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Chapter 15

Traffic Calming

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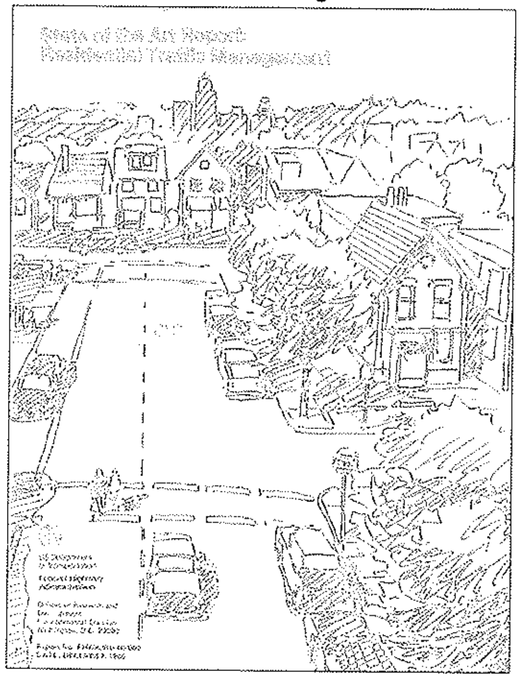
I. INTRODUCTION

The field of traffic calming in the United States has evolved since the 1970s to become a commonly featured function on many municipal organizational charts. Although various traffic calming techniques date back to the late 1940s or early 1950s, it was not until the publication of the *State of the Art Report: Residential Traffic Management* (see Figure 15-1) that traffic calming caught on in the United States.[1] That publication reported that by 1978, more than 120 jurisdictions in North America had had experience with traffic calming in one form or another.

Figure 15-1. *State of the Art Report: Residential Traffic Management.*



Source: *State of the Art Report: Residential Traffic Management.* Washington, DC, USA: Federal Highway Administration, 1980.

A second widescale survey was conducted nearly two decades later. *Traffic Calming State of the Practice* (see Figure 15-2) documented the history and practices of nearly 50 agencies nationwide, such as the Stevens neighborhood demonstration in Seattle, WA, USA (1971), Eugene, OR, USA's adoption of possibly the first traffic calming program and Berkeley, CA, USA's adoption of the first city-wide traffic management plan.[2]

Other more focused surveys have documented the magnitude of usage in individual traffic calming projects, legal issues, the effectiveness of devices and the results of independent case studies. One survey of approximately 120 agencies representing 27 U.S. states investigated whether before-and-after performance data were collected for nine traffic calming measures and the nature of legal issues surrounding those measures. The survey results indicated that nearly 60 percent of the respondents conducted before-and-after performance summaries, and six lawsuits were associated with the more than 1,000 devices reportedly installed. Only two of those six lawsuits resulted in paid claims.

A. Purpose

In North America, traffic calming is part of a profound transformation in the way transportation systems are viewed. With the passage of the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA), transportation planning and engineering became more multimodal and sensitive to the social costs of automobile use. The latest surface transportation act—the Safe, Accountable, Flexible, Efficient Transportation Equity Act—A Legacy for Users (SAFETEA-LU)—makes traffic calming eligible for funding under the Highway Safety Improvement Program and the Safe Routes to School Program.

The states' role in traffic calming has also grown in recent years. Pennsylvania has an illustrated handbook on the subject. Massachusetts and New York have adopted traffic calming guidelines. California has made traffic calming eligible for funding under its Safe Routes to School program. Several states have offered training programs aimed at local programs were reactive. A traffic calming program may make spot improvements, street by street, or may plan and implement improvements on an *area-wide* basis, with multiple streets treated at the same time. The same Berkeley survey found that almost all programs operated on a spot-treatment basis.

Traffic Calming State of the Practice predicted a more proactive, area-wide approach to traffic calming in the ensuing years. A decade later, there is a definite trend toward neighborhood-wide treatments because spot treatments tend to simply shift traffic problems from one neighborhood street to another. This trend is evident by reviewing the list of traffic calming programs at www.trafficcalming.org.

However, project initiation has remained largely reactive: Projects are initiated mainly through complaints from residents. Even in Seattle, which is known for proactively targeting high-collision locations, about 95 percent of projects are neighbor-initiated. A reactive process may be necessary, however, to maintain a high level of political support for a program.

Within complaint-driven processes, different threshold levels of neighborhood support are required before any action is taken. Some (Bellevue, WA and Howard County, MD, USA) allow individuals to initiate a needs study with a phone call, written request, or online request. Others (Charlotte, NC, USA and Los Angeles, CA) require petitions signed by a specified number or percentage of residents. Still others (Montgomery County, MD and Vancouver, British Columbia, Canada) require the responsible neighborhood association (or city council member where no association exists) to request a study. A few (Broward County, FL, USA and Minneapolis, MN, USA) first require a petition with signatures, then concurrence of a neighborhood association. The increased emphasis on neighborhood associations is a trend that has emerged since the publication of *Traffic Calming State of the Practice*. If initiated by individual citizens, a threshold level of support should be demonstrated before a project enters the system.

Once a project is nominated, staff should define the affected area, which becomes the study and the balloting area. This area should include all streets that might be affected by traffic calming treatments and should generally be bounded by major features (main roads, topographic features and such). In one jurisdiction, a significant effect is conservatively defined as a change of more than 100 vehicles per day (vpd) on any local street, more than 600 vpd on any minor collector and more than 1,000 vpd on all other residential streets.

The affected area may vary with the type of treatment or the functional classification of the treated street. For traffic circles in Seattle, the affected area includes all properties within one block of the treated intersection. For other measures, it is delineated by staff on a case-by-case basis. For local and collector streets in Charlottesville, VA, USA, the affected area includes all properties within one block of an intersection treatment and all properties on the block itself for a mid-block treatment. In addition, roads whose main access is from study blocks are included in the affected area. For arterials in Charlottesville, the affected area is defined for local and collector streets but includes potentially affected parallel roads. In addition, if the study street passes through more than one neighborhood, each neighborhood has a vote.

The affected area will ordinarily be larger for volume-control measures than for speed-control measures. It will also be larger for severe speed-control measures, such as speed humps, than for mild measures, such as center island narrowings. In projecting the affected area, staff may wish to consult volume impact information contained in *Traffic Calming State of the Practice* (see Table 15-4). Volume reductions on one street translate into volume increases on nearby parallel streets to which the traffic is likely diverted.

Staff then collects "before" traffic data on all significant streets within the affected area, measuring all traffic variables required to determine funding priority (see "Priority Rating Systems") and eligibility for different treatments (see "Application Guidelines"). In La Habra, data collection includes speed and volume counts, origin-destination data from a license plate survey and multiyear collision data (see Figure 15-4). These data are used to rank project requests for possible funding and, ultimately, to guide plan development. Elected officials have the final decision. They may select projects that are at the top of the list or further down based on other considerations. The selected projects then move to the plan development stage.

2. Plan Development

Residents consider the streets they live on to be extensions of their homes. They care deeply about conditions on their streets and about government actions affecting them. They harbor strong opinions about the nature and extent of traffic problems and about appropriate solutions. It is a practical necessity to involve residents in the planning and implementation of traffic calming measures.

In the years since the passage of ISTEA, the public has become increasingly engaged in transportation planning. Plans are likely to be better and more favorably received if those most affected are significant participators in their formulation.

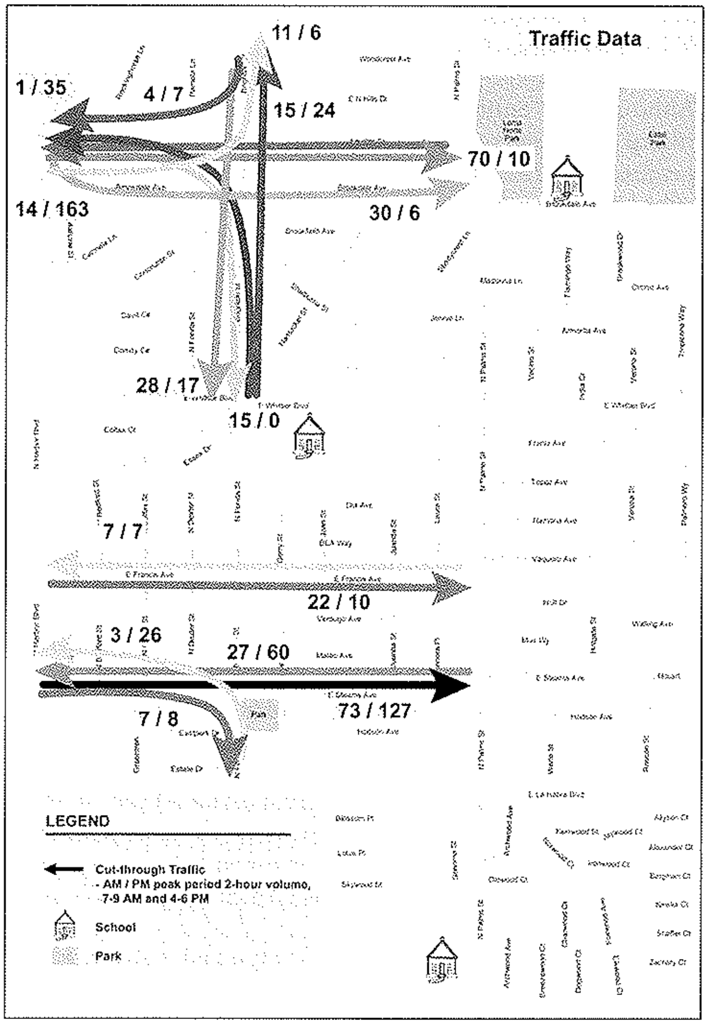
In about half of the areas surveyed in 2004, public involvement was limited to passing petitions, voting on plans, or voicing opinions at public hearings. The public reacted to plans but did not participate in their development. Thus, the only option available to the public was to support or oppose the entire plan.

The remaining areas involved citizens in planning in one of two ways: informally through citizen surveys to solicit ideas, meetings with staff to discuss ideas, or open houses to get comments on a draft plan; or formally through a neighborhood traffic committee (NTC) established to work with staff or consultants on a plan.

Since publication of *Traffic Calming State of the Practice*, the last of these approaches has gained in popularity. U.S. practitioners include Albuquerque, NM, USA, Bellevue, Howard County, Los Angeles, Montgomery County and the City of Sacramento.

The appropriate type of public involvement may depend on the nature of the treatment. On simple speed hump projects, the Portland staff prepares a plan and holds an open house while residents pass petitions and gather funds. On complex projects, an NTC is formed and staff act as consultants to the committee regarding policies, regulations and measures.

Figure 15-4. Cut-Through Traffic Volumes for the East Neighborhood Study Area, La Habra, CA, USA.



Source: Courtesy of Fehr and Peers.

If an NTC is used, usually either volunteers are recruited or members are appointed by neighborhood associations. Committee size ranges anywhere from three or four members in Howard County to as many as 30 members in Albuquerque. The City of Sacramento believes that five to 10 members is the ideal size for NTC committees (with provision for alternates).

There are many ways to involve the NTC in what were once viewed as purely technical matters best left to experts. New techniques have been developed to help citizens visualize design alternatives and participate constructively in the design process. These include visual preference surveys, computer simulations, design charrettes and focus groups. Methods of involvement are described in *Public Involvement Techniques for Transportation Decision-Making*, from FHWA and the Federal Transit Administration (FTA).[12] Another resource that has been put to good use in traffic calming is *Participation Tools for Better Land-Use Planning.*[13]

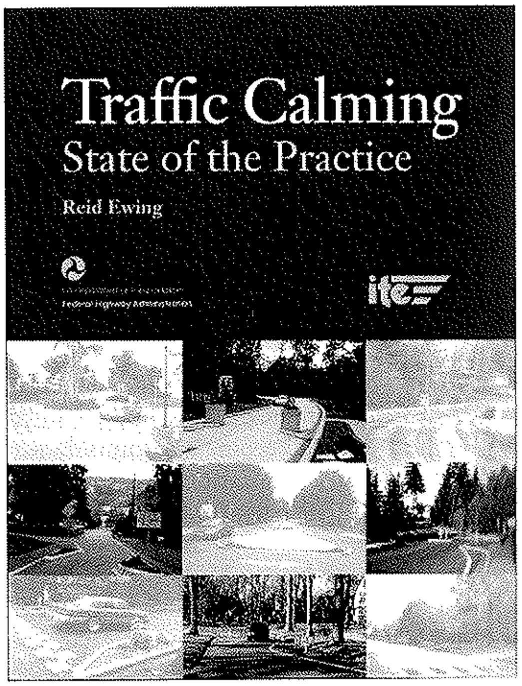
Community involvement in the form of an NTC was used in La Habra. The City first held a neighborhood meeting following project selection. This first meeting was widely publicized, and residents either attended and participated or submitted written comments and concerns on a mail-in survey form. At the meeting, staff provided basic education on the process used to develop, approve and implement a neighborhood traffic calming plan. Residents and business owners were given the opportunity to identify and discuss traffic problems within the neighborhood and to volunteer for the NTC, which developed a neighborhood traffic calming plan with the help of staff.

The entire affected area needs to be equitably represented on an NTC. Membership may include the original petitioners for traffic calming, residents appointed by the neighborhood association, citizens volunteering at an initial public meeting, businesses within the affected area and any other stakeholders deemed important for balanced traffic engineers. South Carolina and Virginia have adopted typical designs for traffic calming measures, and Delaware has a complete design manual, which this chapter draws on.

At the local level, traffic calming has expanded from a few scattered programs with limited scopes and toolboxes to a mainstream transportation engineering activity. As of May 2007, www.trafficcalming.org had links to programs in 159 communities. A recent Internet search uncovered an additional 51 programs and, for every program on the Internet, there are probably several programs that operate anonymously. Additionally, streetscape enhancement or beautification projects abound across North America, particularly in rejuvenating urban cores such as Portland, OR's Pearl District; Denver, CO, USA's Lower Downtown (LoDo) District; Seattle's University Avenue; and San Francisco, CA's Octavia Boulevard.

This chapter provides professional engineers and planners general guidance on the appropriate use, design and signing and marking of traffic calming measures with a goal of moving toward standardization of traffic calming practice in North America. Even with standardization, ample flexibility will remain. The chapter offers options rather than dictating single solutions.

Figure 15-2. *Traffic Calming State of the Practice.*



Source: Ewing, R. *Traffic Calming State of the Practice*. Washington, DC, USA: Institute of Transportation Engineers/Federal Highway Administration, 1999.

B. Relationship to Other ITE Documents and Design Practices

This chapter is a companion to the Institute of Transportation Engineer's (ITE) 1999 report, *Traffic Calming State of the Practice*, by the same author. The ITE report defines traffic calming as follows:

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

The ITE definition emphasizes the ultimate purposes of traffic calming—traffic speeds or volumes are reduced as a means to other ends, such as improving the quality of life in residential areas, increasing walking safety in commercial areas, or making bicycling more comfortable on commuter routes.

Other publications have similar traffic calming definitions, such as the *Canadian Guide to Neighbourhood Traffic Calming*, which follows the ITE international definition:[3]

> *Traffic calming is the combination of mainly physical measures that reduce the negative effects of motor vehicle use, alter driver behavior and improve conditions for non-motorized street users.*

Traffic Calming State of the Practice is a joint publication of ITE and the Federal Highway Administration (FHWA). This report contains background information on legal authority and liability, emergency response and other agency concerns, the effects of traffic calming and many other subjects. It also contains a bibliography of traffic calming publications. The report can be downloaded at www.ite.org.

This chapter also relies heavily on a 2004 survey of 20 jurisdictions that was conducted for Sacramento County, CA and printed in *ITE Journal*.[4] The survey found that the field of traffic calming has matured considerably since *Traffic Calming State of the Practice* was published in 1999. Some of the most significant changes include mainstreaming of programs within transportation or public works departments; less apparent public controversy surrounding programs; greater reliance on private financing of construction; more public involvement in planning through neighborhood traffic committees; expansion of eligibility beyond local streets to collectors and in some cases arterials; and expansion of toolboxes to the full range of speed control measures.

Finally, this chapter relies on material from ITE's *Guidelines for the Design and Application of Speed Humps*, a proposed recommended practice from August 2007, and the Transportation Association of Canada's *Canadian Guide to Neighbourhood Traffic Calming* from 1997. Both of these documents should be referenced for additional resources. Specifically, *Guidelines for the Design and Application of Speed Humps* should be utilized for additional detail regarding speed humps.[5]

This chapter is more prescriptive and less purely descriptive than the 1999 ITE report or the 2005 *ITE Journal* article. It answers important questions regarding *who* should be engaged in traffic calming, *where* traffic calming is appropriate, *what* measures are effective and *how* measures could be designed, signed and marked.

The information in this chapter can help implement several ITE recommended practices, all of which call for lower target speeds on urban streets: *Context Sensitive Solutions in Designing Major Urban Thoroughfares for Walkable Communities: A Proposed Recommended Practice, Guidelines for Residential Subdivision Design, Smart Growth Transportation Guidelines* and *Promoting Sustainable Transportation Through Site Design: An ITE Proposed Recommended Practice.*[6,7,8,9]

This chapter relates to other roadway design practices as outlined. Frequent reference is made to traffic calming in the American Association of State Highway and Transportation Officials' (AASHTO) *A Policy on Geometric Design of Highways and Streets* (the Green Book) and FHWA's *Manual on Uniform Traffic Control Devices* (MUTCD).[10,11]

II. BASICS

A. The Right Process

At the heart of any traffic calming program is a structured process—from an initial determination that traffic poses a problem through implementation of devices and, in rare cases, to removal of traffic calming measures that have not met community or engineering expectations. Traffic calming programs should strike a balance between extensive traffic studies and implementation without planning, and simply responding to neighborhood wishes based solely on technical judgment. They must be sufficiently process-oriented to avoid political and legal fallout yet sufficiently output-oriented to satisfy constituents.

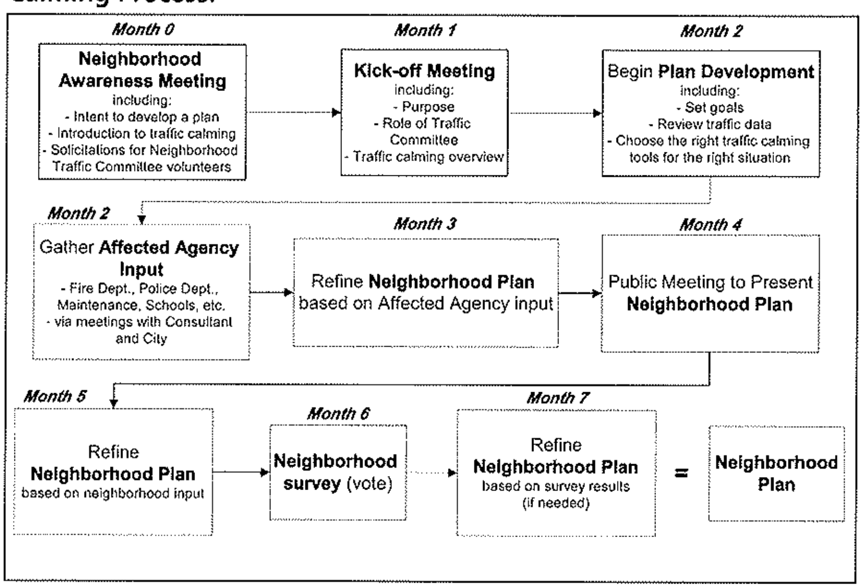
A traffic calming process that was originally developed for the Delaware Department of Transportation has been refined with each successive application. In the United States, Delaware was followed by Ithaca, NY, USA, then Sacramento, Denver and ultimately a dozen others. The guidelines contained in this chapter most heavily reflect recent experience with La Habra, CA.

There are four key steps in the process of traffic calming: project initiation, plan development, plan approval and plan implementation. This section describes choices facing jurisdictions at each step, common practices and preferred practices. The text is accompanied by a process flowchart (see Figure 15-3).

1. Project Initiation

A traffic calming program may be *reactive*, responding to citizen requests for action, or *proactive*, with staff identifying problems and initiating action. A 1997 survey by researchers at the University of California at Berkeley determined that all but a "handful" of

Figure 15-3. Typical Flow Chart and Milestone Dates for Traffic Calming Process.



Source: Courtesy of Fehr and Peers.

representation. Representatives of emergency services, school districts, the bicycling community and transit agencies may also be invited to attend NTC meetings.

Although the entire neighborhood has the opportunity to offer comments and suggestions as the process progresses, the NTC commits the time and effort necessary to develop a neighborhood traffic calming plan. At a series of meetings, the NTC receives basic training in traffic calming, reviews traffic data from the study area and formulates a plan either through a design charrette or through review and comment on staff-generated plans. Using the charrette process, a preliminary plan was developed in a single evening for each of the neighborhoods in La Habra. Figure 15-5 shows the NTC planning process in La Habra.

Figure 15-5. Design Charrette for the East Neighborhood of La Habra, CA, USA.

Source: Courtesy of Reid Ewing.

Whether staff or the NTC generate and refine the plan, the choice of traffic calming measures is subject to application guidelines specifying those measures that are eligible for use on different streets with different traffic characteristics (see "Application Guidelines").

From the 2004 survey of leading jurisdictions, agency interests are most often accommodated by allowing affected agencies to review and comment on plans. This mechanism is used by at least nine of the surveyed jurisdictions. Once a preliminary plan has been generated, staff solicit feedback from affected agencies, which may include:

- fire department;
- police department;
- transit agency;
- local school district;
- environmental services (garbage collection);
- street division;
- postal carriers; and
- ambulance services.

At the agency meeting in La Habra, both the fire and the police departments expressed some opposition to traffic calming, particularly about the enforceability of turn restrictions, the use of chicanes and the installation of speed lumps on a main road. The preliminary plan was modified accordingly.

The next step of the process is to hold a neighborhood meeting to present the proposed plan to the neighborhood at large. The meeting in La Habra was well publicized by sending out flyers with a plan map and posting meeting signs within the neighborhood. At the neighborhood meeting, the NTC members (not staff) presented the proposed plan and described the types and locations of measures proposed. At this point in the process, the plan belongs entirely to the committee. The public is invited to provide feedback on the plan, and the NTC should consider this input and refine the plan once more, if deemed appropriate. In La Habra, NTC members had sufficient knowledge of traffic calming and familiarity with the plan that they were able to successfully run the meeting with only moderate assistance from staff and consultants.

In the case of La Habra, the neighborhood plan required modification one more time to stay within budget. All but one member of the NTC approved the final plan.

3. Plan Approval

The main reason so few traffic calming measures are ever removed may be the show of neighborhood support required to install measures in the first place. In most places, strong support must be demonstrated before measures are even tested. Before they are installed permanently, 50, 60, or even 70 percent of property owners, tenant businesses and/or residents must concur.

Petition requirements used to be the most common way of establishing support. They served as a screening mechanism for depth of commitment because residents had to take the time to solicit signatures. Petition requirements also were easier to administer than ballots or surveys. On the negative side, signed petitions were not always the best indicator of public sentiment. Among surveyed communities, there have been cases of residents feeling pressured to sign or being misled into signing by advocates of traffic calming.

In response, many communities have adopted (or switched to) a balloting procedure to determine public support for the plan. With three exceptions, all jurisdictions surveyed in 2004 conducted a mail-in survey (ballot) before plans were adopted and implemented. Typically, all residents, both property-owners and renters, are eligible to vote on traffic calming plans. In about half the surveyed jurisdictions, this eligibility is extended to business proprietors.

Every jurisdiction has its own plurality requirements for plan approval. Minimum approval rates vary from 30 percent of those voting for temporary measures in Charlottesville to 100 percent of those voting for permanent measures paid for with special assessments in Broward County. The median approval requirement for jurisdictions surveyed is two-thirds of those voting.

Some jurisdictions also have required response rates for those eligible to vote. Such requirements are imposed to ensure a degree of general public acceptance. For jurisdictions with such requirements, the median required response rate is 50 percent.

Several programs have variable approval and/or response rate requirements. The City of Sacramento requires higher approval and response rates for volume-control measures than speed-control measures where the minimum response rate is 25 percent. Broward County has higher approval requirements for permanent than for temporary measures. Charlottesville does as well, and it adds a response rate requirement for permanent measures. Montgomery County has higher approval requirements for residents of treated streets than connecting streets.

The higher the required response rate and approval margin, the more demand for traffic calming will be limited. In a community with excess demand far beyond the supply of traffic calming funds, it is tempting to create administrative hurdles that disqualify competitors. The problem with this approach is that raising administrative hurdles will not ensure that the most worthy projects are built. It is more common to open the process and prioritize based on need (see "Priority Rating Systems").

In La Habra, neighborhood support for the plans was assessed through ballot-like, mail-in surveys. Surveys were mailed to all neighborhood area residents, property owners and business owners. Before the surveys were distributed, the City alerted residents to their arrival through public notices, mailers and newsletters.

The surveys used in La Habra included a description and map of the proposed plan that indicated the type and location of traffic calming measures. The surveys also included a mail-back postcard with three questions for residents to respond to (as shown in Figure 15-6):

- Do you support the proposed plan?

Figure 15-6. Mail-Back Survey Used in La Habra, CA, USA.

NEIGHBORHOOD TRAFFIC CALMING SURVEY

Please complete the following survey
and place it in the mail (postage is paid).

[Affix Label Here]

☐ **Yes,** I am in favor of the measures indicated on the neighborhood traffic calming plan.

☐ **No,** I am not in favor of the measures indicated on the neighborhood traffic calming plan.

In addition, please answer the following:

	Yes	No
Would you oppose a traffic calming device adjacent to your property?	☐	☐
Would you support funding, if any, of the requested neighborhood plan?	☐	☐

Comments:

Source: Courtesy of Fehr and Peers.

- Would you oppose a traffic calming measure adjacent to your property?
- Would you support funding, if any, for the requested neighborhood plan?

The mail-back postcard also provided a space for residents to write comments about the proposed plan.

A minimum response rate and approval rate were established as part of initial program development in La Habra. For implementation of a plan, a minimum of 50 percent of all surveys had to be returned with 67 percent of residents in favor.

For the final step of the survey process, staff count all received surveys and determine whether the minimum response rate and support rate are satisfied. If the minimum number of surveys is not received, staff can send out a second round of surveys because each survey form should be coded to allow identification of respondents.

If the minimum response rate is met but the support rate is not, the NTC has one opportunity to revise the plan. This would require modifying the plan to address aspects that were not favored by residents. Modifying the plan would also require consulting the affected agencies, holding a public meeting to present the revised plan and redistributing surveys to the study area.

If the minimum response rate and support rate are then met, the plan would continue to the implementation stage. In La Habra's two neighborhoods, both the minimum response rate and the approval rate were met. The final tally of the surveys resulted in response and approval rates slightly greater than the required minimum.

4. Plan Implementation

Final designs are prepared almost exclusively in-house by city or county staff. This is the case even where consultants prepare traffic calming plans. One exception is Vancouver, where consultants design complex devices when time and funding permit.

Within local governments, responsibilities for traffic calming are sometimes divided among sub-units. In Portland, speed hump projects are implemented by the maintenance bureau. More complex treatments in Portland are designed by the design section of the transportation bureau. In Charlottesville, the Department of Neighborhood Development Services designs treatments, and the Public Service Department installs them.

Traffic calming measures are constructed in accordance with geometric, aesthetic, signing and marking guidelines. Construction is subject to narrow tolerances. For example, plus or minus one-eighth inch is not an unrealistic tolerance for the height of a 3-inch speed hump.[14]

The performance of the traffic calming measures is assessed after installation to learn from each project and acquire impact data for use in subsequent budget deliberations. At a minimum, speed and volume measurements are often taken after permanent installation to permit before-and-after comparisons. Collision and resident satisfaction survey data may also be gathered.

A little over one-half of the surveyed jurisdictions use trial periods to test treatments. Seattle stopped doing so for traffic circles (which are hardly ever removed) but continues to hold trials for partial closures and speed humps. Portland no longer conducts trials for speed-control measures but continues to do so for volume-control measures meant to divert traffic. Among surveyed jurisdictions, the minimum time of a trial is 1 month, the maximum is 1 year and the most common range is 1 to 6 months. In areas with a range of trial times, the exact length of time depends on the nature of the treatment.

Trial installations may be warranted when implementing complex area-wide plans whose traffic diversion potential is difficult to predict. Trial installations may also be warranted when deploying novel traffic calming measures, such as when vertical measures with unconventional profiles are first used. The fact that installation is on a trial basis does not mean that unsightly materials may be used. The national experience suggests the importance of aesthetics for public acceptance.

In La Habra, after an affirmative survey process, the city council is asked to approve the plan and allocate funds for its design and construction. If it does, engineering designs are prepared and, if necessary, environmental reviews are completed. If for some reason the city council does not approve the plan, it may be modified one more time by the NTC and the process repeated.

The traffic calming measures may be constructed either as temporary or permanent devices. Temporary measures can be constructed at staff's discretion based on previous experience. Temporary measures can be converted to permanent measures after 4 to 6 months of acceptable performance.

After construction, staff monitors the performance of constructed measures and collects "after" data in 3 to 6 months. If the constructed plan has not produced satisfactory results (consistent with initial expectations), staff can recommend one or more of the following actions:

- Collect additional traffic data.
- Modify constructed measures as deemed appropriate.
- Construct additional, less intrusive measures as deemed appropriate.
- Return to plan development and modify the plan.

Traffic calming measures may be removed, at staff discretion, if proven ineffective.

5. Priority Rating Systems

Both *Traffic Calming State of the Practice* and the 2004 follow-up survey reviewed priority rating systems used by different jurisdictions to allocate funds among competing projects. The majority of leading jurisdictions have adopted priority rating systems. The main alternatives are first come first served and city council earmarks. Priority rating reduces political influences and increases program effectiveness in the face of public demands that exceed the supply of available funds.

The most common factors used to prioritize projects are traffic speeds, traffic volumes and crash rates. The next most common are residential density, lack of sidewalks, proximity to schools and proximity to other named pedestrian generators.

Ithaca used a rating system to prioritize projects in its pilot program. Because factor values for individual projects were expressed in different units (vpd, miles per hour and so forth), they were converted into numbers of standard deviations above or below the average values. Overall priority scores were then computed with the formula:

$$\text{PRIORITY SCORE} = \textit{ADT} + \textit{85th Speed} + \textit{Collisions} + \textit{Generators} \qquad (15\text{-}1)$$

In the above equation, the italics represent standardized values of priority rating factors. Applied to the set of projects in Table 15-1, the average value of average daily traffic (ADT) for competing projects was 7,729, and the standard deviation from the average was 4,314. For the first project, Fall Creek Avenue, the normalized value of the first factor was:

$$ADT_{Fall\ Creek} = (4{,}950 - 7{,}729)/4{,}314 = -0.64 \qquad (15\text{-}2)$$

Repeating this calculation for other factors and projects and summing standardized values for individual projects (see Table 15-2), this procedure assigned South Aurora Street the highest priority, with an overall score of 3.66. South Baker Street was assigned the lowest priority, with an overall score of –3.38. The five highest-priority projects were selected for the pilot program. Planning charrettes were conducted for all five, and plans were ultimately developed for funding in three of the five. Figures 15-7 and 15-8 illustrate portions of the first plan implemented in Ithaca.

Table 15-1. Factor Values for Competing Projects in Ithaca, NY, USA.

Project	ADT	85th Speed	Annual Collisions	Number of Generators
Fall Creek Ave.	4,950	28.8	1.92	3
South Baker St.	5,770	16.0	0.00	0
North Baker St.	7,760	18.3	1.59	4
Hector St.	5,250	14.8	0.00	1
South Aurora St.	15,000	31.0	0.73	6
Hudson St.	2,870	23.6	5.54	2
Cliff St.	6,600	35.0	0.00	4
University Ave.	13,630	37.5	0.22	0

Source: Courtesy of Fehr and Peers.

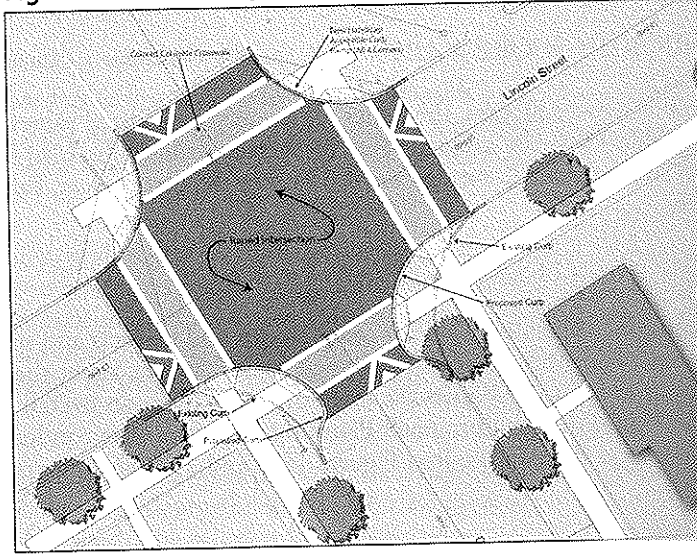
Table 15-2. Normalized Factor Values for Competing Projects in Ithaca, NY, USA.

Project	ADT	85th Speed	Annual Collisions	Number of Generators	Overall
Fall Creek Ave.	–0.64	0.37	0.35	0.23	0.31
South Baker St.	–0.45	–1.10	–0.66	–1.17	–3.38
North Baker St.	0.01	–0.83	0.18	0.70	0.05
Hector St.	–0.57	–1.23	–0.66	–0.70	–3.17
South Aurora St.	1.69	0.62	–0.28	1.64	3.66
Hudson St.	–1.13	–0.23	2.27	–0.23	0.68
Cliff St.	–0.26	1.07	–0.66	0.70	0.85
University Ave.	1.37	1.36	–0.54	–1.17	1.01

Source: Courtesy of Fehr and Peers.

For area-wide projects, values of priority rating factors may be averaged across the streets proposed for traffic calming, or the value for the worst street in the neighborhood may determine its relative priority. In the preceding example, if South Aurora Street and South Baker Street were included in the same area-wide traffic calming proposal, their traffic volumes, speeds and other factors could be averaged and the average values substituted into the formula to determine the project's relative priority. The neighborhood might or might not remain a priority when the low rating of South Baker Street was factored in.

Figure 15-7. First Implemented Plan in Ithaca, NY, USA.



Source: Courtesy of Fischer Associates.

6. Program and Project Funding

The general fund remains the main source of funds for traffic calming, often in combination with gas tax revenues. Therefore, traffic calming competes with all other local governmental priorities, or at least with other local transportation priorities.

A few places have dedicated revenue sources. Gwinnett County, GA, USA, has a 1-percent sales tax from which traffic calming and other transportation programs are funded; the City of Sacramento funds its program through gas and transportation sales taxes (Measure A). Albuquerque and Howard County both rely on local bond funds, which have certain logic for longer-lived investments.

Figure 15-8. Raised Intersection as Part of First Plan.

Source: Courtesy of the City of Ithaca, NY, USA.

Willingness to fund citizen-approved traffic calming plans may be the ultimate test of public support. Yet, whether cost-sharing is a good idea or a bad one is subject to debate. Also debated is the appropriate level of cost-sharing—whether the level should vary with circumstances and what circumstances are relevant.

One change noted in the 2004 survey is an increasing reliance on neighborhood residents to help finance their own traffic calming projects. When *Traffic Calming State of the Practice* was published, many jurisdictions were uncomfortable with any funding mechanism that might favor wealthy neighborhoods over poorer ones. Now, perhaps due to local fiscal constraints, about one-half of the governments surveyed rely partially or fully on private financing: Bellevue (fully for gateway treatments but not other measures), Broward County (fully), Charlottesville (fully in the speed hump program), Minneapolis (fully) and Seattle (partially through matching requirements).

Localities that rely on private financing mostly allow local residents to pay for aesthetic upgrades. This too represents a change from *Traffic Calming State of the Practice*, when equity considerations ruled. In Charlotte, NC, USA, for example, residents can opt to pay for decorative features and thereby move themselves to the head of the list of funded projects. While Albuquerque offers the same option, no neighborhood has yet taken advantage of it. This is one advantage of private financing schemes: Asking residents to pay for traffic calming measures is the surest test of the value they place in them.

B. The Right Tools

Traffic calming involves first identifying the nature of traffic problems on a given street or in a given neighborhood, then selecting traffic calming measures capable of solving identified problems cost-effectively. The measures come from a *toolbox* of possibilities. If the problem is cut-through traffic on local streets, one set of measures should be considered. If the problem is speeding on streets whose abutting uses are adversely affected, another set is appropriate. If the problem is a high rate of collisions, a third set may be preferred.

1. Physical Measures

The emphasis is on physical measures because of their proven effectiveness in reducing traffic speeds, volumes and/or collisions. Physical traffic calming measures are usually classified according to their dominant effect. *Volume-control* *measures* use barriers to preclude one or more movements along a street or at an intersection. Their primary purpose is to discourage or eliminate cut-through traffic. Full- and half-street closures, diverters of various types, median barriers and forced-turn islands are classified as *volume-control measures.*

Speed-control measures use deflection of vehicle travel paths to moderate speeds. Their primary purpose is to slow traffic to the posted speed limit. Speed humps, speed lumps, speed tables, raised intersections, traffic circles, chicanes, chokers, lateral shifts and realigned intersections are classified as *speed-control measures.*

The following subsections describe, illustrate and assess each of the commonly used physical measures.

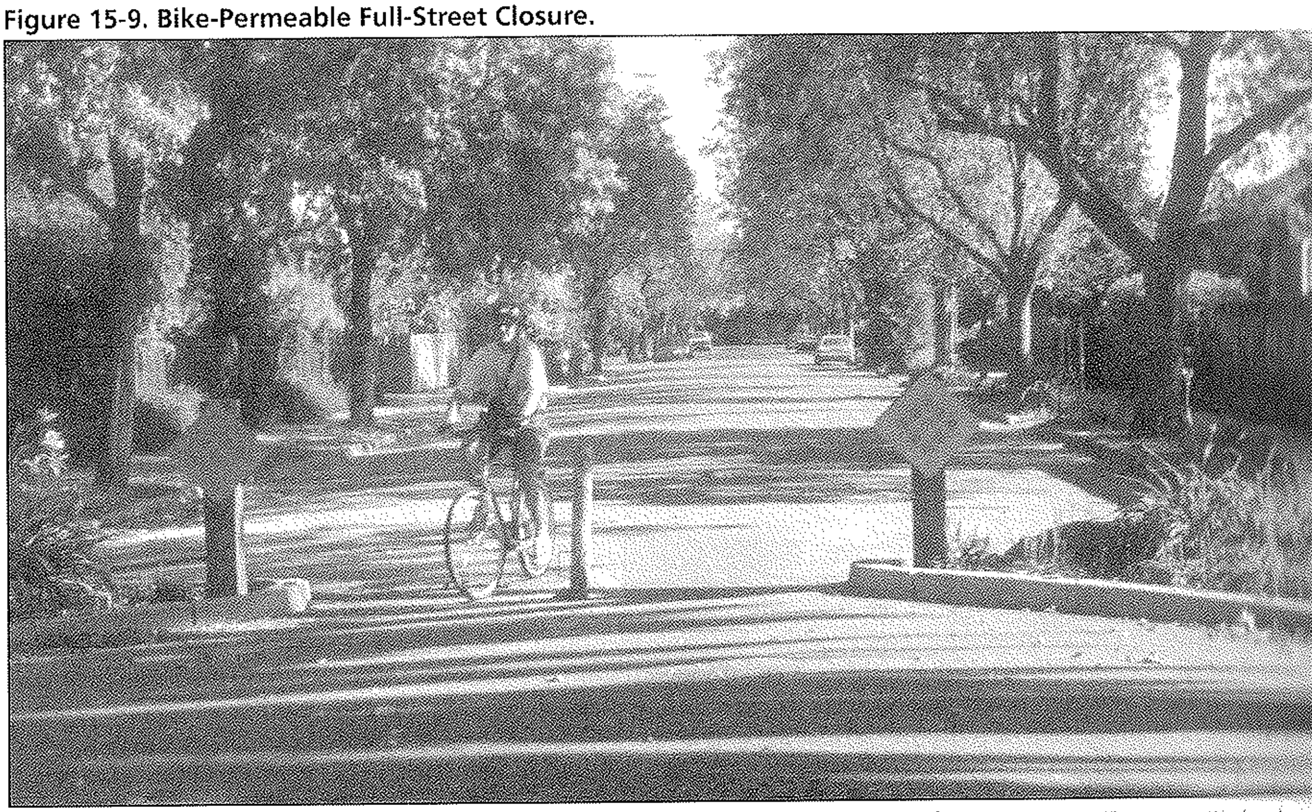
Volume-Control Measures. *Full-street closures* are barriers placed across a roadway to completely close the street to through traffic, usually leaving only sidewalks and bikeways open (see Figure 15-9). The full-street closure barrier can be placed mid-block or at an intersection.

The barriers may consist of landscaped islands, walls, gates, side-by-side bollards, or any other obstructions that leave openings smaller than the width of a passenger car. They may be fixed or have the ability to open or retract for service providers. Because they divert traffic problems and reduce street connectivity, they are typically a traffic calming measure of last resort.

Half closures are barriers that block travel in one direction for a short distance on otherwise two-way streets (see Figure 15-10). They are, therefore, less restrictive than full closures and seem to have replaced full closures as the most popular volume-control measure. When two half closures are placed across from one another at an intersection, the result is a *semi-diverter* that blocks through movement on a cross-street. Half closures can be placed at a mid-block location at an intersection.

Diagonal diverters are barriers placed diagonally across intersections, blocking all through movement and turns in one direction (see Figure 15-11).

Figure 15-9. Bike-Permeable Full-Street Closure.

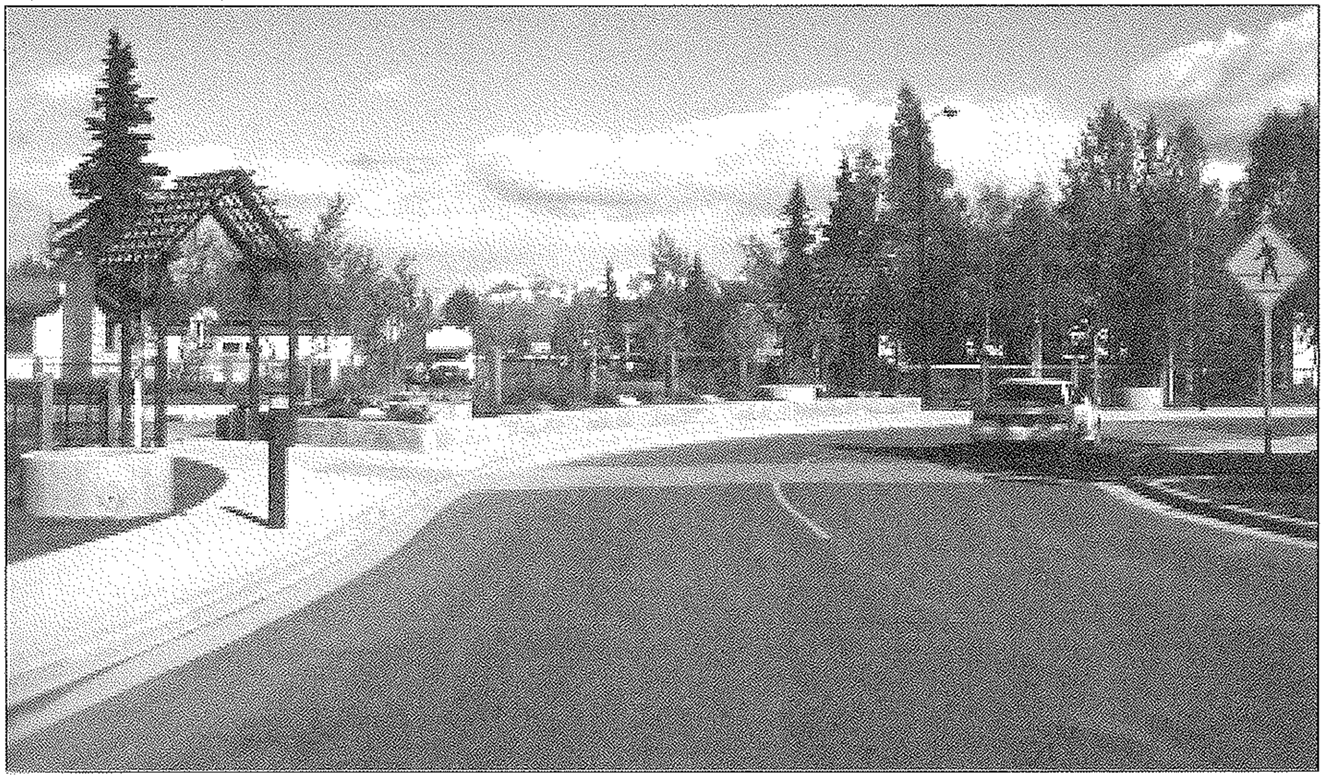


Source: Ewing, R. *Traffic Calming State of the Practice.* Washington, DC, USA: Institute of Transportation Engineers/Federal Highway Administration, 1999.

Figure 15-10. Half Closure.

Source: Courtesy of Reid Ewing.

Figure 15-11. Diagonal Diverter.



Source: Courtesy of Reid Ewing.

Median barriers are raised islands or raised obstructions (decorative bollards are shown as an example in Figure 15-12) located along the centerline of a street and continuing through an intersection so as to block through movement at cross-streets.

Forced-turn islands are raised islands on approaches to intersections that block certain movements (see Figure 15-13). In their most common incarnation, they are *right-turn islands*.

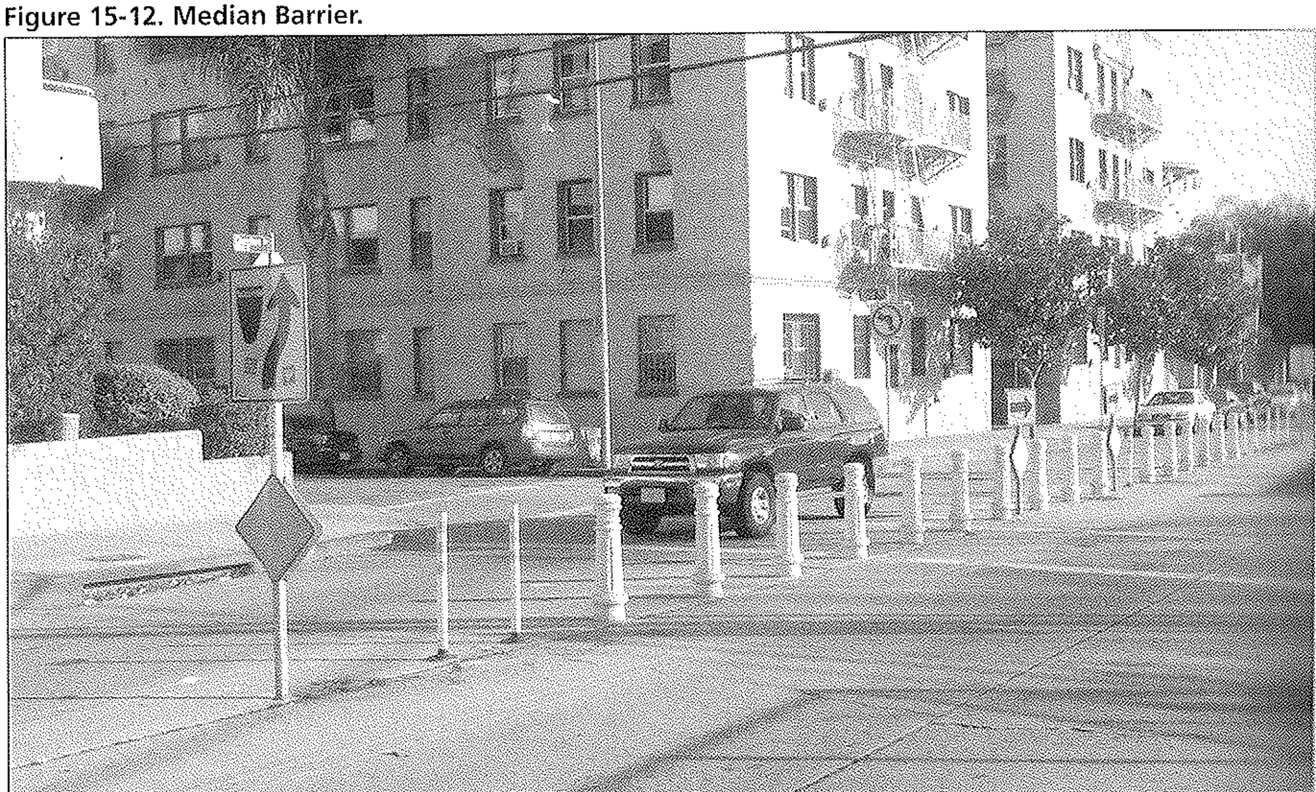
Speed Control with Vertical Measures. *Speed humps* are rounded raised areas placed across the roadway (see Figure 15-14). When used in close proximity, they are also referred to as *undulations*. Speed humps are the only speed-control measure, at present, for which ITE provides design and application guidance (see ITE's *Guidelines for the Design and Application of Speed Humps*).[15] Hump profiles longer than the Watts Profile—a 12-foot (ft.) hump (in the direction of travel) that rises 3 inches—have been found to result in higher design speeds and smoother transitions, which may be more appropriate on main roads.

Speed lumps (also called speed cushions) are rounded or flat-topped raised areas placed across the road with wheel cut-outs designed to allow large vehicles, such as fire trucks and buses, to pass with minimal slowing or rocking (see Figure 15-15). The center lump is often narrower than the outside lumps, allowing emergency vehicles to straddle it by crossing the centerline. Smaller vehicles, wherever they cross, and larger vehicles that stay in their travel lanes have at least one set of wheels up while passing over the outside lumps. Speed lumps are beginning to replace speed humps as the traffic calming measure of choice on emergency response routes.

Speed tables are flat-topped speed humps often constructed with brick or other textured materials on the flat section (see Figure 15-16). Speed tables are typically long enough for the entire wheelbase of a passenger car to rest on top. Longer ones may even accommodate trucks and buses. Their length and extended flat-topped sections give speed tables higher design speeds and smoother rides than humps, hence they tend to be used on higher-order roads.

Raised crosswalks are speed tables marked and signed as pedestrian crossings (see Figure 15-17). They often rise to sidewalk level or slightly below (to provide a "lip" for the visually impaired). Their height increases pedestrian visibility.

Figure 15-12. Median Barrier.

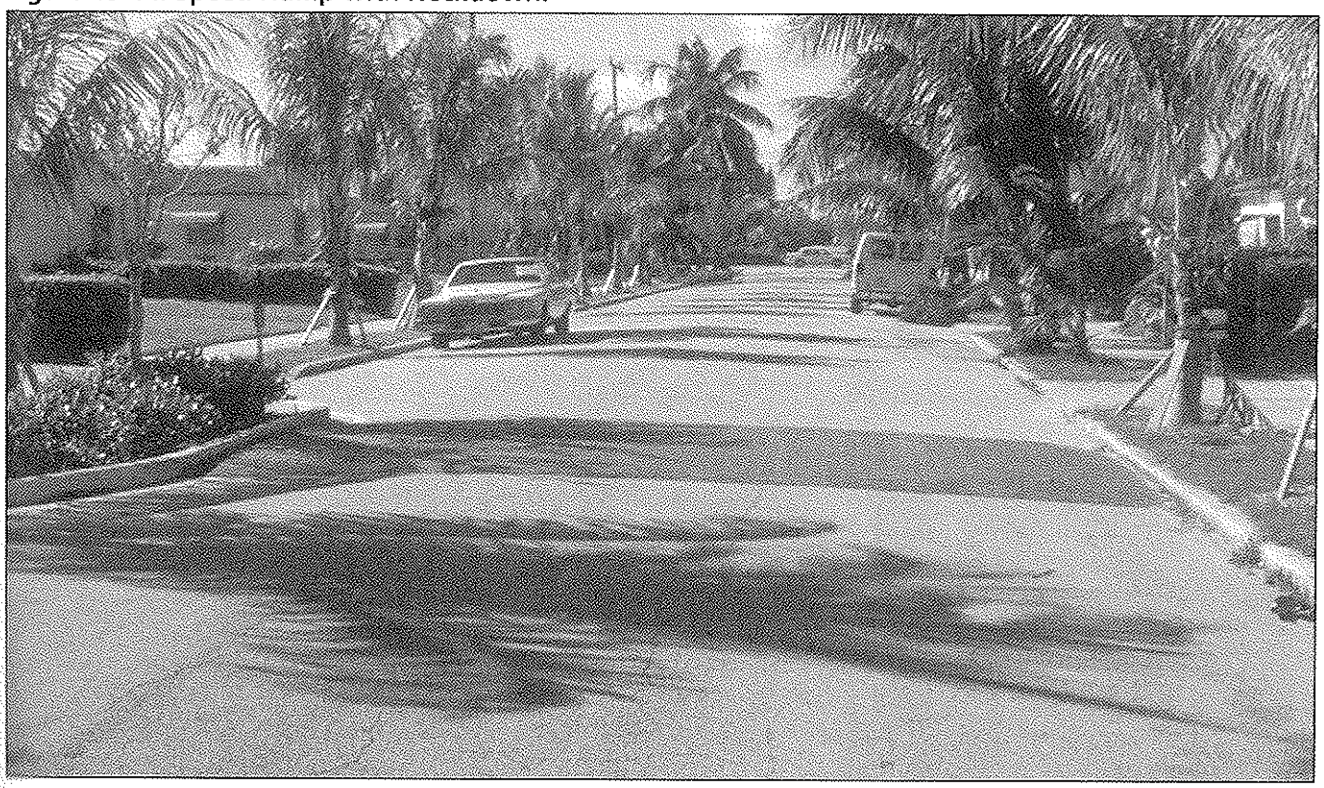


Source: Courtesy of Reid Ewing.

Figure 15-13. Forced-Turn Island.

Source: Ewing, R. *Traffic Calming State of the Practice.* Washington, DC, USA: Institute of Transportation Engineers/Federal Highway Administration, 1999.

Figure 15-14. Speed Hump with Neckdown.



Source: Courtesy of Reid Ewing.

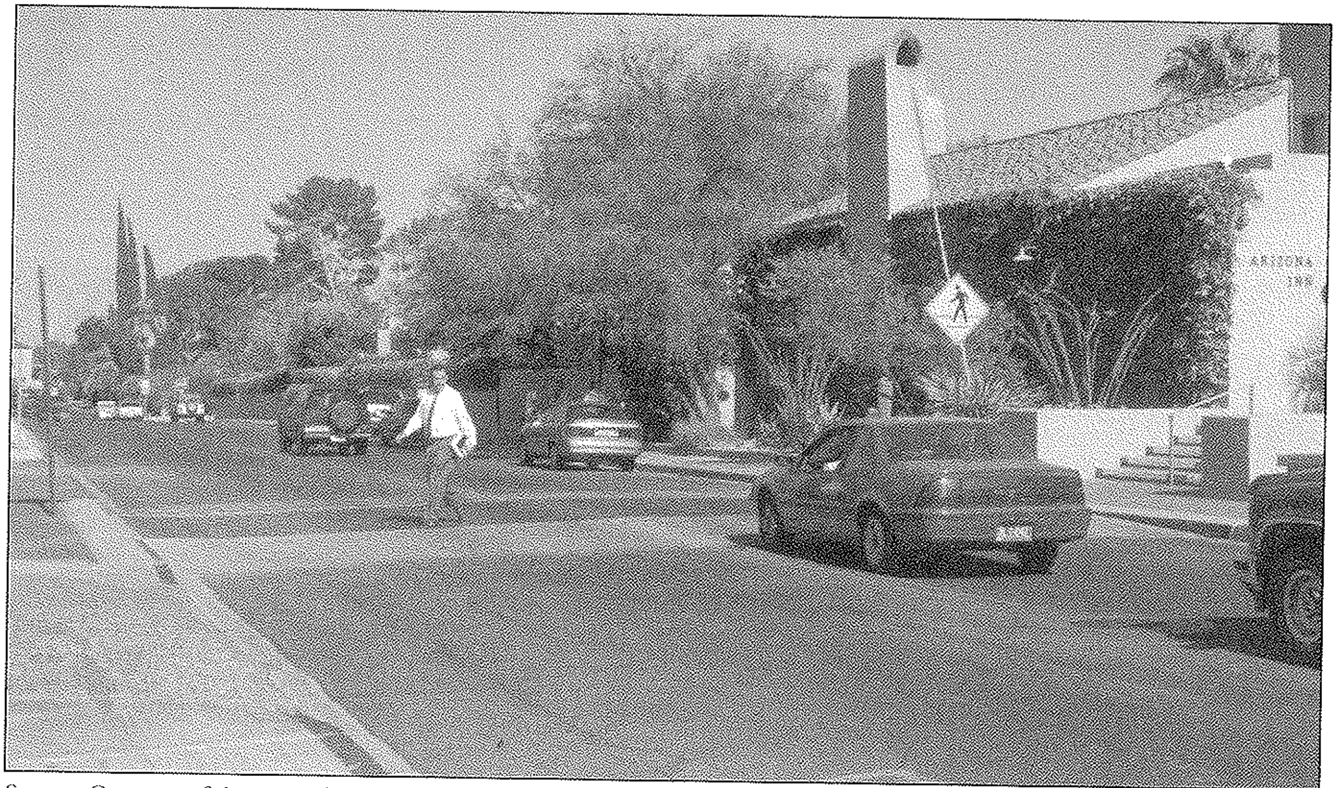
Figure 15-15. Speed Lumps.

Source: Courtesy of Fischer Associates.

Figure 15-16. Speed Table.

Source: Ewing, R. *Traffic Calming State of the Practice.* Washington, DC, USA: Institute of Transportation Engineers/Federal Highway Administration, 1999.

Figure 15-17. Raised Crosswalk.



Source: Courtesy of the City of Tucscon, AZ, USA.

Their flat sections, often brick or other textured materials, increase the visibility of the crosswalks themselves. The two together convert the crossing into pedestrian territory.

Raised intersections are flat, raised areas covering entire intersections with ramps on all approaches and often with textured crosswalks across the flat sections or plateau (see Figure 15-18). They make entire intersections, including the crosswalks, pedestrian territory. While relatively expensive, they have the advantage of calming two streets at once.

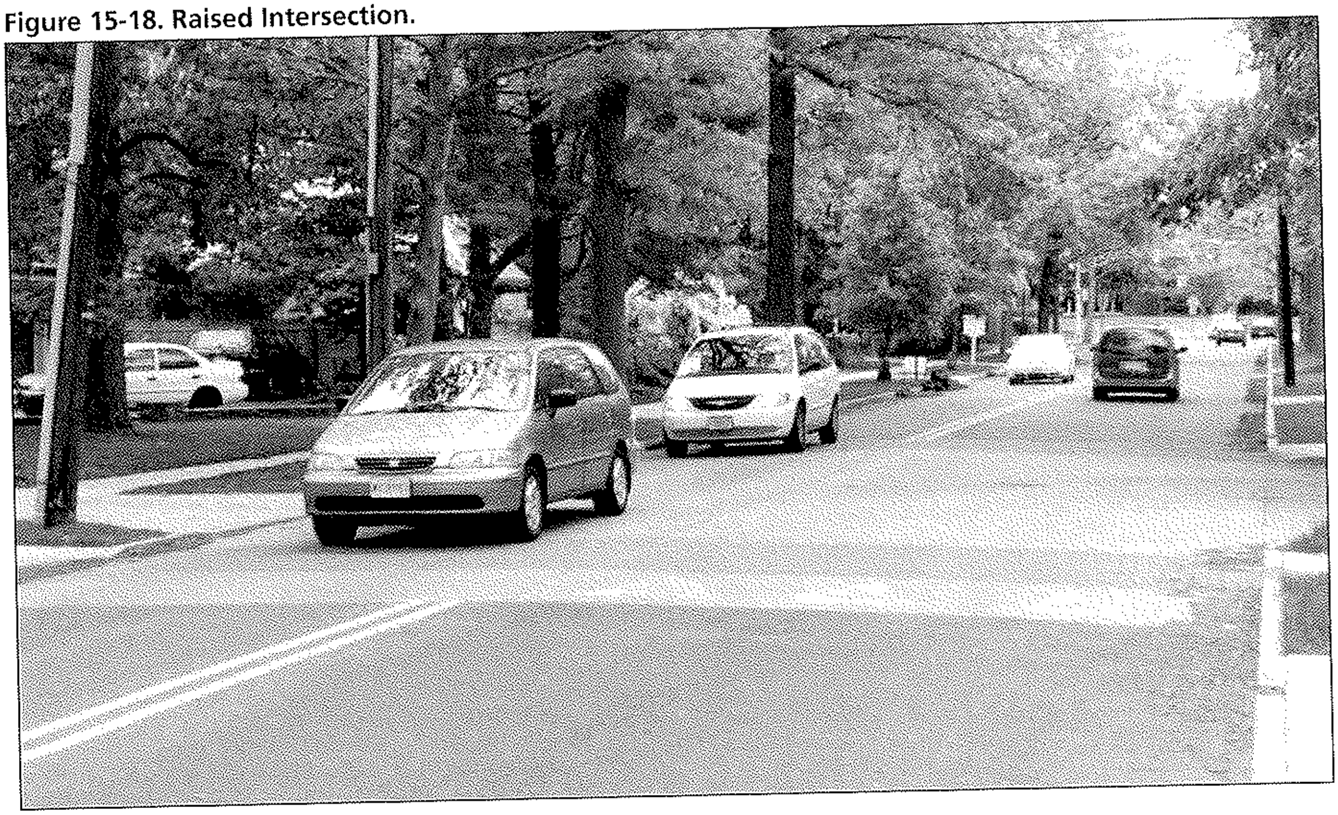
Speed Control with Horizontal Measures. *Mini traffic circles* are raised islands placed in intersections around which traffic circulates (see Figure 15-19). They are usually circular in shape but may be oval to fit the given intersection, and they are usually landscaped in their center islands for better aesthetics. In many cases, mini-circles result in horizontal clearances that are too small for left-turning trucks to circulate counterclockwise, even with partially mountable center islands. Instead, left turns are made in front of the islands. It is not uncommon to use STOP sign control in conjunction with circles, particularly where STOP signs pre-date traffic circle installation.

Roundabouts are similar to mini traffic circles in that traffic circulates around a center island, but they are used at higher-volume intersections to assign the right of way to traffic already in the roundabout and to require entering traffic to yield, if necessary (see Figure 15-20). Roundabouts are large enough for truck traffic to circulate counterclockwise. They are YIELD-controlled on all approaches to minimize delay. Roundabouts should not be confused with the older, even larger rotaries that operate on different principles and are gradually being replaced in the northeastern United States. Roundabouts force traffic to slow down as it enters an intersection, while traffic can speed around old-fashioned traffic circles.

Lateral shifts are realignments on otherwise straight streets that cause travel lanes to bend one way and then the other to head in the original direction of travel (see Figure 15-21). Lateral shifts, with just the right degree of horizontal curvature, are one of the few measures that can be used on collectors or even arterials where high traffic volumes and high posted speeds preclude more abrupt measures. They have become a mainstay of traffic calming on European thoroughfares.

Chicanes are curb extensions or edge islands that alternate from one side of the street to the other to form s-shaped curves. They are often designed as a series of lateral shifts rather than continuous curves (see Figure 15-22).

Figure 15-18. Raised Intersection.



Source: Courtesy of Reid Ewing.

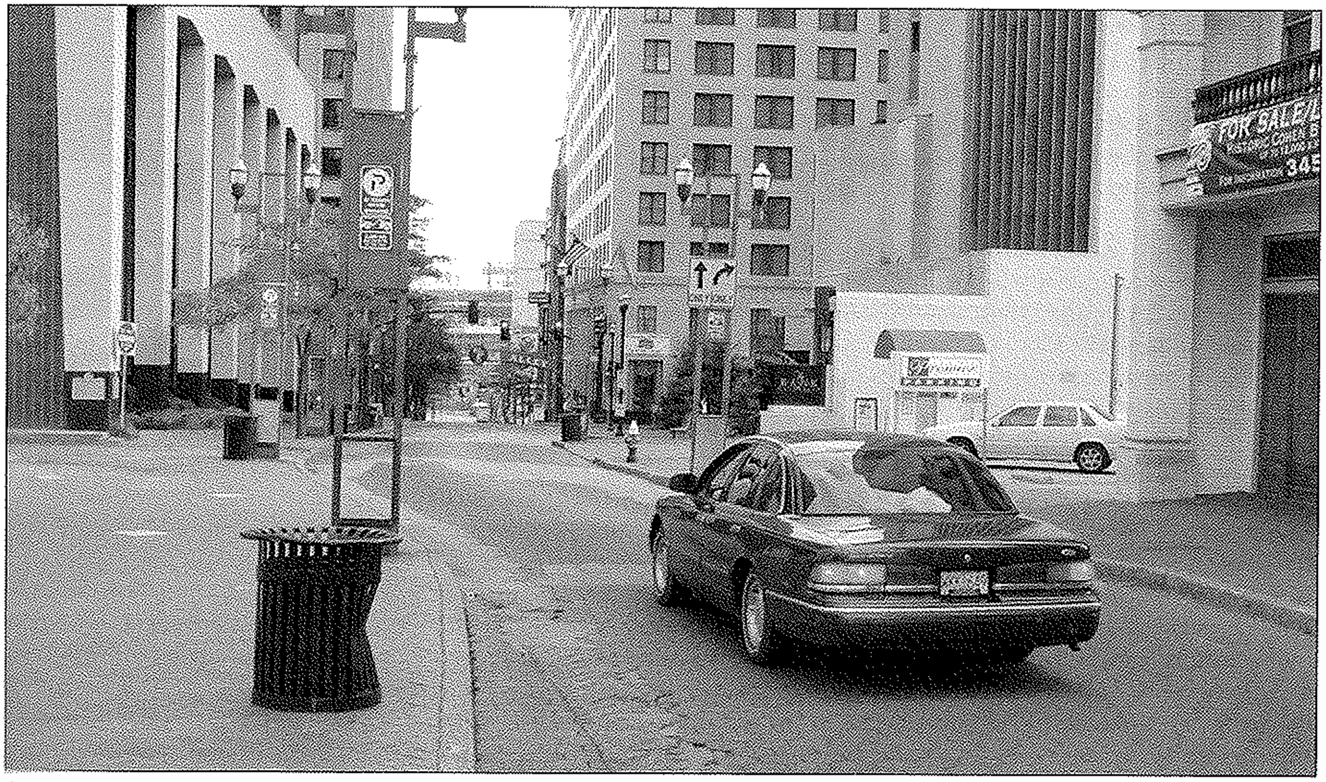
Figure 15-19. Mini Traffic Circle.

Source: Courtesy of Reid Ewing.

Figure 15-20. Roundabout with a Mountable Apron.

Source: Courtesy of Fehr and Peers.

Figure 15-21. Lateral Shift.



Source: Courtesy of Reid Ewing.

Figure 15-22. Chicane with Median.

Source: Courtesy of the City of Austin, TX, USA.

Realigned intersections are changes in alignment that convert T-intersections with straight approaches into curving streets meeting at right angles (see Figure 15-23). A direct path along the top of the T becomes a turning movement.

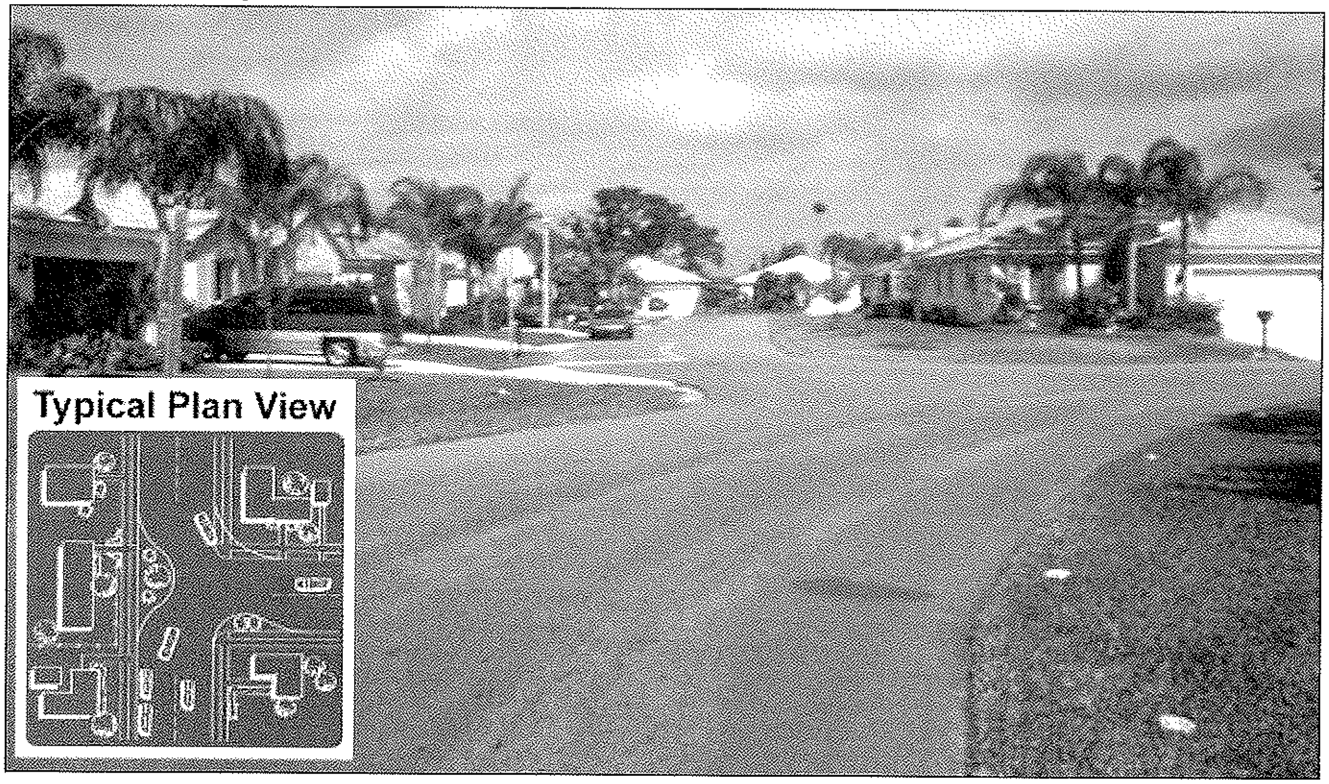
Speed Control with Narrowings. *Neckdowns* are curb extensions at intersections that reduce roadway width from curb to curb (see Figure 15-24). They are sometimes called *nubs* or *bulbouts*. Combined with on-street parking, they create *protected parking bays*. Placed at the entrance to a neighborhood, often with textured paving between them, they are called *gateways* or *entry features*. Their effect on vehicle speed is limited by the absence of pronounced vertical or horizontal deflection. Instead, their primary purpose is to "pedestrianize" intersections. They slow vehicle turning speeds, shorten pedestrian crossing distances and increase pedestrian visibility.

Chokers are curb extensions or edge islands at mid-block that narrow a street at that location (see Figure 15-25). Unlike neckdowns, which are limited to intersections, chokers can be located at any spacing desired for traffic calming. If marked as crosswalks, they are also called *safe crosses*. They are often combined with on-street parking to create *protected parking bays*. Chokers can leave the street cross-section with two lanes, albeit narrower lanes than before, or reduce it to one lane. One-lane chokers force two-way traffic to alternate going through the pinch point.

Center island narrowings are raised islands located along the centerlines of streets and narrow the street at those locations (see Figure 15-26). They are also called *median chokers*. Straddling the centerline, they may introduce slight deflection into travel paths on otherwise straight streets. Placed at the entrance to a neighborhood, often with textured paving on either side, they create *gateways* or *entry features*. They may serve as pedestrian refuges at marked crossings.

Combined Measures. The search for the optimal traffic calming measure may lead to various combinations of measures at single slow points. A hallmark of European practice, which may account for the greater reported impacts of traffic calming in Europe, is combining two or three measures at a single point. A standard traffic circle cannot control speeds on the top of a T-intersection, so curb extensions may be added on the approaches to achieve some horizontal deflection. A choker cannot control speeds in the absence of opposing traffic, so speed humps may be added in the gap between the curb extensions. Individual measures can be combined in any number of ways (illustrated in Figure 15-27). There is limited available evidence to suggest that when measures are combined they directly compound the effects on crossing speeds.

Figure 15-23. Realigned Intersection.



Source: Ewing, R. *Traffic Calming State of the Practice.* Washington, DC, USA: Institute of Transportation Engineers/Federal Highway Administration, 1999.

Figure 15-24. Neckdown.

Source: Courtesy of Reid Ewing.

Figure 15-25. Choker.

Source: Ewing, R. *Traffic Calming State of the Practice.* Washington, DC, USA: Institute of Transportation Engineers/Federal Highway Administration, 1999.

Figure 15-26. Median Choker.

Source: Courtesy of Reid Ewing.

Figure 15-27. Raised Crosswalk with Median Choker.

Source: Ewing, R. *Traffic Calming State of the Practice*. Washington, DC, USA: Institute of Transportation Engineers/Federal Highway Administration, 1999.

2. Effects of Traffic Calming Measures

Traffic calming involves matching physical measures to specific traffic problems. From the toolbox of measures described, the designer (or NTC) attempts to choose the most cost-effective and conservative measures that will do the job. For this reason, low-cost measures, such as speed humps and speed tables, are more common than high-cost measures, such as raised intersections and chicanes.

To assist with this choice, effectiveness data are presented in Tables 15-3 through 15-5. They are mostly taken, with some updating, from ITE's *Traffic Calming State of the Practice*, which draws on hundreds of before-and-after studies. On average, the different traffic calming measures all reduce speeds, volumes and collisions. However, certain measures are more effective than others and produce statistically significant effects. Sample averages, while not a substitute for detailed analyses of proposed treatments, can be used to initially screen traffic calming measures for further consideration.

Speed Effects. Speed effects of traffic calming measures depend primarily on geometrics and spacing. Geometrics determine the speeds at which motorists cross slow points. Spacing determines the extent to which motorists speed up between slow points.

The speeds reported in Table 15-3 are midpoint speeds after traffic calming. Of all traffic calming measures, speed humps have the greatest effect on 85th-percentile speeds at the midpoint (between devices), reducing them by an average of more than 7 miles per hour (mph), or 20 percent. Among speed-control measures, raised intersections and narrowings have the least effect. Interestingly, half closures—a volume-control measure—have as comparable an effect on speeds as speed tables.

Table 15-3. Speed Effects of Traffic Calming Measures.				
	Sample Size	**Average Speed After Traffic Calming (standard deviation from the average)**	**Average Change in Speed with Traffic Calming (standard deviation from the average)**	**Average Percent Change in Speed with Traffic Calming (standard deviation from the average)**
12-Ft. Humps	184	27.3 mph (4.0 mph)	–7.8 mph (3.7 mph)	–22 percent (–9 percent)
14-Ft. Humps	15	25.6 (2.1)	–7.7 (2.1)	–23 (6)
Lumps	48	26.9 (3.4)	–9,0 (5.3)	–20 (3)
22-Ft. Tables	78	29.2 (3.1)	–7.3 (3.4)	–20 (8)
Longer Tables	11	31.3 (2.9)	–3.6 (2.6)	–10 (7)
Raised Intersections	3	34.3 (6.0)	–.3 (3.8)	–1 (10)
Mini-Circles	45	30.3 (4.4)	–3.9 (3.2)	–11 (10)
Narrowings	7	32.3 (2.8)	–2.6 (5.5)	–7 (22)
One-Lane Slow Points	5	28.6 (3.1)	–4.8 (1.3)	–14 (4)
Half Closures	16	26.3 (5.2)	–6.0 (3.6)	–19 (11)
Diagonal Diverters	7	27.9 (5.2)	–1.4 (4.7)	–4 (17)

Note: Values in parentheses are standard deviations from the average.

Source: Ewing, R. *Traffic Calming State of the Practice.* Washington, DC, USA: Institute of Transportation Engineers/Federal Highway Administration, 1999, p. 104.

Volume Effects. Volume effects are much more complex and case-specific than speed impacts. They depend on the entire network, of which a street is a part, not just the characteristics of the street itself. The availability of alternate routes and the application of other measures in area-wide treatments may have as large an impact on volumes as geometrics and spacing of slow points.

Volume impacts depend fundamentally on the split between local and through traffic. Traffic calming measures will not affect the amount of local traffic unless they are severe. With rare exceptions, traffic calming measures in North America are unlikely to be restrictive enough to affect motor vehicle trip rates. What traffic calming measures do instead is reroute non-local traffic.

As expected, the largest volume reductions occur with street closures and other volume-control measures (see Table 15-4). However, significant reductions also occur with humps and other speed-control measures. The distinction between volume controls and speed controls becomes blurred in practice.

Table 15-4. Volume Effects of Traffic Calming Measures.

	Sample Size	Average Change in Volume with Traffic Calming (standard deviation from the average)	Average Percent Change in Volume with Traffic Calming (standard deviation from the average)
12-Ft. Humps	143	–355 vpd (591)	–18 percent (24 percent)
14-Ft. Humps	15	–529 (741)	–22 (26)
Lumps	18	–165 (211)	0 (0)
22-Ft. Tables	46	–415 (649)	–12 (20)
Mini-Circles	49	–293 (584)	–5 (46)
Narrowings	11	–263 (2178)	–10 (51)
One-Lane Slow Points	5	–392 (384)	–20 (19)
Full Closures	19	–671 (786)	–44 (36)
Half Closures	53	–1611 (2444)	–42 (41)
Diagonal Diverters	27	–501 (622)	–35 (46)
Other Volume Controls	10	–1167 (1781)	–31 (36)

Note: Values in parentheses are standard deviations from the average.

Source: Ewing, R. *Traffic Calming State of the Practice*. Washington, DC, USA: Institute of Transportation Engineers/Federal Highway Administration, 1999, p. 106.

Safety Effects. By slowing traffic, eliminating conflicting movements and/or sharpening drivers' attention, traffic calming may result in fewer collisions. Due to lower speeds, collisions may be less serious when they do occur. What makes safety effects so consequential politically is that opposition to traffic calming is based principally on safety concerns—concerns related to emergency response.

Collision effects of traffic calming measures, with and without adjustments for traffic diversion, are presented in Table 15-5. A difference-of-means test for paired samples was used to check for significant changes in collision frequencies after traffic calming. As a whole, collisions decline to a significant degree after traffic calming (the difference being statistically significant at the .001 probability level). Adjusting for changes in traffic volumes and dropping cases for which volume data are not available, collisions decline to a less significant degree (but still statistically significant at the conventional .05 level). This drop in statistical significance has as much to do with the exclusion of Seattle's circles (with their amazing safety record) as with the adjustment for lower traffic volumes after traffic calming.

As for individual traffic calming measures, all reduce the average number of collisions on treated streets, and 22-ft. tables and traffic circles produce differences that are statistically significant. Including the Seattle data, circles are by far the best performers.

Table 15-5. Safety Effects of Traffic Calming Measures.	Sample Size	Average Number of Collisions Before/ After Treatment	Percent Change in Collisions After Treatment	t-Statistic (Significance Level—Two-Tailed Test)
Humps	54	2.8/2.4	–14	–1.2 (.22)
22-Ft. Tables	51	1.5/.8	–47	–3.0 (.005)
Mini-Circles				
without Seattle	17	5.9/4.2	–29	–2.2 (.05)
with Seattle	130	2.2/.6	–73	–10.8 (.001)
Roundabouts	11	9.3/5.9	–37	N/A
All Measures*				
without Volume Adjustments	235	2.2/1.1	–50	–8.6 (.001)
with Adjustments	47	1.8/1.2	–33	–2.5 (.05)

Note: These figures do not include data for roundabouts. In the second line, collision frequencies were adjusted proportionally for changes in traffic volumes and, therefore, exposure after traffic calming.

Source: All but the roundabout data are taken from Ewing, R. *Traffic Calming State of the Practice.* Washington, DC, USA: Institute of Transportation Engineers/Federal Highway Administration, 1999, p. 112. The roundabout data come from Troutbeck, R. et al. *Roundabouts: An Informational Guide.* Washington, DC, USA: Federal Highway Administration, 2000, p. 112.

3. Application Guidelines

Application guidelines are traffic calming measures that are appropriate for use on streets of different types with different traffic characteristics. Application guidelines are advisory only. They do not constitute a set of warrants or minimum requirements but rather can be overridden in specific cases by engineering judgment. In traffic calming, there is a trend away from warrants and toward guidelines. Application guidelines have been adopted by many jurisdictions. Summarizing practices from the 2004 survey:

- *Traffic Calming State of the Practice* predicted an expansion of U.S. programs to streets higher up the functional hierarchy. To a limited degree, this has occurred. Many surveyed jurisdictions now treat collector streets. Six jurisdictions—Bellevue, Charlottesville, Eugene, Howard County, Portland and Vancouver—have extended eligibility to arterials. This is mostly done on an exception basis with a limited array of measures deemed appropriate.

- Moving up the roadway hierarchy from to local streets to arterials, the set of eligible traffic calming measures becomes more limited. Howard County has a complete toolbox for local streets but limits major collectors to restriping, roundabouts, chokers and medians (and then only if enforcement and education have proven ineffective). Vancouver is similar with respect to local streets but limits arterials to landscaping, high-visibility striping, roundabouts, chokers, medians and photo enforcement.

- Volume-control measures are available only under limited circumstances. In Sacramento, they come into play in the second phase of traffic calming, only after speed-control measures have been applied. Full closures have been dropped from the toolboxes of several agencies because they are too restrictive to traffic flow, emergency access and public service in general. If volume controls are used at all, they typically take the form of half closures or forced-turn islands.

- Among speed-control measures, speed humps, speed lumps and one-lane chokers are applicable to the lowest traffic volumes and speeds; speed tables, chicanes and realigned intersections are applicable to intermediate volumes and speeds; and lateral shifts, roundabouts and narrowings are applicable to higher volumes and speeds (though not to the highest volumes or speeds).

One particularly complete set of guidelines adopted by the City of Sacramento is reproduced in Table 15-6. Such guidelines may be tailored to other jurisdictions through the process described in "The Right Process."

Table 15-6. Application Guidelines for the City of Sacramento, CA, USA.

Types of Measures	Roadway Classification			Bus or Emergency Response Route	Other Considerations
	Arterials	Collectors	Local Streets		
Phase I Non-Restrictive Measures					
Edgeline/Centerline Striping	ADT < 10,000; Speed Limit • 35 mph			OK	(None)
Angled Parking	ADT < 4,000; Width • 48 feet; Speed Limit • 30 mph			No	Not used with bike lanes
Phase I Vertical Measures					
Speed Humps	No	ADT < 4,000; Speed Limit • 30 mph		No	Grade • 8%
Speed Lumps	No			OK	
Speed Tables	ADT < 7,500; Speed Limit • 35 mph			OK	
Raised Crosswalks				OK	
Raised Intersections				OK	
Textured Pavement	Yes			OK	(None)
Phase I Horizontal Measures					
Traffic Circles	No	Daily Entering Volume < 7,500; Speed Limit • 35 mph		No	Grade • 10%
Roundabouts (Single-Lane)	Daily Entering Volume < 18,000; Speed Limit • 45 mph		No	Desired design radius of 50+ feet	Grade • 6%; On bike routes, design with clear bike accommodations
Lateral Shifts	No	ADT < 10,000; Speed Limit • 35 mph		OK	Grade • 10%
Chicanes	No	ADT < 5,000; Speed Limit • 35 mph		OK	Grade • 8%
Realigned Intersections	No	Daily Entering Volume < 5,000; Speed Limit • 35 mph		OK	Grade • 8%
Phase I Narrowing Measures					
Neckdowns	ADT < 20,000; Speed Limit • 35 mph			OK	On bike routes, design with clear bike accommodations
Two-Lane Chokers				OK	
Center Island Narrowings/ Pedestrian Refuges	ADT < 20,000; Speed Limit • 35 mph			OK	
One-Lane Chokers	No		ADT < 3,000; Speed • 30	No	Public Works must review sight distance, other physical constraints
Phase II Restrictive Measures[1]					
Full Closures	No	No	Yes	No	(None)
Half Closures	No	ADT < 5,000; > 25% Non-Local Traffic		Public Works & RT must review	(None)
Diagonal Diverters	No			No	(None)
Median Barriers	No			No	(None)
Forced Turn Islands	No			No	(None)
Combined Measures	Subject to Constraints of Component Measures				
Note: [1] Only if other measures are deemed unsatisfactory. Not to be used on new streets.					

Source: Courtesy of the Department of Public Works, City of Sacramento, CA, USA, 2003.

III. CURRENT PRACTICES

A. Design

1. General Guidance

Geometric design of traffic calming measures is based primarily on the desired speed at slow points, which is the *design speed* for this design activity. Once this speed is set, appropriate spacing of slow points can be determined based on target speeds midway between such points.

Ordinarily, crossing speeds at slow points are no more than *5 mph below* the posted speed limit (although with advisory speed signs, greater differences are acceptable). Also, as a rule, midpoint speeds should be no more than *5 mph above* the posted speed limit. The speed differential on a given stretch of roadway is thus limited to 10 mph in the interest of traffic safety, noise control, fuel conservation and driver acceptance. This also limits the spacing of slow points because midpoint speeds increase as spacing increases.

Geometric design is also based on the dimensions of vehicles in the traffic stream. For most typical designs, a passenger car or single-unit truck is the design vehicle. Geometrics of slow points are set so a *design vehicle* can negotiate them at the design speed. Larger trucks and buses are accommodated in different ways, such as with mountable overrun areas. While large vehicles may be forced to cross slow points at a crawl speed, this is acceptable given the relatively few large vehicles on streets treated with the most restrictive measures. In application guidelines, the most restrictive measures are reserved for the lowest-order streets.

Typical designs of traffic calming measures are described in the following subsections. The designs come with geometric details and markings. Signing conventions are described in the next section. Typical designs were originally developed for the Delaware *Traffic Calming Manual* but have since been updated for the manuals of Sacramento and other California communities.

2. Volume-Control Measures

Full closures are ordinarily considered only when other volume-control measures have proven inadequate. Given the rarity of such cases and the fact that turnarounds can be designed in so many ways, no typical design has been developed for a full-street closure.

The typical *half closure* has two geometric features designed to encourage compliance with the one-way restriction (see Figure 15-28). Proper design is important to deter illegal maneuvers around the device. First, the curb extension or edge island extends more than a car length along the roadway. Motorists traveling the wrong way through the half closure are doing so for an uncomfortable distance. Second, the curb extension or edge island extends all the way to the centerline of the street or beyond on a wide street. This leaves a relatively tight opening for wrong-way traffic.

To further enhance compliance with the one-way designation, half closures should be located at intersections. Once through-traffic is already traveling down a street in the restricted direction, there is a strong tendency to continue through a half closure.

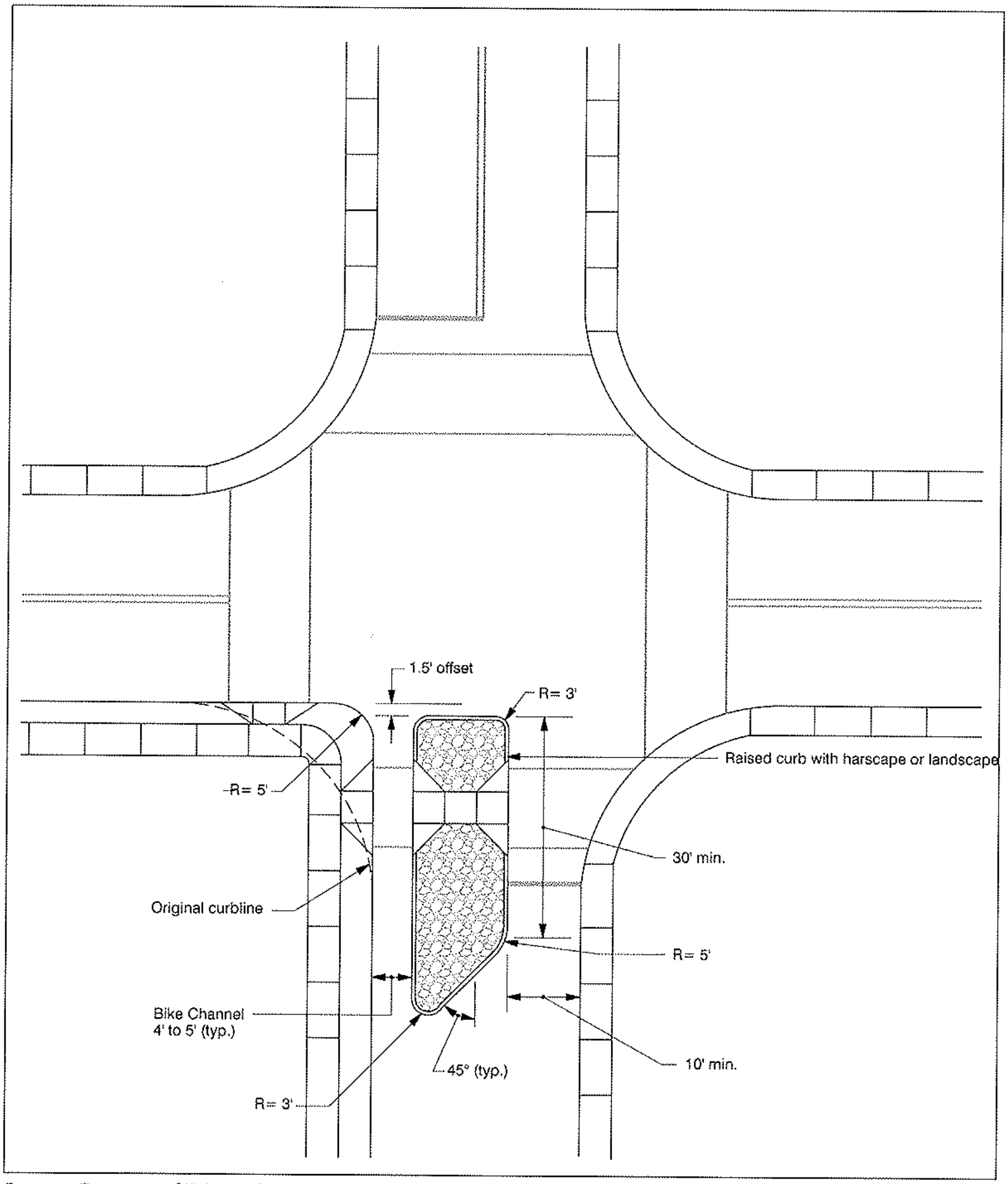
Along bicycle routes, the preferred design is a bicycle pass-through lane through the half closure. When bicycle lanes are bordered on both sides by vertical curbs, their channel widths should be 4 to 5 ft., which is wide enough to provide clearance for bicyclists but narrow enough to exclude passenger cars.

Diagonal diverters, median barriers and *forced-turn islands* have clear widths sufficient for the design vehicle to make turns at treated intersections without encroaching into opposing lanes. At pedestrian crossing points, at-grade pedestrian cut-throughs or Americans with Disabilities Act (ADA)–compliant ramps and plateaus need to be provided. Diagonal diverters should have openings 4 to 5 ft. wide, sufficient for bicyclists—but not motorists—to pass through. Median barriers should extend far enough through the intersection to prevent motorists on cross-streets from going around the barriers. Forced-turn islands should be sharply angled toward the right on the approach to discourage wrong-way movement.

3. Vertical Speed-Control Measures

The profile of vertical devices may vary depending upon the most pressing concerns (speed reduction, snow equipment accommodation, bicyclist accommodations and so forth). Three typical types of vertical curves are used in the approach and departure to vertical devices (see Figure 15-29):

Figure 15-28. Partial Closure.



Source: Courtesy of Fehr and Peers.

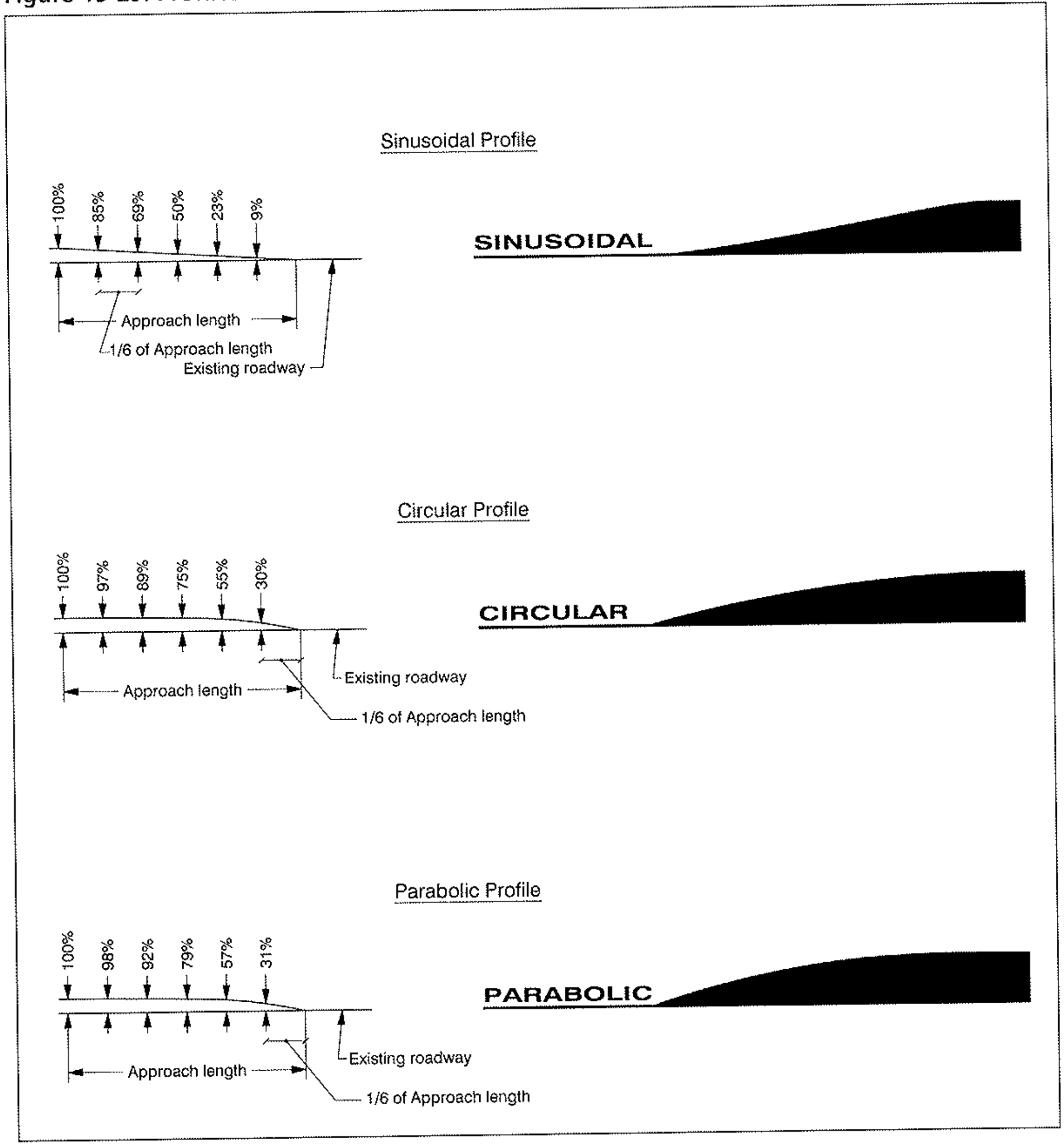
- **Sinusoidal** profiles reduce speed slightly less than circular or parabolic profiles but provide greater comfort levels for drivers and bicyclists. They are typically more difficult and expensive to construct. Snow clearance may also be facilitated by the sinusoidal profile.

- **Circular** profiles reduce speed moderately (compared to the other two profiles) and provide moderate comfort levels for drivers and bicyclists.

- **Parabolic** profiles reduce speed the most but are the least comfortable for drivers and bicyclists.

ITE's *Guidelines for the Design and Application of Speed Humps* recommends either sinusoidal or parabolic profiles for speed humps.[16]

Figure 15-29. Profiles for Vertical Devices.



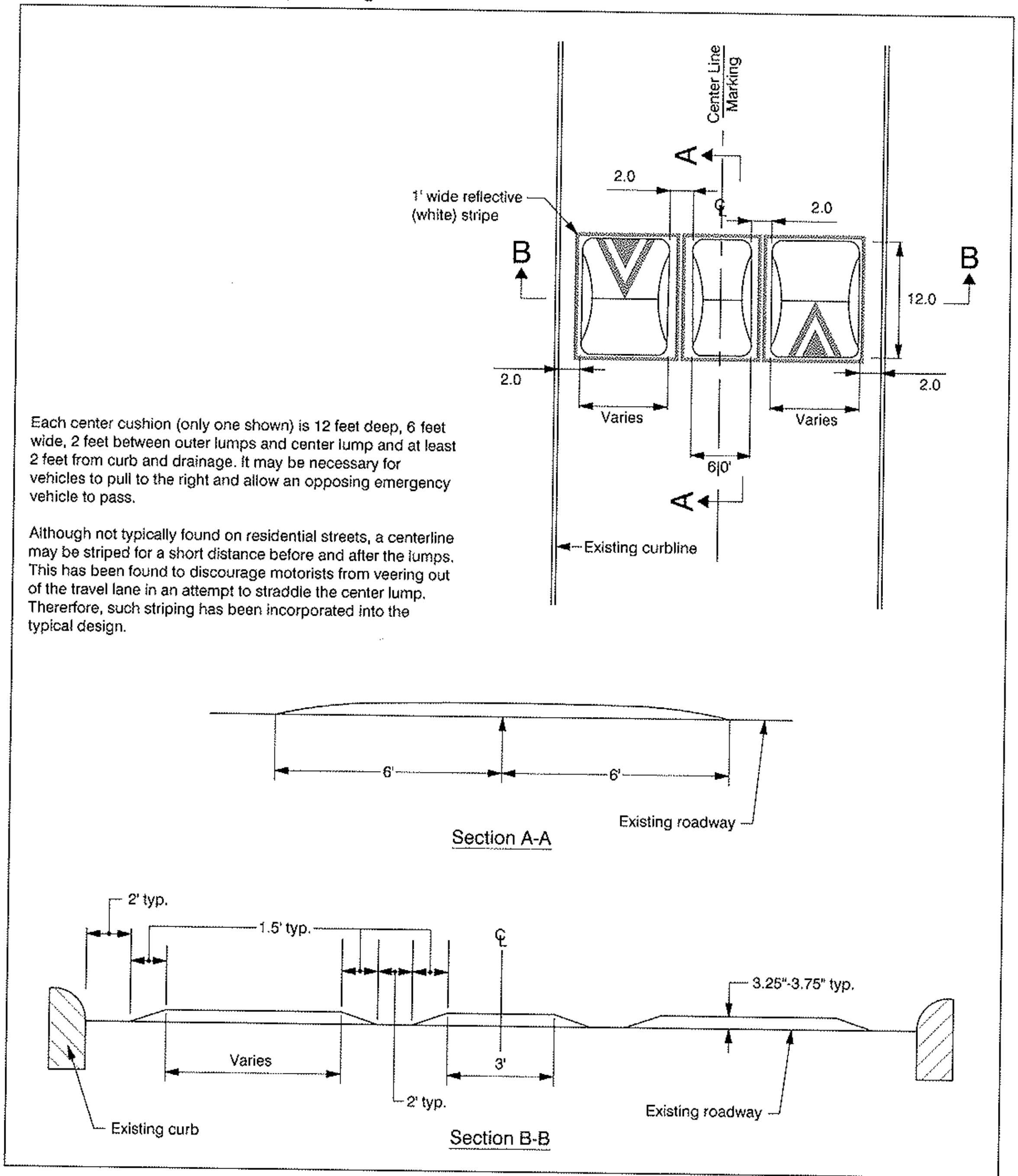
Source: Courtesy of Fehr and Peers.

Speed humps were developed and tested by Britain's Transport and Road Research Laboratory. They are the only traffic calming measure sanctioned by ITE, which has issued a recommended practice. The typical speed hump is 12 to 14 ft. in the direction of travel, 3 inches high, with construction tolerances ranging from a minimum of 2.75 to 3.5 inches. ITE's proposed *Guidelines for the Design and Application of Speed Humps* provides detailed recommendations about speed hump installation.

To achieve particular crossing speeds, humps may range in height. Less than 2 inches produces little speed reduction; more than 4 inches greatly increases the risk of grounding. Humps may be longer than the typical design. Portland's 14-ft. hump has received a measure of acceptance nationally.

Speed lumps are usually the same basic parabolic shape, same length in the direction of travel and same 3- to 4-inch height as speed humps (see Figure 15-30). The difference is that they have gaps, or cut outs, spaced such that emergency and transit vehicles can straddle individual lumps, while passenger cars and mid-size sports utility vehicles must

Figure 15-30. Speed Lumps Design.



Source: Courtesy of Fehr and Peers.

ride up and over them on at least one set of wheels. In the typical design, the center lump is 6 ft. wide and the opening for the wheels is 2 ft. wide.

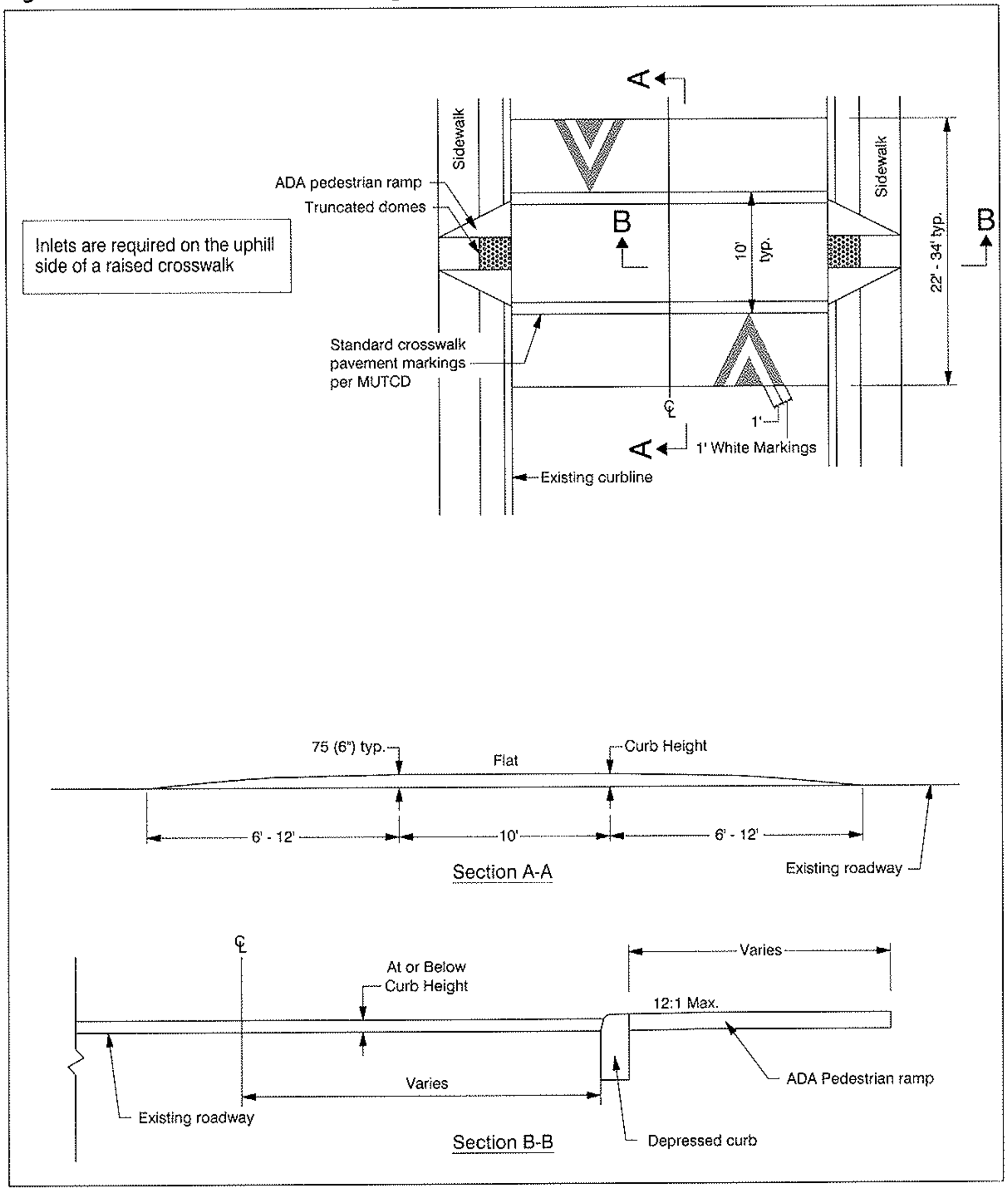
The number and width of lumps required on a given cross-section is a function of street width. Alternative designs are flat-topped like speed tables and/or shorter in the direction of travel. Asphalt permanent lumps and rubberized temporary lumps are about equally popular.

Speed tables come with two different profiles. The original profile, from Seminole County, FL, is modeled after the 12-ft. hump. It has 6-ft. ramps with the same parabolic shape as the rises of a 12-ft. hump; a flat 10-ft. plateau has simply been inserted between the two ramps to create a speed table. Having the same vertical rise as the 12-ft. hump over almost twice the length and having a flat section upon which the wheels of a passenger car can rest, the 22-ft. speed table has a much higher design speed and gentler ride than a 12-ft. speed hump.

For various reasons, including aesthetics and ease of construction, Gwinnett County developed an alternative design that seems to be gaining popularity. It uses straight rather than curved ramps, making them trapezoidal in shape like European and British speed tables. The plateau is made of asphalt, concrete, brick or concrete pavers, stamped asphalt, or other patterned materials.

Raised crosswalks are speed tables marked and signed for pedestrian crossing (see Figure 15-31). The main difference between the two is their placement. Raised crosswalks are located at pedestrian crossings. If built to typical speed table specifications, a raised crosswalk will stop 2 to 3 inches short of standard curb height and sidewalk level. A raised

Figure 15-31. Raised Crosswalk Design.



Source: Courtesy of Fehr and Peers.

crosswalk may extend all the way to the sidewalk or may dip down and then up again to maintain drainage channels. The sidewalk must connect to the crosswalk via curb ramps that meet ADA standards for accessible design.

Raised intersections are speed tables that cover entire intersections. They have ramps on all approaches and, in the typical design, they also have crosswalks on all approaches. All other geometric requirements for speed tables also apply to raised intersections.

With both raised crosswalks and raised intersections, the visually impaired must be warned at the street edge that they are entering a hazardous area. This warning is usually accomplished through truncated domes or comparable tactile surfaces. These may be supplemented by bollards or other street furniture to protect waiting pedestrians and to prevent corner-cutting by motorists.

Encroachment of a raised crosswalk or raised intersection into the gutter area will block normal drainage flows and may add considerably to the cost of installation. Drainage needs to be provided on the uphill side of the raised crosswalk, or a drainage pipe may be embedded in the pavement to carry stormwater. Because drainage pipes tend to become clogged with debris, they require frequent maintenance.

4. Horizontal Speed-Control Measures

Mini traffic circles were pioneered in Seattle in the 1980s. Because Seattle circles are sized to fit intersections, they cannot have a single geometric design. Rather, standard specifications are defined by intersection geometrics. Seattle's standard specifications were developed using a single-unit truck as the design vehicle. Dimensions of the circles are sufficient for the truck to circulate clockwise around the center island; larger vehicles must mount the curb on the center island or turn left in front of the center island. This unconventional circulation pattern in advance of the circle is workable if its use is limited to intersections with low left-turning volumes.

The wider the intersecting streets, the bigger the center island must be to achieve adequate lateral deflection (see Figure 15-32). If the intersecting streets have different widths, the center island must be oblong to achieve adequate deflection on all approaches. Seattle's design parameters are also being used in places such as Dayton, OH, USA, and Madison, WI, USA.

Most traffic circles are deployed at four-way intersections because this is where they generate the greatest safety benefits. For traffic circles at T-intersections, curbs should be either extended at the entrance and exit to the intersection or reconstructed within the intersection to ensure adequate deflection of vehicle paths along the top of the T.

Design of traffic circles has a vertical dimension as well. The cross-slopes at intersections are usually away from center islands. This makes center islands more visible to approaching motorists and also helps with drainage. Center islands typically have mountable outer curbs (or *aprons*) with vertical inner curbs that protect landscaped centers. The outer, mountable curbs allow circles to be negotiable by larger vehicles but discourage passenger cars from following a racing line to minimize lateral deflection.

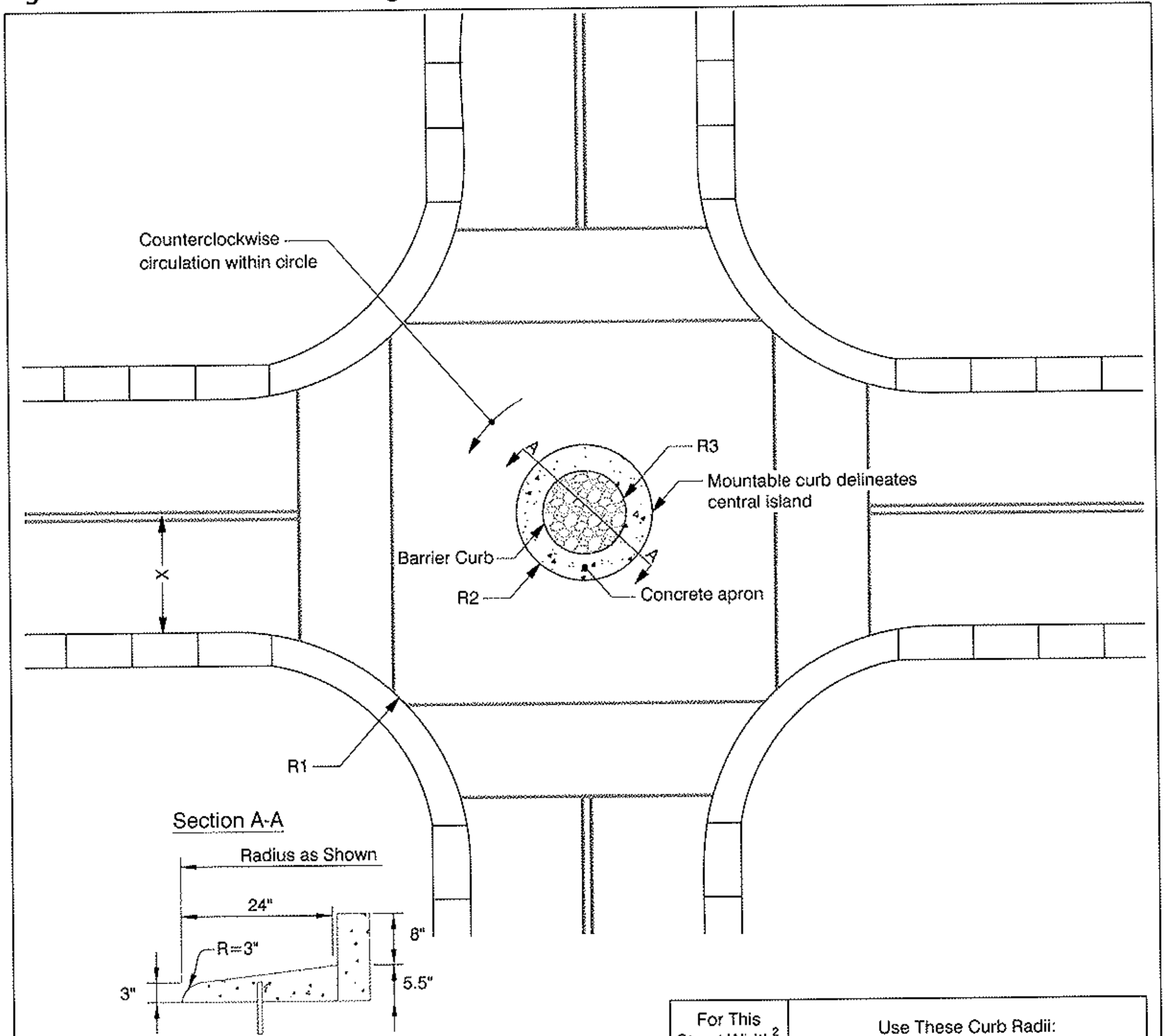
Roundabouts are distinguished from mini-circles by larger radii; correspondingly higher design speeds and capacities; and splitter islands on all approaches to slow traffic and discourage wrong-way movements. They usually have outer rings (called truck aprons) that are mountable to accommodate the largest vehicles. Roundabout entry and exit curves form the envelope of each splitter island. Pavement markings and a raised island fill the envelope.

Like mini-circles, roundabouts may be elongated to better fit into intersections whose entering roadways have different widths. Skewed intersections, offset intersections and combinations of two or more close intersections are common reasons that a roundabout might not be an ideal circle. However, non-circular design is not preferred because European experience suggests that oval-shaped roundabouts have higher collision rates than circular ones.

If pedestrians are anticipated, the splitter islands should extend back from the intersection, and the pedestrian crossing points should be set back at least one car length from the yield line so that pedestrians can cross behind waiting cars. The pedestrian crossing points should be marked as crosswalks.

Lateral shifts are changes in roadway alignment that create reverse curves. The shift in alignment is typically one lane width or more over a short distance longitudinally (see Figure 15-33). It is created by bending or angling curb lines, or by means of edge and center islands. Edge islands leave existing drainage channels open and tend to be less expensive to construct.

Figure 15-32. Traffic Circle Design.



NOTES: 1. Distance X is referenced from the center of the roadway to the lip of gutter.
2. Assumes equal street widths; For unequal street widths, use truck turning template (AASHTO or local truck dimensions) to ensure adequate turning radii for the desired design vehicle.

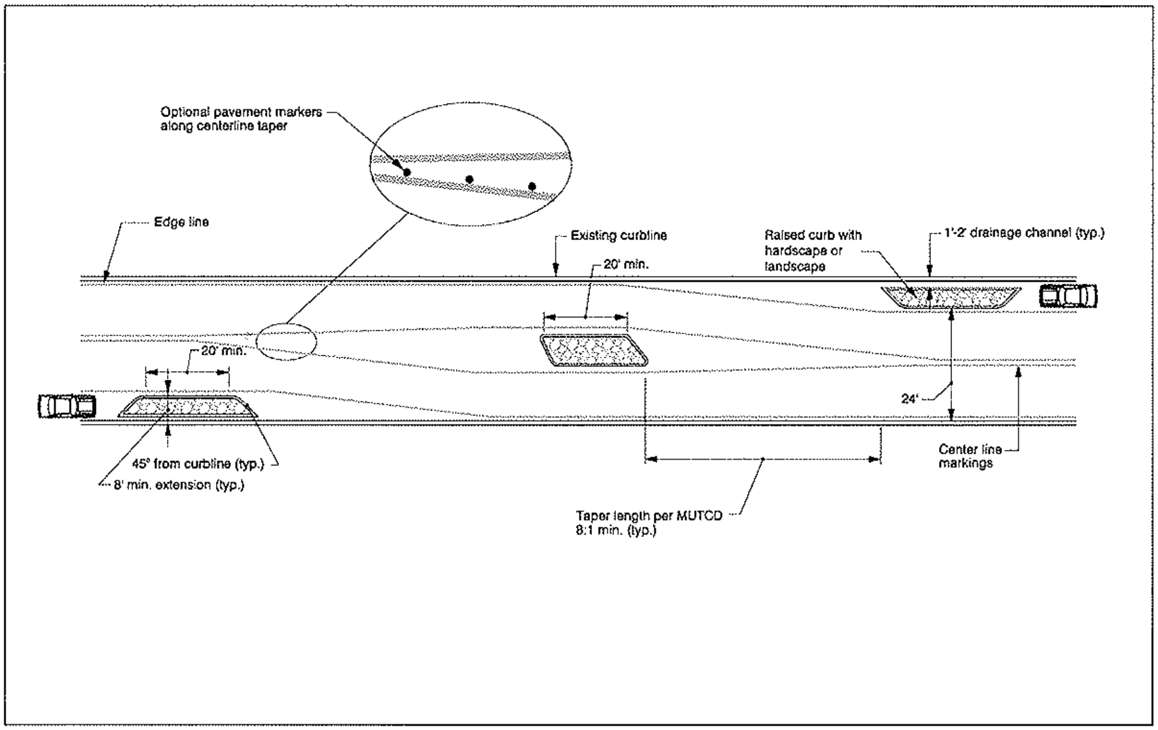
For This Street Width[2]:	Use These Curb Radii:		
X	R1	R2	R3
16'	15'	12'	7'
	20'	18'	7'
	25'	20'	7'
14'	15'	10'	5'
	20'	11'	5'
	25'	12'	5'
12'	15'	6'	3'
	20'	8'	3'
	25'	9'	3'

Source: Courtesy of Fehr and Peers.

The curb extensions or edge islands may be semi-circular or trapezoidal. The typical lateral shift has trapezoidal islands with edge line tapers that conform to the MUTCD taper formula. A center island separates opposing traffic. Absent such an island, some drivers will cross the centerline to minimize deflection. Lateral shifts may be formed with alternating parking bays.

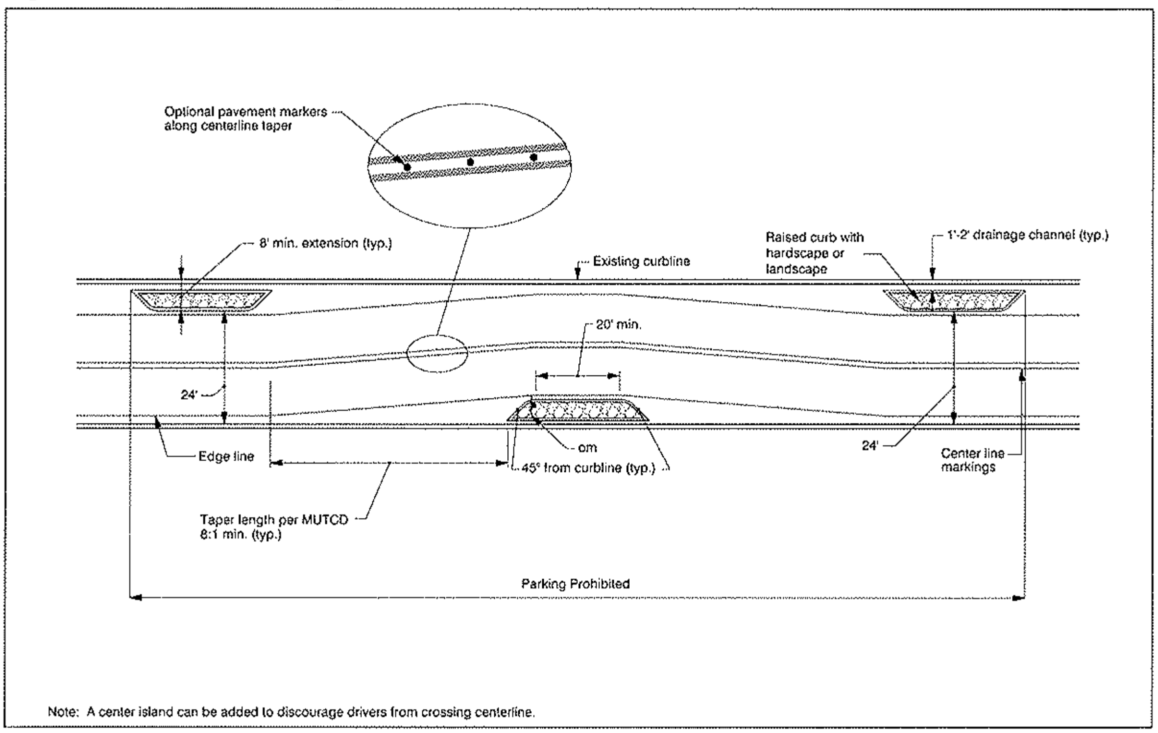
Chicanes are s-shaped curves on otherwise straight roads (see Figure 15-34). They are often designed as a series of lateral shifts rather than continuous curves and can be created either by means of curb extensions or edge islands. The typical chicane is just twice the typical lateral shift. It has trapezoidal edge islands based on the finding that this shape is more effective in reducing speeds than is a semi-circular shape. Because the roadway alignment shifts twice, the typical chicane has a lower design speed than the equivalent lateral shift.

Figure 15-33. Lateral Shift Design.



Source: Courtesy of Reid Ewing.

Figure 15-34. Chicane Design.



Source: Courtesy of Reid Ewing.

Mountable curbs are often used on curb extensions and edge islands that form chicanes. The use of mountable curbs is prompted by the complexity of movement through chicanes and the fact that curb extensions and edge islands within chicanes are not expected to serve as pedestrian refuges.

5. Narrowings

Neckdowns are sized to minimize cross distances for pedestrians while still allowing right turns to be made safely by larger vehicles. When streets are wide to begin with, and have parking lanes on main and cross-streets, intersections can be necked-down without forcing turning vehicles to encroach on opposing lanes. When streets are narrow and/or without curbside parking, some encroachment may be unavoidable.

Neckdowns are usually built in combination with on-street parking, so curb extensions can follow the inside turning radius of a smaller vehicle. In the typical design, the curb return radii and street widths are such that the design vehicle can stay to the right of the centerline when making right turns, but larger vehicles have to encroach. Stop lines on cross-streets can be set back from the intersection to avoid conflicts with opposing traffic (these are referred to as advance stop lines).

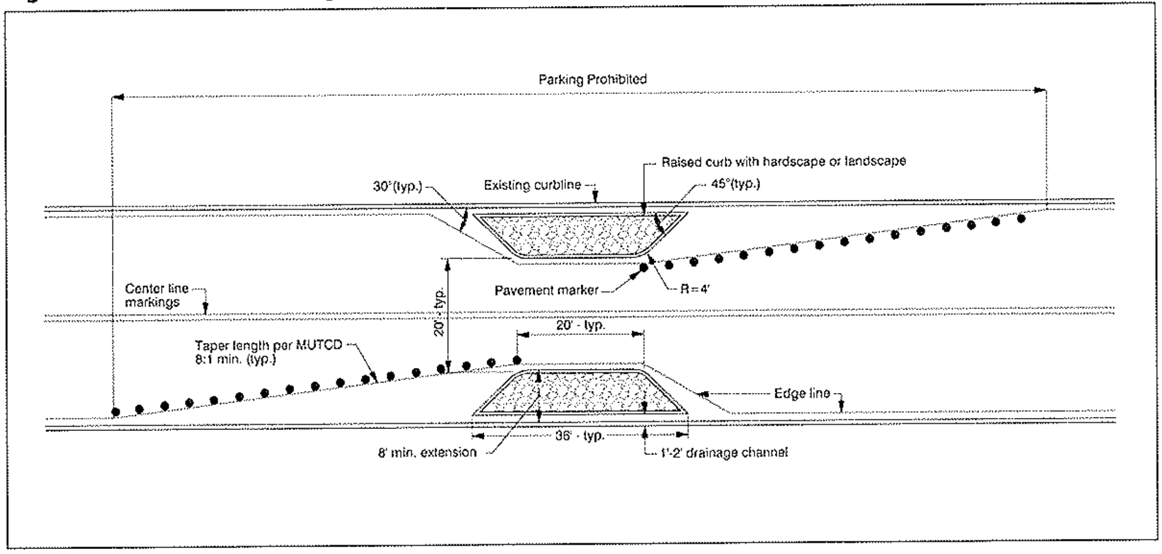
Chokers can be created either by means of curb extensions or edge islands. The latter are less aesthetic but leave existing drainage channels open. They also make it possible to provide bicycle bypass lanes on streets without curbside parking. Chokers can be hazardous to bicyclists who get squeezed by passing motorists. For this reason, bypass lanes should be considered when both bicycle and motor vehicle traffic are heavy and curb-to-curb width allows.

Chokers should have vertical elements to draw attention and form a visual street edge (see Figure 15-35). When used in connection with curbside parking, chokers may extend to the edge of the travel lane to form protected parking bays. Chokers should extend far enough to fully shadow parked cars. If roadway width is insufficient to allow curb extensions and parked cars on both sides, they can be provided on only one side of the street.

Center island narrowings are most effective in reducing speeds when they are short interruptions to an otherwise open street section, rather than long median islands. The latter may actually increase travel speeds by channelizing traffic and separating opposing flows, while the former slow traffic to a degree by deflecting vehicle travel paths. Stubby islands have the added advantage of keeping driveway access open and no-parking zones short, which is desirable at lower functional classification levels where traffic calming is most often practiced. Like chokers, center islands should have vertical elements to draw attention to themselves.

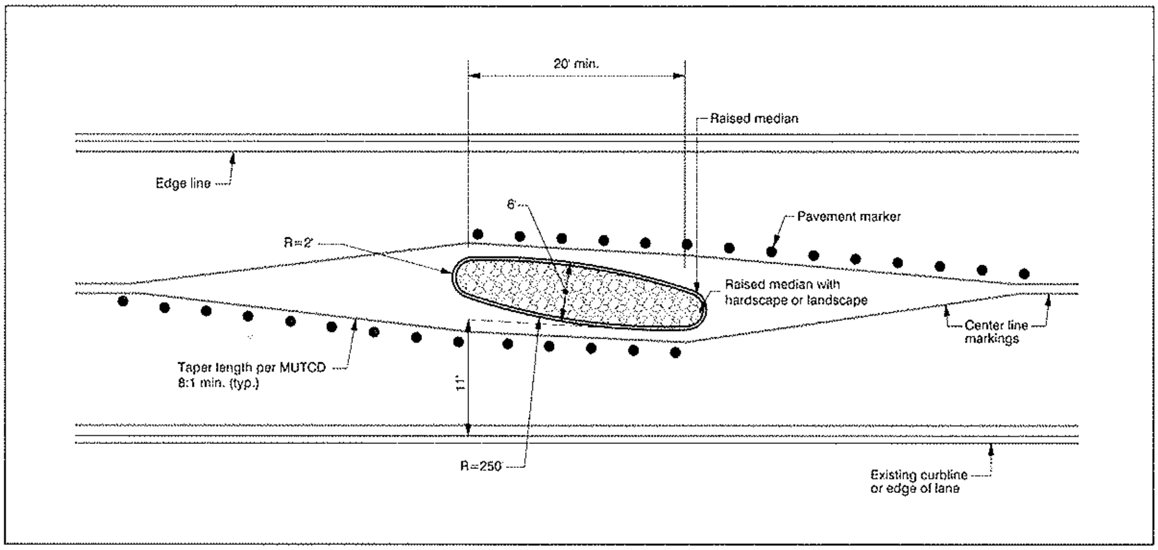
The typical center island narrowing incorporates three features (see Figure 15-36): The center island is large enough to command attention; the approach nose is offset to the left, from the perspective of approaching traffic; and the center island curb forms a diverging taper to deflect traffic toward the right.

Figure 15-35. Choker Design.



Source: Courtesy of Reid Ewing.

Figure 15-36. Center-Island Narrowing Design.



Source: Courtesy of Reid Ewing.

When center islands are placed at pedestrian crossings, ADA requires that they have pass-throughs that are traversable by the disabled. This requirement is usually fulfilled with cut-throughs flush with the roadway to provide a level crossing. For center islands that serve as pedestrian refuges, vertical curbs are used to provide an added measure of pedestrian comfort and safety. Otherwise, mountable curbs are preferred.

6. Accommodation of Bicyclists

Bicyclists tend to get squeezed or cut off at horizontal measures and narrowings. On streets with little bicycle traffic and/or low-volume motor vehicle traffic, special accommodation of bicyclists is typically not necessary. Where volumes of both bicycle and motor vehicle traffic are high, special accommodation should be made.

Typical designs assume that bicycle lanes will end 70 to 100 ft. upstream of slow points. This provides ample opportunity for bicyclists to merge into the traffic stream. At higher traffic volumes, bypass lanes should be considered. If bypass lanes are used, they should be separated from the main travel lanes by raised islands.

7. Speed Estimates

Speeds on a calmed roadway should be lowest at the location of the traffic calming measures and approximately equal to the design speed of such measures. Design speed depends on geometrics, most importantly on the vertical and horizontal curvature of traffic calming measures.

Speed on a calmed roadway will reach a maximum midway between traffic calming measures, and the magnitude depends on both the design speed and the spacing of devices. Thus, it is possible to back into geometric design and spacing requirements by setting design speeds first, then using those to estimate maximum spacing of measures.

For vertical measures that are approximately circular in shape—for example, speed humps with standard profiles—crossing speeds can be estimated using a formula from *Traffic Calming State of the Practice*. The formula was derived using the standard 12-ft. speed hump as a reference point. Whatever forces of centrifugal acceleration are tolerable going over this hump at its 85th-percentile speed should be tolerable going over other vertical measures at their 85th-percentile speeds.

The following formula applies to any vertical measure of approximately circular shape:

$$R = V^2/5.81 \qquad (15\text{-}3)$$

where:
R = radius of a vertical curve (ft.)
V = velocity at which the curve is traversed (mph)

or, equivalently:

$$V = 2.41\ (R)^{1/2} \qquad (15\text{-}4)$$

Insert values of V and to obtain the necessary R, or values of R to achieve the resulting V.

For speed tables and raised crosswalks with circular (or near-circular) ramps, speeds can be estimated using the methodology introduced in ITE's *Traffic Calming State of the Practice*. For vertical measures with trapezoidal shapes, field testing should be used. Empirical observations are summarized in the Delaware *Traffic Calming Manual*.

Most horizontal speed-control measures, including chicanes, lateral shifts and even traffic circles, consist of reverse curves. They require a turn in one direction and then back in the original direction, sometimes more than once. The physics of movement is complex in reverse curves. No standard highway design text or manual provides insight into comfortable speeds on such curves. Fortunately, reverse curves can often be analyzed as a series of simple curves, and where they cannot, there has been enough field testing to make speed estimates possible.

For simple horizontal curves, crossing speeds can be estimated with graphs and tables from AASHTO's *A Policy on Geometric Design of Highways and Streets* (the Green Book).[17] All of these graphs and tables are based on the formula from mechanics:

$$R = V^2/15(e + f) \qquad (15\text{-}5)$$

where:
R= horizontal curve radius (ft.)
V = speed of travel around a curve (mph)
e = superelevation rate
f = side friction factor

For horizontal traffic calming measures on low-speed streets, e is usually close to zero. Therefore, equivalently:

$$V = 3.87(Rf)^{1/2} \qquad (15\text{-}6)$$

Friction factors can be obtained from *A Policy on Geometric Design of Highways and Streets*. At locations with super-elevation or reverse superelevation, these can be inserted into the above equations.

For horizontal measures with short reverse curves, such as chicanes and lateral shifts, empirical observations are summarized in the Delaware *Traffic Calming Manual*.

8. Landscaping and Drainage

The previous sections have called for *vertical elements* on circles, roundabouts, chokers and center island narrowings. In most cases this means landscaping. Landscaping contributes to both the aesthetics and the identification of traffic calming measures.

Landscaping should be carefully planned to allow unrestricted visibility. To preserve sight lines, trees should have clear stem heights of at least 8 ft. and should be no more than 4 inches in diameter to ensure that they break away upon impact. Bushes or shrubs should grow to no more than 2 ft. in height. Groundcover plantings are particularly useful because they leave sight lines open and pose no danger to out-of-control drivers.

It is not uncommon for agencies to require or allow residents to maintain the landscaping in traffic calming devices. The advantage to this practice is lower cost for the agency and greater pride of ownership for the residents. The disadvantage is less consistency in maintenance quality. Agencies that employ this practice have not indicated a concern regarding liability.

Drainage should be considered when installing traffic calming devices. Adding traffic calming to existing roadways has the potential to disrupt drainage. Drainage issues can often be avoided with vertical devices by reducing the height of the device to roadway level before the curb and gutter, such as with speed humps. Another option is to include channels between the outer edges of the device and the curb to allow adequate room for drainage. Jurisdictions should be aware that drainage channels included in traffic calming devices will require maintenance to ensure they are clear of debris to prevent water from pooling on the roadway.

B. Signing and Marking

If driven at excessive speeds significantly above the design speed, traffic calming measures may pose a hazard to motorists. Governments have a duty to warn motorists of any hazardous conditions of which they are aware or that they create. It is this "duty to warn" that compels the judicious signing and marking of traffic calming measures.

Different communities in North America use nearly a dozen different traffic circle signs and a dozen different speed-hump marking patterns. From an operational standpoint, the lack of standard signing and marking means that as traffic calming practice expands across North America, warning signs and markings will not be universally recognized as they are for horizontal curves, dips and other roadway geometric features.

1. Guidance from MUTCD

In the United States, FHWA's MUTCD is the official guide to signing and marking of roadway physical features. In this section, general principles from MUTCD are applied to the practice of traffic calming. The section also suggests how to apply standard signs from MUTCD to certain traffic calming measures.

Although this section discusses MUTCD as used in the United States, other manuals should be referenced for specific regions in North America: In Canada, refer to the *Manual of Uniform Traffic Control Devices* published by the Transportation Association of Canada; in Ontario, the Ministry of Transportation of Ontario has been developing its own traffic manual.

Standard MUTCD Signs. Certain standard MUTCD signs are perfectly suited to certain traffic calming measures:

- DEAD END signs (W14-1) in advance of full closures to allow traffic to turn off at the nearest intersecting street;
- DO NOT ENTER signs (R5-1) and ONE WAY signs (R6-1) at half closures;
- Turn signs (W1-1) in advance of diagonal diverters and Large Arrow signs (W1-6) on the outside curves of diagonal diverters;
- Mandatory Movement Lane Control signs (R3-5) at forced-turn islands;
- Reverse Curve signs (W1-4) at lateral shifts; and
- Keep Right signs (R4-7) on center-island narrowings.

Special MUTCD Signs and Markings. The 2000 edition of MUTCD was the first edition to provide special signs and markings for traffic calming measures. It included a warning sign and pavement marking pattern for speed humps and tables, and marking patterns for traffic circles and roundabouts. The 2003 edition recommends the use of a SPEED HUMP sign (W17-1) with an advisory speed plaque to warn of vertical deflection at speed humps or speed tables. It introduces an optional CIRCULAR INTERSECTION sign (W2-6) with an educational TRAFFIC CIRCLE plaque (W16-12p) on the approach to traffic circles or roundabouts.

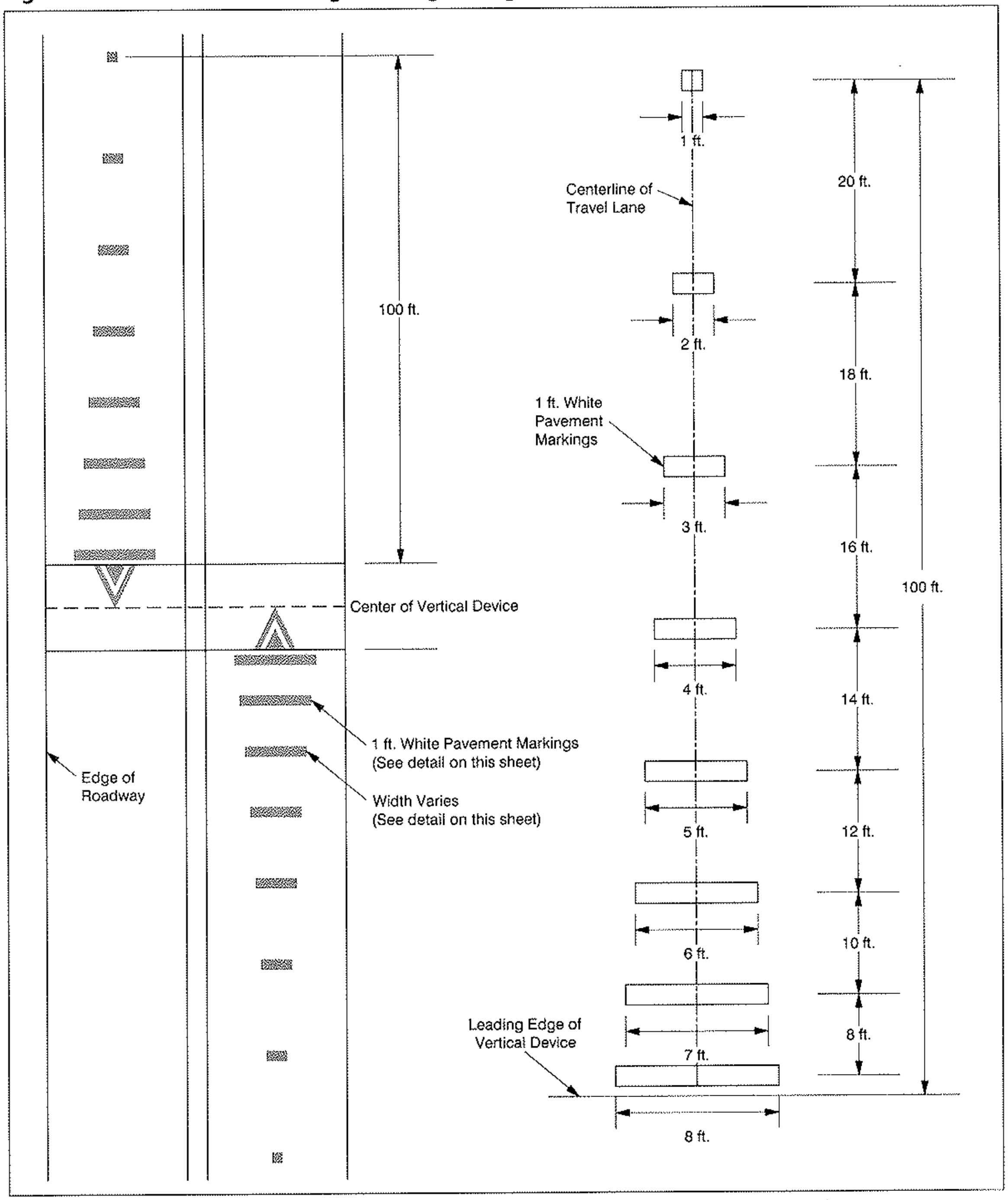
The 2003 edition also provides examples of markings for roundabouts, with options, recommendations and one prohibition. The options include a yellow edge line around the inner (left) edge of the circulating roadway and yield lines at the entries. Recommendations include a white line around the outer (right) side of the circulating roadway and solid lines around the splitter islands. Where crosswalk markings are used, these markings should be located a minimum of 25 ft. upstream of the yield lines, or if there are no yield lines, 25 ft. upstream of dotted white lines at the entries. The one prohibition is against bicycle lane markings on the circulating roadway of the roundabout. The 2003 edition provides that traffic circles may be marked the same as roundabouts when engineering judgment indicates that this will benefit drivers or pedestrians.

The 2003 edition requires that if markings are used at all, a series of white markings should be used to identify the rise on speed humps (see Figure 15-37). An optional marking pattern is provided. A comparable marking pattern may be used for speed tables and raised crosswalks. It also provides the option of using advance pavement wording such as BUMP or HUMP.

Flexibility in MUTCD. MUTCD provides a high degree of flexibility in signing and marking. It states:[18]

> *...engineering judgment is essential to the proper use of signs, the same as with other traffic control devices. Traffic engineering studies may indicate that signs would be unnecessary at certain locations.*

Figure 15-37. Advance Warning Markings Design.



Source: *Manual on Uniform Traffic Control Devices.* Washington, DC, USA: Federal Highway Administration, 2003.

The use of "may" or "should" rather than "shall" in connection with many MUTCD conventions provides additional flexibility. "May" is an optional or permissive word that implies no requirement or recommendation. "Should" is recommended but not mandatory; a recommended practice can be can be overridden by engineering judgment. Only "shall" statements set standards that become mandatory.

Use of the new special signs and markings is optional rather than mandatory. Inclusion of these signs and markings carries no requirement or even recommendation. It would not be reasonable to expect communities with long-standing traffic calming programs to re-sign or re-mark all of their measures to conform. Nor are the optional signs and markings in MUTCD necessarily the most easily recognized.

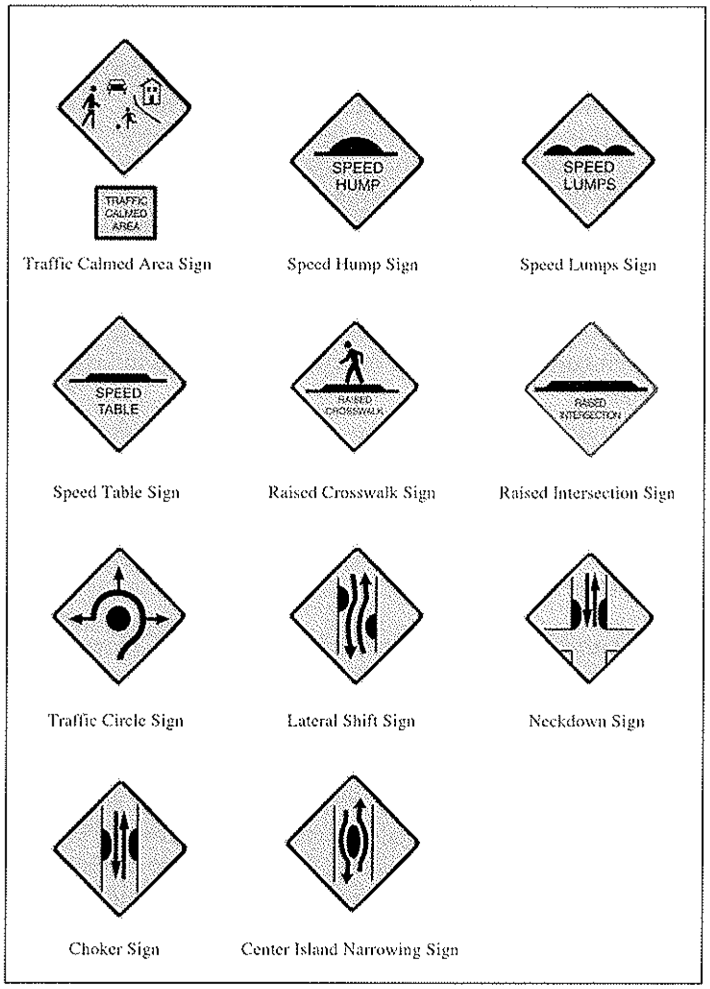
Seattle circles date back to 1971, and hundreds of circles are already in place. While Seattle follows general MUTCD guidelines for warning signs, it has not adopted the new MUTCD traffic circle sign.[19] Eugene and Portland have been installing speed humps for years and are reluctant to re-mark all of their humps in the new MUTCD pattern. They are satisfied with their existing patterns: a chevron pattern in Portland and a shark's tooth pattern in Eugene.

2. Guidance from the Delaware Manual

In 2000, Delaware became the first U.S. state to adopt a traffic calming manual through a formal rule-making process (as part of its roadway design manual). In some respects, the following Delaware conventions go beyond MUTCD and are more attuned to the special challenges of traffic calming.

At the time Delaware adopted its manual, no MUTCD signs were available for most traffic calming measures. Even now, gaps remain. This prompted the Delaware Department of Transportation (DelDOT) to adopt special warning signs for use throughout the state. Since then, other special warning signs have been designed for use elsewhere (see Figure 15-38).

Figure 15-38. Traffic Calming Warning Signs.



Source: Courtesy of Fehr and Peers; and *Manual on Uniform Traffic Control Devices.* Washington, DC, USA: Federal Highway Administration, 2003.

The design of these signs reflects a preference, in accordance with MUTCD, for symbols over word messages. The operative principle in the design of symbol signs is that the symbol itself faithfully represents the *geometrics* and *traffic flow pattern* of the measure. However, it should be noted that many of these symbols adopted by Delaware are not included in MUTCD. MUTCD requires that symbols shall be subject to research for comprehension and approved by FHWA before their inclusion in MUTCD, or their approval for use must be requested through experimental procedures. The use of these symbols in a jurisdiction other than Delaware, without approval for experimentation or adoption in that jurisdiction's traffic control standards, means they are unapproved traffic control devices and caution should be used to minimize the potential for enforcement and litigation problems.

Area-Wide Sign. For aesthetic and operational reasons, DelDOT wanted to keep signage to a necessary minimum. Following Australia's lead, a traffic calming sign with a TRAFFIC CALMED AREA plaque (see Figure 15-38) was adopted to replace individual warning signs when three conditions are met:

- signs are installed on all access routes, preferably on both sides of the street to emphasize the gateway effect;
- an appropriate, uniform advisory speed is posted; and

- a slow point is proximate to each traffic calming sign, and subsequent slow points are no more than 500 ft. apart.

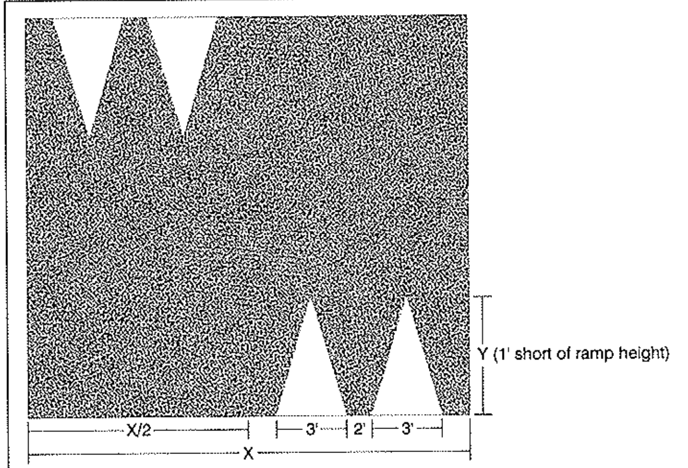
Signing and Marking of Vertical Measures. Advance warning signs in Delaware are placed upstream of vertical measures, including speed humps, speed tables, raised crosswalks and raised intersections. Pavement markings are displayed on the up-ramps of the vertical measures themselves. Pavement legends are not required in front of vertical measures, nor are signs or object markers ordinarily required at individual humps, tables, raised crosswalks, or raised intersections.

Signs or object markers may be used on curbless sections to keep motorists from veering off the roadway to avoid vertical deflection. They may also be used to mark vertical measures on snowplow routes. However, for both of these purposes, other marking alternatives are available. Landscaping and decorative bollards, for example, could serve the same purpose with better aesthetics.

Vertical measures in Delaware are marked with a simple shark's tooth pattern (see Figure 15-39). However, the arrow pattern was approved by MUTCD in 2000 and has since been used to mark vertical devices. Both marking patterns are widely used in the United States. Both have two advantages relative to most other common patterns:

- The large marked area is highly visible.
- The asymmetric pattern directs drivers to the proper crossing point.

Figure 15-39. Delaware Vertical Measure Markings.



Source: Delaware Department of Transportation.

A community may consider exceptions to the standard marking pattern where more context-sensitive approaches are desired. For example, up-ramp markings may be omitted where the plateaus of raised crosswalks are marked in accordance with MUTCD guidelines for at-grade crosswalks; that is, with traverse white lines marking both edges of the crosswalk, with longitudinal white lines perpendicular to the crosswalk, or with both longitudinal and diagonal lines. In a low-speed context such as a traditional main street, a community may even consider omission of separate markings in favor of colored and patterned surfaces of brick or concrete paver materials.

It should be noted that the Delaware vertical measure markings have been designed and approved for use in Delaware and are not consistent with MUTCD or ITE recommended practice. However, MUTCD lacks signing and marking guidance for many of the traffic calming measures included in the Delaware manual and those previously discussed in this work.[20] ITE's *Guidelines for the Design and Application of Speed Humps* provides the latest recommendations on speed hump marking.[21]

Signing and Marking of Center Islands. MUTCD requires the approach ends of traffic islands to have marked triangular neutral areas in front to guide vehicles in desired paths of travel along island edges. These areas may be identified by painting or by use of contrasting materials. Appropriate signs, such as the KEEP RIGHT (R4-7) sign, are placed on the approach ends facing traffic. Object markers are also placed on approach ends.

MUTCD conventions apply to pedestrian refuge islands, traffic divisional islands and traffic channelizing islands, which are all found on major streets and highways. On lesser streets, signing and marking requirements may be relaxed somewhat. Center-island narrowings are often designated with a single KEEP RIGHT sign and no object marker, and center lines shear off to the right to guide traffic past center islands rather than forming marked triangular neutral areas. Sometimes in other states, signs and object markers are omitted entirely in favor of reflective raised pavement markers on the approach ends and prominent landscaping within the islands.[22] Few if any collisions occur because islands are still plainly delineated.

Signing and Marking of Traffic Circles and Roundabouts. The distinction between roundabouts and mini traffic circles, from a geometric standpoint, is outlined earlier in this chapter. For both, an advance warning sign conveys the essential geometry and traffic flow pattern.

Center islands of roundabouts are so large that the required movement of entering traffic may best be conceived as a right turn. Roundabout center islands are usually signed with large arrows, although Chevron signs and ONE WAY signs are also used. Outer curbs are ringed by reflective raised pavement markers. Center islands are landscaped for greater visibility than can be achieved by signs and markings alone. Splitter islands have raised curbs, marked neutral areas and KEEP RIGHT signs on their approach ends. Splitter islands may be landscaped as well.

Mini traffic circles require less signing and marking than roundabouts and local and state laws should be referenced when signing. While KEEP RIGHT signs and circular intersection signs are sometimes displayed, it is sufficient to have Type 1 object markers on the center islands facing traffic on all approaches. These should be supplemented by reflective raised pavement markers on their curbs. Center islands should be landscaped for better aesthetics and greater visibility than can be achieved with signs and markings alone.

Marking of Curb Extensions and Edge Islands. Special signing or marking is generally not required on curb extensions or edge islands that fall outside the direct path of travel, such as when curb extensions within a designated parking lane form protected parking bays. There are exceptions to this general rule. Object markers may be used on snow plow routes to mark curbs that might otherwise be undetectable. Also, on curbless sections, object markers may be used to draw attention to the occasional island. However, for both of these purposes, other marking alternatives are available. Landscaping and monument signage, for example, can perform the same function more effectively than a simple object marker.

For curb extensions or edge islands that deflect traffic (including chicanes, lateral shifts and one-lane chokers), object markers should be placed on the extensions or islands toward the side on which traffic will pass. Ordinarily, Type 3 object markers are used to mark these measures.

Special Signing for Bicycle Routes. Special signing should be provided along traffic-calmed streets that are designated as bicycle routes. Appropriate signing should be used at closures and diverters to indicate that bicycle access is maintained; appropriate signing should be used at horizontal measures to protect bicyclists from deflected motor vehicles.

IV. EMERGING TRENDS

This section expands on emerging trends in the techniques, technologies and tools used in the traffic calming field and/or its integration with other fields. This section also discusses future research topics that may provide meaningful insight into the effectiveness of recent traffic calming devices and techniques.

A. New Engineering Techniques and Technologies

1. Avoiding the Need for Traffic Calming

Traffic calming has long been considered a fix to problematic residential street layouts and excessively wide street standards. In response, some municipalities are looking back to pre–World War II street standards for connectivity, block length (intersection spacing), curb return radii and street width to minimize the need for future traffic calming fixes. *Planning for Street Connectivity: Getting from Here to There* examined 12 cities (including one metropolitan planning organization) in Oregon, Colorado, North Carolina, Delaware and Florida that were undertaking such changes to their roadway standards.[23] At the time of the research, most of the cities were still developing their standards (see Table 15-7); however, several success stories followed the adoption of the new standards.

Table 15-7. Summary Requirements for Intersection Spacing.

City	Max Intersection Spacing for Local Streets (ft.)	Max Intersection Spacing for Arterials	Are Street Stubs Required (to future connections)?	Are Cul-de-Sacs Allowed?	Max Cul-de-Sac Length (ft.)	Local Street Widths (paved, ft.)
Metro, OR, USA	530	530	Yes	No (with exceptions)	200	<28 encouraged
Portland, OR, USA	530	530	Yes	No (with exceptions)	200	Not regulated
Beaverton, OR, USA	530	1,000	Yes	No (with exceptions)	200	20–34
Eugene, OR, USA	600	None	Yes	No (with exceptions)	400	20–34
Fort Collins, CO, USA	[1]	660–1,320[2]	Yes	Limited	660	24–36
Boulder, CO, USA	[3]	None	Yes	Yes, discouraged	600	24–36
Huntersville, NC, USA	250–500	No data	Yes	No (with exceptions)	350	18–26
Cornelius, NC, USA	200–1,320	[4]	Yes	No (with exceptions)	250	18–26
Conover, NC, USA	400–1,200	No data	Yes	Yes	500	22
Raleigh, NC, USA	1,500[5]	No data	Yes	Yes	400–800[6]	26

Notes:
[1] Maximum block size is 7-12 acres, depending on zoning district.
[2] Limited-movement intersections required every 660 ft.; full-movement intersections required every 1,320 ft.
[3] Not specified by code, but staff tries to achieve 300- to 350-ft. spacing.
[4] Intersection spacing on arterials is regulated by the state department of transportation.
[5] Within a mixed-use center, no street block face shall exceed 660 ft. in length.
[6] 400 ft. in residential areas, 800 ft. in commercial areas; transportation director may approve up to 10-percent longer.

Source: Handy, S. et al. *Planning for Street Connectivity: Getting from Here to There.* American Planning Association Planning Advisory Service Report Number 515, 2003, pp. 45–46.

Fort Collins, CO, reported difficulties in implementing street stubs into adjacent parcels owned by uncooperative property owners. This requirement for providing street stubs ultimately led to delays in development projects until an easement or agreement between property owners could be reached. Eugene faced a similar challenge in implementing the new standards in infill projects. In this case, existing residents believed that they lived on a cul-de-sac in perpetuity and fought the extensions of stub streets. Huntersville, NC, faced resistance from developers due to the additional costs of creating greater connectivity. To offset the resistance, the city offset the costs by allowing developers to build streets as narrow as 18 ft. with no on-street parking (25 to 26 ft. if on-street parking was allowed).

Coincidently, the Huntersville, Fort Collins, Eugene and Cary, NC, fire departments all supported the changes due to decreased travel times and increased connectivity.

2. Incorporating Traffic Calming into the Initial Design

Another trend is the incorporation of traffic calming devices into new developments. This concept provides multiple benefits, including lower cost to the municipality, residents buying into a neighborhood with full knowledge of the traffic calming elements and landscape maintenance incorporated into landscape and lighting districts.

Engineers and planners alike can proactively identify roadway segments ripe for excessive vehicle speeds or cut-through traffic and recommend various traffic calming measures to minimize the problem. *Traffic Calming State of the Practice* foresaw a shift in emphasis from retrofits to traffic calming within new developments. The shift has occurred only to a limited degree and does not appear to be a strict standard utilized by municipalities. Table 15-8 summarizes the efforts of the communities featured in *Traffic Calming State of the Practice* to incorporate traffic calming in new developments.

Another study found that Albuquerque, NM; Eugene; Minneapolis, MN; and Sacramento make case-by-case recommendations as part of the development review and approval process. None reported opposition from developers. Charlotte and Vancouver are developing formal policies on traffic calming in new developments. Vancouver reports that developers are more receptive to traffic calming than they once were. Howard County already has such a policy in place. Slow points are required at regular intervals between 600 and 1,000 ft. Adopting formal requirements today may be the best way to avoid the need for retrofits in the future.

Table 15-8. Efforts to Promote Traffic Calming in New Developments.

Location	Measures
Austin, TX, USA	Code requires neighborhood traffic analyses where commercial developments have direct access to residential streets—mitigation is required if more than 300 vehicles are added to daily volumes—one large residential development will include traffic calming measures as a result of a design charrette.
Bellevue, WA, USA	Heightened awareness by design engineers—in one case, curb extensions were required at a connection to new development.
Berkeley, CA, USA	In three cases, traffic calming measures were required as conditions of development approval—an office developer paid for reconstruction of an entire street as a "slow street".
Boulder, CO, USA	Narrower street standards.
Charlotte, NC, USA	During subdivision review, T-intersections and circuitous routes are suggested to avoid cut-through traffic on local streets.
Eugene, OR, USA	Code provides for narrow streets, alternating parking, etc.—subdivision plans reviewed for speeding and cut-through traffic problems.
Gainesville, FL, USA	In several cases, developers were encouraged to install and pay for traffic circles—done voluntarily because circles are popular with homeowners.
Gwinnett County, GA, USA	Developers occasionally advised to install speed humps voluntarily—county code may be amended to make humps mandatory.
Howard County, MD, USA	New subdivision road standards proposed to calm traffic naturally—narrowing streets, adding roundabouts at intersections and requiring slow points at regular intervals.
Montgomery County, MD, USA	New town will be test case—raised crossings, humps, chokers and neckdowns to be required.
Phoenix, AZ, USA	Subdivision regulations and design review standards discourage cut-through traffic—guidance to developers contained in *Calming Phoenix Traffic*.
San Diego, CA, USA	During development review, staff refers to Transit-Oriented Development Design Guidelines.
San Jose, CA, USA	During site plan review, developers asked to address potential for cut-through traffic—traffic study required if more than 100 vehicles per peak hour.
Seattle, WA, USA	In one redevelopment project, circles required to prevent speeding when grid re-established.
Tallahassee, FL, USA	Comprehensive plan being amended to require traffic calming in new developments —in one case, unspecified measures required at 400-600-ft. intervals
West Palm Beach, FL, USA	Large infill project required to construct narrow streets with on-street parking, neckdowns, raised intersections and raised crosswalks.

Source: Ewing, R. "Traffic Calming in New Developments (or Avoiding the Need for Future Fixes)." *Transportation Research Record*, No. 1685 (1999): 209-220.

3. Technologies

The emergence of new technologies in the traffic calming field, whether they are physical devices or educational improvements, has been slow in comparison with the traffic operation and simulation fields. For example, the first speed-monitoring radar trailer was introduced in the late 1980s and a pole-mounted sign version became available in the late 1990s. Other advances have included the variations of speed humps (such as split speed humps) and speed lumps to minimize response times and physical impacts on emergency response vehicles.

Speed lumps (see Figure 15-40) are modular humps made of recycled rubber that are anchored to the asphalt. Speed lumps come in a variety of sizes, but generally conform to 3 inches high and 6 ft. wide (length varies by manufacturer). Because some speed lumps are pre-manufactured, they provide more consistent ride quality than asphalt versions. In addition, they exhibit similar speed-reduction characteristics than traditional speed humps while minimizing the delay incurred by emergency response. Austin, TX, USA, may have been one of the first municipalities to use speed lumps, and it has even incorporated the device into its toolbox.

Figure 15-40. Speed Lumps, City of La Habra, CA, USA.

Source: Courtesy of Fehr and Peers.

In a time where Internet accessibility, content and user understanding are dramatically increasing, the Internet possesses the potential to increase public outreach and education efforts. Often, the public outreach and education processes are limited to a few public workshops, the distribution of flyers (through mail or even e-mail) and possibly workshop notes posted to the department's Web site. Using the municipality's existing Web site can allow for interactive updates for projects, data sharing, opinion polls, or even hosting a discussion forum. Harnessing the power of technology in this manner can extend and enhance the public outreach and education efforts of any municipality without overburdening staff.

B. Emerging Enforcement Technologies

Traffic Calming State of the Practice investigated the use of photo radar for speed enforcement purposes. However, it did not predict a widespread use of photo radar due to its cost. At the time, San Jose, CA, was conducting a demonstration project involving a van equipped with a photo radar unit (a combination of a radar and high-resolution camera) rotating among local streets. In 1998, the City transformed the pilot program into a full-time program called the Neighborhood Automated Speed Compliance Program (NASCOP).

Under NASCOP, neighborhood associations or residents requested enforcement of their street. Where a neighborhood association was not organized, a 50-percent-plus-one vote of the properties along the street in question had to be in support of the program. However, after approximately 10 years of operation, the city council terminated the project due to growing concern over the legality of the program.

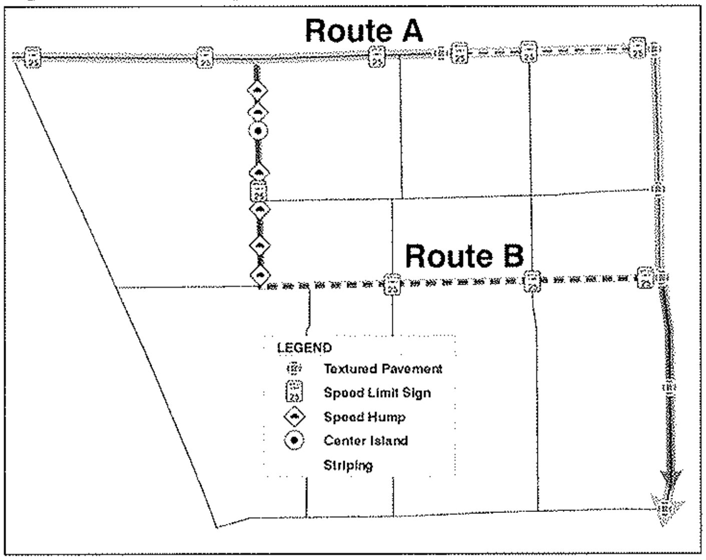
Rockville, MD, recently received permission to establish a trial program as authorized by the Maryland General Assembly in 2006. The trial program began in March 2007 utilizing a mobile unit rotated throughout the city on residential streets and school zones where the speed limit is 35 mph or lower. City staff determined locations for the speed cameras in Rockville by compiling data to determine the top 50 residential speeding areas in the city. A citizen advisory committee helped prioritize locations based on speed data and proximity to schools, parks and crosswalks; locations lacking sidewalks; and expressed community concern. Motorists caught speeding in excess of 11 mph over the posted limit are issued a $40 fine, but the citation will not affect the individual's driving record. Rockville is expected to report back to the Maryland General Assembly in 2009 on the effectiveness of its speed monitoring programs.

C. New Analysis Tools

Few advances have been made in the areas of analysis tools to assist engineers and planners in more accurately predicting the effects of neighborhood-wide traffic calming plans or understanding driver preferences in route choice. At the most basic level, engineers and planners rely on performance survey results to determine the effectiveness of various traffic calming devices and equations to estimate potential speed reductions. At more complex levels (that is, neighborhood-wide plans), basic assumptions are made regarding the diversion to alternative routes based on directness, traffic congestions and travel time. However, the widespread use of software to assist in these calculations has not occurred.

One analysis tool that is widely available but has not emerged as a more robust instrument in the traffic calming field is geographic information systems (GIS). GIS platforms have provided engineers and planners the analytical and visual communication capabilities to understand large amounts of interrelated data. GIS has successfully been used to estimate the change in travel time for roadways treated with various traffic calming devices (see Figure 15-41). The relative travel time between alternative routes affects individual driver decisions about the path they will select. The resulting traffic volumes on the subject streets are simply an aggregation of these individual travel choices.

Figure 15-41. Using GIS to Estimate Travel Time.



Source: Courtesy of Fehr and Peers.

As an example, a neighborhood-wide traffic calming study may employ a global positioning system (GPS) to better predict the amount of cut-through traffic that would be diverted after the installation of traffic calming devices. Field work can be performed using a GPS receiver and tracking device located in the data collection automobile, which records the route and travel time (and provides for integration with a computer-based GIS program). Trips to and from two or more points in the neighborhood can be recorded under existing conditions during the peak congestion periods. Figure 15-41 shows two prominent routes through a neighborhood. Larger study areas could have more routes. The amount of time required to travel the cut-through routes is compared to that of the intended route. Delays associated with proposed traffic calming devices can be added to the cut-through route travel time, and reasonable estimations of the increase in travel along that route can be made. This method can assist planners in determining an adequate number of traffic calming devices to increase cut-through travel times above those of the intended route.

In addition, the data obtained during the field observations can be used to show where traffic travels fastest along the routes and may indicate a need for specific traffic calming action. The use of GPS as described in this example is intended to assist—rather than replace—the methods of spacing and selecting appropriate traffic calming devices as discussed in previous sections.

As previously noted, travel time plays an important factor in travel route choices and driver willingness to tolerate a series of traffic calming measures to achieve travel time savings. The technology to monitor real-time traffic flows currently exists in cell phone GPS and vehicle infrastructure integration (VII). Engineers and planners can develop detailed maps of travel patterns on an average day or during special events; receive average daily traffic counts or traffic speeds on select routes; re-time traffic signals on the fly; update transit route schedules; better estimate project trip distributions for development projects; and identify residential cut-through routes.

The VII initiative was due to report back in late 2008 on outstanding technological, legal and logistical issues before recommending national deployment to the U.S. Congress.

D. Bicycle Boulevards

Neighborhood traffic management programs (NTMPs) often include goals relating to the improvement in neighborhood livability for pedestrians and bicyclists by reducing vehicle speeds and excessive traffic volumes, thereby minimizing the potential for collisions. Many NTMPs indirectly enhance the pedestrian and bicyclist experience; however, some communities have proactively utilized traffic calming measures to create *bicycle boulevards*.

Bicycle boulevards are roadways that have been modified with the explicit objective of enhancing bicyclist safety and convenience. Bicycle boulevards have the following attributes:

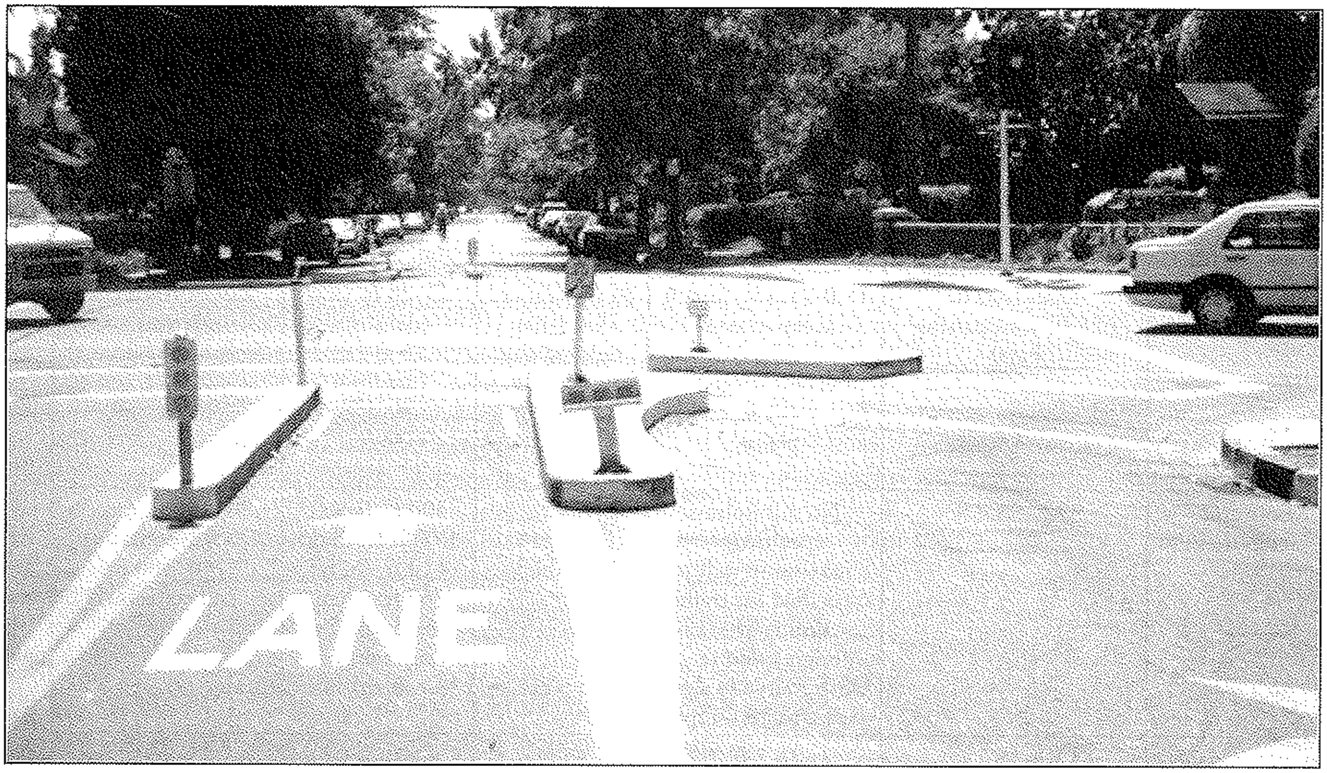
- low traffic volumes;
- discouragement of non-local motor vehicle traffic;
- free-flow travel for bikes by assigning the right of way to the bicycle boulevard at intersections wherever possible;
- traffic control to help bicycles cross major streets (arterials); and
- a distinctive look and/or ambiance, so cyclists become aware of the existence of the bike boulevard and motorists are alerted that the roadway is a priority route for bicyclists.

Palo Alto, CA, may have been the first city to conceive this concept (in the 1980s) with its development of the Bryant Street Bike Boulevard. Bryant Street is a typical two-lane residential street spanning approximately 4 miles, with on-street parking and signalized intersections with major cross-streets. To implement the bicycle boulevard concept, the City constructed two full-street closures that permit through bicycle traffic, a traffic circle, way-finding signage and right-turn channelization at a new bike-actuated signal. The result of this effort is a 4-mile enhanced Class III bikeway with limited through traffic and slower vehicle speeds where bicyclists can travel at full speed (see Figure 15-42).

Berkeley is another community supportive of the benefits gained from the integration of on-street bikeways and traffic calming measures. The city's bicycle plan envisioned seven bicycle boulevards to traverse the city. Two years later, Berkeley developed the *Bicycle Boulevard Design Tools and Guidelines* manual that further defined the standards by which bicycle boulevards should be constructed. Berkeley utilizes the following traffic calming devices to successfully implement bicycle boulevards:

- wayfinding signage (see Figure 15-43);
- unique pavement;
- traffic circles;
- bulbouts;
- traffic signals; and
- high-visibility crosswalks.

Figure 15-42. Bryant Street Bike Boulevard, Palo Alto, CA, USA.



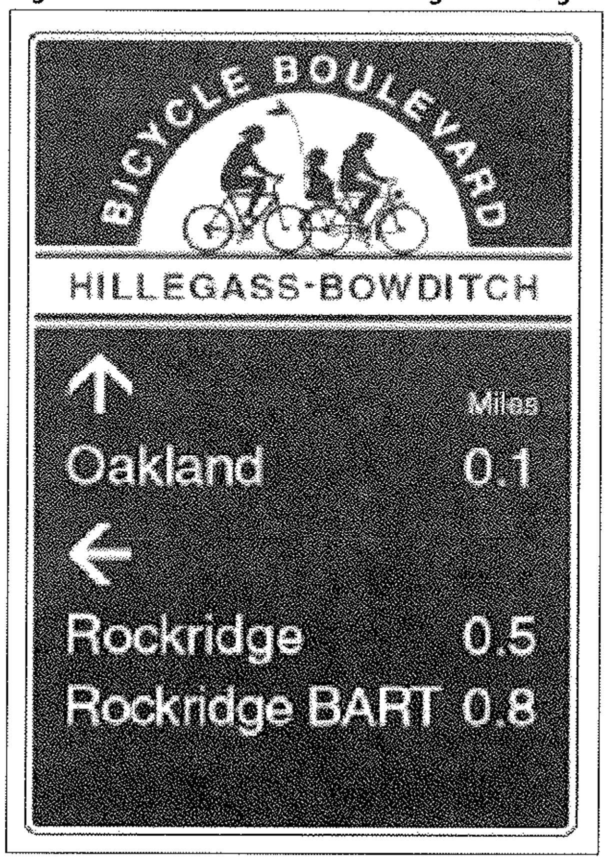
Source: Courtesy of Michelle DeRobertis, Santa Clara Valley Transportation Authority.

E. Pedestrian Priority Streets

Similar to bicycle boulevards, pedestrian-priority streets place pedestrian mobility and safety above vehicles. Historically, European countries have designed streets with the pedestrian in mind.

The Netherlands was one of the first countries to reclaim its streets for pedestrian uses—called *woonerven*, or *living yard* or *shared streets*. This concept utilized various traffic calming measures, parking bays and other obstacles to create a shared area to reduce vehicle speeds to about 9 mph. Other European countries emphasize the pedestrian realm through design standards, such as narrower streets and lower design speeds, curve and curb radii. Table 15-9 compares the differences between European and U.S. local roadway design standards.

Figure 15-43. Bike Boulevard Designation Sign.



Source: Courtesy of the City of Berkeley, CA, USA.

Table 15-9. Design Guidelines for Local/Access Roads.					
	British Design Guide 32	**Australian Model Code**	**American AASHTO**	**American ITE**	**American ASCE/NAHB/ULI**
Design Speed	30 mph (major access roads) 20 mph (minor access roads) Below 20 mph (shared surface streets)	24.8 mph (major access streets) 18.6 mph (minor access streets) 9.3 mph (access places)	20-30 mph	30 mph (level) 25 mph (rolling) 20 mph (hilly)	20 mph (access street and subcollector)
Pavement Width	12.0–18.0 ft. (9.8 ft. with passing bays)	18.0-21.3 ft. (major access streets) 16.4–18.0 (minor access streets) 11.5–16.4 ft. (access places)	26 ft. standard (less when right of way is severely limited)	22–28 ft. (low density) 28–34 ft. (medium density) 36 ft. (high density)	22–24 ft. (access street) 26 ft. (subcollector)
Minimum Curve Radius	32.8–98.4 ft.	No minimums specified—maximum radius specified for traffic calming at each design speed (e.g. 98-ft. curve to slow traffic to 18.6 mph)	100 ft. (as large as possible)	300 ft. (level) 175 ft. (rolling) 110 ft. (hilly) (50 ft. when street makes right-angle turn)	100–150 ft. (access streets) 150–300 ft. (subcollector)
Curb (Corner) Radius	13.1–19.7 ft. (depending on road width and volumes)	26.2 ft.	15 ft. (minimum of 25 ft. is desirable)	20 ft.	15–20 ft.
Sidewalks	normally on both sides	Not required on access places At least one side of access streets	At least one side	Only at medium and high densities	Not required on access streets One side of subcollectors
Minimum Sidewalk Width	4.4–6.6 ft.	3.9 ft.	4 ft.	4–6 ft.	4 ft.

Note: ASCE = American Society of Civil Engineers; NAHB = National Association of Home Builders; ULI = Urban Land Institute

Source: Ewing, R. "Residential Street Design—Do the British and Australians Know Something We Americans Don't?" *Transportation Research Record*, No. 1455 (1994): 42-49.

In addition to reducing vehicle speeds and traffic volumes, engineers and planners have combined traditional traffic calming measures with the following to prioritize pedestrian streets:

- high-visibility crosswalks;
- ADA upgrades;
- street trees or other landscaping;
- street furniture;
- advance stop bars at crosswalks;
- mid-block pedestrian signals or crossings;
- pedestrian-scale lighting;
- limited vehicle access or car-free zones;

- wider sidewalks;
- pedestrian refuge islands;
- narrowed roadways;
- bulbouts;
- raised crosswalks; and
- signal timing treatments: pedestrian early release phase.

Santa Cruz has identified pedestrian priority areas and major activity centers where pedestrians are a high priority for implementing pedestrian-oriented design concepts.

> *The key recommendation is to adopt major activity center "pedestrian priority areas"—based on the 1/4- to 1/2-mile walking distance of neighborhoods to activity centers—with a focus on priority pedestrian building frontages and streetscape improvements to promote walkable communities and mixed-use development.*

The City's master transportation study recommends the following enhancements to areas identified as *pedestrian priority areas*:

- complete the sidewalk and wheelchair access ramp system;
- focus on the proposed sidewalk assistance program;
- add traffic signals on busy streets to facilitate crossing;
- develop long-term streetscape plans that include wider sidewalks, street trees, pedestrian lighting, street furniture and other pedestrian amenities;
- remove pedestrian barriers to walking and improving sidewalk maintenance;
- provide pedestrian-activated signals, multimodal intersection design and crossings;
- investigate red-light and video speed enforcement at major streets; and
- provide more frequent crossings to shorten the distance between protected crossings; a 300-ft. maximum standard is recommended.

Pedestrian *activity center* enhancements include:

- attractive, safe walking connections from the surrounding neighborhoods;
- landscape setbacks and street tree plantings;
- prioritizing the creation of pedestrian school zones for ease of walking to and from school (this could reduce morning peak traffic congestion where elementary school parents drive their kids to school);
- traffic calming measures to reduce speeds;
- design sensitivity to the adjacent residential areas;
- participation in the Pace Car Program; and
- walking "school buses"—groups of children walking to school with the guidance of a parent volunteer.

F. Topics of Research

Research topics on traffic calming in North America have traditionally focused on speed, volume, emergency response times and collision-reduction affects. *Traffic Calming State of the Practice* ascertained that little to no information had been collected on traffic calming's effects on people with disabilities, air quality, or social interactions among neighbors. Unfortunately, few data on these topics have been collected since publication of *Traffic Calming State of the Practice.*

More recent developments in traffic calming devices have provided the profession with new tools but limited data on the effectiveness. The following areas— in addition to topics discussed in *Traffic Calming State of the Practice*—should continue to be the focus of research in the future to better understand the effectiveness of such impacts and devices:

- in-pavement lighting;
- speed feedback signs;
- signage and striping;
- durability of speed cushions;
- neighborhood awareness programs (pledge programs, neighborhood signs, trash can brigade);
- bicycle boulevards; and
- pedestrian priority streets.

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