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Key City Staff to contact for more information:

Traffic Engineering Services
1000 I Street, Suite 170
Sacramento, CA 95814

Martin W. Hanneman, City Traffic Engineer, 916-264-5307
E-mail: mhanneman@cityofsacramento.org

Karen Shipley, Neighborhood Traffic Management Program, 916-264-8365
E-mail: kshipley@cityofsacramento.org

For more information about the City of Sacramento's Neighborhood Traffic Management Calming Program (NTMP), please visit our website at:

http://www.pwsacramento.com/traffic/ntmp.html

Consultants

Fehr & Peers Associates, Inc.

Dr. Reid Ewing, Rutgers University

I. INTRODUCTION

Purpose

These guidelines provide a framework for the selection, application, and design of traffic calming measures in the City of Sacramento. The document is primarily intended to be used by City staff and neighborhood residents for developing traffic calming plans as part of the Neighborhood Traffic Management Program (NTMP) and by City staff and developers concerned with avoiding traffic problems in new neighborhoods. This document may also be helpful for members of the general public that are interested in finding out how the City of Sacramento implements traffic calming.

Being guidelines, the contents are not intended as rigid requirements; rather, they are a tool for use by citizens, Public Works staff, and other interested parties to help develop effective traffic calming plans that adequately accommodate motor vehicles, pedestrians, and bicyclists, while enhancing the neighborhood environment.

HOW TO USE THIS DOCUMENT

The use of this document depends on whether the reader is planning traffic calming for an existing neighborhood or for a new neighborhood.

If you are a City Staff Person or Resident, Working in an Existing Neighborhood, you should focus on the following chapters:

Chapter II. Process for Existing Neighborhoods, to find out how to approach your traffic calming problem and develop solutions;

Chapter IV. Toolbox of Traffic Calming Measures, to discover what particular devices are available; and

Chapter V. Design Guidelines, to learn about some additional design considerations that may apply to your preferred traffic calming solutions.

If you are a City Staff Person or Developer, Planning for a New Neighborhood, you should focus on the following chapters:

Chapter III. Process for New Neighborhoods, to find out how to anticipate traffic calming problems and prevent them through proper street layout;

Chapter IV. Toolbox of Traffic Calming Measures, to discover what particular devices are available when street layout changes cannot fix the problem; and

Chapter V. Design Guidelines, to learn about some additional design considerations that may apply to your preferred traffic calming solutions.

Goals & Objectives

The goals and objectives of this document are patterned after the NTMP. The driving goal of the NTMP is:

> To improve neighborhood livability by reducing the impact of traffic in residential neighborhoods, which promotes safe and pleasant conditions for all users of local streets.

The NTMP strives to meet this goal through three primary objectives:

- To improve driver behavior, concentration, and awareness;
- To reduce speeds and traffic volumes; and
- To enhance the neighborhood environment.

These objectives are met through a combination of several parallel strategies, known collectively as the "Three E's":

- **Education –** Residents receive the information and tools necessary to become active participants in addressing their neighborhood traffic concerns;
- **Engineering –** Engineering principals are used to develop traffic calming strategies that address community-identified traffic issues; and
- **Enforcement –** Targeted police enforcement supports the traffic calming plan developed by residents and Public Works.

The role of the guidelines in supporting the goal, objectives, and strategies above is to articulate the method by which tools and strategies are considered and selected for use in meeting those goals and objectives.

How the Guidelines Were Developed

The contents of the guidelines were developed with the assistance of an advisory panel, composed of City staff, citizen and community group leaders, and developer representatives. The advisory panel was convened for two workshops designed to gather input on the traffic calming guidelines.

Workshop 1

The first workshop included a tutorial on traffic calming, focusing on the types of devices available. The panel also completed a questionnaire on various engineering and aesthetic issues related to traffic calming measures and on implementation issues.

Workshop 2

At the second workshop, the survey results were summarized for the panel, and the panel actively discussed each of the survey questions. Through this discussion, the panel reached a consensus on each of the engineering and aesthetic issues. The panel members also participated in a visual preference survey using 10-second video clips of 20 streets within the City of Sacramento. For each video clip, panel members marked on a survey form which traffic calming measures would be most acceptable. This exercise helped define the range of acceptable roadway characteristics that should be included in the application guidelines.

ADVISORY PANEL MEMBERS:

- Ron Anderson, *Walk Sacramento*
- Steve Balbierz, *Wood Rogers, Inc.*
- Fritz Buchman, *City of Sacramento Public Works Department*
- Edward Cox, *City of Sacramento Alternative Modes Coordinator*
- Ann Geraghty, *Walk Sacramento*
- Martin Hanneman, *City of Sacramento Traffic Engineer*
- Jose Ledesma, *City of Sacramento Traffic Engineering*
- Debb Newton, *City of Sacramento Neighborhood Traffic Management Program*
- Stephen Pyburn, *City of Sacramento Public Works Department*
- Walt Seifert, *Sacramento Area Bicycle Advocates*
- Karen Shipley, *City of Sacramento Neighborhood Traffic Management Program*
- Wanda Thornsberry, *Sacramento City Unified School District*
- Elaine Williams, *Private Citizen*
- Michael Whipple, *City of Sacramento ADA Coordinator*
- Capt. David Whitt, *City of Sacramento Fire Department*

For More Information

The guidelines draw from various earlier traffic calming studies and from two documents written by Reid Ewing: *Traffic Calming: State of the Practice* (Reid Ewing, FHWA, 1999) and *Delaware Traffic Calming Design Manual* (Reid Ewing, Delaware Department of Transportation, 2000). For more detailed information on the topics addressed in this document, please refer to these reports. A more comprehensive list of resources is also listed in Chapter VI.

II. PROCESS FOR EXISTING NEIGHBORHOODS

This chapter addresses how to think about traffic calming problems and solutions for a particular set of circumstances in an existing neighborhood. Typically, this process will occur as a part of the larger Neighborhood Traffic Management Program (NTMP), which is described in detail in Appendix A. By clearly identifying traffic problems, setting goals and objectives, and selecting appropriate traffic calming measures to meet those goals and objectives, a Traffic Calming Committee (TCC) can develop a traffic calming plan that has a greater likelihood of being approved and of meeting its goals. Figure 1 summarizes the steps that should be taken in the plan development process.

Figure 1. Plan Development Flowchart

1. Characterizing the Problem and Its Environment

The first step in developing a traffic calming plan is to characterize the problem type and to gather information about other conditions present at the problem location. This is accomplished through three tasks:

- Gathering neighborhood input on problems and priorities,
- Characterizing problem details, and
- Collecting quantitative data and characterizing physical and environmental conditions.

Neighborhood Input

Resident input must be used to determine whether the primary concern is one of vehicle safety, pedestrian safety, congestion, noise, inconvenience, or something else entirely. If speeding is raised as the main issue, it is important to determine whether the noise factor, the safety factor, or some other concern is paramount. If cut-through traffic is a concern, it is important to know why the traffic is problematic: does it travel too fast, or is there simply such a high volume that it bogs down traffic flow through the neighborhood? If safety is the main concern, then what seems to be the cause: high speeds, cut-corners, or a particularly dangerous conflict location? In many cases, a problem that initially looks like a speeding problem may be a safety problem, or one that initially looks like a volume problem may turn out to be a speeding problem.

TYPES OF TRAFFIC DATA:

- **Roadway Geometry:** Street widths, block lengths, roadway curvature, grades, and locations of stop signs and traffic signals.
- **Roadway Users:** Traffic volumes during peak hours, the entire day, and any particular periods when the problem occurs; pedestrian and bicycle volumes; truck volumes; existence of Regional Transit or other bus routes; designation as a primary emergency response route; and origin-destination studies.
- **Vehicle Performance Data:** travel speeds, stop sign violations, noise levels, rates of unsafe driving practices (e.g. cutting corners or crossing the centerline), and accident records.

Characterizing Problem Details

When the primary problem type is determined, the details of the problem need to be characterized: exactly where does it occur, and at what times of day and days of week? Is there a traffic control device (such as all-way stop control at an intersection) that does not seem to work?

Collecting Data

Knowing the exact nature of the problem, the next step is to collect relevant information about the problem itself and about the environment of the problem. See the sidebar "Types of Traffic and Environmental Data" for some examples.

2. Setting Goals and Objectives

Before selecting traffic calming devices, the TCC should have some idea of what the desired outcome is. Goals should also be stated to express, in qualitative terms, the kind of neighborhood the TCC members desire to have. Quantitative objectives should be set for each traffic problem to help assess the success of the traffic calming plan in solving the problems. There are no standards of "reasonability" for setting these objectives. Consequently, the objectives should be seen simply as rough yardsticks of success for use when reviewing the installed plan.

3. Selecting Measures

The first task in developing solutions to the traffic problems is to narrow the toolbox of traffic calming measures to those that will most closely target the key traffic issue, those that are appropriate for the type of location concerned, and those that are compatible with the traffic volumes, geometrics, and adjacent land uses at that location. When the list has been narrowed, devices should be considered in an order that balances effectiveness and likelihood of acceptance. Finally, the selected devices need to be placed in manner that will produce the desired results.

Selecting Measures for the Problem Type

The first task when selecting the most appropriate traffic calming device is to narrow the field of devices to those that address the primary traffic problem. The major types of traffic calming problems are:

- **Speeding** – motor vehicle speeds are too high;
- **Traffic Volumes** – motor vehicle usage levels (all trips or non-local trips only) are too high;
- **Vehicle Safety** – motor vehicles have an inordinate level of risk;

- **Pedestrian Safety –** motor vehicles cause an unnecessary risk to pedestrians; and
- **Noise/Vibration/Air Pollution –** motor vehicles cause excessive levels of these environmental effects.

Each device in the toolbox is appropriate to a different subset of the above problem types. The appropriateness of each device is summarized in Table 1 (page 9).

Selecting Measures for the Location Type

Identification of appropriate traffic calming measures should start by determining which measures are applicable to the location of the problem. If the traffic problem is confined to a specific roadway segment, then only measures applicable to roadway segments can be considered. Some other measures can be considered at intersections. Furthermore, certain types of devices are appropriate in residential areas but not in non-residential areas. Table 2 (page 10) indicates the locations where each traffic calming measure is applicable.

Selecting Measures for the Street Environment

The last step in narrowing the field of devices requires finding which devices are compatible with the traffic volumes, posted speeds, and special roadway users at the proposed location. For example, many devices have an upper boundary of traffic volumes beyond which any greater volume could result in traffic congestion that might be perceived as worse than the original traffic problem.

Also, since most devices cause some delay for emergency vehicles and transit buses, only certain devices can be used on primary emergency response routes and transit routes. Some measures have additional restrictions, such as curves and bicycle routes, that must be considered. Table 3 (page 12) summarizes the constraints on the use of traffic calming devices in these various environments.

Table 1 – Traffic Calming Measures and Problem Types

Types of Measures	Type of Problem				
	Speeding	Traffic Volume	Vehicle Accidents	Pedestrian Safety	Noise
Phase I Non-Restrictive Measures					
Targeted Speed Enforcement	●	○	◒	◒	◒
Radar Trailer	●	○	○	○	◒
Lane Striping	●	○	○	○	○
Speed Limit Signage	●	○	○	○	○
Speed Legends	●	○	○	○	○
Truck Restriction Signs	○	◒	○	○	●
"Cross Traffic Does Not Stop" Signage	○	○	●	◒	○
Botts Dots/Raised Reflectors	○	○	●	◒	○
High-Visibility Crosswalks	◒	○	○	●	○
Angled Parking	●	◒	○	○	○
Phase I Vertical Measures					
Speed Humps	●	●	◒	◒	×
Speed Lumps	●	●	◒	◒	×
Speed Tables	●	◒	◒	◒	×
Raised Crosswalks	●	◒	◒	●	×
Raised Intersections	●	◒	◒	●	×
Textured Pavement	◒	○	○	◒	×
Phase I Horizontal Measures					
Traffic Circles	●	◒	●	◒	○
Roundabouts (Single-Lane)	◒	◒	●	○	●
Lateral Shifts	◒	◒	○	○	○
Chicanes	●	◒	○	○	○
Realigned Intersections	●	◒	○	○	○
Phase I Narrowing Measures					
Neckdowns	●	◒	○	●	○
Two-Lane Chokers	●	◒	○	○	○
Center Island Narrowings/ Pedestrian Refuges	●	◒	◒	●	○
One-Lane Chokers	●	●	◒	◒	×
Phase II Measures					
Full Closures	●	●	○	○	○
Half Closures	●	●	○	○	○
Diagonal Diverters	●	●	○	○	○
Median Barriers	○	●	◒	○	○
Forced Turn Islands	○	●	◒	○	○

Key: ● = Strongly Appropriate; ◒ = Moderately Appropriate; × = Inappropriate/Counterproductive; ○ = Indifferent

Table 2 – Traffic Calming Measures and Location Types

<table>
<tr><th rowspan="2">Types of Measures</th><th colspan="3">Residential</th><th colspan="2">Non-Residential</th></tr>
<tr><th>Midblock</th><th>Intersection</th><th>Boundary of Area</th><th>Midblock</th><th>Intersection</th></tr>
<tr><td colspan="6">Phase I Non-Restrictive Measures</td></tr>
<tr><td>Targeted Speed Enforcement</td><td rowspan="2">●</td><td rowspan="2">●</td><td rowspan="2">●</td><td rowspan="2">●</td><td rowspan="2">●</td></tr>
<tr><td>Radar Trailer</td></tr>
<tr><td>Lane Striping</td><td>●</td><td>×</td><td>×</td><td>●</td><td>×</td></tr>
<tr><td>Speed Limit Signage</td><td rowspan="2">●</td><td rowspan="2">●</td><td rowspan="2">●</td><td rowspan="2">●</td><td rowspan="2">●</td></tr>
<tr><td>Speed Legends</td></tr>
<tr><td>Truck Restriction Signs</td><td>×</td><td>×</td><td>●</td><td>×</td><td>●</td></tr>
<tr><td>"Cross Traffic Does Not Stop" Signage</td><td>×</td><td>○</td><td>●</td><td>×</td><td>○</td></tr>
<tr><td>Botts Dots/Raised Reflectors</td><td>On Curves</td><td>×</td><td>×</td><td>●</td><td>×</td></tr>
<tr><td>High-Visibility Crosswalks</td><td>●</td><td>Unsignalized Intersections</td><td>Unsignalized Intersections</td><td>●</td><td>Unsignalized Intersections</td></tr>
<tr><td>Angled Parking</td><td>●</td><td>×</td><td>×</td><td>●</td><td>×</td></tr>
<tr><td colspan="6">Phase I Vertical Measures</td></tr>
<tr><td>Speed Humps</td><td rowspan="2">●</td><td rowspan="2">×</td><td rowspan="2">×</td><td rowspan="2">×</td><td rowspan="2">×</td></tr>
<tr><td>Speed Lumps</td></tr>
<tr><td>Speed Tables</td><td>●</td><td>×</td><td>×</td><td>○</td><td>×</td></tr>
<tr><td>Raised Crosswalks</td><td>●</td><td>○</td><td>○</td><td>○</td><td>×</td></tr>
<tr><td>Raised Intersections</td><td>×</td><td>●</td><td>●</td><td>×</td><td>●</td></tr>
<tr><td>Textured Pavement</td><td>●</td><td>●</td><td>●</td><td>●</td><td>●</td></tr>
<tr><td colspan="6">Phase I Horizontal Measures</td></tr>
<tr><td>Traffic Circles</td><td>×</td><td>Especially 4-Ways</td><td>○</td><td>×</td><td>○</td></tr>
<tr><td>Roundabouts (Single-Lane)</td><td>×</td><td>○</td><td>○</td><td>×</td><td>●</td></tr>
<tr><td>Lateral Shifts</td><td rowspan="2">●</td><td rowspan="2">×</td><td rowspan="2">×</td><td rowspan="2">●</td><td rowspan="2">×</td></tr>
<tr><td>Chicanes</td></tr>
<tr><td>Realigned Intersections</td><td>×</td><td>●</td><td>●</td><td>×</td><td>●</td></tr>
<tr><td colspan="6">Phase I Narrowing Measures</td></tr>
<tr><td>Neckdowns</td><td>×</td><td>●</td><td>●</td><td>×</td><td>●</td></tr>
<tr><td>Two-Lane Chokers</td><td>●</td><td>×</td><td>×</td><td>●</td><td>×</td></tr>
<tr><td>Center Island Narrowings/ Pedestrian Refuges</td><td>●</td><td>●</td><td>●</td><td>●</td><td>●</td></tr>
<tr><td>One-Lane Chokers</td><td>●</td><td>×</td><td>×</td><td>×</td><td>×</td></tr>
<tr><td colspan="6">Phase II Measures</td></tr>
<tr><td>Full Closures</td><td>×</td><td>●</td><td>●</td><td>×</td><td>×</td></tr>
<tr><td>Half Closures</td><td>×</td><td>●</td><td>●</td><td>×</td><td>×</td></tr>
<tr><td>Diagonal Diverters</td><td>×</td><td>●</td><td>×</td><td>×</td><td>×</td></tr>
<tr><td>Median Barriers</td><td>×</td><td>○</td><td>●</td><td>×</td><td>×</td></tr>
<tr><td>Forced Turn Islands</td><td>×</td><td>○</td><td>●</td><td>×</td><td>●</td></tr>
<tr><td colspan="6">Key: × = Seldom or never applicable. ● = Generally applicable.
○ = Not applicable except in some cases.</td></tr>
</table>

Prioritizing the Options

When multiple traffic calming measures remain at this point, the options should be prioritized such that the measures most likely to be effective in reaching the objectives are given some preference over those less likely to succeed. Encompassed in the likelihood of success is both the quantitative effectiveness of a measure in reducing speeds or traffic volumes and the likelihood that a measure will be accepted by those that have a voice: the residents of the neighborhood and the City Council.

Non-Physical Measures – Of the Phase I measures (which include all but the Diversion Measures), the first solutions to consider should always be the Non-Physical Measures, such as signs and markings, since these can be most easily removed if unanticipated problems occur.

Narrowing Devices – The next type of traffic calming measure to consider should be Narrowing Measures, such as neckdowns or center island medians, which are less obtrusive and more aesthetically appealing than some other devices since they can be combined with landscaping.

Horizontal Deflection Devices – Narrowing Devices are followed by Horizontal Deflection Devices, such as chicanes and traffic circles, which are more intrusive but also more effective because they force vehicles to navigate horizontally around physical objects. These can also be combined with landscaping.

Vertical Deflection Devices – The last type of Phase I measure to consider is a Vertical Deflection device, such as a speed table or raised intersection. These are generally the most effective at reducing travel speeds, but they can also be controversial because of driver discomfort and because of their aesthetics.

Diversion Devices – The structure of the NTMP process stipulates that Phase II measures cannot be considered until Phase I measures have been attempted and have failed to meet the TCC's goals. Consequently, they will generally not be considered simultaneously with the other types of measures.

Table 3 – Traffic Calming Measures and Traffic Constraints

Types of Measures	Roadway Classification: Arterials	Roadway Classification: Collectors	Roadway Classification: Local Streets	Bus or Emergency Response Route	Other Considerations
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.

4. Placing the Traffic Calming Measures

The last task in laying out a traffic calming plan is to identify the actual locations where devices should be placed. Strategies for layout devices differ depending on whether the major issue is speed-control, volume-control, or safety.

Placing Speed-Control Measures

If feasible, traffic calming measures should be spaced in such a way that the following two design speeds are achieved:

- **Slow-Point 85th Percentile Design Speed –** the speed that exactly 85% of vehicles are going less than, when they are *crossing* a traffic calming device; the target slow-point speed is defined as 5 mph *below* the posted speed limit;
- **Midpoint 85th Percentile Design Speed –** the speed that exactly 85% of vehicles are going less than, when they are *halfway between two* traffic calming devices; the target midpoint speed is defined as 5 mph *above* the posted speed limit.

The spacing of traffic calming measures directly affects the Midpoint speeds: the farther apart they are, the higher the Midpoint speed. See the sidebar "Estimating Midpoint Speeds" for more information on setting spacing based on Midpoint speeds.

In some cases, the Midpoint speed may not be achievable if resources are limited. If this is the case, devices may need to be constructed in stages. A limited number of fundable devices would be constructed first, followed by an evaluation of the results and, if necessary, a second round of construction when additional funding becomes available.

ESTIMATING MIDPOINT SPEEDS

In mathematical terms, the relationship between midpoint speed and spacing of slow points is given by an exponential function:

$$85^{th}_{midpoint} = 85^{th}_{slow\ point} + (85^{th}_{street} - 85^{th}_{slow\ point}) * 0.56 * (1 - e^{-0.004 * spacing})$$

where,

$85^{th}_{midpoint}$ = resulting 85th percentile speed at midpoint after calming;
$85^{th}_{slow\ point}$ = estimated 85th percentile speed at the slow point after treatment;
85^{th}_{street} = 85th percentile speed of street before treatment;
spacing = distance in feet between two devices.

When placing speed-control measures, the above formula should be used to test proposed spacings to determine whether the estimated midpoint speeds would be acceptable.

Placing Volume-Control Measures

Traffic calming devices intended to control traffic volumes can be placed either at entrances to a neighborhood or internally to the neighborhood.

Gateway Measures **–** Volume-control measures placed at entrances or gateways to the neighborhood can be more immediately effective in reducing volumes because non-local traffic is made aware even before entering the neighborhood that passing through is not a desirable option, causing them to choose to take other routes. However, these measures can also cause local traffic to take more circuitous paths than internal measures would.

Internal Measures **–** When placed internal to a neighborhood, internal measures have a less direct effect on non-local traffic. First-time attempts to cross the neighborhood will occur more frequently, especially soon after the devices are constructed. However, this type of placement can cause less of an inconvenience to local traffic.

Placing Safety Measures

The placement of safety-oriented traffic calming devices is dependent on the particulars of the problem and of the characteristics of the selected traffic calming device. For example, if the problem involves pedestrian safety, then the solution—a raised crosswalk, for example—should be placed at a location where it is likely to be heavily used by pedestrians. Or if a traffic circle is selected as a means of reducing vehicle collisions and the problem is not limited to a particular intersection, then preference should be given to four-way intersections, since T-intersections require special considerations (see Chapter V).

III. PROCESS FOR NEW NEIGHBORHOODS

In addition to existing neighborhoods, new neighborhoods in the planning stage can also benefit from traffic calming. Often traffic problems can be anticipated and prevented by properly reviewing street and lot plans for a neighborhood and prescribing refinements to the plan or identifying traffic calming measures that can be constructed concurrent with street construction. The process for reviewing new residential subdivisions is as follows:

1. ***Development Services Review –*** Prior to final approval of a street and lot plan, the plan will be reviewed by the City's Development Services. In this review, staff will identify proposed roadway layout features that are likely to cause traffic problems, such as inducing speeding or cut-through traffic or presenting an unnecessary risk of collisions.

2. ***Traffic Engineering Review –*** The City's Traffic Engineering Division will review the recommendations of Development Services. Any discrepancies will be discussed and resolved in consultation with Development Services.

3. ***Plan Revisions –*** Development Services staff submit comments on the street layout to the developer. If the indicated roadway changes are infeasible due to other constraints, then City Development Services will prescribe traffic calming measures based on the guidelines contained in this document. The cost of the traffic calming measures will be borne by the developer.

Designing Street Networks

The guidelines below describe some common street design features and their propensity to lead to traffic calming problems such as speeding and cut-through traffic. These guidelines are intended assist developers in laying out streets in new residential developments and City staff in reviewing them pursuant to the process described above. This chapter is by no means comprehensive on the layout of new residential streets. For detailed information, the following documents are recommended:

- Residential Street Design and Traffic Control, Homburger, Deakin, Bosselmann, Smith, and Beukers (Institute of Transportation Engineers), 1989;
- Residential Streets, American Society of Civil Engineers, National Association of Home Builders, and the Urban Land Institute, 1990; and
- Traditional Neighborhood Development: Street Design Guidelines, Institute of Transportation Engineers, 1999.

Designing for Appropriate Speeds

The following paragraph from *Residential Streets* (ASCE/NAHB/ULI, 1990) provides a useful summary of the task of designing residential streets to minimize speeding problems:

> The selection of appropriate pavement widths must account for probable peak traffic volume, parking needs and controls, likely vehicle speeds, and limitations imposed by sight distances, climate, terrain, and maintenance requirements. Designers should select the *minimum* width that will reasonably satisfy all realistic needs, thereby minimizing construction and average annual maintenance costs. The tendency of many communities to equate wider streets with better streets and to design traffic and parking lanes as though the street were a "microfreeway" is a highly questionable practice. Certainly the provision of 11- or 12-foot clear traffic lanes is an open invitation to increased traffic speeds.

STREET WIDTH STANDARDS

Street Type	Lane Width	Gutter	Other
Local Street, 2000 ADT or less	12'6"	2'6"	--
Local Street, 2000-4000 ADT	12'6"	2'6"	6' planter
Minor Collector, 4000-7000 ADT	12'	7' parking lane (includes gutter)	

Residential Streets goes on to recommend pavement widths for access streets, subcollectors, and collector streets (see sidebar

"Recommended Pavement Widths"). In addition to wide streets, long, straight, and uninterrupted stretches of residential roadways can also induce drivers to accelerate to unsafe speeds, increasing noise and risk of accidents with pedestrians and other vehicles. The following roadway geometry attributes should be considered when designing residential streets:

- ***Travel Lane Width –*** Travel lanes are often designed with excessive widths. To minimize drivers' propensity to speed, residential travel lanes should be designed to be no more than 12.5 feet wide. Wide shoulders should not be included unless they are needed to accommodate demand for parking or are striped as bicycle lanes. If excess width is provided in anticipation of a future need for traffic capacity, then in the short-term this width should be occupied by appropriately spaced chokers or other traffic calming measures (see Chapter II).

- ***Parking Lanes –*** Excessive width is sometimes provided for on-street parking in places where adjacent land uses generate little parking demand, leaving long gaps of unused space adjacent to the travel lane. This can often be the case along residential collector streets with few front-on houses. If the parking demand can be accommodated elsewhere, the parking lanes should be eliminated and the street width reduced accordingly.

- ***Block Length –*** Some street networks leave excessively long blocks without interrupting intersections. Drivers that travel a long distance (500 feet or greater) without being required to slow or stop by traffic control devices tend to travel at excessive speeds. To minimize this effect, the street network can be designed such that street blocks are interrupted by streets of sufficient traffic volumes to warrant a traffic control device (e.g. a traffic circle or stop sign) on the street of concern. Shorter block lengths also facilitate pedestrian movement throughout the neighborhood.

Designing for Local Traffic

If designed improperly, some residential collector streets can become cut-through routes, or routes used by non-local motorists as a means of bypassing congested or circuitous arterial roads. In these cases, the residential collector should be modified in one of three ways:

- A single collector can be replaced with a series of collectors such that more turns are required within the residential area than would be required by using the arterial system;
- The collector can be designed with a deviating path so that the overall distance by collector is greater than the distance by arterial; or
- The residential roadway network can be designed such that traffic-controlled intersections interrupt the parallel collector route sufficiently that the travel time by collector is greater than the travel time by arterial.

Pedestrian/Vehicle Conflict Areas

Some elements of residential areas, such as schools and parks, have particularly high potential for vehicle and pedestrian conflicts because of the pedestrian activity they generate. For schools, the major pedestrian routes to school should be identified and traffic controls should be structured so that the number of crossings at uncontrolled cross-streets is minimized. For both schools and parks, entrances tend to focus pedestrian street crossings on particular locations. These entrances can be made safer by combining them with roadway intersections, so that the intersection's traffic control can also allocate right-of-way to pedestrians.

If a pedestrian-oriented land use is located in an area where speeding or high traffic volumes are unavoidable, then traffic calming measures should be selected that incorporate pedestrian accommodations. For example, at an intersection, pedestrian bulbouts, neckdowns, or raised intersections should be given some preference over other measures, such as an intersection realignment. At a midblock location, a choker or raised crosswalk should be given some preference over a chicane.

Developing a Traffic Calming Plan

When a proposed street layout cannot be modified in such a way that will eliminate all potential traffic problems, a traffic calming plan should be developed. The procedure for developing a traffic calming plan should be the one described in Chapter II, with the following exceptions:

- For volume-related problems, traffic volume data will only be available in the form of traffic forecasts, and these will typically be limited to the major roads. Some manual traffic volume estimates may be required using land use quantities and trip generation rates for the proposed development.

- For speed-related problems, existing travel speed data will not be available. Consequently, a response to anticipated speeding problems would need to rely on roadway geometry. For example, if a block length is greater than 500 feet, then traffic calming measures could be used to break up the block into segments that are each shorter than 500 feet.

- Anticipated safety problems will likely revolve around land uses that generate pedestrian activity, such as schools, parks, and community centers. The placement of traffic calming devices that include pedestrian crossings should take into consideration the planned locations of walkways, gates, and building entrances for these land uses.

- For some traffic calming measures, particularly those involving modified roadway curbs, significant cost-savings can be achieved by constructing them concurrent with roadway construction. Consequently, when selecting a type of traffic calming measure, some additional preference should be given to measures that take advantage of these cost-savings.

IV. TOOLBOX OF TRAFFIC CALMING MEASURES

The following traffic calming measures constitute the standard "toolbox" of devices available to citizens and Public Works staff when developing neighborhood traffic management plans. The devices are divided into the following types:

- Phase I Measures:
  - Non-Physical Measures;
  - Vertical Deflection Measures;
  - Horizontal Deflection Measures;
  - Narrowing Measures;
- Phase II Measures:
  - Diversion Measures.

For each physical traffic calming measure in the toolbox, a data sheet is provided including a description, photograph, overhead schematic, and list of advantages and disadvantages of the measure. Detailed standard designs are included in Appendix C. Descriptions of the non-physical measures are also included.

Phase I Measures
Non-Physical Measures

Description

Non-physical measures include any measures that do not require the construction of physical modifications to the roadway. This category includes signing and striping modifications, as well as temporary use of certain enforcement strategies.

- **Targeted Speed Enforcement;**
- **Radar Trailers;**
- **Lane Striping;**
- **Signage;**
- **Speed Legends;**
- **Centerline or Edgeline Botts Dots;**
- **High-Visibility Crosswalk; and**
- **Angled Parking.**

TARGETED SPEED ENFORCEMENT

The TCC identifies locations for temporary targeted enforcement enhancements, based on personal observations and survey comments. A request is then submitted to the Police Department for the desired enforcement. Because of limited citywide resources, the targeted enforcement will not be continued indefinitely. Targeted enforcement may also be used in conjunction with new traffic calming devices to help drivers become aware of the new restrictions.

Approximate Cost: Varies.

Advantages

- Inexpensive if used temporarily;
- Does not require time for design;
- Does not slow trucks, buses, and emergency vehicles; and
- Effective in reducing speeds in a short time frame.

Disadvantages

- Expensive to maintain an increased level of enforcement; and
- Effectiveness may be temporary.

RADAR TRAILER

A radar trailer is a device that measures each approaching vehicle's speed and displays it next to the legal speed limit in clear view of the driver, reminding speeding drivers to slow to the speed limit. They can be easily placed on a street for a limited amount of time then relocated to another street, allowing a single device to be effective in many locations.

Approximate Cost: varies

Advantages

- Inexpensive if used temporarily;
- Does not require time for design;
- Does not slow emergency vehicles; and
- Effective in reducing speeds in the short-run.

Disadvantages

- Effectiveness may be temporary;
- Aesthetics;
- Only effective on one lane of traffic; and
- Subject to vandalism.

LANE STRIPING

Lane striping can be used to create formal bicycle lanes, parking lanes, or simple edge lines. As a traffic calming measure, they are used to narrow the travel lanes for vehicles, to encourage drivers to lower their speeds. The past evidence on speed reductions is, however, inconclusive.

Approximate Cost:
$2 per lineal foot

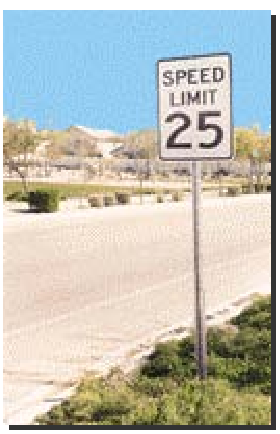
Advantages

- Inexpensive;
- Can be used to create bicycle lanes or delineate on-street parking;
- Does not require time for design; and
- Does not slow emergency vehicles.

Disadvantages

- Has not been shown to significantly reduce travel speeds; and
- Increases regular maintenance.

SIGNAGE



Signage that can be used as a traffic calming measure include:

- Speed Limit Signs;
- Truck Restriction Signs; and
- "Cross Traffic Does Not Stop" Signs.

Note that speed limit signs, to be eligible for radar enforcement, must be set using an appropriate engineering and speed study.

Approximate Cost: $150 per sign.

Advantages

- Inexpensive;
- Does not require time for design;
- Turn restrictions can reduce cut-through traffic; and
- Does not significantly slow emergency vehicles.

Disadvantages

- Speed limit signs are ineffective if unaccompanied by increased police enforcement; and
- If speed limit is set unreasonably low, drivers are more likely to exceed it.

SPEED LEGENDS

Speed legends are numerals painted on the roadway indicating the current speed limit in miles per hour. They are usually placed near speed limit signposts. Speed legends can be useful in reinforcing a reduction in speed limit between one segment of a roadway and another segment. They may also be placed at major entry points into a residential area.

Approximate Cost: $75

Advantages

- Inexpensive;
- Helps reinforce a change in speed limit;
- Does not require time for design; and
- Does not slow emergency vehicles.

Disadvantages

- Has not been shown to significantly reduce travel speeds.

BOTTS DOTS AND RAISED REFLECTORS

Botts dots and raised reflectors, or "raised pavement markers," are small bumps lining the centerline or edgeline of a roadway. They are often used on curves where vehicles have a tendency to deviate outside of the proper lane, risking collision. Raised reflectors improve the nighttime visibility of the roadway edges.

Advantages

- Inexpensive;
- Does not slow trucks, buses, and emergency vehicles; and
- Can help keep drivers in the appropriate travel lane on curves and under low-visibility conditions.

Disadvantages

- Noise caused by rumble strips.

Botts dots can be arranged into a rectangular array across the roadway, creating a *rumble strip*, which causes a rumbling sensation to drivers as they cross. These can reduce travel speeds but also increase roadway noise considerably. Consequently, rumble strips are only placed in very low density areas because of the noise factor.

Approximate Cost: $4.50 per marker

HIGH-VISIBILITY CROSSWALK

High-visibility crosswalks use special marking patterns and raised reflectors to increase the visibility of a crosswalk at night. In Sacramento, a "triple-four" marking pattern is used, in which two rows of four-foot wide rectangles, separated by four feet of unpainted space, are painted across the roadway. Raised reflectors are placed at the approach edges of these rectangles. The unpainted space along the center of the crosswalk allows wheelchairs and foot traffic to cross in the rain without sliding problems across the paint.

Approximate Cost: $250

Advantages

- Increase visibility under low-visibility conditions;
- Focus crossing pedestrians at a single location;

Disadvantages

- May give pedestrians a false sense of security, causing them to pay less attention to traffic;
- Require more maintenance than normal crosswalks.

ANGLED PARKING

Angled parking reorients on-street parking spaces to a 45-degree angle, increasing the number of parking spaces and reducing the width of the roadway available for travel lanes. Angled parking is also easier for vehicles to maneuver into and out of than parallel parking. Consequently, it works well in locations with high parking demand, such as multi-family residences, and high turnover rates, such as commercial and mixed-use areas.

Approximate Cost: varies by length

Advantages

- Reduces speeds by narrowing the travel lanes;
- Increases the number of parking spaces;
- Makes parking maneuvers easier and take less time than with parallel parking; and
- Favored by businesses and multi-family residences.

Disadvantages

- Precludes the use of bike lanes (unless roadway is wider than 58 feet);
- Ineffective on streets with frequent driveways; and
- May be incompatible with one-way streets approaching a two-way segment.

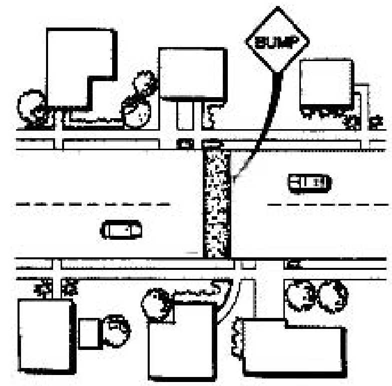
Phase 1 Measures
Vertical Deflection Devices

Description

Vertical deflection devices use variations in pavement height and alternative paving materials to cause drivers discomfort at high travel speeds. The vertical deflection devices in the toolbox include:

- **Speed Humps;**
- **Speed Lumps;**
- **Speed Tables;**
- **Raised Crosswalks;**
- **Raised Intersections; and**
- **Textured Pavement.**

SPEED HUMP



Speed Humps are rounded raised areas placed across the road. They are generally 12 feet long (in the direction of travel), 3 ¼ to 3 ¾ inches high, and parabolic in shape, and have a design speed of 15 to 20 mph. They are usually constructed with AC and have a taper on each side to allow unimpeded drainage between the hump and curb. When placed on a street with rolled curbs or no curbs, bollards are placed at the ends of the speed hump to discourage vehicles from veering outside of the travel lane to avoid the device. Speed humps have been used in many neighborhood within the City of Sacramento.

Approximate Cost: $1,500.

Measured Impacts		
Speed Impacts	**Reduction in 85th Percentile Speeds between Slow Points**	**-18%**
Safety Impacts	**Reduction in Average Annual Number of Collisions**	**-13%**
Source: Traffic Calming: State of the Practice, 2000.		

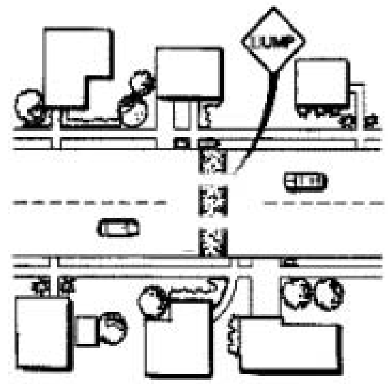
Advantages

- Relatively inexpensive;
- Relatively easy for bicyclists to cross if taper is designed appropriately; and
- Very effective in slowing travel speeds.

Disadvantages

- Causes a "rough ride" for all drivers, and can cause severe pain for people with certain skeletal disabilities;
- Slows emergency vehicles, such as large vehicles that have rigid suspensions;
- Increase noise and air pollution; and
- Aesthetics.

SPEED LUMP



The speed lump is a variation on the speed hump, adding two wheel cut-outs designed to allow large vehicles, such as buses and emergency vehicles, to pass without slowing. The spacing of the cut-outs is designed such that all wheels of a larger vehicle will pass through both cut-outs, but for a standard size vehicle to pass, at least one set of wheels will be affected by the hump. The speed lump was designed in the City of Sacramento and has been installed in a small number of locations.

Approximate Cost: $2,000.

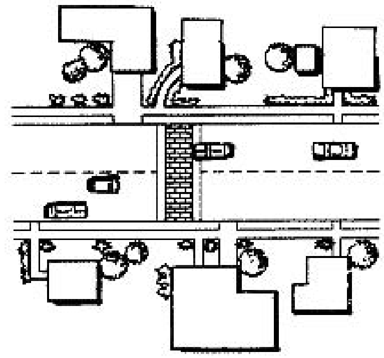
Advantages

- Effective in reducing speeds;
- Maintains rapid emergency response times;
- Inexpensive; and
- Relatively easy for bicyclists to cross if taper is designed appropriately.

Disadvantages

- Aesthetics;
- Private vehicles with large wheel widths can avoid the lump using the wheel cut-outs; and
- Increased noise to adjacent residences.

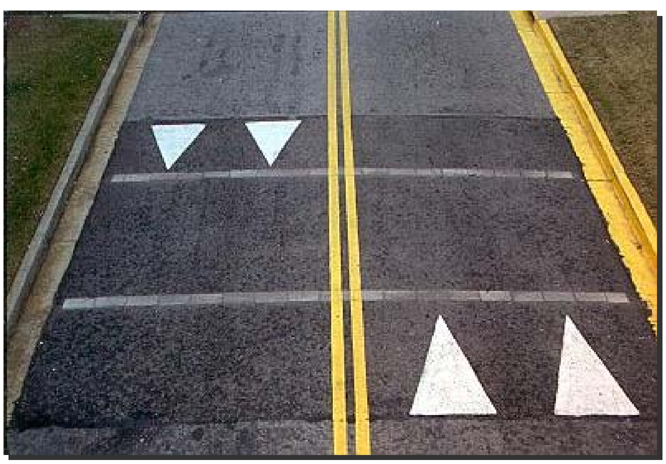
SPEED TABLE



Speed tables are flat-topped speed humps often constructed with a brick or other textured materials on the flat section. Speed tables are typically long enough for the entire wheelbase of a passenger car to rest on top. Their long flat fields, plus ramps that are sometimes more gently sloped than speed humps, give speed tables higher design speeds than humps. The brick or other textured materials improve the appearance of speed tables, draw attention to them, and may enhance safety and speed reduction.

Approximate Cost: $4,000 with basic materials.

Measured Impacts		
Speed Impacts	**Reduction in 85th Percentile Speeds between Slow Points**	**-18%**
Volume Impacts	**Reduction in Vehicles per Day**	**-12%**
Safety Impacts	**Reduction in Average Annual Number of Collisions**	**-45%**
Source: Traffic Calming: State of the Practice, 2000.		



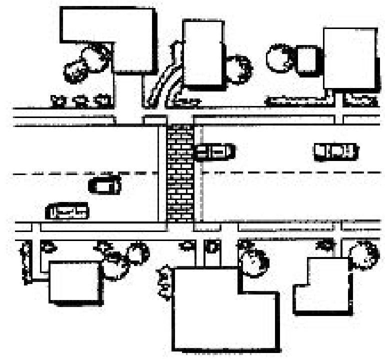
Advantages

- Smoother on large vehicles (such as fire trucks) than speed humps; and
- Effective in reducing speeds, though not to the extent of speed humps.

Disadvantages

- Aesthetics, if no textured materials are used;
- Textured materials, if used, can be expensive; and
- Increased noise to adjacent residences.

RAISED CROSSWALK



Raised Crosswalks are speed tables outfitted with crosswalk markings and signage to channelize pedestrian crossings, providing pedestrians with a level street crossing. Also, by raising the level of the crossing, pedestrians are more visible to approaching motorists.

Approximate Cost: $4,000 with basic materials.

Measured Impacts		
Speed Impacts	**Reduction in 85th Percentile Speeds between Slow Points**	**-18%**
Volume Impacts	**Reduction in Vehicles per Day**	**-12%**
Safety Impacts	**Reduction in Average Annual Number of Collisions**	**-45%**
Source: Traffic Calming: State of the Practice, 2000.		

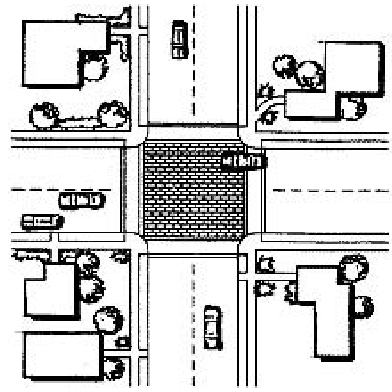
Advantages

- Improve safety for both vehicles and pedestrians;
- If designed well, can have positive aesthetic value; and
- Effective in reducing speeds, though not to the extent of speed humps.

Disadvantages

- Textured materials, if used, can be expensive;
- Impact to drainage needs to be considered; and
- Increased noise to adjacent residences.

RAISED INTERSECTION



Raised intersections are flat raised areas covering entire intersections, with ramps on all approaches and often with brick or other textured materials on the flat section. They usually rise to sidewalk level, or slightly below to provide a "lip" for the visually impaired. By modifying the level of the intersection, the crosswalks are more readily perceived by motorists to be pedestrian territory. They are particularly useful in dense urban areas, where the loss of on-street parking associated with other traffic calming measures is considered unacceptable.

Approximate Cost: $70,000

Measured Impacts		
Speed Impacts	**Reduction in 85th Percentile Speeds between Slow Points**	**-1%**
Source: Traffic Calming: State of the Practice, 2000.		

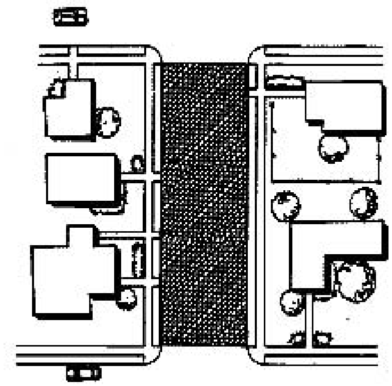
Advantages

- Improves safety for both pedestrians and automobiles;
- If designed well, can have positive aesthetic value; and
- Can calm two streets at once.

Disadvantages

- Less effective in reducing vehicle speeds than speed humps and speed tables; and
- Expensive, varying by materials used.

TEXTURED PAVEMENT



Textured colored pavement includes the use of stamped pavement (asphalt) or alternate paving materials to create an uneven surface for vehicles to traverse. They may be used to emphasize either an intersection or a pedestrian crossing. Textured pavement is currently exists only in a few locations in the City of Sacramento.

Approximate Cost: varies by area and materials.

Advantages

- Can reduce vehicle speeds over an extended length;
- If designed well, can have positive aesthetic value; and
- Placed at an intersection, it can calm two streets at once.

Disadvantages

- Expensive, varying by materials used;
- If used on a crosswalk, can make crossing difficult for wheelchair users or the visually impaired.

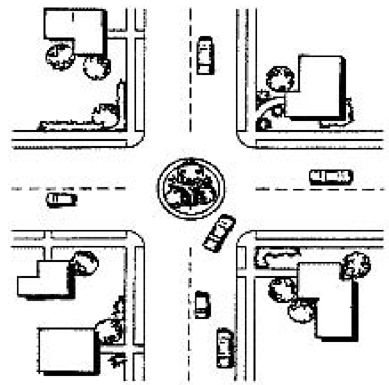
Phase I Measures
Horizontal Deflection Devices

Description

Horizontal deflection devices use raised islands and curb extensions to eliminate straight-line paths along roadways and through intersections. The horizontal deflection devices in the toolbox include:

- **Traffic Circles;**
- **Roundabouts;**
- **Lateral Shifts;**
- **Chicanes; and**
- **Realigned Intersections.**

TRAFFIC CIRCLE



Traffic circles are raised islands, placed in intersections, around which traffic circulates. They are usually circular in shape and landscaped in their center islands, though not always. Traffic controls at the approaches vary by location. Circles prevent drivers from speeding through intersections by impeding the straight-through movement and forcing drivers to slow down to yield. Drivers must first turn to the right, then to the left as they pass the circle, and then back to the right again after clearing the circle. Traffic circles have been installed in some neighborhoods in the City of Sacramento.

Measured Impacts		
Speed Impacts	**Reduction in 85th Percentile Speeds between Slow Points**	**-11%**
Volume Impacts	**Reduction in Vehicles per Day**	**-5%**
Safety Impacts	**Reduction in Average Annual Number of Collisions**	**-71%**
Source: Traffic Calming: State of the Practice, 2000.		

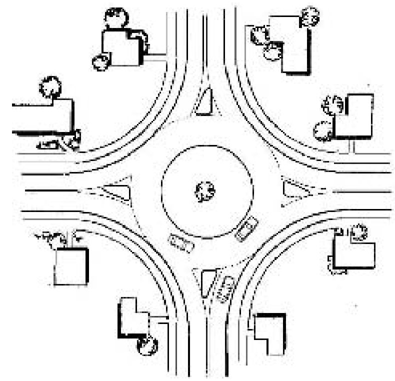
Advantages

- If designed well, can have positive aesthetic value; and
- Very effective in moderating speeds and improving safety.

Disadvantages

- Difficult for large vehicles (such as fire trucks) to circumnavigate;
- Must be designed so that the circulating lane does not encroach on crosswalks;
- Potential loss of on-street parking; and
- Landscaping must be maintained, either by City or by residents.

ROUNDABOUT



Like traffic circles, roundabouts require traffic to circulate counterclockwise around a center island. But unlike circles, roundabouts are used on higher volume streets to allocate rights-of-way among competing movements. They are found primarily on arterial and collector streets, often substituting for traffic signals or all-way STOP signs. They are larger than neighborhood traffic circles and typically have raised splitter islands to channel approaching traffic to the right.

Approximate Cost: varies by the dimensions of the roundabout.

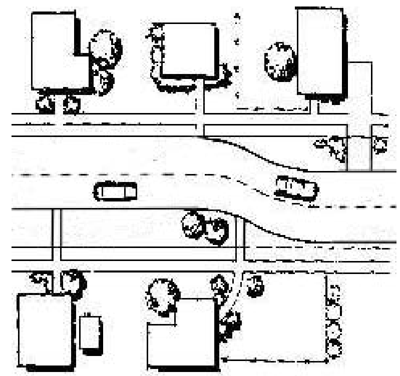
Advantages

- Moderates traffic speed on an arterial;
- Aesthetics;
- Enhanced safety compared to a traffic signal;
- Minimizes queuing at approaches to the intersection; and
- Less expensive to operate than traffic signals.

Disadvantages

- May require major reconstruction of an existing intersection;
- Loss of on-street parking;
- Increases pedestrian distance from one crosswalk to the next; and
- Requires more right-of-way than a signalized intersection.

LATERAL SHIFT



Lateral shifts are curb extensions on otherwise straight streets that cause travel lanes to bend one way and then bend back the other way to the original direction of travel. Lateral shifts, with just the right degree of deflection, are one of the few measures that have been used on collectors or even arterials, where high traffic volumes and high posted speeds preclude more abrupt measures.

Approximate Cost: varies by size of offset and length of transition.

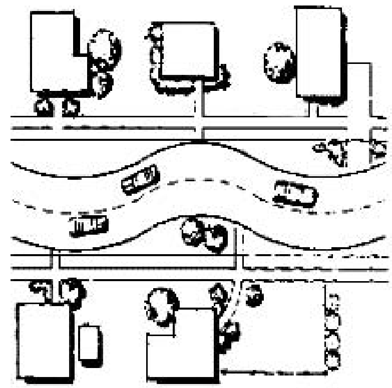
Advantages

- Can accommodate higher traffic volumes than many other traffic calming measures; and
- Easily negotiable by large vehicles (such as fire trucks).

Disadvantages

- Not as effective reducing speeds as other traffic calming measures;
- Potential loss of on-street parking; and
- Must be designed carefully to discourage drivers from deviating out of the appropriate lane.

CHICANE



Chicanes are curb extensions that alternate from one side of the street to the other, forming S-shaped curves. Chicanes can also be created by alternating on-street parking, either diagonal or parallel, between one side of the road and the other. Each parking bay can be created either by restriping the roadway or by installing raised, landscaping islands at each end, creating a protected parking area.

Approximate Cost: $8,000-14,000.

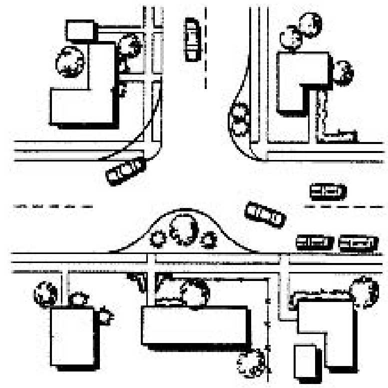
Advantages

- Discourages high speeds by forcing horizontal deflection; and
- Easily negotiable by large vehicles (such as fire trucks) except under heavy traffic conditions.

Disadvantages

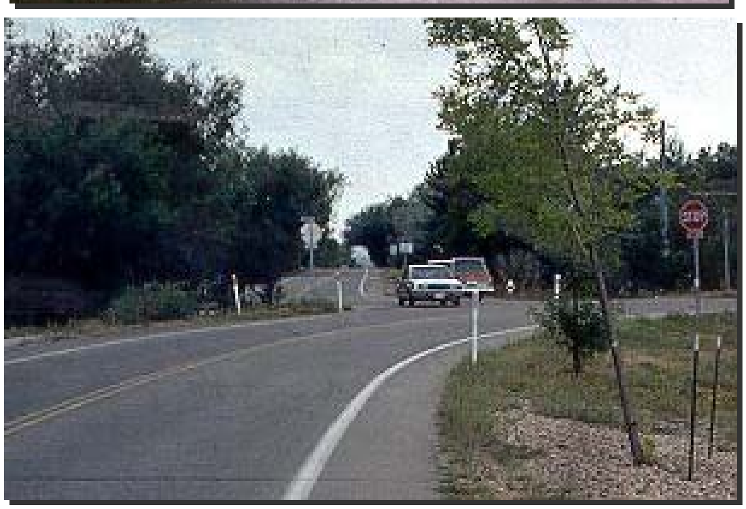
- Must be designed carefully to discourage drivers from deviating out of the appropriate lane;
- Curb realignment and landscaping can be costly, especially if there are drainage issues; and
- Potential loss of on-street parking.

REALIGNED INTERSECTION



Realigned intersections are changes in alignment that convert T-intersections with straight approaches into curving streets that meet at right angles. A former "straight-through" movement along the top of the T becomes a turning movement. While not commonly used, they are one of the few traffic calming measures for T-intersections, because the straight top of the T makes deflection difficult to achieve, as needed for traffic circles.

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



Advantages

- Can be effective reducing speeds and improving safety at T-intersection that is commonly ignored by motorists.

Disadvantages

- Curb realignment can be costly;
- May require some additional right-of-way on the cut corner.

Department of PUBLICWORKS City of Sacramento

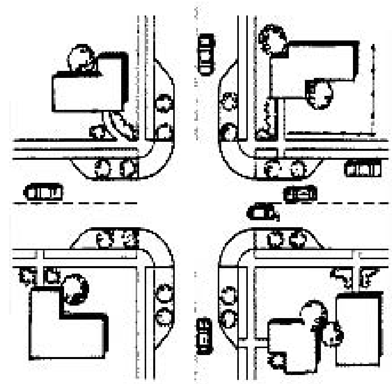
Phase I Measures
Narrowing Devices

Description

Narrowing devices use raised islands and curb extensions to narrow the travel lane for motorists. The narrowing devices in the toolbox include:

- **Neckdowns/Bulbouts;**
- **Two-Lane Chokers;**
- **One-Lane Chokers; and**
- **Center Island Narrowings.**

NECKDOWN/BULBOUT



Neckdowns and bulbouts are curb extensions at intersections that reduce roadway width curb to curb. Bulbouts are simple raised curbs at an intersection that narrow the travel lane but do not provide additional pedestrian space. Neckdowns actually "pedestrianize" intersections by shortening crossing distances for pedestrians and drawing attention to pedestrians via raised peninsulas. Both measures tighten curb radii at the corner, shortening the pedestrian crossing distance and reducing the speeds of turning vehicles. Both of these effects increase pedestrian comfort and safety at the intersection.

Approximate Cost: $40,000-80,000 for four corners.

Measured Impacts		
Speed Impacts	**Reduction in 85th Percentile Speeds between Slow Points**	**-7%**
Volume Impacts	**Reduction in Vehicles per Day**	**-10%**
Source: Traffic Calming: State of the Practice, 2000.		

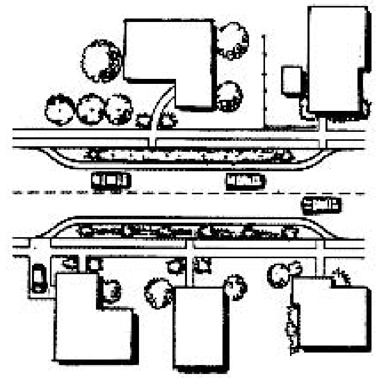
Advantages

- Improves pedestrian circulation and space;
- Through and left-turn movements are easily negotiable by large vehicles;
- Creates protected on-street parking bays; and
- Reduces speeds (especially right-turning vehicles) and traffic volumes.

Disadvantages

- Effectiveness is limited by the absence of vertical or horizontal deflection;
- May slow right-turning emergency vehicles;
- Potential loss of on-street parking; and
- May require bicyclists to briefly merge with vehicular traffic.

TWO-LANE CHOKER



Chokers are curb extensions at midblock that narrow a street by widening the sidewalk or planting strip. If marked as crosswalks, they are also called safe crosses. Chokers leave the street cross section with two lanes that are narrower than the normal cross section.

Approximate Cost: $7,000-10,000.

Measured Impacts		
Speed Impacts	**Reduction in 85th Percentile Speeds between Slow Points**	**-7%**
Volume Impacts	**Reduction in Vehicles per Day**	**-10%**
Source: Traffic Calming: State of the Practice, 2000.		

Advantages

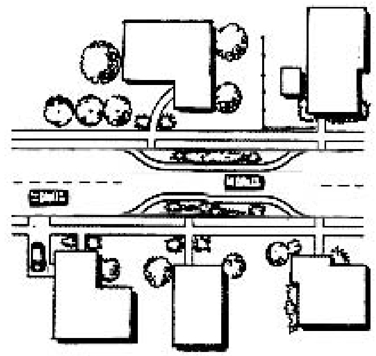
- Easily negotiable by large vehicles (such as fire trucks);
- If designed well, can have positive aesthetic value; and
- Reduces both speeds and volumes.

Disadvantages

- Effect on vehicle speeds is limited by the absence of any vertical or horizontal deflection;
- May require bicyclists to briefly merge with vehicular traffic; and
- Potential loss of on-street parking.

ONE-LANE CHOKER

One-lane chokers narrow the roadway width such that there is only enough width to allow travel in one direction at a time. They operate similarly to one-lane bridges, where cars approaching on one side must wait until all traffic in the other direction has cleared, then they proceed through the choker.



Approximate Cost: $7,000-10,000.

Measured Impacts		
Speed Impacts	**Reduction in 85th Percentile Speeds between Slow Points**	**-14%**
Volume Impacts	**Reduction in Vehicles per Day**	**-20%**
Source: Traffic Calming: State of the Practice, 2000.		

Advantages

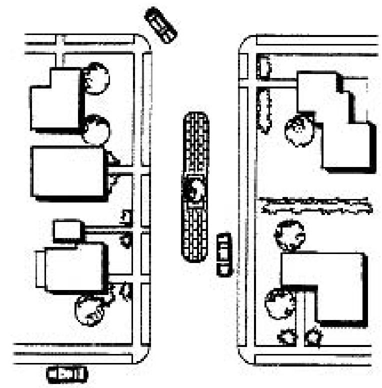
- Maintains two-way vehicle access; and
- Very effective in reducing speeds and traffic volumes.

Disadvantages

- Perceived by many as unsafe because opposing traffic is vying for space in a single lane;
- Can only be used on low-volume roads without causing substantial congestion;
- Must be designed so that it is clear to drivers that the gap is wide enough for only one direction of travel; and
- Loss of on-street parking.

CENTER ISLAND NARROWING/PEDESTRIAN REFUGE

Center island narrowings are raised islands located along the centerline of a street that narrow the travel lanes at that location. They are often landscaped to provide visual amenity. Placed at the entrance to a neighborhood, and often combined with textured pavement, they are often called "gateways". Fitted with a gap to allow pedestrians to walk through at a crosswalk, they are often called "pedestrian refuges". Pedestrian refuges exist in some Sacramento neighborhoods.



Approximate Cost: $6,000-9,000.

Measured Impacts		
Speed Impacts	**Reduction in 85th Percentile Speeds between Slow Points**	**-7%**
Volume Impacts	**Reduction in Vehicles per Day**	**-10%**
Source: Traffic Calming: State of the Practice, 2000.		

Advantages

- Increases pedestrian safety;
- If designed well, can have positive aesthetic value; and
- Reduces traffic volumes.

Disadvantages

- Effect on vehicle speeds is limited by the absence of any vertical or horizontal deflection; and
- Potential loss of on-street parking.

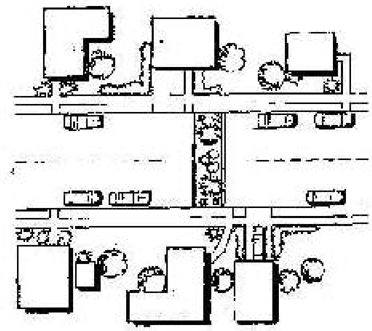
Phase II Measures
Diversion Devices

Description

Diversion devices use raised islands and curb extensions to preclude particular vehicle movements, such as left-turn or through movements, usually at an intersection. These devices can only be considered after Phase I devices have been attempted and failed to resolve the traffic problem. The diversion devices in the toolbox include:

- **Full Closures;**
- **Half Closures;**
- **Diagonal Diverters;**
- **Median Barriers; and**
- **Forced Turn Islands.**

FULL CLOSURE



Full street closures are barriers placed across a street to close the street completely to through traffic, usually leaving only sidewalks or bicycle paths open. The barriers may consist of landscaped islands, walls, gates, side-by-side bollards, or any other obstructions that leave an opening smaller than the width of a passenger car.

Approximate Cost: $30,000-100,000.

Measured Impacts		
Volume Impacts	**Reduction in Vehicles per Day**	**-44%**
Source: Traffic Calming: State of the Practice, 2000.		

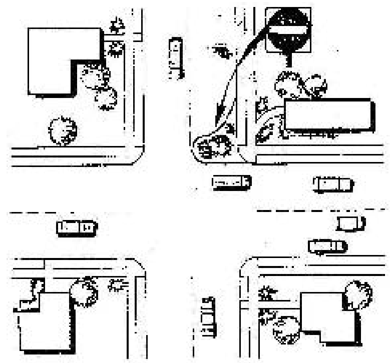
Advantages

- Able to maintain pedestrian and bicycle access; and
- Very effective in reducing traffic volumes.

Disadvantages

- Requires legal procedures for public street closures;
- Causes circuitous routes for local residents and emergency services;
- May be expensive; and
- May limit access to businesses.

HALF CLOSURE



Half street closures are barriers that block travel in one direction for a short distance on otherwise two-way streets. Half closures are the most common volume control measure after full street closures. Half closures are often used in sets to make travel through neighborhoods with gridded streets circuitous rather than direct. That is, half closures are not lined up along a border, which would preclude through movement, but instead are staggered, which leaves through movement possible but less attractive than alternative routes. Half closures exist in the northern part of the Midtown neighborhood in the City of Sacramento.

Approximate Cost: $6,500.

Measured Impacts		
Speed Impacts	**Reduction in 85th Percentile Speeds between Slow Points**	**-19%**
Volume Impacts	**Reduction in Vehicles per Day**	**-42%**
Source: Traffic Calming: State of the Practice, 2000.		

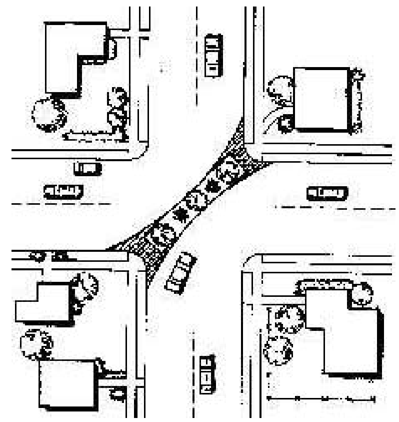
Advantages

- Able to maintain two-way bicycle access; and
- Effective in reducing traffic volumes.

Disadvantages

- Causes circuitous routes for local residents and emergency services;
- May limit access to businesses;
- Drivers can circumvent the barrier.

DIAGONAL DIVERTER



Diagonal diverters are barriers placed diagonally across an intersection, blocking through movement. Like half closures, diagonal diverters are usually staggered to create circuitous routes through neighborhoods.

Measured Impacts		
Speed Impacts	**Reduction in 85th Percentile Speeds between Slow Points**	**-4%**
Volume Impacts	**Reduction in Vehicles per Day**	**-35%**
Source: Traffic Calming: State of the Practice, 2000.		

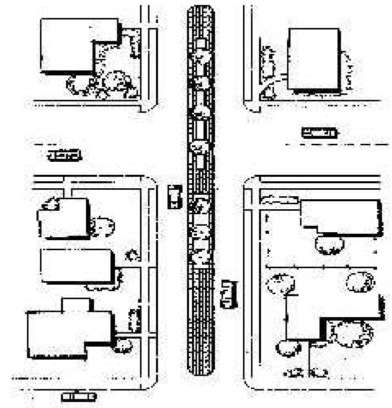
Advantages

- Does not require a closure per se, only a redirection of existing streets;
- Able to maintain full pedestrian and bicycle access; and
- Reduces traffic volumes.

Disadvantages

- Causes circuitous routes for local residents and emergency services;
- May be expensive; and
- May require reconstruction of corner curbs.

MEDIAN BARRIER



Median barriers are raised islands that are located along the centerline of a street and continue through an intersection so as to block through movement at a cross street.

Approximate Cost: $15,000-20,000 per 100 feet.

Measured Impacts		
Volume Impacts	**Reduction in Vehicles per Day**	**-31%**
Source: Traffic Calming: State of the Practice, 2000.		

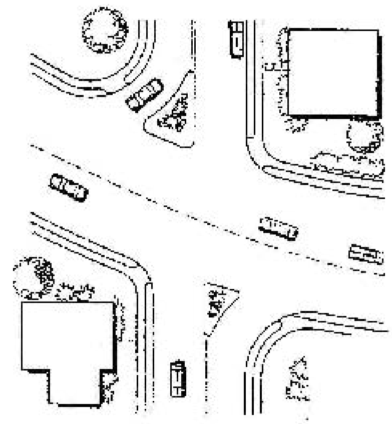
Advantages

- Can improve safety at an intersection of a local street and a major street by prohibiting dangerous turning movements; and
- Can reduce traffic volumes on a cut-through route that crosses a major street.

Disadvantages

- Requires available street width on the major street;
- Limits turns to and from the side street for local residents and emergency services.

FORCED-TURN ISLAND



Forced turn islands are raised islands that block certain movements on approaches to an intersection. Forced turn islands exist in selected locations in the northern port of the Midtown neighborhood in the City of Sacramento.

Approximate Cost: $3,000-5,000

Measured Impacts		
Volume Impacts	**Reduction in Vehicles per Day**	**-31%**
Source: Traffic Calming: State of the Practice, 2000.		

Advantages

- Can improve safety at an intersection of a local street and a major street by prohibiting dangerous turning movements; and
- Reduces traffic volumes.

Disadvantages

- If designed improperly, drivers can maneuver around the island to make an illegal movement;
- May simply divert a traffic problem to a different street.

Effectiveness Comparison

Table 4 summarizes the effectiveness data that has been compiled for each of the traffic calming measures in the toolbox. Note that these data are averages. Actual effectiveness can vary based on site-specific circumstances, such as proximity to major roads and the availability of alternate routes.

Table 4 – Quantitative Impacts of Traffic Calming Measures

Types of Measures	Effectiveness									
	85th Percentile Speeds				Vehicles per Day		Average Annual Collisions			
	Before	After	Change	Percent Change	Change	Percent Change	Before	After	Change	Percent Change
Phase I Non-Restrictive Measures	I/D									
Phase I Restrictive Measures										
Speed Humps	35.0	27.4	-7.6	-22%	-355	-18%	2.62	2.29	-0.33	-13%
Speed Lumps	I/D				I/D		I/D			
Speed Tables	36.7	30.1	-6.6	-18%	-415	-12%	6.71	3.66	-3.05	-45%
Raised Crosswalks										
Raised Intersections	34.6	34.3	-0.3	-1%	I/D		I/D			
Textured Pavement	I/D				I/D		I/D			
Phase I Horizontal Measures										
Traffic Circles	34.2	30.3	-3.9	-11%	-293	-5%	2.19	0.64	-1.55	-71%
Roundabouts (Single-Lane)	Insignificant Speed Effects				Insignificant Volume Effects		Not Recorded			-15% to -33%
Lateral Shifts	I/D				I/D		I/D			
Chicanes	I/D				I/D		I/D			
Realigned Intersections	I/D				I/D		I/D			
Phase I Narrowing Measures										
Neckdowns	34.9	32.3	-2.6	-7%	-293	-10%	I/D			
Two-Lane Chokers										
Center Island Narrowings/ Pedestrian Refuges										
One-Lane Chokers	33.4	28.6	-4.8	-14%	-392	-20%	I/D			
Phase II Divertive Measures										
Full Closures	I/D	I/D	I/D	I/D	-671	-44%	I/D			
Half Closures	32.3	26.3	-6.0	-19%	-1,611	-42%	I/D			
Diagonal Diverters	29.3	27.9	-1.4	-5%	-501	-35%	I/D			
Median Barriers	I/D	I/D	I/D	I/D	-1,167	-31%	I/D			
Forced Turn Islands										

Notes: I/D = Insufficient Data
Source: *Traffic Calming: State of the Practice* (Ewing, 1999)

V. DESIGN GUIDELINES

This chapter identifies some physical design considerations and constraints associated with the traffic calming measures in the toolbox in the previous chapter. Engineering designs for the standard traffic calming measures in Sacramento's NTMP toolbox are contained in Appendix C. These designs were developed to conform to the following considerations expressed by the advisory panel.

Emergency Response Routes

Numerous experimental traffic calming measures, such as offset speed humps and speed lumps, are continuously being developed in locations where emergency response impacts have been a concern. Because every situation is different, such variations on the standard traffic calming devices may be appropriate in many cases. The NTMP promotes the consideration of these existing experimental measures and the exploration of new measures through continuous dialogue between Public Works, emergency services staff, and citizens of the community.

Vertical Deflection Measures

<u>Ramp Profiles</u>

Vertical deflection measures (e.g. speed hump, speed tables, and raised intersections) should use parabolic profiles on ramps of the vehicular approaches to the devices. Parabolic profiles are smoother than trapezoidal humps, cause less driver discomfort, create less noise, and are more comfortable for bicyclists. Sinusoidal profiles, while providing slightly higher comfort levels than parabolic profiles, are more expensive to construct.

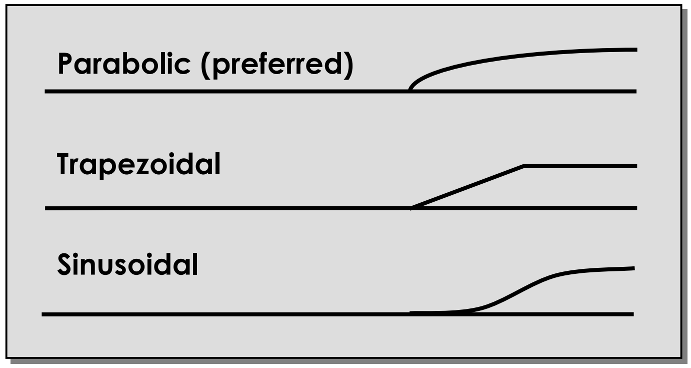


Figure 1 Vertical Measure Ramp Profiles

Edge Tapers

The edge taper refers to the transition area between a vertical device at its full height to its height at the roadway curb. Where on-street parking is provided, this taper should extend across both the bike lane (if one exists) and the parking lane. Consequently, bicyclists will traverse an even section of the device, rather than the taper itself. Where on-street parking is not provided but a bike lane exists, the device should taper back to the level of the pavement before the bike lane, such that bicyclists can bypass the device.

Raised Crosswalk Tapers

When a raised curb exists, raised crosswalks should be designed to a height equal to the curb height. The device should extend entirely to the curb, without a taper down to the pavement. When no curbs exist, the tapers at each end of the raised crosswalk will serve as wheelchair ramps. These tapers will have slopes of not more than 5%, and they will include truncated domes to indicate the beginning of the slope. The Public Works ADA (Americans with Disabilities Act) Coordinator should be consulted on the design.

Horizontal Deflection Measures

Traffic Circle Center Island Profile

Traffic circles should be designed with both a square inner curb and a mountable apron. The apron is a shallow-sloped curb extending out from the bottom of a square curb; the apron has a low lip at its pavement-side edge. This apron effectively reduces the diameter of the center island for large vehicles, facilitating easier turns. The low lip at the apron's edge discourages vehicles from using it unless it is necessary.

Traffic Circle Turn Operations

All vehicles should circulate around the center island on left-turns. However, an exception can be made for large vehicles in some cases if geometric constraints require it.

Traffic Circles at T-Intersections

Traffic circles should have deflection on all approaches if implemented at a T-intersection. This can be implemented using one of two methods. First, a raised island can be placed at the right side of the un-deflected approach to the traffic circle to artificially introduce deflection, as shown in Figure 2 (a). Alternatively, the street curbs can be modified to allow the center island to be located at the center of the intersection, as shown in Figure (b). This method may require the acquisition of additional right-of-way.

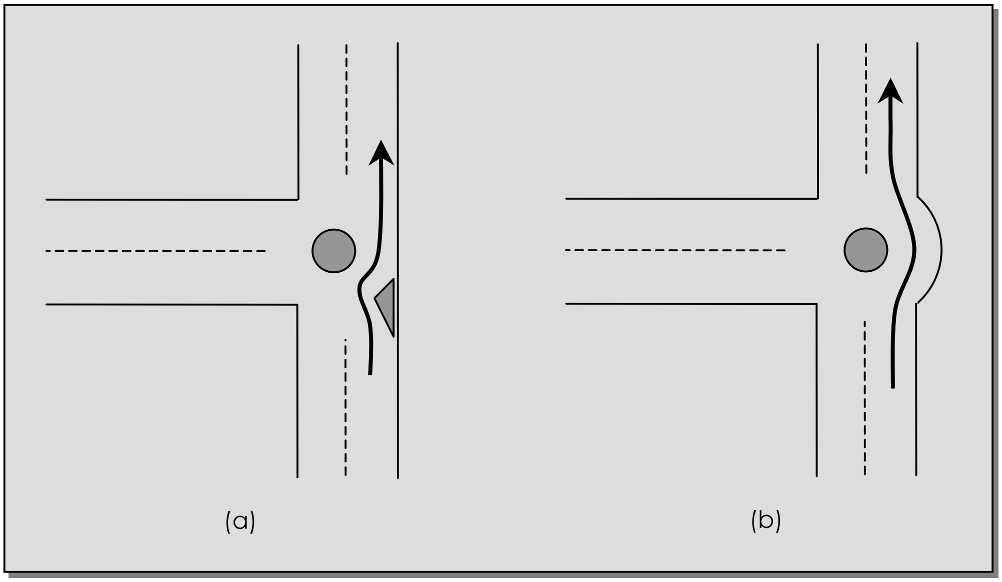


Figure 2. Roundabouts at T-Intersections

Landscaping

Landscaping on traffic calming devices serves two primary purposes. First, it increases the visibility of a device, such as a raised center island, by extending the device's vertical size and introducing more varied colors. Second, landscaping generally improves the aesthetic quality of traffic calming devices, making them more acceptable to nearby residents. Landscaping should be included on all raised islands unless it is physically infeasible to do so. In those cases, hardscape (e.g. grouted cobble) should be used instead. Trees planted on center islands must allow adequate sight distances for motorists.

Signing & Marking

Concurrent with the installation of traffic calming devices, device-specific symbol-based signs will be installed (see Figure C-16). At the discretion of Public Works staff, advanced warning signs may also be installed. Traffic circle center islands will include signage symbolically indicating the permitted travel paths around the center island (see Figure C-18).

Vertical traffic calming measures will generally include a horizontal line marking pattern on the approach ramps. Raised crosswalks and raised intersections with crosswalks should always have pavement markings due to concerns about visibility of pedestrians to drivers.

Special signing for bicyclists should be provided on designated bikeways. For example, the approaches to narrowing devices that do not include a bypass lane for bicyclists will include signage warning motorists to watch for merging bicyclists.

Combined Measures

Some measures from the toolbox can be combined to increase the combined effect on traffic volumes and speeds. For example, a raised crosswalk may be combined with neckdowns, with the effect being a crosswalk that is both shortened and raised above the level of the roadway. Motorists must then react to both a vertical deflection and a narrowing. In assessing the suitability of a proposed combined measure, the guidelines in Table 1 for both of the component devices should be applied.

Roundabouts

Roundabouts are a unique traffic control device that may be useful in a variety of situations. They are often used in lieu of all-way stop control or traffic signals as a means of increasing the capacity of the intersection and improving its operations. However, roundabouts require a considerably more rigorous design process than the other traffic calming devices in the toolbox. Because of their complex design features, no generic design is included in this document. However, roundabouts should generally have the following characteristics:

- A circular travel lane operating counter-clockwise for collecting and distributing traffic;
- A raised center island;

- Channelized approaches;
- Yield control at all approaches; and
- Tapered approaches to encourage entering vehicles to travel in the correct direction through the circular travel lane.

In general, roundabouts in the United States tend to be used on collector streets and on low-volume minor arterial streets. The use of roundabouts is primarily constrained by traffic volumes and by geometrics. Detailed designs should be developed using detailed traffic and geometric information and procedures beyond what is presented here. The cursory check found in Appendix B can be helpful in determining whether a roundabout is a reasonable option to consider. Also, the following examples illustrate cases where a roundabout may be appropriate:

- ***History of Accidents –*** One example roundabouts are placed at intersections with a history of accidents, especially head-on collisions and right-angle collisions. A roundabout can help improve safety by substantially reducing the number of conflict points and by simplifying interactions between vehicles.
- ***Minimizing Queues –*** Another case is a collector/arterial intersection located near an arterial/arterial intersection. A roundabout may be useful here because it can give allocate right-of-way between both the arterial and the collector, while minimizing the queues on the approach stemming from the arterial/arterial intersection.
- ***Handling Irregular Approach Geometry –*** An intersection with greater than four approaches or with approaches that meet the intersection at irregular angles may be a candidate for a roundabout. Standard traffic control devices, such as side-street stop control and traffic signals, work best on intersections where the main street and side street are clear and the concepts of the “through”, “left-turn”, and “right-turn” paths are evident. For roundabouts, however, the hierarchy of streets is essentially irrelevant.

- ***Inexpensive Traffic Control –*** In some cases, traffic volumes at an intersection may be too high to allow acceptable operations with all-way stop control, a traffic signal is considered too expensive to construct and operate. If ample right-of-way is already available, a roundabout may be considered.

- ***High Proportion of U-Turns –*** If an intersection is situated where U-turns are frequent, a roundabout can facilitate those U-turns without adversely affecting the operations of the intersection as a whole.

- ***Pedestrian Accommodation –*** Roundabouts represent a trade-off for pedestrians. They can be inconvenient for pedestrians because the crosswalks are set back farther from the intersection. However, they are also superior to signalized intersections because crossing distances are shorter and are broken by a pedestrian refuge, and because pedestrians do not need to wait for the pedestrian signal through a long traffic signal cycle.

- ***Abundant Right-of-Way –*** Finally, an intersection that already includes abundant right-of-way may be a good candidate for a roundabout simply because the operations and safety improvements would then outweight the minimal costs of acquiring additional right-of-way and expanding the intersection.

VI. REFERENCES

To find out more about Traffic Calming and Neighborhood Traffic Management, please see the web sites and documents listed below:

Traffic Calming in Sacramento

- City of Sacramento. (2002a). Neighborhood Preservation Transportation Plan (Web Site: http://pw.sacto.org/traffic/nptp.html). Sacramento, CA: City of Sacramento, Department of Public Works.

- City of Sacramento. (2002b). Neighborhood Traffic Management Program (Web Site: http://pw.sacto.org/traffic/ntmp.html). Sacramento, CA: City of Sacramento, Department of Public Works.

Other Local Traffic Calming Programs

- City of Austin (2002). Neighborhood Traffic Management Program (Web Site: http://www.ci.austin.tx.us/roadworks/tc.htm). Austin, TX: City of Austin Department of Public Works and Transportation.

- City of Portland (2002). Portland Traffic Calming Program (Web Site: www.trans.ci.portland.or.us/Traffic_Management/trafficcalming). Portland, OR: City of Portland Neighborhood Traffic Management.

- City of Seattle (2002). Neighborhood Traffic Control Program (Web Site: http://www.ci.seattle.wa.us/td/trafcirc.asp). Seattle, WA: Seattle Transportation.

- Ewing, R. (2000). *Delaware Traffic Calming Design Manual*. Wilmington, DE: Delaware Department of Transportation.

- Howard County (2000). Community Speed Control Program (Web Site: http://www.co.ho.md.us/spdcntrl.htm). Ellicot City, MD: Howard County Department of Public Works.

General Information on Traffic Calming

- Burden, Dan. (1999). *Street Design Guidelines for Healthy Neighborhoods*. Sacramento, CA: Local Government Commission.
- County Surveyors Society. (1994). *Traffic Calming in Practice.* London: Landor Publishing.
- Ewing, R. (1999). *Traffic Calming: State of the Practice*. Washington, DC: Institute of Transportation Engineers/Federal Highway Administration.
- Fehr & Peers. (1999). Traffic Calming .Org (Web Site: http://www.trafficcalming.org). Lafayette, CA: Fehr & Peers Associates, Inc.
- ITE (2002). *Traffic Calming…for Communities (Web Site: http://www.ite.org/traffic/index.html)*. Washington, DC: Institute of Transportation Engineers.
- Hass-Klau, C. et al. (1992). *Civilised Streets: A Guide to Traffic Calming.* Brighton, U.K.: Environment & Transport Planning.
- Hehrstedt, L. et al. (1993). *An Improved Traffic Environment: A Catalogue of Ideas.* Copenhagen, Denmark: Danish Road Directorate.
- Litman, T. (2001). Online TDM Encyclopedia (Web Site: http://www.vtpi.org/tdm/). Victoria, BC: Victoria Transport Policy Institute.
- Smith, D. T. Jr. and D. Appleyard. (1980). *State of the Art: Residential Traffic Management*. Washington, DC: Federal Highway Administration.

- TAC. (1998). *Canadian Guide to Neighbourhood Traffic Calming.* Ottawa, Canada: Transportation Association of Canada.

- Tolley, R. (1990). *Traffic in Residential Areas.* Brefi, U.K.: Brefi Press.

Roundabouts

- Robinson, B. W. et al (2000). *Roundabouts: An Informational Guide*. Washington, DC: Federal Highway Administration.

- Wallwork, M. (2002). *Modern Roundabouts (Web Site: http://www.roundabouts.net)*. Orange Park, FL: Alternate Street Design, P.A.

Appendix A
Neighborhood Traffic Management Program

The Department of Public Works developed the Neighborhood Traffic Management Program (NTMP) as a partnership between the City and the community. The NTMP was adopted by the City Council in December 1995 and officially began in May 1996 with a lottery to determine the order of neighborhood participation out of those that submitted a petition. Subsequent to the initial lottery, interested citizens submit a petition requesting that the NTMP process be conducted in their neighborhood. These petitions are added to the list of neighborhoods by the City Council. The program goal is to start 12 new neighborhoods per year. The NTMP process is summarized by the flowchart in Figures A-1 and A-2.

Getting the Process Started

Public Works kicks off the NTMP in each selected area by inviting all residents to learn more about the program at a community meeting. At this meeting, interested residents can volunteer to participate on the Traffic Calming Committee (TCC) for their neighborhood. Although all residents provide input and receive updates as the plan develops, the TCC is more actively involved, committing the time and effort necessary to develop a comprehensive plan.

Timeframe

Depending on the issues and level of community involvement, it could take twelve months to two years to develop and implement a traffic calming plan.

Traffic Calming Plan: Phase I

All neighborhoods begin by developing a traffic calming plan aimed at changing driver behavior through less restrictive measures, such as visibility, signage and striping improvements, as well as the placement of more restrictive measures, such as speed humps, traffic circles or chokers. These measures are coupled with police enforcement and educational outreach for a comprehensive approach to traffic calming.

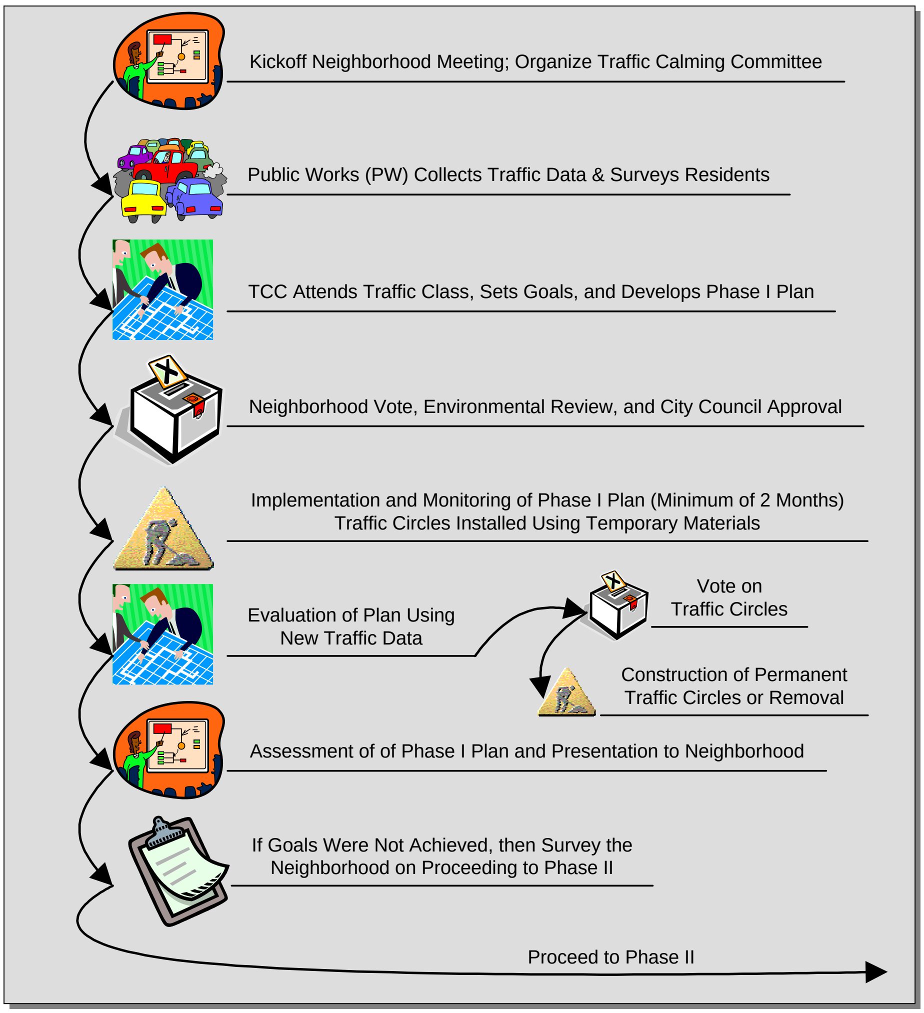


Figure A-1. NTMP Process Flowchart: Phase I

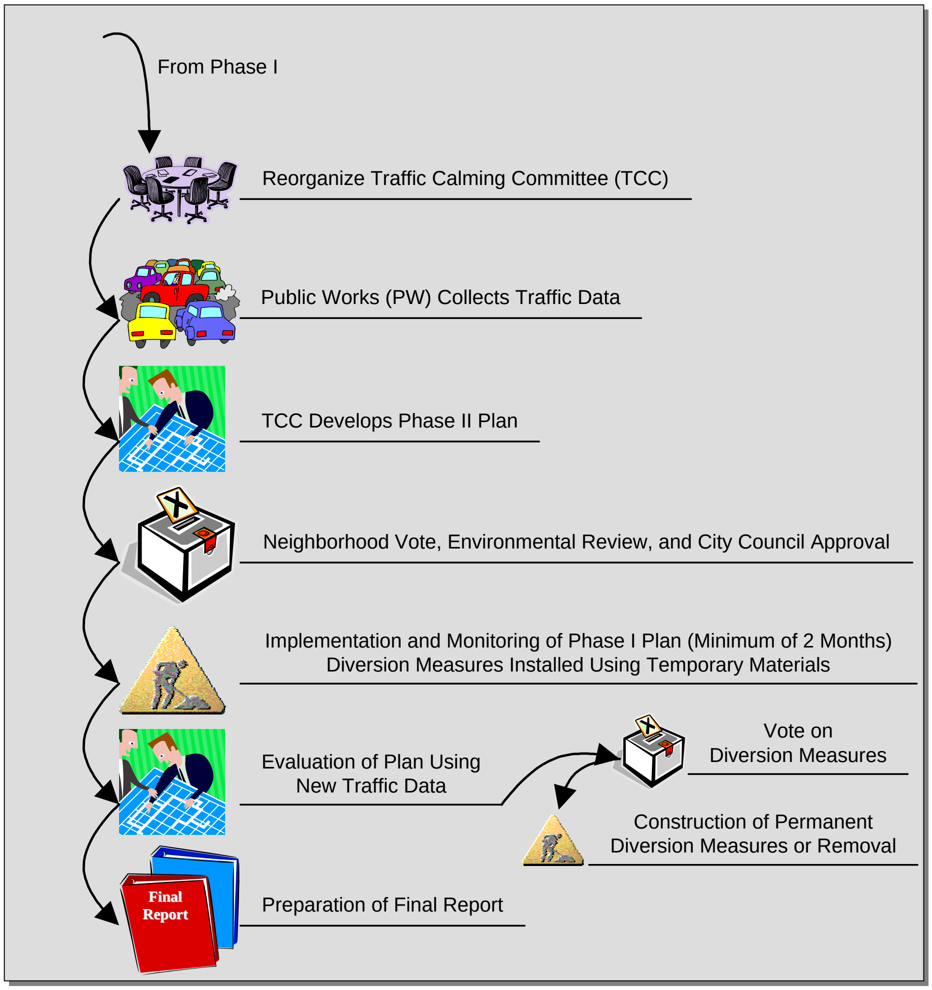


Figure A-2. NTMP Process Flowchart: Phase 2

Developing the Plan

The TCC and Public Works hold regular meetings to:

- Identify specific traffic concerns;
- Establish goals for calming neighborhood traffic;

- Target potential measures;
- Develop a traffic calming plan; and
- Present the plan to the neighborhood at a community meeting.

Two-Step Voting Process

Step 1. All neighborhood residents and businesses (one per address or apartment unit) have the opportunity to vote whether a Phase I plan containing more restrictive devices will be implemented. To proceed, a minimum of 25% of all ballots must be returned with a simple majority in favor of the plan.

Step 2. If the community supports the plan through the vote, an environmental review is completed. The plan is then presented to the City Council for final approval and funding.

Putting the Plan into Action

The Phase I plan is implemented. A monitoring period of 3-6 months begins when all the devices are installed. Traffic circles (and other devices at Public Works' discretion) are installed as temporary devices to allow residents to experience the effects before making a final decision.

Evaluating Phase I

After the monitoring period Public Works evaluates the effectiveness of the traffic calming plan and presents the results to the TCC. If Phase I has met the TCC's goals, a final report is then provided to neighborhood residents. If temporary devices were installed, then the residents are asked to vote again on whether the device(s) will remain as is, be replaced with permanent devices, or be removed. If the TCC's goals have not been met, then residents are also asked whether to refine the Phase I plan or to move into Phase II of the program, if the Phase I plan did not meet their goals and Phase II measures could potentially meet those goals.

Traffic Calming Plan: Phase II

If Phase II is determined necessary by the TCC, the process continues by developing a Traffic Calming Plan that diverts traffic using devices such as diagonal diverters, half or full street closures, and changes in one-way or two-way traffic operations.

<u>Revising the Plan</u>

Residents will reestablish the TCC and meet with Public Works to:

- Target remaining traffic concerns;
- Analyze potential Phase II measures;
- Revise the traffic calming plan; and
- Present the revised plan to the neighborhood.

<u>Two-Step Voting Process</u>

Because Phase II devices are designed to explicitly divert traffic, thereby altering access to property, the Phase II plan has a more stringent requirement for neighborhood approval than the Phase I plan. To proceed, a minimum of 1/3 of all ballots must be returned and 2/3 of those received must be in favor of the plan. If approved, the plan must then be adopted by the City Council.

Putting the Plan into Action

As with traffic circles, Phase II is first implemented using temporary control devices. These temporary devices are installed and monitored for period of 3-6 months.

Evaluating Phase II

After the monitoring period, Public Works evaluates the effectiveness of the traffic calming plan and presents the results to the TCC. A final report that evaluates Phase II is provided to the neighborhood. The community is then asked to vote on whether the device(s) will remain or be removed.

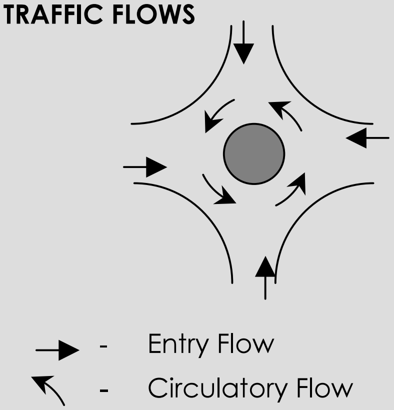
Appendix B
Checking Roundabout Compatibility

When considering a roundabout for a particular intersection, the expected traffic volumes and the available geometry must be taken into consideration, along with several other considerations.

Traffic Volumes

The first check is to determine whether a roundabout could accommodate the traffic volumes at a particular intersection. Two quantities are required: the Maximum Entry Flow and the Maximum Circulatory Flow (see Figure B-1). The Maximum Entry Flow is the traffic volume entering the intersection (including left-turning, through, and right-turning vehicles) at the highest-volume approach. Circulatory Flow is calculated for each quadrant of the circulating lane by adding up the contributing Entry Flows:

FIGURE B-1. TYPES OF ROUNDABOUT TRAFFIC FLOWS



$$V_{EB,circ} = V_{WB,LT} + V_{SB,LT} + V_{SB,TH} + V_{NB,U\text{-}turn} + V_{WB,U\text{-}turn} + V_{SB,U\text{-}turn}$$

$$V_{WB,circ} = V_{EB,LT} + V_{NB,LT} + V_{NB,TH} + V_{SB,U\text{-}turn} + V_{EB,U\text{-}turn} + V_{NB,U\text{-}turn}$$

$$V_{NB,circ} = V_{SB,LT} + V_{EB,LT} + V_{EB,TH} + V_{WB,U\text{-}turn} + V_{SB,U\text{-}turn} + V_{EB,U\text{-}turn}$$

$$V_{SB,circ} = V_{NB,LT} + V_{WB,LT} + V_{WB,TH} + V_{EB,U\text{-}turn} + V_{NB,U\text{-}turn} + V_{WB,U\text{-}turn},$$

where $V_{i,circ}$ = Circulatory flow immediately downstream of approach *i*.

$V_{i,j}$ = Traffic volume at approach *i* taking turning movement *j*;

EB, WB, NB, SB = Eastbound, Westbound, Northbound, and Southbound, respectively; and *LT, TH, U-turn* = Left Turn, Through, and U-Turn, respectively.

After using the above formula to find the circulatory flows, the highest of the four values is used in Figure B-2 in combination with the Maximum Entry Flow to determine whether an Urban Single-Lane Roundabout could accommodate the traffic volume.

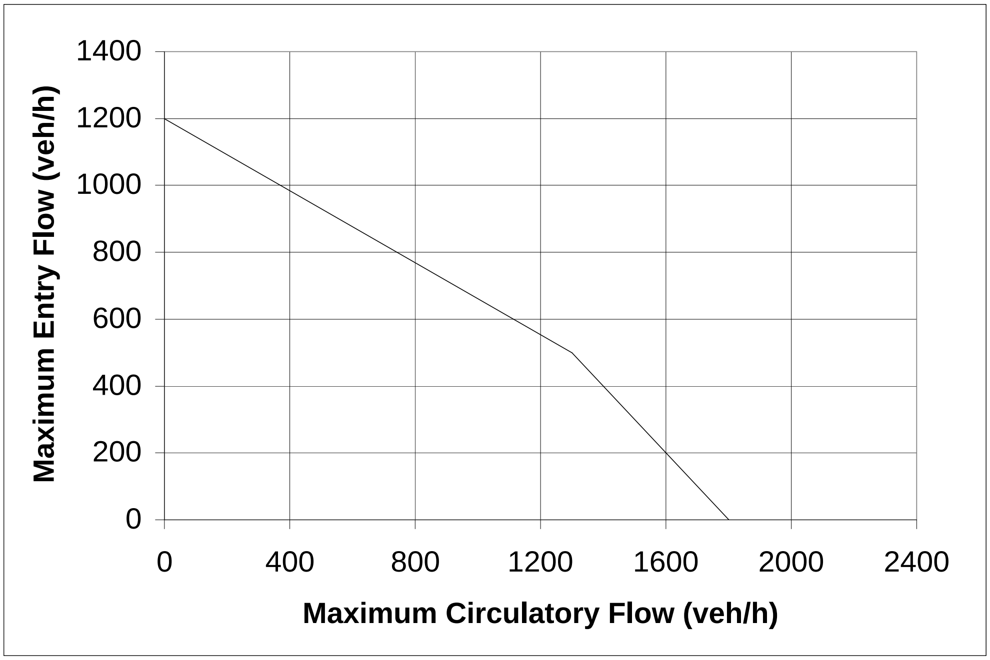


Figure B-2. Approach Capacity of an Urban Single-Lane Roundabout

Geometry

The second check is the available geometry. The width of the approach tapers and the size of the inscribed diameter of a roundabout can vary over a wide range. However, it may be possible to eliminate a roundabout from consideration by comparing the available right-of-way to some minimum geometric values:

- The inscribed diameter of an Urban Single-Lane Roundabout should be at least 100 feet;
- To adequately accommodate the approach tapers, the curb radii of the four corners should be at least 110 feet;

Roundabouts can be used on intersections whose streets have existing cross-sections of up to four lanes with center turn lane, but these lanes must be transitioned to a two-lane section prior to the approach using lane-drop dimensions contained in the *Traffic Manual* (Caltrans, 1996).

Appendix C
Standard Traffic Calming Device Designs