The study also included whether any speed dispersion occurred because of the transitional zone and the results showed that no dispersion occurred. Therefore, the transitional zone had neither a positive or negative effect, which Hildebrand concluded could not justify their use by road authorities.

Appropriateness

The use of transitional zones may not slow down vehicles as much as needed, so they should be used in conjunction with other traffic-calming measures.

Cost

To extend the transition zone, additional signs may be needed for a smoother transition. The possible addition of sign will be the only cost.

Self-Explaining Roads

Description

The concept behind self-explaining roads is to design the road so that drivers have the feeling they should slow down or speed up by the design alone. The designer should be able to convey to drivers exactly what is expected of them solely by the design. The geometric roadway design can be used to convey the desired speed by manipulating the sharpness and banking of curves, the rate of grade, stopping sight distance, and intersection sight distance (Archer et al., 2008).

The idea of self-explaining roads is a developing concept and one of the current practices for self-explaining roads is to be consistent. If roads are consistently following the same design or expectations of drivers, they will be much easier to know how to drive, which in turn will make each road safer.

Self-explaining roads also incorporate many of the traffic-calming measures discussed in this toolbox, which can be integral and/or supplemental to the roadway design.

Placement

Self-explaining road concepts should be considered whenever designing a roadway. The designer should use themselves as a virtual user to design the road the way they want it driven (Campbell et al., 2008).

Advantages

- Road design conveys to the driver how they should be driving including speed and movements
- Safer because the user should not have to guess how fast or what they should be doing

Disadvantages

- High cost because of design

Effectiveness

A study by Kaptein in 2002 (SPACE, 2010) showed how self-explaining roads were effective. Pictures of roads were laid out and participants sorted the pictures into similar categories. What the researchers found was that drivers categorize roads into consistent groups based on expectations and that it will be safer to design roads in similar self-explaining ways. There isn't much evidence to show that self-explaining roads actually lower speeds, but there are many studies supporting the concept of self-explaining roads.

Appropriateness

Most roads that are being designed today should have a self-explaining design that does not confuse users with unexpected situations. Although it would be expensive to redesign all roads so that they are self-explaining, it may be appropriate to use other measures.

Cost

Redesigning and reconstructing roads are a major cost. If roads are being reconstructed, self-explaining roads should be considered into the design.

Pace Car Program

Description

The pace car program is a community effort to encourage safe driving. NCHRP Report 500 Volume 23 explains that citizens from a community commit to "drive within the speed limit, stop to let pedestrians cross, walk when they can, and do something to their car to make others smile, with the goal of calming drivers rather than streets." The program encourages drivers from the community to calm other drivers, such as those passing through town, by requiring that they obey the speed limit (TRB, 2009).

Placement

Pace car programs can be implemented in almost any town. However, most pace car programs have been implemented in urban cities, like Salt Lake City, Utah and Santa Cruz, California, but could be used in rural communities (TRB, 2009).

Advantages

- No cost to community
- Forces other motorists to obey speed limits

Disadvantages

- Ineffective without a large supporting community or when committed members are not driving
- Does not really help long term

Effectiveness

The pace car program has been shown to be effective in communities around the US, but the long-term effects should be studied in more depth.

Appropriateness

Any community that wants to implement a program like this should, because there are no negative safety issues. The program does require a commitment from a relatively large group.

Cost

There is not necessarily any cost for a volunteer pace car program.

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