Effective Application of Traffic Calming Techniques

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The Caltrans Division of Research and Innovation (DRI) receives and evaluates numerous research problem statements for funding every year. DRI conducts Preliminary Investigations on these problem statements to better scope and prioritize the proposed research in light of existing credible work on the topics nationally and internationally. Online and print sources for Preliminary Investigations include the National Cooperative Highway Research Program (NCHRP) and other Transportation Research Board (TRB) programs, the American Association of State Highway and Transportation Officials (AASHTO), the research and practices of other transportation agencies, and related academic and industry research. The views and conclusions in cited works, while generally peer reviewed or published by authoritative sources, may not be accepted without qualification by all experts in the field.

Executive Summary

Background

Traffic calming uses engineering and nonengineering techniques to reduce speeds and traffic volumes in residential and commercial areas. A 1999 report jointly published by the Institute of Transportation Engineers (ITE) and the Federal Highway Administration (FHWA)[1] defines traffic calming as follows:

> … traffic calming involves changes in street alignment, installation of barriers, and other physical measures to reduce traffic speeds and cut-through volumes in the interest of street safety, livability, and other public purposes.

Caltrans does not have design guidance to assist in the selection and design of the most effective traffic calming techniques for various facility types, land use and speed limits. Without guidance, planners and designers cannot efficiently select the most effective traffic calming techniques.

This Preliminary Investigation aims to synthesize federal and state design guidance on traffic calming, the potential for success of various traffic calming measures given the current body of research, and the experience of other states in addressing the legal and policy matters associated with implementing traffic calming techniques. The scope of this Preliminary Investigation is limited to engineering-related measures implemented in the United States.

Summary of Findings

We gathered information in seven topic areas related to the application of traffic calming techniques:

- Background.
- National Guidance.
- State DOT Manuals and Other State Guidance.
- Related Research.
- Legal Issues.

[1] Traffic Calming: State of the Practice, Institute of Transportation Engineers, Federal Highway Administration, August 1999: 3.

- Web Resources.
- Research in Progress.

Following is a summary of findings by topic area.

Background

- The publications cited in this Preliminary Investigation include references to an expansive list of devices and terminology specific to traffic calming. To set the stage for the citations that follow, we provide a brief description of the commonly used engineering-based traffic calming measures in three categories:
    - *Vertical measures*, which use forces of acceleration to discourage speeding. Examples include speed humps, speed bumps, speed lumps, speed tables, speed cushions and textured pavements.
    - *Horizontal measures*, which force drivers to reduce speeds by impeding straight-through movements. Examples include traffic circles, roundabouts, and chicanes or serpentine streets.
    - *Road narrowing*, which elicits a psychological sense of enclosure to discourage speed. Examples include center island narrowing, chokers and curb extensions.

National Guidance

- Two 2009 publications provide the most recent and comprehensive national guidance on traffic calming:
    - ITE's Traffic Engineering Handbook includes a chapter on traffic calming that focuses on physical measures for volume and speed control. Included are the speed effects of traffic calming measures, application guidelines, descriptions of typical designs and emerging trends.
    - With a focus on engineering measures, the American Planning Association's U.S. Traffic Calming Manual attempts to standardize the process used to select and implement traffic calming.
- A 2007 ITE publication provides guidelines for the design and application of speed humps.
- Traffic calming measures are considered in a 2004 AASHTO publication offering guidance on flexible highway design. The guide recommends caution and notes that "traffic-calming measures are still experimental in the United States."
- Two NCHRP reports provide guidance in implementing traffic calming measures.
- A 1999 report published by ITE and FHWA takes a comprehensive look at traffic calming in the United States and Canada. Appendices address the effectiveness of traffic calming measures and provide before and after data.

State DOT Manuals and Other State Guidance

In this section we highlight manuals and other publications prepared for state DOTs in 14 states—California, Delaware, Indiana, Maine, Massachusetts, Minnesota, New Jersey, New York, Oregon, Pennsylvania, South Carolina, Vermont, Virginia and Washington. Highlights of this guidance include:

- Delaware DOT's Traffic Calming Design Manual is the first traffic calming manual taken through a formal rule-making process and adopted by a state DOT. The manual served as the basis for the 2009 publication U.S. Traffic Calming Manual. With more than 88 percent of all

streets and highways in Delaware under state jurisdiction, the manual's guidance has broad application.

- Pennsylvania DOT's Traffic Calming Handbook is a comprehensive examination of traffic calming. In addition to summarizing the effects of traffic calming measures, the handbook also addresses the study and approval process that precedes selection and implementation of traffic calming treatments.
- Traffic calming guidelines developed by South Carolina DOT serve the needs of local governments wishing to apply traffic calming measures. Eligibility criteria for residential and commercial areas include a maximum speed limit of 30 mph, and traffic volumes of less than 4,000 annual average daily traffic (AADT) for residential areas and 6,000 AADT in commercial zones.
- The Vermont Agency of Transportation published its Traffic Calming Study and Approval Process for State Highways in 2003. Companion documents include standard drawings and a traffic calming matrix that shows the applicability of traffic calming devices for specific highway settings and traffic volumes.
- A guide developed by Virginia DOT provides communities with a traffic management tool to deal with speeding on local streets; some collector streets may also qualify for traffic calming measures.

Related Research

We examined domestic research related to traffic calming in the following areas:

- **Engineering-based traffic calming measures.**
    - **Horizontal treatments.** NCHRP reports published in 2007 and 2010 provide detailed guidance on the planning, design and construction of one of the more common horizontal treatments—roundabouts. The 2007 report provides before and after data on the safety effects of roundabout conversions.
    - **Vertical treatments.** Research is relatively plentiful on this class of treatments that includes speed humps, speed cushions, speed tables and a newer variation—the speed lump. The reports and articles we cite examine the devices' effects on speed, appropriate application and ways to limit impacts to emergency response vehicles.
    - **Road narrowing/road diets.** A 2005 Oregon DOT study examines the effect of curb extensions on pedestrian safety. The road diet, which typically involves converting a road from four lanes to three lanes, with one through lane in each direction and a two-way continuous left-turn lane, is explored in a 2009 handbook and reports describing the effects of road diet conversions in Minnesota and Iowa.
    - **Rural/urban transition.** Speed transition areas near the urbanized limits of small towns are prime candidates for the application of traffic calming measures. Reports from Oregon and Iowa DOTs provide recommendations for the use of transition treatments and assess their effectiveness.
- **Accident modification or crash reduction factors.** These factors provide a simple way of estimating crash reductions. Two 2008 publications provide factors for the installation of roundabouts and raised medians.
- **General design and policy issues.** The journal articles and reports included in this section take a broader view of traffic calming, addressing design issues associated with a range of treatments and underscoring the importance of developing a clear policy with defined goals.

- **Case studies.** These publications explore the lessons learned from traffic calming programs that apply traffic calming techniques to arterial roadways (Calabasas, CA, and Amherst, MA); improve safety on low-volume local roads (Iowa); require new subdivisions to include approved traffic calming devices (Gwinnett County, GA); recommend designing smaller and narrower highways (Trenton, NJ); and use less aggressive physical traffic calming interventions (Brooklyn, NY).

Legal Issues

- An April 2011 conference presentation addresses the liability concerns of engineers and public entities associated with the implementation of traffic calming measures. Directed to New Jersey agencies and practitioners, this presentation provides information that might also be helpful to Caltrans, including a series of publications that provide standards for traffic calming treatments.
- A 2009 American Planning Association manual states that "there is now more litigation for failure to calm traffic than for calming traffic and thereby somehow contributing to accidents."
- Most of the 21 agencies surveyed for a 2005 journal article reported either no litigation or none in recent years, with only three lawsuits reported by the surveyed agencies since 1997.
- The most focused analysis of legal issues comes from two less recent publications:
    - PennDOT's Traffic Calming Handbook includes a chapter devoted to legal issues. The discussion begins with the observation that few local traffic calming programs have encountered liability issues, and the manual goes on to provide recommendations to minimize liability.
    - A chapter in an often-cited 1999 joint publication of ITE and FHWA presents a discussion of legal authority and liability. A survey of almost 50 cities and counties with active traffic calming programs is used to assess the state of the practice at the time of publication.

Web Resources

- ITE maintains an online Traffic Calming Library in the form of a searchable database of reports, articles and other documents related to traffic calming. Instructional materials are also available.
- The Victoria Transport Policy Institute's TDM Encyclopedia describes the benefits and challenges of traffic calming practices and provides links to research studies and other resources.
- Minnesota's Local Road Research Board maintains an online database of traffic calming projects implemented in Minnesota as well as research findings from studies funded by the board.

Research in Progress

- Projects in process are developing guidance for traffic calming in small communities and assessing the effectiveness of various traffic calming measures.

Gaps in Findings

Traffic calming as a practice has matured over the last decade, evidenced by the volume of research and national and state guidance published on the topic. Even with a fairly significant body of research to examine, broad generalizations do not appear to be appropriate to identify the best or most effective treatments given the variety of conditions that impact the application of specific treatments. Recommendations tend to come in the form of tables or matrices that allow the user to select a treatment based on specific site conditions.

Much of the guidance we located, including manuals prepared for state DOTs, addresses the needs of local, not state, agencies. Some of the state DOT guidance is a bit dated, with several publications dating back to the late 1990s and early 2000s. It is not known if agencies are considering updates to these less recent publications.

Vermont Agency of Transportation publications refer to the availability of standard drawings that include construction details, typical dimensions, signage and markings for various traffic calming devices. These drawings are not publicly available.

Recent publications take a more general approach to an examination of liability issues associated with traffic calming, and we found little guidance related to immunity for practitioners applying nonstandard engineering designs.

Next Steps

Caltrans might consider the following in its evaluation of engineering-based traffic calming measures:

- Reviewing two 2009 publications—ITE's Traffic Engineering Handbook and the American Planning Association's U.S. Traffic Calming Manual—to gather in-depth information about developing and implementing a traffic calming program.
- Comparing the recommendations reflected in state guidance and related research to identify commonalities among the criteria for applying traffic calming treatments.
- Following up with the state DOTs that have developed detailed guidance for traffic calming, including:
    - Delaware DOT, an early adopter of traffic calming measures, which published its traffic calming design manual in 2000.
    - Massachusetts DOT, which published the Project Development & Design Guide that addresses basic design controls and traffic calming.
    - New Jersey DOT, one of the first locations where traffic calming was implemented in the United States.
    - Pennsylvania DOT, which published its Traffic Calming Handbook in 2001 and collaborated with New Jersey DOT on the 2008 publication Smart Transportation Guidebook.

Background

The publications cited in this report include references to an expansive list of devices and terminology specific to traffic calming. To set the stage for the citations that follow, we begin this Preliminary Investigation with brief descriptions of common traffic calming measures taken from a 2008 University of California Transportation Center (UCTC) literature review[2] that gathered information about the effects of corridor design features.

The table below presents traffic calming treatments in three categories of interest to this Preliminary Investigation:

[2] The Effects of Transportation Corridors' Roadside Design Features on User Behavior and Safety, and Their Contributions to Health, Environmental Quality, and Community Economic Vitality: A Literature Review, University of California Transportation Center, UCTC Research Paper No. 878, 2008: 49.

- Vertical measures that use forces of acceleration to discourage speeding.
- Horizontal measures that force drivers to reduce speeds by impeding straight-through movements.
- Road narrowing that elicits a psychological sense of enclosure to discourage speed.

Traffic Calming Techniques	
Vertical Measures	
Treatment	**Definition**
Speed hump	Rounded, raised areas placed across the roadway to slow speed. Recommended length of 12 to 14 feet in the direction of travel, with a 3- to 4-inch height. Shape can be parabolic, sinusoidal or circular. ITE recommends a 12-foot parabolic hump to achieve an 85th percentile speed of 15 mph to 20 mph.
Speed bump	Smaller versions of the speed hump, ranging from 1 to 3 feet long and 3 to 6 inches tall. Used mostly in parking lots and private roadways, where speeds should be very low.
Speed table	Modified speed hump with a flat top that allows the wheelbase of a passenger car to rest on top. Provides a gentler slope than speed humps, but less reduction in speed can be expected.
Speed cushion	Several small speed humps installed across the width of the road with spaces between them. Installed in a series across a roadway resembling a split speed hump, speed cushions are designed to force cars to slow down as they ride with one or both wheels on the humps. Emergency vehicles with wider axles are able to straddle the cushions without affecting their speed.
Textured pavements	The use of brick and other special pavers to alert drivers about pedestrian territory by altering the feel of the road.

Traffic Calming Techniques	
Horizontal Measures	
Treatment	**Definition**
Traffic circle	Raised island in the middle of an intersection around which traffic circulates. Meant to prevent driver speeding by making it difficult to pass straight through intersections. The minimum diameter should be 24 feet; 26 to 33 feet is preferred. A truck apron can be added to facilitate movement through the intersection by larger vehicles. Often used with lower-speed roads (less than or equal to 35 mph) with lower volumes of traffic (300 to 3,000 ADT).

Roundabout	Much larger version of a traffic circle that provides yield control to all entering vehicles and channelized approaches to support a higher ADT (more than 20,000 in some cases). Generally designed to encourage travel speeds to be less than 30 mph but can have two travel lanes. Diameters range from 45 to 200 feet, depending on the number of lanes, speed and ADT.
Chicane	Curb extensions that create an S-shaped curve on a street. Not always considered effective, as a driver can maintain speed and drive down the centerline if there is no oncoming traffic. Another option is to alternate on-street parking from one side of the street to the other.
Road Narrowing	
Treatment	**Definition**
Center island narrowing	Raised island along the centerline of a street that narrows the travel lanes at that location. Often used on curves where speeding is common or downstream of intersections. The island can act as a pedestrian refuge.
Choker	A narrowed roadway formed by extending the curb on both sides of the street. The curb extensions can be placed parallel to one another or at an angle.

Other traffic calming measures addressed in this Preliminary Investigation include:

- **Curb extension.** Also known as a bulbout or neckdown, this treatment extends the sidewalk or curb line into the parking lane, thereby reducing the effective street width.
- **Road diet.** This measure typically involves converting a road from four lanes to three lanes, with one through lane in each direction and a two-way continuous left-turn lane.
- **Serpentine street.** This treatment uses a winding pattern with built-in visual enhancements that allow movement but not fast driving.
- **Speed lump.** This relatively new treatment consists of two or more raised and rounded areas placed laterally across a roadway with precisely spaced gaps, which allows the wheel tracks of emergency vehicles to pass between the lumps.
- **Woonerf.** A Dutch word that translates as "living street," this measure is typically a narrow residential street without curbs or sidewalks.

National Guidance

Below we highlight recent publications by national associations that provide practitioners with the current thinking on planning, designing and implementing traffic calming measures. A 1999 ITE/FHWA publication provides a historical perspective.

Traffic Engineering Handbook, 6th Edition, Institute of Transportation Engineers, 2009.
Publisher's description available at
http://www.ite.org/emodules/scriptcontent/orders/ProductDetail.cfm?pc=TB-010B; see Chapter 15, Traffic Calming, which begins on page 531 of the manual.
Chapter 15 of the handbook presents a toolbox of traffic control measures from which a practitioner may choose the most appropriate treatment capable of cost-effectively solving a traffic problem. The manual focuses on physical measures for volume and speed control, including:

- **Volume control measures.** Full street closures, half closures, diagonal diverters, median barriers and forced-turn islands.
- **Speed control with vertical measures.** Speed humps, lumps and tables; raised crosswalks; and raised intersections.
- **Speed control with horizontal measures.** Mini traffic circles, roundabouts, lateral shifts, chicanes and realigned intersections.
- **Speed control with narrowings.** Neckdowns or bulbouts, chokers and center island narrowings.

Other highlights include:

- Table 15-3, Speed Effects of Traffic Calming Measures (page 554).
- Application guidelines (pages 556 and 557).
- Current design practice, with descriptions of typical designs (begins on page 558).
- Signing and marking (page 569).
- Emerging trends (page 573), including incorporating traffic calming into the initial design and new analysis tools.

U.S. Traffic Calming Manual, American Planning Association, ASCE Press, 2009.
Publisher's description available at http://www.planning.org/media/trafficcalming/
The manual's purpose is to standardize the initiation, planning, design and implementation of traffic calming measures. The authors focus on four areas: process, toolbox, design, and signing and marking.

Described as the first complete how-to manual developed in the country, this publication is based on the first traffic calming manual taken through a formal rule-making process and adopted by a state DOT (Delaware DOT) as a supplement to its standard design manual.

Note: The authors note that the Delaware DOT manual applies to all streets and highways under state jurisdiction (an estimated 88 percent of all streets and highways in Delaware). See page 10 of this Preliminary Investigation for more information about the Delaware DOT manual.

The manual focuses on engineering measures, with the authors observing that nonengineering measures such as planting trees on a roadside, more intensively enforcing traffic laws or sponsoring neighborhood traffic-safety campaigns cannot be counted on to slow or divert traffic. Generally, state DOTs do not install traffic calming measures, focusing instead on promoting traffic calming through technical assistance. Exceptions to this rule are states such as South Carolina and Virginia, where the state owns and operates local and collector roads.
The manual concludes with an examination of lessons to be learned from traffic calming practices in Europe. Appendices provide an overview of leading local traffic calming programs, the politics of traffic calming, a case study of arterial traffic calming, a discussion of speed lumps, skinny street standards, emergency response tests and traffic diversion.

A Guide for Reducing Speeding-Related Crashes, *NCHRP Report 500,* Vol. 23, 2009.
http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_500v23.pdf
See page V-83 of the report (page 112 of the PDF) for a discussion of reducing speed or volumes on low-speed neighborhood and downtown streets with the use of traffic calming and related countermeasures. For a more detailed discussion of traffic calming measures used to reduce speeds, see the citation below for Volume 10 of *NCHRP Report 500*.

Related Resource:

A Guide for Reducing Collisions Involving Pedestrians, *NCHRP Report 500*, Vol.10, 2004.
http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_500v10.pdf
Page V-48 of the report (page 77 of the PDF) begins a discussion of reducing vehicle speed with the use of roadway or engineering measures. Road narrowing measures (see page 77 of the PDF) include:

- Reducing lane widths to 10 or 11 feet; excess pavement can be striped for use as a bicycle lane or shoulder.
- Removing through travel lanes or converting them into medians or bike lanes.
- Narrowing the street by extending sidewalks and landscaped areas and/or by adding on-street parking within the former curb lines.

Roadway treatments (see page 84 of the PDF) include traffic calming measures that can be used on midblock segments of local streets and some low-volume collector streets or commercial-area streets. Examples include a serpentine street; chicane; choker; speed hump or speed table; and Woonerf.

Intersection treatments (see page 87 of the PDF) include curb radius reduction; minicircle; curb extension; raised intersection; and roundabout.

Guidelines for the Design and Application of Speed Humps, Institute of Transportation Engineers, August 2007.
Citation at http://trid.trb.org/view/2007/M/836753
This updated recommended practice provides guidelines for the design and application of speed humps. The publication's seven chapters include considerations for speed humps use, community relations and administrative procedures, design guidelines, construction and maintenance guidelines, monitoring and evaluation, and other key considerations.

Related Resource:

"Updated Guidelines for the Design and Application of Speed Humps," Margaret Parkhill, Rudolph Sooklall, Geni Bahar, *2007 ITE Annual Meeting and Exhibit Compendium of Technical Papers*, 2007.
http://www.ite.org/traffic/documents/AB07H1101.pdf
This conference paper described the activities undertaken to produce ITE's updated guidelines for speed humps and speed tables. Included are a recommended framework for agencies wishing to implement speed humps or speed tables, and the following installation guidance:

- These traffic calming measures are typically installed on roadways functionally classified as local streets and neighborhood or residential collector streets as defined in AASHTO's Green Book.
- The surrounding land use for streets where speed humps are applied is generally residential in nature and may include schools, parks or community centers.
- Speed humps are not recommended on streets with more than two travel lanes. In addition, the pavement should have good surface and drainage qualities.
- Speed humps are generally not recommended for use on bus routes or emergency vehicle routes; speed tables may be more appropriate.

A Guide for Achieving Flexibility in Highway Design, 1st Edition, American Association of State Highway Transportation Officials, May 2004.
Publisher's description available at https://bookstore.transportation.org/Item_details.aspx?id=103
Section 3.11, Traffic Calming, which begins on page 87, addresses the application of traffic calming measures, advising designers to consider the effects of route diversion. The guide recommends caution and notes that "traffic-calming measures are still experimental in the United States."

Traffic Calming: State of the Practice, Institute of Transportation Engineers, FHWA, August 1999.
Chapters of the report available for download at http://www.ite.org/traffic/tcstate.asp
This report contains a synthesis of traffic calming experiences to date in the United States and Canada. It includes information about traffic calming in residential areas and in areas where high-speed rural highways transition into rural communities. The report contains background information about legal authority and liability, emergency response and other agency concerns, and a discussion of traffic calming impacts. Appendices consider the effectiveness of traffic calming measures and provide before and after data.

State DOT Manuals and Other State Guidance

Below we highlight manuals and other publications prepared for state DOTs in 14 states—California, Delaware, Indiana, Maine, Massachusetts, Minnesota, New Jersey, New York, Oregon, Pennsylvania, South Carolina, Vermont, Virginia and Washington—that provide guidance in selecting and implementing traffic calming measures.

California

Main Streets: Flexibility in Design & Operations, Caltrans, January 2005.
http://ntl.bts.gov/lib/24000/24000/24003/main-streets-flexibility-in-design.pdf
This booklet examines the use of traffic calming measures appropriate for use on local main streets that are also state highways. The measures outlined in the handbook, which "may be used to enhance established traffic engineering and design practices, policies and standards," include lane reductions, transverse rumble strips, roundabouts and raised median islands.

Delaware

Traffic Calming Design Manual, *Delaware Register of Regulations*, Vol. 4, No. 3, September 1, 2000.
http://www.deldot.gov/information/pubs_forms/manuals/traffic_calming/pdf/deldotfinal.pdf
This manual served as the basis for the 2009 publication U.S. Traffic Calming Manual (page 8 of this Preliminary Investigation). The manual augments, not supersedes, Delaware DOT's Road Design Manual by providing alternative means to address speeding and cut-through problems. The opening chapters provide procedures for selecting traffic calming measures and specify which measures are acceptable in given applications. (See the table on page 21 of the PDF.)

Chapter 4, Geometric Design of Traffic Calming Measures, which begins on page 22 of the PDF, provides guidance on the geometric design of traffic calming measures selected. This chapter presents a typical geometric design for each type of traffic calming measure described previously in the manual and in most cases specifies the range of acceptable design alternatives. The treatments for which guidance is provided include:

- Volume control measures (full and half closures, diagonal diverters, median barriers and forced turn islands).
- Vertical speed control measures (speed humps, speed tables, raised crosswalks and raised intersections).

- Horizontal speed control measures (mini traffic circles, roundabouts, chicanes and lateral shifts).
- Narrowings (neckdowns, chokers and center island narrowings).

The manual includes speed estimates for many of these measures and guidance on signage and markings. The last page of the PDF describes the process of manual preparation.

Indiana

Traffic Calming Plan & Policies, Managing Transportation and Infrastructure, I-69 Planning Toolbox, Indiana Department of Transportation, 2007.
http://www.in.gov/indot/div/projects/i69planningtoolbox/_pdf/Traffic%20Calming%20Plan%20and%20Policies.pdf
Indiana DOT designed the I-69 Community Planning Program toolbox to meet a variety of needs and circumstances that exist along the I-69 highway corridor between Indianapolis and Evansville, IN. Included in the toolbox of approximately 60 tools is this traffic calming plan and policies document. Page 1 of the document offers this about the application of traffic calming devices:

> Traffic calming devices are not appropriate for all locations. Their use should be limited to low volume local roadways, typically with daily traffic volumes less than 2,500 vehicles per day. The use of traffic calming devices should be limited to two-lane roadways. As with most traffic control devices, they should not be used unless a need is clearly indicated, usually where speeds typically exceed 35 miles per hour or where there is a significant history of accidents.

Maine

Appendix 15-B, Traffic Calming Policy, Chapter 15, Flexible Design Practices, Highway Design Guide, Maine Department of Transportation, March 2006.
http://www.maine.gov/mdot/technicalpubs/documents/pdf/hwydg/vol1/chpt15.pdf
The table on page 23 of this PDF specifies treatments by federal functional classification.

Massachusetts

Traffic and Safety Engineering 25% Design Submission Guidelines, Highway Division, Massachusetts Department of Transportation, February 15, 2011.
http://www.mhd.state.ma.us/downloads/trafficMgmt/FunctionalDesignReportGuidelines.pdf
Used in conjunction with MassDOT's Project Development & Design Guide, these guidelines provide information related to the traffic and safety engineering elements of a project. From page 6 of the PDF:

> *Traffic Calming* – If a project is submitted to MassDOT for review that includes any form of traffic calming, it should follow the "Traffic Calming Guidelines" as developed by the New England Section of the ITE on behalf of MassHighway. Traffic Calming is primarily intended for functionally classified local roads.

Related Resources:

> **Traffic Calming Guidelines**, Highway Division, Massachusetts Department of Transportation, November 2000.
> http://www.neite.org/committees/tech/trafcalm.pdf
> Projects submitted to MassDOT for review that include any form of traffic calming follow these guidelines. The tables on pages 15 through 17 of the PDF summarize the applicability of traffic calming devices by roadway classification (arterial, collector and local) for use in reducing speed, volume and truck traffic.

Project Development & Design Guide, Highway Division, Massachusetts Department of Transportation, January 2006.
http://www.vhb.com/mhdGuide/mhd_GuideBook.asp
This web page provides links to all chapters of the guide. See below for portions of the manual relating to traffic calming.

Chapter 3, Basic Design Controls, Project Development & Design Guide, Highway Division, Massachusetts Department of Transportation, January 2006.
http://www.mhd.state.ma.us/downloads/designGuide/CH_3_a.pdf
See page 37 of the PDF for 3.6.6, Design Speed and Traffic Calming, which recommends that "traffic calming elements should not result in operating speeds substantially lower than the target speed at certain points along the corridor and higher speeds elsewhere."

Chapter 16, Traffic Calming and Traffic Management, Project Development & Design Guide, Highway Division, Massachusetts Department of Transportation, January 2006.
http://www.mhd.state.ma.us/downloads/designGuide/CH_16.pdf
The guide describes traffic calming as "physical road design elements intended to reduce vehicle speeds and improve driver attentiveness." This chapter addresses three major categories of traffic calming design measures:

- Narrowing the real or apparent width of the street with raised curbs; spot narrowing of pavement; medians and crossing islands; and allocation of pavement width and road diets.
- Deflecting, or introducing curvature to, the vehicle path with chicanes and lane offsets; short medians/crossing islands; midblock traffic circles; lane offsets at intersections; crossing islands; curb extensions; roundabouts; and mini traffic circles.
- Altering the vertical profile of the vehicle path with speed humps; speed cushions; raised crosswalks; raised intersections; textured pavement; and rumble strips.

See page 6 of the PDF for Exhibit 16-2, Traffic Calming and Traffic Management Applicability by Roadway Type.

Minnesota

Chapter 4, On-Road Bikeways, Mn/DOT Bikeway Facility Design Manual, Minnesota Department of Transportation, March 2007.
http://www.dot.state.mn.us/bike/pdfs/manual/Chapter4.pdf
See page 119 of the manual (page 57 of the PDF) for 4-6.6, Traffic-Calmed Roadways. The manual notes that traffic-calmed roadways are often used as routes in bicycle and pedestrian networks. General design guidelines to accommodate bicycles on roadways with traffic calming follow:

- Provide bicyclists with alternative paths (minimum width of 4 feet) around physical obstacles such as ramps and through barriers such as cul-de-sacs.
- Where roads are narrowed as a speed control measure, consider how bicyclists and motorists can share the remaining space.
- Ensure surface materials have good skid resistance. Textured areas should not be so rough as to create instability for bicyclists.
- Provide smooth transitions on entry and exit slopes adjacent to raised surfaces, with clear indication and transition gradients of no more than 6:1.
- Consider overall gradients, noting that bicyclists are likely to approach grade changes at different speeds uphill and downhill.

- Combine appropriate signing with public awareness campaigns to remind drivers about traffic-calmed areas.

New Jersey

Roadway Design Manual, New Jersey Department of Transportation, last document correction: August 17, 2011.
http://www.state.nj.us/transportation/eng/documents/RDM/
The foreword to this manual notes that generally, New Jersey DOT will not consider traffic calming measures for roadways where the posted speed limit is above 35 mph. Designers are advised to "carefully weigh whether the use of these elements creates a desirable balance between the competing interests."

Chapter 3, Guidelines for Encouraging Pedestrian Travel, Pedestrian Compatible Planning and Design Guidelines, New Jersey Department of Transportation, 1996.
http://www.state.nj.us/transportation/publicat/PEDESTRI/CHAPTER3.PDF
These guidelines include three general observations culled from successful traffic calming implementations:

- Where consistently low speeds—less than 20 mph—are required, physical traffic calming features should be positioned sufficiently closely together to deter unnecessary acceleration and braking.
- The use of appropriate signing is important to remind drivers that they are entering a traffic restraint area; public awareness campaigns facilitate the acceptance of lower speeds.
- Sympathetic speed limits, such as 20 mph in residential areas, are used to reinforce the physical speed control measures.

Descriptions and design considerations are included for a range of traffic calming measures, including road humps and speed tables; traffic throttles/chokers or neckdowns; roundabouts or traffic circles; raised intersections; plug "no-entry" (with bicycle slip); irregular or textured surfaces; tortuous roads; and woonerf or shared surfaces.

Speed Hump Law, New Jersey Department of Transportation, undated.
http://www.state.nj.us/transportation/eng/documents/speedhumps/
This web page presents the text of a law adopted by the New Jersey Legislature with regard to speed humps. This law applies only to municipal roads. New Jersey DOT has adopted the engineering practices recommended for speed humps by ITE as the applicable design standard and practice for speed humps on municipal roads. See page 9 of this Preliminary Investigation for the citation for ITE publication Guidelines for the Design and Application of Speed Humps.

New Jersey/Pennsylvania

Smart Transportation Guidebook: Planning and Designing Highways and Streets that Support Sustainable and Livable Communities, New Jersey Department of Transportation, Pennsylvania Department of Transportation, March 2008.
http://www.state.nj.us/transportation/community/mobility/pdf/smarttransportationguidebook2008.pdf
This guidebook applies to rural, suburban and urban areas. Chapter 9, Road System Issues, includes a section on traffic calming (see page 81 of the PDF). A table on page 84 of the PDF provides a list of traffic calming measures and the roadway classifications for which each is appropriate (regional or community arterial, community or neighborhood collector, or local street). Treatments include cross section measures such as lane reduction, bulbouts and medians, and street trees. Periodic measures include horizontal and vertical treatments and road narrowing.

New York

Chapter 25, Traffic Calming, Highway Design Manual, New York State Department of Transportation, Revision 36, February 5, 1999.
https://www.nysdot.gov/divisions/engineering/design/dqab/hdm/hdm-repository/chapt_25.pdf
Included in this guidance to assist New York State DOT regions in implementing traffic calming measures are "test questions" to help determine if traffic calming is viable; a discussion of the applicability of traffic calming techniques and descriptions of the speed categories established specifically for traffic calming measures; and an outline of the of community involvement process.

Oregon

Traffic Manual, 2009 Edition, With Revisions 1 and 2 Incorporated, Oregon Department of Transportation, September 2010.
http://www.oregon.gov/ODOT/HWY/TRAFFIC-ROADWAY/docs/pdf/Traffic_Manual_09.pdf?ga=t
A discussion of traffic calming begins on page 57 of the PDF. Highlights include:

- Traffic calming for neighborhood streets may include speed bumps, speed humps and traffic circles. While these may be effective in reducing speeds, they create additional neighborhood noise, driver discomfort and hardships for emergency response.
- Traffic calming treatments should not be designed to physically restrict motorists to slower speeds, in effect establishing an illegal speed limit and posing a hazard to the motoring public.
- Traffic calming on state highways, primarily arterial streets, involves changes to the roadway environment to cue drivers to the mixed-use environment. These changes include such traffic calming treatments as pedestrian islands, curb bulbouts, wide sidewalks and streetscaping.
- Roundabouts, used in the right places, are another strategy for improving driver behavior on arterial streets.
- Strategies such as narrowing lanes and adding on-street parking may result in lower speeds, but often increase safety concerns.

Pennsylvania

Pennsylvania's Traffic Calming Handbook, Pennsylvania Department of Transportation, Publication No. 383, January 2001.
ftp://ftp.dot.state.pa.us/public/pdf/TrafficCalming/TrafficcalmingHandbook2001.pdf
The handbook's introduction provides a concise description of its contents:

> This Handbook contains information on various traffic calming issues such as legal authority, liability, funding, impacts on emergency services, as well as many others. Chapter 4 includes a "Traffic Calming Study and Approval Process" which is critical for the development of a well organized traffic calming program. Finally, the effects of specific traffic calming measures are discussed.

Readers are advised to use this handbook in conjunction with the ITE publication Traffic Calming: State of the Practice. See page 10 of this Preliminary Investigation for the citation for this publication.

Other highlights of the handbook include:

- Page 28 of the PDF provides a list of commonly used traffic calming measures that are discussed in the handbook. The figure that follows describes the effects of each traffic calming measure (volume, speed or conflict reduction, and emergency response).

- Page 30 of the PDF begins an examination of each traffic calming measure, including a description, appropriate location, typical uses, expected speed/volume reductions, approximate cost, signings and markings, other considerations, and advantages and disadvantages.
- Appendix A (which begins on page 70 of the PDF) includes discussions of funding, community approval and gathering traffic data.

South Carolina

Traffic Calming Guidelines, South Carolina Department of Transportation, 2006.
http://www.scdot.org/doing/pdfs/SCDOT_TCG_06.pdf
The introduction to this manual indicates that the majority of roads in South Carolina's state highway system are secondary routes classified as minor collectors or local streets, and many of these roadways serve residential properties. South Carolina DOT developed this publication to address the needs of local governments in responding to requests to address cut-through and speeding traffic within neighborhoods.

Eligibility criteria are provided for residential areas and a central business district. Speed limits cannot exceed 30 mph, and traffic volumes are specified (between 4,000 and 6,000 AADT). The manual includes this with regard to establishing eligibility:

> The SCDOT has patterned its policy after successful programs in other states, particularly Virginia and Delaware. Each of these programs based installation eligibility on volume, characteristics of the area, grades, sight distance, and neighborhood acceptance. For example, there are high volume roadways, classified as either major collectors or minor or major arterials, where traffic calming could potentially reduce roadway capacity to an undesirable level. These roadways are ineligible for any physical traffic calming measures, and enforcement, education, and engineering studies are the best methods to address speeding issues.

Appendix A, which begins on page 11 of the PDF, provides detailed information about the application of traffic calming measures, including eligibility requirements, construction details and markings. Not-to-scale drawings are included for some measures.

Vermont

Traffic Calming Study and Approval Process for State Highways, Vermont Agency of Transportation, September 2003.
http://www.aot.state.vt.us/planning/Documents/Planning/TrafficCalming.pdf
Drafted to provide information about the process for planning, evaluating and implementing traffic calming projects on state highways in Vermont, this document is a companion to VTrans' Traffic Calming Standard Drawings. These standards include construction details, typical dimensions, signage and markings for various traffic calming devices. The Traffic Calming Matrix shows the applicability of each device for specific highway settings and traffic volumes. The drawings and matrix do not appear to be publicly available.

Virginia

Traffic Calming Guide for Local Residential Streets, Traffic Engineering Division, Virginia Department of Transportation, July 2008.
http://www.virginiadot.org/business/resources/TrafficCalmingGuideOct2002.pdf
This guide provides communities with a traffic management tool dealing specifically with speeding, with a focus on subdivision streets classified as local streets. Certain collector streets that have many of the characteristics of local residential streets may also qualify for traffic calming measures.

Counties initiate the process to implement traffic calming measures, with Virginia DOT staff providing technical support. Physical traffic calming measures are appropriate for traffic volumes of 600 to 4,000 vehicles per day. Alternative actions should be considered when traffic volumes exceed 4,000 vehicles per day. The guide advises designers to address potential traffic calming concerns in new developments with changes in roadway design geometry, including narrowing roadway width.

The guide lists the following measures as effective in slowing traffic in neighborhoods: speed hump, choker, raised crosswalk, mini roundabout, crosswalk refuge, raised median island and chicane. To ensure minimum delay in emergency response time, the installation of speed humps and raised crosswalks is discouraged on major emergency routes.

An appendix provides guidance for implementation, addressing design and installation with a checklist and drawings of the traffic calming treatments noted above.

Related Resource:

> **Evaluation of the Virginia Department of Transportation's Residential Traffic Calming Guide**, Virginia Department of Transportation, Report No. VTRC 02-R15, May 2002.
> http://www.virginiadot.org/vtrc/main/online_reports/pdf/02-r15.pdf
> This report documents the activities of the two-year pilot implementation (January 1998 to December 1999) of Virginia DOT's traffic calming guide. See the citation above for the current version of the guide.

Washington

Pedestrian Facilities Guidebook: Incorporating Pedestrians Into Washington's Transportation System, Washington State Department of Transportation, Puget Sound Regional Council, County Road Administration Board, Association of Washington Cities, September 1997.
http://www.wsdot.wa.gov/publications/manuals/fulltext/M0000/PedFacGB.pdf
Developed for transportation design practitioners, the focus of this guidebook is on design of pedestrian facilities. Toolkit 8, Traffic Calming, begins on page 167 of the PDF. This section of the guidebook addresses the reasons traffic calming is used, alternatives for residential traffic management, and traffic calming and management methods.

Related Research

Below we examine domestic traffic calming research in the following areas:

- Traffic calming measures.
  - Horizontal treatments.
  - Vertical treatments.
  - Road narrowing/road diets.
  - Rural/urban transition.
- Accident modification or crash reduction factors.
- General design and policy issues.
- Case studies.

Traffic Calming Measures—Horizontal Treatments

Roundabouts: An Informational Guide, Second Edition, *NCHRP Report 672*, 2010.
http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_672.pdf
This report, which updates the 2000 publication *Roundabouts: An Informational Guide*, addresses the planning, design, construction, maintenance and operation of roundabouts.

Page 35 of the PDF summarizes the safety benefits of roundabouts:

> Roundabouts have been demonstrated to be safer than other forms of at-grade intersections. The safety benefit is particularly notable for fatal and injury crashes … . The safety performance of a roundabout is a product of its design. At roundabouts, vehicles travel in the same direction, eliminating the right-angle and left-turn conflicts associated with traditional intersections. In addition, good roundabout design places a high priority on speed control. Speed control is provided by geometric features, not just by traffic control devices or by the impedance of other traffic. Because of this, speed control can be achieved at all times of day.

The report notes that the most up-to-date knowledge on the safety effects of roundabout conversions in the United States is summarized in *NCHRP Report 572* (see the citation below). Using before and after conversion data from 55 locations, researchers found an observed reduction of 35 percent and 76 percent in total and injury crashes, respectively, following conversion to a roundabout. These values are consistent with results from international studies.

A more detailed discussion of safety-related research is included in Chapter 5, Safety, which begins on page 122 of the PDF.

Roundabouts in the United States, *NCHRP Report 572*, 2007.
http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_572.pdf
Researchers found that overall, single-lane roundabouts have better safety performance than multilane roundabouts. The safety performance of multilane roundabouts appears to be especially sensitive to design details.

While this report notes the majority of the roundabouts in the United States appear to operate without any significant operational or reported safety deficiencies, findings from this project suggest areas where special attention is needed, including:

- Multilane roundabouts need to be carefully designed to avoid entry and exit path overlap.
- Roundabout exits tend to have a higher percentage of vehicles that do not yield to pedestrians than roundabout entries. As a result, the design of the exit should be carefully considered to ensure that vehicle speeds are reasonable and that good sight lines exist between drivers and pedestrians.
- Multilane roundabouts tend to have a higher percentage of vehicles that do not yield to pedestrians on either entry or exit. While no quantifiable crash experience has resulted from this behavior, it may reduce the usability of the roundabout crosswalk for pedestrians.

Related Resource:

> **Appendixes to *NCHRP Report 572: Roundabouts in the United States***, *NCHRP Web-Only Document 94*, May 2006.
> http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_w94.pdf
> This appendix to *NCHRP Report 572* includes detailed reviews of the literature on safety performance and operational models, the master inventory of U.S. roundabouts assembled for this project and results of the statistical testing of various models.

Traffic Calming Measures—Vertical Treatments

"New Traffic Calming Device of Choice," Jeff Gulden, Reid Ewing, *ITE Journal*, Vol. 79, No.12, December 2009: 26-31.
Citation at http://trid.trb.org/view/2009/C/908722
From the abstract: This article highlights a relatively new traffic calming device—the speed lump. Speed lumps consist of two or more raised and rounded areas placed laterally across a roadway with precisely spaced gaps allowing the wheel tracks of emergency vehicles to pass between the lumps with minimal difficulty. Speed lumps offer similar speed reduction for cars as speed humps, but because speed lumps do not significantly slow emergency vehicles, they are more appropriate for emergency response routes. The gaps in speed lumps also help minimize ride discomfort for bicyclists. Although the cost of speed lumps varies depending on the size of the lumps, width of the roadway and materials used, speed lumps cost approximately the same as speed humps.

"Positive Effects of Road Surface Discontinuities," Francesca La Torre, *Transportation Research E-Circular*, No. E-C134, May 2009: 25-31.
http://onlinepubs.trb.org/onlinepubs/circulars/ec134.pdf
This paper includes an analysis of an intervention commonly used for traffic calming:

> **Speed humps**. Some studies have estimated a 48 percent reduction in accidents after employing this traffic calming technique. The author notes that the vertical acceleration induced by speed humps is extremely high for high driving speeds. For this reason, in most countries speed humps are used only on urban roads with low design speed and with lighting to allow the driver to reduce speed well in advance of the humps.

"Developing Design Standards for Speed Cushions," Kevin N. Chang, Matthew Nolan, Nancy L. Nihan, *Transportation Research Record*, Vol. 2030, 2007: 22-28.
Citation at http://dx.doi.org/10.3141/2030-04
The author notes that the primary drawback of speed humps has been the increased response times experienced by emergency response personnel when traveling over this traffic calming device. The King County (WA) DOT designed, constructed and evaluated an alternative traffic calming device—the speed cushion. Speed cushions resemble speed humps but are constructed with channels to allow for minimal impact and delay to wider-wheel-based emergency vehicles such as fire engines.

To evaluate the effectiveness of a pilot installation of 10 speed cushions as part of a neighborhood traffic calming project, researchers conducted speed and volume studies before and after installation. Study results indicate that speed cushions can provide traffic calming benefits without significantly affecting emergency response vehicles. The authors note that the increased popularity of speed cushions has accelerated the need for standardized design and construction, and provide specific recommendations.

"Effectiveness of Traffic Management in Salt Lake City, Utah," Wayne D. Cottrell, Naree Kim, Peter T. Martin, H. Joseph Perrin Jr., *Journal of Safety Research*, Vol. 37, No. 1, 2006: 27-41.
Citation at http://trid.trb.org/view.aspx?id=781315
Researchers investigated the effectiveness of speed humps and speed tables on 12 streets in Salt Lake City. Among the issues under consideration: mean and 85th percentile spot speeds, speed limit compliance, motor vehicle crashes and resident opinions. At least 78 percent of the test sites experienced a decrease in the mean or 85th percentile speed, or an increase in speed limit compliance.

"Offset Speed Tables for Reduced Emergency Response Delay," S. M. Batson, *Intersection Safety: Achieving Solutions Through Partnerships*, Conference Proceedings, 2004.
Citation at http://trid.trb.org/view/2004/C/755397
In this conference paper, the author reported on an investigation conducted by the city of Portland, OR, to evaluate the use of an offset speed table on designated emergency response routes. Results show a reduction in maximum delay from 4.8 seconds at standard speed tables to a two-second delay at offset speed tables—a more than 50 percent reduction in emergency vehicle delay. The offset speed tables are also expected to reduce speeding. The author also reported on minor adjustments made by the Portland DOT to improve constructability of the speed tables.

"A Comparative Study of Speed Humps, Speed Slots and Speed Cushions," LaToya Johnson, A. J. Nedzesky, *ITE 2004 Annual Meeting and Exhibit*, 2004.
http://www.ite.org/traffic/documents/AB04H1502.pdf
This project compared speed humps with the speed slot and speed cushion by measuring crossing speed and driver behavior at selected traffic calming devices on roadways in metropolitan Washington, D.C., during the summer of 2003. Researchers used video surveillance technology to collect data, including vehicle crossing speed, lateral placement and braking frequency. Findings include:

- Speed slots followed by 22-foot speed humps allowed the highest average and 85th percentile crossing speeds.
- Twelve-foot speed humps, speed cushions and prefabricated 14-foot speed humps recorded the lowest crossing speeds.
- The design of the speed hump encouraged drivers to travel centrally within their lane.

Traffic Calming Measures—Road Narrowing/Road Diets

Pedestrian Safety Impacts of Curb Extensions: A Case Study, Oregon Department of Transportation, FHWA, Report No. FHWA-0R-DF-06-01, July 2005.
http://www.oregon.gov/ODOT/TD/TP_RES/docs/Reports/PedestrainSafetyCurbExt.pdf
This report documents a case study evaluating motorist yielding behavior at a crosswalk in Albany, OR. Results include:

- The presence of a curb extension resulted in a significant reduction in the mean number of vehicles that passed from the time a pedestrian arrived at a crosswalk to the time the pedestrian was able to cross.
- While the change in the percentage of pedestrian crossings with a yielding vehicle and the percentage of vehicles yielding at the advance stop bar proved insignificant, there are other safety benefits that curb extensions provide to the pedestrian, including improved sight distance, elimination of exposure to turning vehicles and shorter crossing distance.

Road Diet Handbook: Setting Trends for Livable Streets, Parsons Brinckerhoff, July 2009.
Publisher's description available at
http://www.ite.org/emodules/scriptcontent/Orders/ProductDetail.cfm?pc=LP-670
Designed to be a comprehensive guide for decision-making on the applicability of road diets, this handbook takes a practitioner through planning, analysis, design and implementation of road diet projects. It includes guidelines for identifying and evaluating potential road diet sites, design concepts such as typical cross sections and lessons learned.

Related Resource:

"Road Diet Handbook – Overview," Jennifer A. Rosales, *2007 District 6 Annual Meeting*, Oregon Section of the Institute of Transportation Engineers.
http://www.oregonite.org/2007D6/paper_review/D4_201_Rosales_paper.pdf
This conference paper summarized the findings from research that the author conducted in connection with the publication of the *Road Diet Handbook: Setting Trends for Livable Streets*.

"The Safety and Operational Effects of 'Road Diet' Conversions in Minnesota," Tim J. Gates, David A. Noyce, Vijay Talada, Loren Hill, *TRB 86th Annual Meeting Compendium of Papers CD-ROM*, Paper #07-1918, 2007.
Citation at http://trid.trb.org/view/2007/C/801948
In this conference paper, the authors examined the safety and operational effects of converting four-lane undivided roadways to three lanes with a center two-way left-turn lane. Using multiple years of before and after speed and/or crash data for nine road diet sites in Minnesota, researchers performed statistical analyses using empirical Bayes and grouped comparison procedures. Results include:

- The empirical Bayes statistical analysis of total crashes found consistent decreases in the total crashes after the road diet conversions at all seven sites for which crash data were available. Crash reductions at the sites ranged from 37.3 percent to 54.3 percent, with an overall total crash reduction of 44.2 percent (408 crashes reduced).
- A grouped comparison procedure analyzed crashes by injury status (injury versus noninjury) and type (rear end, right angle and left turn). Results indicate a net reduction in crashes after the conversions for noninjury and right-angle crashes, with crash reductions of 45.7 percent and 37.0 percent, respectively. Injury crashes showed negligible change.
- Researchers noted reductions in the mean and 85th percentile speeds after the conversions at each of the six sites for which speed data were available, with a median reduction in both the mean and 85th speeds of 2 mph.

"Four-Lane to Three-Lane Conversions: An Update and a Case Study," Keith K. Knapp, Jennifer A. Rosales, *3rd Urban Street Symposium*, June 2007.
http://www.urbanstreet.info/3rd_symp_proceedings/Four-Lane%20to%20Three-Lane.pdf
This conference paper summarized guidelines for four- to three-lane conversions and presented the results of several research projects. Highlights include:

- Four-lane to three-lane conversions have been suggested as a traffic calming measure for highways entering urban areas.
- Intersection operations and the details of the geometrics and turning at these intersections are critical to the success or failure of any roadway cross-section conversion.
- The conversion of a roadway from a four-lane undivided to a three-lane cross section will result in larger impacts on and from heavy vehicles.
- Raised medians and/or other pedestrian crossing treatments are options midblock and at major intersections along many cross-section designs. Researchers recommend a raised median design that includes a jog or angle that requires pedestrians to look at oncoming traffic.

"Safety Impacts of 'Road Diets' in Iowa," Thomas B. Stout, Michael D. Pawlovich, Reginald R. Souleyrette, Alicia Carriquiry, *ITE Journal*, Vol. 76, No. 12, December 2006: 24-28.
http://www.eugene-or.gov/portal/server.pt/gateway/PTARGS_0_2_267705_0_0_18/Safety%20Impacts%20of%20Road%20Diets%20in%20Iowa%20ITE%20Journal%20Dec%202006.pdf
This article analyzes the safety impacts of 15 road diet conversions in Iowa using a full Bayes approach and a classical before and after study. The two study methods produced similar results. Findings showed significant reductions in the crash frequency per mile, crash rate, number of injury crashes and crash severity. Significant reductions were also found in the number of crashes related to left turns and stopped traffic.

Traffic Calming Measures—Rural/Urban Transition

Determining Effective Roadway Design Treatments for Transitioning from Rural Areas to Urban Areas on State Highways, Oregon Department of Transportation, FHWA, Report No. FHWA-OR-RD-09-02, September 2008.
http://www.oregon.gov/ODOT/TD/TP_RES/docs/Reports/2008/Rural_to_Urban.pdf
This research effort sought to identify ways to calm operating speeds as vehicles transition into developed suburban/urban areas from rural roads. A simulator study evaluated scenarios that either physically or perceptually narrow the road at rural-to-urban transitions. Transition treatments used in the simulation include:

- Layered landscape.
- Gateway with lane narrowing.
- Median treatment only.
- Median with gateway treatment.
- Medians in series with no pedestrian crosswalks.
- Medians in series with pedestrian crosswalks.

Though all enhanced speed reductions were minimal, the scenarios with median treatments (particularly the medians in a series or the treatment combined with a gateway) produced the most effective speed reduction results. The layered landscape treatment and the gateway with lane narrowing treatment did not result in statistically significant speed reductions.

Evaluation of Gateway and Low-Cost Traffic-Calming Treatments for Major Routes in Small, Rural Communities, Iowa Highway Research Board, Iowa Department of Transportation, FHWA, CTRE Project 06-185, October 2007.
http://www.iowadot.gov/operationsresearch/reports/reports_pdf/hr_and_tr/reports/tr523%20.pdf
Researchers' evaluation of traffic calming treatments on major routes through small Iowa communities identified that, in many cases, even the most effective treatments produced only modest speed reductions. Results indicate that the treatments were more effective in reducing the number of vehicles traveling over the speed limit. Specific findings include:

Gateway Treatments

- Converging chevrons and a "25 MPH" on-street pavement marking were reasonably effective. Speeds decreased for all speed metrics for all of the after periods and decreases remained constant over the yearlong data collection period.
- Transverse markings appear to be moderately effective in decreasing vehicle speeds directly downstream of the markings, although none of the recorded differences were large.
- Lane narrowing using center island widening did not appear to be effective.

Low-Cost Treatments

- A speed table was successful in decreasing speeds for all speed metrics both immediately upstream and downstream of the speed table for all of the after periods. The table slowed speeds in both directions.
- A modified European entrance treatment that consisted of red pavement markings and on-pavement speed signing were effective in reducing speeds at all three of the locations where they were tested.
- On-pavement "SLOW" markings were not found to be effective.
- Two center islands created using tubular channelizers and placed one block apart significantly reduced speeds.

Accident Modification or Crash Reduction Factors

Accident modification factors (AMFs), also known as crash reduction factors (CRFs), provide a simple way of estimating crash reductions. These factors designate the percentage crash reduction that might be expected after implementing a given countermeasure at a specific site. In the citations below, we call attention to the limited references to common traffic calming measures in national publications and an Oregon DOT report.

Accident Modification Factors for Traffic Engineering and ITS Improvements, *NCHRP Report 617*, 2008.
http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_617.pdf
Using the results of a literature review and a survey of state DOTs, researchers developed a list of 100 treatments considered important in improving safety. The project team employed statistical evaluation of crash data and input from expert panels to whittle the initial list of 100 down to 35 AMFs considered to be of high or medium-high quality. While traffic calming as a general practice was included in the initial list of 100 AMFs under consideration, researchers' analysis indicates that the general practice has no level of predictive certainty. The final list of 35 does include the following often associated with traffic calming:

- Install roundabout (page 36 of the report; page 46 of the PDF).
- Reduce mean travel speed (page 67 of the report; page 77 of the PDF).

Desktop Reference for Crash Reduction Factors, FHWA, Report No. FHWA-SA-08-011, September 2008.
http://safety.fhwa.dot.gov/tools/crf/resources/fhwasa08011/fhwasa08011.pdf
This report documents the estimates of the crash reduction that might be expected if a specific countermeasure or group of countermeasures is implemented with respect to intersections, roadway departure and other nonintersection crashes, and pedestrian crashes. See page 32 of the PDF for Table 2, Geometric Countermeasures, which includes the following countermeasures often used in traffic calming:

- Convert intersection to roundabout (page 33).
- Install median or refuge islands (pages 36 and 37).

Table 2 includes references to the studies conducted for these countermeasures. Most of the roundabout studies employed before and after analysis.

Update and Enhancement of ODOT's Crash Reduction Factors, Oregon Department of Transportation, FHWA, Final Report SPR 612, June 2006.
http://ntl.bts.gov/lib/41000/41600/41695/Crash_Reduction_Factors.pdf
This study provided a comprehensive update to Oregon DOT's CRF database. In a process similar to that conducted in connection with *NCHRP Report 617*, researchers obtained data through a literature review and input from an expert advisory group. A discussion of traffic calming measures begins on page 119 of the PDF. Recommendations include installing chicanes or serpentine roadways, speed tables and speed bumps, and narrowing travel lanes.

General Design and Policy Issues

"The Built Environment and Traffic Safety: A Review of Empirical Evidence," Reid Ewing, Eric Dumbaugh, *Journal of Planning Literature*, Vol. 23, No. 4, May 2009: 347-367.
http://www.reconnectinglee.org/resources/1/PDFFiles/Built%20Environment%20and%20Traffic%20Safety%20--%20Review%20of%20Empirical%20Evidence.pdf
This article reaches two conclusions counter to accepted transportation engineering theory:

- The traffic environments of dense urban areas appear to be safer than the lower-volume environments of the suburbs. The authors note that this is due to the many fewer miles driven on a per capita basis in urban areas, and the lower speeds are less likely to produce fatal crashes.
- In dense urban areas, less-forgiving design treatments—such as narrow lanes, traffic calming measures and street trees close to the roadway—appear to enhance a roadway's safety performance when compared to more conventional roadway designs. The authors conclude that less-forgiving designs provide drivers with clear information on safe and appropriate operating speeds.

The authors note that "the fundamental shortcoming of conventional traffic safety theory is that it fails to account for the moderating role of human behavior on crash incidence" and recommend further developing an understanding of how design influences the behavior of specific roadway users, and how these behaviors in turn influence crash incidence.

"Traffic Calming Progress Report," Reid Ewing, Steven J. Brown, *Planning*, Vol. 75, No. 10, November 2009: 32-35.
Citation at http://trid.trb.org/view.aspx?id=907828
This article highlights some of the differences between European and U.S. traffic calming policies and design, and discusses what U.S. cities can do to move closer to the European model. The authors note that the encouragement of bicycling and walking must be an explicit goal of traffic calming policies. As in Europe, traffic calming programs should be made areawide and expanded to encompass main roads. U.S. programs should also make use of European devices for giving pedestrians and bicyclists priority on busy roads.

The Effects of Transportation Corridors' Roadside Design Features on User Behavior and Safety, and Their Contributions to Health, Environmental Quality, and Community Economic Vitality: A Literature Review, University of California Transportation Center, UCTC Research Paper No. 878, 2008.
http://www.uctc.net/papers/878.pdf
This literature review is the first phase of a research project to provide transportation agencies with information to assist in measuring the effects of corridor design features on the quality of life. Of particular interest:

- Appendix I, which begins on page 186 of the PDF, summarizes appropriate traffic calming treatments by roadway type (local residential streets or collectors and arterials).

- Page 49 of the PDF begins a discussion of research that addresses traffic calming measures used to improve pedestrian safety.

"Traffic Calming," Janet Jenkins, *Transportation Planning*, Vol. 31, No. 1, January 2006: 1-2, 4-5.
Citation at http://trid.trb.org/view/2006/C/806891
The author presents a traffic calming toolbox that describes the use of vertical and lateral shifts, constrictions, circles, route modifications, traffic control devices and other measures. Among the topics discussed is the importance of developing a clear policy with defined goals, objectives and evaluation criteria to create broad support for plans.

Effectiveness of Certain Design Solutions on Reducing Vehicle Speeds, New Jersey Department of Transportation, FHWA, Report No. FHWA-NJ-2005-007, December 2005.
http://www.state.nj.us/transportation/refdata/research/reports/FHWA-NJ-2005-007.pdf
New Jersey is cited as one of the first locations in the United States where traffic calming was implemented. This research focused on design solutions for reducing vehicle speeds in business and residential areas. Researchers identified state routes with a posted speed limit of 25 mph as possible locations for evaluating the potential benefits of traffic calming. Although the research identified locations on state routes where design solutions would be appropriate for reducing speeds, these types of roadways tend to have higher volumes and truck volumes that may limit the applicability of design solutions for reducing speeds.

A visual preference survey assessed four traffic calming measures: speed humps, speed tables, median dividers and medians with a breakpoint for pedestrians. The median with the breakpoint received the highest overall rating for improving safety for pedestrians and bicycles, for its driver convenience and for the aesthetics of the measure. Speed humps received the lowest rating.

Further research is recommended to better estimate the impact of traffic calming on speeds. Given the volume levels and geometric conditions on the roadway, speed models can be used to better determine the potential impacts of various traffic calming measures on operating speeds.

Case Studies

"Comprehensive Traffic Calming Program for Arterials and Neighborhoods," Tatiana L. Holden, *ITE 2009 Annual Meeting and Exhibit Compendium of Technical Papers*, Conference Paper AB09H411, 2009.
Citation at http://trid.trb.org/view/2009/C/925131
Since 1997, the city of Calabasas, CA, has been implementing traffic calming measures in residential neighborhoods. In the past few years, the city expanded its traffic calming program—Comprehensive Traffic Calming for Arterials and Neighborhoods—to include collectors and arterial roadways that carry a higher volume of traffic. Traditional arterial traffic calming measures such as median landscaping, lane narrowing and roundabouts have been supplemented by the use of high-tech traffic calming and safety devices such as electronic LED signs and in-pavement flashing crosswalks. Using as an example one of the most challenging arterials in the city—Mulholland Highway—this conference paper described the effectiveness of traffic calming measures implemented in Calabasas.

Best Practices for Low-Cost Safety Improvements on Iowa's Local Roads, Iowa Department of Transportation, FHWA, CTRE Project 08-338, December 2008.
http://www.ctre.iastate.edu/reports/low-cost-safety-practices.pdf
This best-practices guide to improve safety on low-volume local roads offers details on the potential benefits, costs and CRFs associated with projects that employ a range of traffic calming measures, including:

Speed displays.

- Lane width reduction with channelizers.
- Speed limit pavement markings.
- Pavement marking with convergent chevrons.
- Shoulder marking to reduce perceived width of traveled way.
- Speed humps or tables.
- Optical speed bars for speed reduction.
- Red-painted pavement markings.

See page 38 of the PDF for a summary of treatment effectiveness that describes changes in before and after data, cost, maintenance and appropriate application.

"Calming by Design," W. Martin Bretherton Jr., *ITE 2008 Annual Meeting and Exhibit Compendium of Technical Papers*, Conference Paper AB08H413, 2008.
Citation at http://trid.trb.org/view.aspx?id=921283
In 2006, the Gwinnett County (GA) Board of Commissioners passed an ordinance requiring developers to design and build their subdivisions with approved traffic calming devices or build the design using geometric designs that control speed. This conference paper described Gwinnett County's traffic calming efforts over the past 20 years, the success of the new calming by design program and lessons learned with regard to process improvements.

"Trenton Redesigns Its Freeways to Slow Down Traffic," Christopher Swope, *Cities and Cars: A Handbook of Best Practices*, McFarland and Company Inc., 2007: 181-186.
Citation at http://trid.trb.org/view.aspx?id=849464
From the abstract: Some parts of New Jersey are rethinking highway design. Rather than design highways that can accommodate the most traffic at the greatest speeds, they are designing smaller and narrower roads that will slow down traffic, take cars through neighborhoods, and encourage walking. They are finding creative solutions to join together neighborhoods and roads.

"An Evaluation of Traffic Calming Measures and Their Impact on Vehicular Speeds on an Urban Principal Arterial Roadway on the Periphery of an Activity Center," Daniel M. Dulaski, *2006 ITE Annual Meeting and Exhibit Compendium of Technical Papers*.
http://www.ite.org/traffic/documents/AB06H5202.pdf
This conference paper described the result of traffic calming measures applied to an arterial roadway in Amherst, MA, with the primary goal of improving pedestrian safety. Town officials selected pedestrian refuge islands accompanied by a roadway width reduction. Results indicate modest speed reductions (an average reduction of 1.5 mph for northbound vehicles; a 5 mph reduction for the southbound lane) and a significant increase in pedestrian crosswalk compliance (from an average of 54.2 percent before treatment to 96.2 percent after installation of the traffic calming measure). The author recommends establishing warrants and bylaws that specify the types of roads where traffic calming can be installed and thresholds for speeds and volumes.

"Downtown Brooklyn Traffic Calming Implementation: Calming Clinton Street with the Traffic Engineering Toolbox," Ryan Russo, Seth Berman, *ITE 2006 Technical Conference and Exhibit Compendium of Technical Papers*.
http://www.ite.org/traffic/documents/CB06C0602.pdf
This conference paper noted that "the more dense central cities of the United States, particularly in the northeast, have not widely implemented the aggressive physical traffic calming interventions imported from Europe … ." New York City DOT's Downtown Brooklyn Traffic Calming Project employs curb regulations, street markings and signal timing plans.

Legal Issues

We highlight below publications that address in some detail issues such as immunity; a historical perspective of litigation associated with traffic calming; and the case law pertaining to statutory authority, constitutionality and tort liability.

"Engineers' and Public Entities' Liability Concerns on Installing Bike, Pedestrian and Traffic Calming Measures," Sharon Z. Roerty, Janine G. Bauer, *New Jersey's TransAction Conference*, April 8, 2011.
http://www.njtransactionconf.com/2011%20Transaction%20info/2011%20ta%2060a.pdf
This conference presentation begins with a simple question: Will engineers and public entities be held liable if they don't design to maximum or desirable targets? The presenters' response:

- Possibly: If our plan and design decisions do not take into account reasonably foreseeable users of the roadways.
- Maybe: If we don't have support for our decisions in adopted standards.
- Not likely: If we don't create dangerous conditions or have policies or property that are palpably unreasonable.

The presentation includes a discussion of immunity as provided for under New Jersey Annotated Statutes (see the statute below):

> **59:4-6. Plan or design immunity**
> a. Neither the public entity nor a public employee is liable under this chapter for an injury caused by the plan or design of public property, either in its original construction or any improvement thereto, where such plan or design has been approved in advance of the construction or improvement by the Legislature or the governing body of a public entity or some other body or a public employee exercising discretionary authority to give such approval or where such plan or design is prepared in conformity with standards previously so approved.

The New Jersey statute, available at http://www.njleg.state.nj.us/, refers to standards previously approved as providing protection from liability. The presentation provides the following as sources of previously approved standards that include some traffic calming measures:

- Traffic Engineering Handbook. (See the citation on page 8 of this Preliminary Investigation.)
- Manual on Uniform Traffic Control Devices. (The 2009 edition is available at http://mutcd.fhwa.dot.gov/pdfs/2009/mutcd2009edition.pdf.)
- A Policy on Geometric Design of Highways and Streets. (Purchase information for this manual, also known as the "Green Book," is available at https://bookstore.transportation.org/item_details.aspx?id=110.)
- Highway Design Handbook for Older Drivers and Pedestrians (available at http://www.fhwa.dot.gov/publications/research/safety/humanfac/01103/; the handbook is being revised, and a new edition will be posted on the FHWA web site after completion of the 2011 update).
- Highway Capacity Manual, 2010 edition. (Purchase information is available at http://www.trb.org/Main/Blurbs/Highway_Capacity_Manual_2010_HCM2010_164718.aspx; a summary of the 2010 edition is available at http://onlinepubs.trb.org/onlinepubs/trnews/trnews273HCM2010.pdf.)

- Appendix A to Part 1191—Americans with Disabilities Act (ADA) Accessibility Guidelines for Buildings and Facilities. (See http://www.access-board.gov/adaag/ADAAG.pdf.)

U.S. Traffic Calming Manual, American Planning Association, ASCE Press, 2009.
Publisher's description available at http://www.planning.org/media/trafficcalming/
Appendix A, which begins on page 183 of the manual, includes this about liability and litigation associated with traffic calming:

> There is now more litigation for failure to calm traffic than for calming traffic and thereby somehow contributing to accidents. The decision to spend money on traffic calming, or to spend money on a particular street, is a discretionary function of government, not a ministerial function with little room for discretion. As such, lawsuits over the failure to calm traffic are unlikely to be successful. … Only a couple of damage claims have been reported, and these involved small payouts. The earlier conclusion, that a carefully designed and administered program can avoid liability, still seems to hold.

"Traffic Calming Practice Revisited," Reid Ewing, Steven J. Brown, Aaron Hoyt, *ITE Journal*, Vol. 75, No. 11, November 2005: 22-28.
http://www.ite.org/traffic/documents/JB05KA22.pdf
The authors conducted a survey of 21 U.S. jurisdictions to gather input for an update of the Sacramento County, CA, traffic calming program. Survey findings are compared to previous studies to demonstrate how policies and practices have evolved. Among the findings:

- **Legal issues.** Most surveyed agencies reported either no litigation or nothing in recent years. Only three lawsuits were reported by the surveyed agencies since 1997. One was settled out of court; the other two were decided in the cities' favor. The authors note that this data bears out an earlier conclusion that a carefully designed and administered program can avoid liability.
- **Emergency responders.** All of the agencies surveyed involve the fire department in the design of the available devices and/or during the plan development process. Some agencies give veto power to the fire department. Several agencies have designated primary emergency response routes that preclude certain types of treatments.
- **Treatment of arterials.** Six of the surveyed agencies consider treating arterials with a limited toolbox of eligible devices. None of these agencies allow the use of vertical devices on arterials.

Chapter 3, Legal Issues, Pennsylvania's Traffic Calming Handbook, Pennsylvania Department of Transportation, Publication No. 383, January 2001.
See page 14 of the PDF at
ftp://ftp.dot.state.pa.us/public/pdf/TrafficCalming/TrafficcalmingHandbook2001.pdf
This chapter of PennDOT's traffic calming guide addresses the legal questions that may relate to the installation of traffic calming measures and begins with this observation:

> Hundreds of local governments across the country have implemented traffic calming programs. Few have encountered liability issues. Almost all lawsuits that have arisen have been dismissed, denied, or withdrawn. Where lawsuits have succeeded, they have done so not because a traffic calming measure was found inherently unsafe, but because signs or pavement markings were poorly maintained.

To minimize liability, local governments are advised to:

- Maintain documentation illustrating that their traffic calming programs are appropriate, and that traffic calming installations are based upon objective data. This documentation should also state the goals to be served by the traffic calming program as well as the procedures to be followed when considering and installing any measure.

- Establish guidelines for speed, volume and/or crash history conditions under which traffic calming measures may be installed.
- Establish a "Traffic Calming Study and Approval Process" (described in Chapter 4 of the handbook; see page 18 of the PDF).
- Design a traffic calming measure so that a driver acting reasonably and exercising ordinary care would perceive the intent of the measure and safely negotiate it. Geometric design, signing, pavement markings and lighting should conform to standard engineering principles as much as possible.

Chapter 6, Legal Authority and Liability, Traffic Calming: State of the Practice**,** Institute of Transportation Engineers, FHWA, August 1999.
http://www.ite.org/traffic/tcsop/Chapter6.pdf
This chapter of ITE's guide to traffic calming summarizes the legal histories of 20 of the almost 50 cities and counties surveyed for this report. The authors note that:

> Many have had no legal problems at all, and the remainder have experienced more threats than legal actions. The legal maneuvering has more often involved city attorneys concerned about potential liability than private attorneys claiming actual damages.

Included is a discussion of case law with regard to legal authority, tort liability, loss of access, failure to calm traffic on streets with excessive volumes or speeds, and damage claims.

Web Resources

The web sites below offer access to an abundance of publications related to traffic calming as well as site-specific data related to the implementation of traffic calming measures.

Traffic Calming, Speed Management Safety, FHWA Safety Program.
http://safety.fhwa.dot.gov/speedmgt/traffic_calm.cfm
This FHWA site is a gateway to the FHWA-funded ITE traffic calming web site. See below for direct links to the ITE site.

> **Traffic Calming Library**, Institute of Transportation Engineers.
> http://www.ite.org/traffic/
> This site offers a searchable database of reports, articles and other documents related to traffic calming.
>
> **Selected Reports**, Traffic Calming Library, Institute of Transportation Engineers.
> http://www.ite.org/traffic/tcstate.asp
> This site provides online access to three ITE publications about traffic calming:
>
> - **Traffic Calming: State of the Practice**, ITE/FHWA, August 1999.
> - **Canadian Guide to Neighbourhood Traffic Calming**, Transportation Association of Canada/Canadian Institute of Transportation Engineers, December 1998.
> - **State of the Art: Residential Traffic Management**, FHWA, 1980.

Traffic Calming Seminar Instructional Material, Institute of Transportation Engineers.
http://www.ite.org/traffic/tcseminar.asp
This site includes links to PowerPoint presentations used in connection with a one-day traffic calming seminar developed by ITE and FHWA. The 1999 publication Traffic Calming: State of the Practice provided source material for the presentations.

Traffic Calming: Roadway Design to Reduce Traffic Speeds and Volumes, TDM Encyclopedia, Victoria Transport Policy Institute, updated March 16, 2011.
http://www.vtpi.org/tdm/tdm4.htm
This site provides a good overview of typical traffic calming measures and numerous links to research studies and other resources.

Traffic Calming in Minnesota, Minnesota Local Road Research Board.
http://mn-traffic-calming.org
This web site provides information about traffic calming projects implemented in Minnesota. The "Search Tools" page at http://mn-traffic-calming.org/cgi-bin/search.cgi provides a searchable database of all projects submitted by city and county engineers in Minnesota and research findings from previous Local Road Research Board-funded traffic calming studies. The database presents before and after data (if available) along with qualitative assessments of effectiveness.

Research in Progress

The projects presented below are developing guidance for traffic calming in small communities and assessing the effectiveness of various traffic calming measures.

"Evaluation and Guidance on Effective Traffic Calming for Small Communities," Iowa State University, expected completion date: July 31, 2012.
http://trid.trb.org/view.aspx?id=1095130
Sponsored by Iowa Highway Research Board, this research expands on a recent project to summarize information about effective transition zone planning and design practice. Researchers will also develop an application toolbox to aid practitioners in designing speed transition areas from high- to low-speed roadways, determining when speed management is necessary, and selecting and monitoring appropriate techniques.

"Road Diet or No Road Diet: A Case Study of the Fifth Street Corridor," Caltrans, expected completion date: September 30, 2011.
http://trid.trb.org/view/2009/P/1098901
Researchers are conducting a systematic evaluation of various alternative traffic engineering/road diet plans for the Fifth Street Corridor that runs through downtown Davis, CA, by examining the interrelationship of road design, traffic behavior, traffic safety, system efficiency and mode share. The project will produce guidelines for the adoption of road diet plans in small- to medium-size communities.

"Effectiveness of Traffic Calming Measures," New York City Department of Transportation, expected completion date: December 31, 2010. (A final report does not appear to be available.)
http://www.utrc2.org/research/projects.php?viewid=181
This project seeks to develop an enhanced analytic tool that will evaluate the appropriateness of traffic calming and other safety measures. Researchers will also determine the safety impacts of recently implemented and new candidate traffic calming measures.