City of Benicia
Traffic Calming Program
for Major Roads and Neighborhoods

September, 2006

Prepared for:
City of Benicia
# Table of Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACKNOWLEDGEMENTS</td>
<td>II</td>
</tr>
<tr>
<td>EXECUTIVE SUMMARY</td>
<td>1</td>
</tr>
<tr>
<td>I. TRAFFIC CALMING PLAN</td>
<td>5</td>
</tr>
<tr>
<td>II. TOOLBOX OF TRAFFIC CALMING MEASURES</td>
<td>16</td>
</tr>
<tr>
<td>III. DESIGN GUIDELINES</td>
<td>66</td>
</tr>
<tr>
<td>IV. REFERENCES</td>
<td>71</td>
</tr>
<tr>
<td>APPENDIX A DETAILED TRAFFIC CALMING PROCESS - MAJOR ROADS</td>
<td>73</td>
</tr>
<tr>
<td>APPENDIX B DETAILED TRAFFIC CALMING PROCESS - NEIGHBORHOOD</td>
<td>74</td>
</tr>
<tr>
<td>APPENDIX C ISSUE REPORT FORM</td>
<td>75</td>
</tr>
<tr>
<td>APPENDIX D PROJECT PRIORITIZATION FORM</td>
<td>76</td>
</tr>
<tr>
<td>APPENDIX E CHECKING ROUNDABOUT COMPATIBILITY</td>
<td>77</td>
</tr>
<tr>
<td>APPENDIX F INSTITUTE OF TRANSPORTATION ENGINEERS ANGLED PARKING JOURNAL ARTICLE</td>
<td>79</td>
</tr>
</tbody>
</table>
ACKNOWLEDGEMENTS

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EXECUTIVE SUMMARY

In January 2006, the City of Benicia retained a consulting team to assist the City with the development of a Traffic Calming Program. This document is the result of that effort. It includes:

- A description of the process for citizens to request traffic calming measures at the neighborhood street and major road levels.
- A description of the prioritization process for selecting projects within a given time frame and/or budget.
- A toolbox of traffic calming measures with guidelines for their selection and placement.

Goal

The main goal of the Traffic Calming Program is to improve neighborhood livability by reducing the impact of traffic in order to promote safe and pleasant conditions for all street users. This is aligned with the goals outlined in the City of Benicia General Plan, which are to create a more livable and sustainable community over time with pedestrian-friendly streets and neighborhoods. These are all quality of life issues that can be achieved by managing traffic issues in communities, which is why many cities implement traffic calming programs.

Purpose

These guidelines provide a framework for the selection, design, and application of traffic calming measures in the City of Benicia. The document is primarily intended to be used by City staff and neighborhood residents for developing traffic calming plans. This document may also be helpful for members of the general public that are interested in finding out how the City of Benicia implements traffic calming.

1 The goals and objectives listed in this section were generated by community members and City Staff at a community workshop and “walkabout” on March 25, 2006.
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. It is anticipated that this will be a living document as changes will be made over time, as needed.

**Objectives**

The main goal of the Traffic Calming Program is mentioned above. This goal has five main objectives:

- To improve traffic management and safety at school intersections
- To reduce traffic speeds
- To enhance and improve the safety of the pedestrian and bicycle environment
- To enhance the neighborhood environment
- To reduce traffic related noise

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.
- **Enforcement** – Targeted police enforcement supports the traffic calming plan developed by residents and Public Works.
- **Engineering** – Engineering principals are used to develop traffic calming strategies that address community-identified traffic issues.

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.

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4 The goals and objectives listed in this section were generated by community members and City Staff at a community workshop and “walkabout” on March 25, 2006.
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, Resident, or Business owner working on Major Roads, you should focus on the following chapters:

Chapter I, Section 2: Process for Major Roads, to see a summary about how to approach your traffic calming problem and develop solutions.

Chapter II. Toolbox of Traffic Calming Measures, to discover what particular devices are available.

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

Appendix A, Detailed Traffic Calming Process – Major Roads, to find out how to approach your traffic calming problem and develop solutions.

If you are a City Staff Person, Resident, or Business owner working on Neighborhood Streets, you should focus on the following chapters:

Chapter I, Section 3: Process for Neighborhood Streets, to see a summary about how to approach your traffic calming problem and develop solutions.

Chapter II. Toolbox of Traffic Calming Measures, to discover what particular devices are available.

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

Appendix B, Detailed Traffic Calming Process – Neighborhood Streets, to find out how to approach your traffic calming problem and develop solutions.
How the Guidelines Were Developed

The contents of the guidelines were developed with the assistance of citizens and key City Staff. The City held two public workshops designed to gather input on the traffic calming guidelines.

City Kick-Off Meeting

The first workshop included a tutorial on traffic calming, focusing on the types of devices available. The panel discussed the existing approach to traffic calming, issues specific to the City of Benicia, goals and objectives for the traffic calming plan, and locations where traffic calming is needed. Also discussed were implementation issues.

Walkable Audit and Charrette

The walkable audit and charrette formed the basis for the first public workshop. Dan Burden presented an introductory tutorial on traffic calming and available solutions, followed by a bus and walking tour of specific locations throughout the City, including Rose Drive, Military West, West Manor neighborhood, and downtown at the 1st Street/D Street intersection. Attendees reconvened to discuss and rank goals and objectives for the traffic calming program, and ranked the locations that are in greatest need for traffic calming improvements. The highest priority locations included areas surrounding schools, 1st Street, and Military West. Other locations included West Manor neighborhood, Larkin Drive, East 5th, East 2nd, and Rose Drive.

The attendees then broke up into groups to develop potential solutions at the various locations visited during the walkable audit.

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 IV.

KEY CITY STAFF:

- Dan Schiada, City of Benicia Public Works Director
- Mike Throne, City Engineer
- Michael Roberts, Senior Civil Engineer
- Ken Hanley, City of Benicia Fire Department Chief
- Jim Trimble, City of Benicia Police Chief
- Ken Davena, City of Benicia Police Department
I. TRAFFIC CALMING PLAN

This chapter illustrates the details of the City of Benicia’s Traffic Calming Plan. First, the need for different processes as a function of roadway class - Major Roads versus Neighborhood Streets - is identified and explained. For each roadway type, the process for citizens to report issues to City staff is described. Currently, citizens present issues to the Traffic, Pedestrian, and Bicycle Safety Committee (TPBSC), who resolve issues as they develop. This chapter formalizes the way that requests are handled.

1.1 Major Roads vs. Neighborhood Streets

The City of Benicia circulation system can be categorized into five functional classes as defined in the City of Benicia 1999 General Plan:

- Freeway
- Major Arterial
- Minor Arterial
- Collector
- Local Street

Roadways are categorized into these functional classes to define the typical user and the level of mobility and access they provide. Mobility is the capability to move quickly from one place to another. Access is the ability to enter or leave a public street, roadway or highway from an abutting property or another public street, roadway or highway.

- Freeways carry regional and sub-regional traffic with maximum mobility and limited access (on and off-ramps).
- Local Streets provide maximum access (driveways) for local residents, with limited mobility.
- Arterials and Collectors provide intermediate levels of access and mobility.

Given that the primary characteristic of a freeway is to provide mobility, they are not considered for the installation of traffic calming measures. In the City of Benicia, arterials, collectors, and local streets are candidates for traffic calming improvements.
In order to implement traffic calming measures on arterials, collectors, and local streets, it is important to understand how those roadways are placed throughout the City and the impact that traffic calming measures will have on the users of those roadways. Arterials and Collectors connect neighborhoods and destinations. Drivers use them to travel between City limits. Local streets provide access to abutting property and primarily serve residents on a street level. As a result, traffic calming measures on arterials and collectors will have a high impact to many users throughout the City, whereas traffic calming measures on local streets will have the highest impact on a distinct group of people, specifically the residents on the particular street where the measures are implemented. Additionally, due to the different user groups on the various roadway classes, the key stakeholders in the development of the traffic calming plan for each type of roadway will be different.

This document provides one process for Major Roads (arterials and collectors) and one process for Neighborhood Streets (local streets), which are summarized in the following sections, and describe in detail in Appendices A and B.

### 1.2 Major Road Traffic Calming Process

Traffic calming on major roads affects residents and business owners along a roadway corridor and the motorists traveling on the corridor, and the boundary of the affected group is not always clear. As a result, the Traffic, Pedestrian, and Bicycle Safety Committee (TPBSC) and a Steering Committee consisting of representatives of all the stakeholders lead the traffic calming process on major roads in conjunction with City Staff. However, additional residents and business owners on the road itself initiate the Traffic Calming Process, and should be invited to participate in the project development process.

The Major Road process includes 8 steps, summarized below. A flow chart depicting the Major Road process is provided. A more complete description of each step of the Major Road process is included in Appendix A.

**Major Road Step 1: Staff Receives a Request**

To initialize the traffic calming process, a citizen completes an Issue Reporting Form addressing their concerns. After collecting at least ten signatures of residents and business owners to substantiate the issue, the form is submitted to City Staff.

A sample Issue Reporting Form is shown in Appendix C.
Major Road Step 2: Initial Evaluation

The City Engineer reviews the Issue Reporting Form and volume, speed, and accident data for the roadway in question to determination the nature of the issue. Based on the results of this initial evaluation, the City Engineer and City Staff can make three decisions:

- No real issue exists.
- The issue poses an immediate safety risk.
- The issue is appropriate for traffic calming.

Major Road Step 3: Data Collection

If an issue is appropriate for traffic calming, City staff collects additional data to understand the details of the issue and to determine the nature of the problem.

Major Road Step 4: Stakeholder Input and Setting Goals

TPBSC staff arranges a meeting with interested stakeholders with the following objectives:

- To share the results of the initial data collection.
- To form a Steering Committee to ensure that all stakeholder interests are represented.
- To familiarize the stakeholders with the City’s traffic calming toolbox and review appropriate solutions.
- To generate specific goals and objectives, and rank each in the order of importance.

Major Road Step 5: Selecting Measures

The TPBSC and the Steering Committee select and rank traffic calming measures from the traffic calming toolbox that target the traffic issue and account for the location, traffic volumes, geometrics, and adjacent land uses of the traffic issue. The selected devices need to be placed in manner that will produce the desired results and should be placed in an order that balances effectiveness and likelihood of acceptance.
Major Road Step 6: Phase I Action Plan

If the issue can be addressed through Education, Enforcement, or Non-Physical Engineering measures alone, the TPBSC and the Steering Committee recommend and implement a temporary Phase I plan. If the issue is abated according to the goals and objectives developed during Step 4, the non-physical engineering components of the Phase 1 plan can be permanently installed with a majority of responses from affected residents and business owners in favor of the plan.

The TPBSC and the Steering Committee can bypass the temporary installation of the Phase 1 plan and can implement the plan components permanently if a consensus is met.

If the issue persists, the TPBSC and the Steering Committee may re-visit the issue and determine that Physical Engineering measures are warranted.

Major Road Step 7: Phase II Action Plan

The TPBSC and the Steering Committee may propose a Phase II (Physical Engineering) Action Plan. If there is consensus among all the TPBSC and Steering Committee members, the Phase II Action Plan is implemented. If consensus cannot be reached, stakeholders vote to approve the plan.

If the Phase II Action plan is approved, the City Council votes to approve the project for inclusion in the prioritization process and eventually into the Capital Improvement Plan (CIP).

Major Road Step 8: Project Prioritization

As Phase II measures are more expensive, the project at this point needs to be prioritized and incorporated into the City of Benicia’s Capital Improvement Plan (CIP), so that funding can be allocated to the projects that are in most need of physical engineering traffic calming measures.

A sample Prioritization Form is provided in Appendix D.
**Major Road Process**

**Steps 1 - 5**
- Initial Request
  - Appeal Process
  - Staff initial evaluation
    - No further action
    - Appropriate for traffic calming process
    - Data collection and evaluation
      - Develop goals and objectives
      - Traffic Calming Class
      - Formation of Steering Committee
      - Select appropriate traffic calming measures

**Step 6**
- Develop Phase I action plan (Levels 1 and 2)
  - Consensus to implement Phase I action plan permanently
    - New data collection
      - Issue persists
        - Not Approved
          - Plan revision; Return to Step 6a
          - No further action
          - Approved
            - Implement Phase I action plan

**Steps 7 - 8**
- Develop Phase II action plan (Level 3)
  - Consensus to implement Phase II action plan permanently
    - Vote to permanently implement Phase II action plan
      - City Council vote
        - Approved
          - Prioritize
            - Install permanent Phase II measure
        - Not Approved
          - Plan revision; Return to Step 7a

- Appeal Process

- Staff initial evaluation
  - Immediate implementation of solution if a safety hazard exists

- Data collection and evaluation

- Select appropriate traffic calming measures

- Vote to permanently implement Phase I action plan
  - Not Approved
    - No further action
  - Approved
    - Implement Phase I action plan

Note: Steps 1 - 5 and Steps 7 - 8 are major road processes with different focuses and processes.
1.3 Neighborhood Street Traffic Calming Process

Traffic calming on Neighborhood Streets most significantly affects residents and business owners within a specific neighborhood and adjacent to where traffic calming measures are placed. Compared to Major Roads, the boundary of the affected group is more clearly defined. As a result, a Neighborhood Committee is formed to lead the Neighborhood Street Traffic Calming Process, as opposed to the Traffic, Pedestrian, and Bicycle Safety Committee (TPBSC), who leads the Major Road Traffic Calming Process. However, City staff and the TPBSC are still involved in the Neighborhood Street Traffic Calming Process to assist in developing quantitative goals and objectives, and collecting data.

The Neighborhood Street process includes 8 steps, summarized below. A flow chart depicting the Neighborhood Street process is provided. A more complete description of each step of the Neighborhood Street process is included in Appendix B.

Neighborhood Streets Step 1: Staff Receives a Request

To initialize the traffic calming process, a citizen completes an Issue Reporting Form addressing their concerns. After collecting at least ten signatures of residents and business owners to substantiate the issue, the form is submitted to City Staff.

A sample Issue Reporting Form is shown in Appendix C.

Neighborhood Street Step 2: Initial Evaluation

The City Engineer reviews the Issue Reporting Form and volume, speed, and accident data for the roadway in question to determine the nature of the issue. Based on the results of this initial evaluation, the City Engineer and City Staff can make three decisions:

- No real issue exists.
- The issue poses an immediate safety risk.
- The issue is appropriate for traffic calming.

Neighborhood Street Step 3: Data Collection

If an issue is appropriate for traffic calming, City staff collects additional data to understand the details of the issue and to determine the nature of the problem.
Neighborhood Street Step 4: Neighborhood Input and Setting Goals

City staff arranges a meeting with interested stakeholders with the following objectives:

- To share the results of the initial data collection.
- To form a Neighborhood Committee to ensure that all stakeholders within the neighborhood boundaries have their interests represented.
- To familiarize the stakeholders with the City’s traffic calming toolbox and review appropriate solutions.
- To generate specific goals and objectives, and rank each in the order of importance.

The TPBSC and the Benicia Police Department shall be informed (via email) of all public meetings planned by the Neighborhood Committee.

Neighborhood Street Step 5: Selecting Measures

City Staff and the Neighborhood Committee select and rank traffic calming measures from the traffic calming toolbox that target the traffic issue and account for the location, traffic volumes, geometrics, and adjacent land uses of the traffic issue. The selected devices need to be placed in manner that will produce the desired results and should be placed in an order that balances effectiveness and likelihood of acceptance.

Neighborhood Street Step 6: Phase I Action Plan

If the issue can be addressed through Education, Enforcement, or Non-Physical Engineering measures alone, City Staff and the Neighborhood Committee recommend and implement a temporary Phase I plan. If the issue is abated according to the goals and objectives developed during Step 4, the non-physical engineering components of the Phase 1 plan can be permanently installed with a majority of responses from affected residents and business owners in favor of the plan.

The TPBSC and the Neighborhood Committee can choose to bypass the temporary installation of the Phase 1 plan and can install the plan components permanently if a consensus is met.

If the issue persists, the TPBSC and the Neighborhood Committee may re-visit the issue and determine that Physical Engineering measures are warranted.
Neighborhood Street Step 7: Phase II Action Plans

The Neighborhood Committee may propose a Phase II (Physical Engineering) Action Plan to discuss with the TPBSC. If accepted, the Neighborhood Committee can implement Phase II improvements temporarily. If the issue is abated according to the goals and objectives developed in Stage 4, the affected residents and business vote to approve permanent installation.

If there is consensus among all the TPBSC and Neighborhood Committee members, affected residents and business can choose to approve permanent installation of the Phase II Action Plan without the temporary installation.

If the Phase II Action plan is approved, the City Council votes to approve the project for inclusion in the prioritization process and eventually into the Capital Improvement Plan (CIP).

Neighborhood Street Step 8: Project Prioritization

Since Phase II measures are more expensive, the project at this point needs to be prioritized and incorporated into the City of Benicia’s Capital Improvement Plan (CIP), so that funding can be allocated to the projects that are in most need of physical engineering traffic calming measures.

A sample Prioritization Form is provided in Appendix D.
1.4 Timeline

Depending on the issues and level of community involvement, it could take at least twelve months to two years to develop and implement a traffic calming plan. Described below is a theoretical timeline of the traffic calming processes that assumes no delays and a three month trial basis for Phase I and Phase II Action Plans; it can be applied to the Major Road and Neighborhood Street processes.

<table>
<thead>
<tr>
<th>Step in Traffic Calming Process</th>
<th>Action Description</th>
<th>Date</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Staff receives Issue Reporting Form</td>
<td>Day 1</td>
<td>0 days</td>
</tr>
<tr>
<td>2</td>
<td>Staff completes initial evaluation</td>
<td>Week 2</td>
<td>2 weeks</td>
</tr>
<tr>
<td>3</td>
<td>Staff completes data collection and evaluation.</td>
<td>Week 6</td>
<td>4 weeks</td>
</tr>
<tr>
<td>4</td>
<td>Public meeting notice is distributed to stakeholders.</td>
<td>Week 8</td>
<td>2 weeks</td>
</tr>
<tr>
<td>4</td>
<td>1st public meeting:</td>
<td>Week 8</td>
<td>1 day</td>
</tr>
<tr>
<td></td>
<td>• City Staff presents data results to stakeholders.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Goals and objectives determined and ranked.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Neighborhood/Stakeholder Committee formed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5/6</td>
<td>1st Committee/TPBSC Meeting:</td>
<td>Week 10</td>
<td>1 day</td>
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<tr>
<td></td>
<td>• Traffic Calming Class (Neighborhood Street Process only)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Development of Phase I Action Plan</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Temporary implementation of Phase I Action Plan (Optional)</td>
<td>Weeks 11-14</td>
<td>4 weeks</td>
</tr>
<tr>
<td>6</td>
<td>Trial period of Phase I Action Plan (Optional)</td>
<td>Week 14-26</td>
<td>12 weeks</td>
</tr>
<tr>
<td>6</td>
<td>City staff collects and evaluates data based on Phase I Action Plan (Optional)</td>
<td>Week 30</td>
<td>4 weeks</td>
</tr>
<tr>
<td>6</td>
<td>2nd Committee/TPBSC Meeting:</td>
<td>Week 30</td>
<td>1 day</td>
</tr>
<tr>
<td></td>
<td>• City Staff presents data results to stakeholders and Committee/TPBSC (Optional)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Consensus or vote to permanently install Phase I measures or to compose Phase II Action Plan</td>
<td></td>
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<tr>
<td>7</td>
<td>3rd Committee/TPBSC Meeting:</td>
<td>Week 32</td>
<td>1 day</td>
</tr>
<tr>
<td></td>
<td>• Committee/TPBSC develops Phase II Action Plan</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>2nd Public Meeting:</td>
<td>Week 33</td>
<td>2 weeks</td>
</tr>
<tr>
<td></td>
<td>• Committee/TPBSC presents Phase II Action Plan to the public</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Temporary implementation of Phase II Action Plan</td>
<td>Weeks 35-38</td>
<td>4 weeks</td>
</tr>
<tr>
<td>Week</td>
<td>Event</td>
<td>Notes</td>
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<td>----------------------------------------------------------------------------------------------------------------------------------------</td>
<td>------------------------</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Trial period of Phase II Action Plan (Optional)</td>
<td>Week 38-50 12 weeks</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>City staff collects and evaluates data based on Phase II Action Plan (Optional)</td>
<td>Week 54 4 weeks</td>
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</tbody>
</table>
|      7| 3rd Public meeting:  
  - City Staff presents data results to stakeholders and Committee/TPBSC (Optional)                                                | Week 56 2 weeks        |
|      7| 4th Committee/TPBSC Meeting:  
  - Final verdict on vote of Phase II Action Plan (Optional)                                                                                 | Week 56 1 day          |
|      8| 1st City Council Meeting:  
  - City Council evaluates and prioritizes the project for inclusion in the Capital Improvement Plan                                       | End of Fiscal Year 1 day|
|      8| Permanent installation of Phase II Action Plan                                                                                           | Based on Prioritization Process 4 weeks |

### 1.5 Prioritizing Traffic Calming Projects

In order to equitably distribute available funds to pay for traffic calming improvements throughout the City of Benicia, a method to prioritize the projects is necessary. To most effectively prioritize the projects, the projects should be compared based on several quantifiable factors. These include traffic volumes, travel speeds, collision history, presence of schools and public facilities, presence of pedestrian and bicycle facilities, and if the roadway segment is along a transit route. A sample Prioritization Form is provided in Appendix D.

### 1.6 City Council and TPBSC Appeal Processes

As part of the traffic calming processes, several decisions are made by the TPBSC and the City of Benicia City Council members. All decisions made by the TPBSC shall be appealed to the City Council, and all City Council decisions are final. In the case where a new traffic calming measure or program is desired, an Issue Report Form shall be submitted as described in Step 1 of the Major Roads and Neighborhood Streets processes.
II. TOOLBOX OF TRAFFIC CALMING MEASURES

2.1 Traffic Calming Toolbox

The following traffic calming measures constitute the standard “toolbox” of devices available to citizens and Public Works staff when selecting traffic calming measures and developing traffic calming plans. The devices are divided into the following levels:

- Level 1 Measures:
  - Education
  - Enforcement
- Level 2 Measures:
  - Non-Physical Engineering Measures
- Level 3 Measures:
  - Physical Engineering Measures
    - Narrowing Measures
    - Horizontal Deflection Measures
    - Vertical Deflection Measures
- Level 4 Measures
  - Physical Engineering Diversion Measures.

Levels 1 and 2 include measures that are appropriate for Phase I Action Plans and Levels 3 and 4 include measures for Phase II Action Plans.

A data sheet is provided for each traffic calming measure in the toolbox, which includes a description, photograph, overhead schematic, and list of advantages and disadvantages of the measure. Descriptions of standard designs are included in Chapter III. Descriptions of the non-physical measures are also included.
Description

Education is a neighborhood driven measure that allows residents to take immediate action to address their issues. City staff is involved in the implementation process of these measures, however formal approval is not required, so these measures can be implemented quicker than higher level measures.

Educational measures include:

- Flyers and Brochures;
- Public Traffic Calming Classes;
- Neighborhood Pledge Program; and
- Neighborhood Sign Campaign
Neighborhood flyers and brochures can be distributed to local residents and can focus on local issues. The primary function is to inform residents about traffic calming, and heighten awareness regarding neighborhood concerns.

The City is currently utilizing the “Street Smarts” suite of educational posters, flyers, and banners as part of a citywide education effort. Neighborhood flyers and brochures should utilize the Street Smarts material when possible.

**Approximate Cost:** Varies, but can be very low cost. Includes cost of printing brochures and some in-kind City staff time.

**Suitable for:** Neighborhood Streets

**Advantages**
- Allows residents to discuss issues;
- Targets specific group; and
- No approval from City staff required.

**Disadvantages**
- Effectiveness may be temporary; and
- Requires time commitment and funding from residents.

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**A sample brochure includes tips on safe driving, cycling, and walking with information on the City’s policies.**
PUBLIC TRAFFIC CALMING CLASSES

Public classes held at local schools and community centers provide a forum for residents to learn about traffic calming, local and city-wide issues, and how they can be part of the solution.

Traffic calming classes are also part of the Neighborhood Street and Major Roads processes.

**Approximate Cost:** Varies. Includes in-kind City staff time and one-time cost of developing the class.

**Suitable for:** All Roadways, All Terrains

**Advantages**
- Allows residents to learn about issues; and
- No approval from City staff required.

**Disadvantages**
- Effectiveness may be temporary; and
- Requires time commitment from residents, police department, and City Staff; and
- Effectiveness is a function of attendance.
NEIGHBORHOOD PLEDGE PROGRAMS

Residents are asked to sign a pledge and implement it into their own driving habits. Residents place bumper stickers on their cars to support local speed limits.

Approximate Cost:  Varies. Generally low cost. Includes cost of printing materials and in-kind City staff time to explain the program.

Suitable for:   Neighborhood Streets
               All Terrains

Advantages
- Inexpensive;
- Heightens driver awareness;
- Does not require City Staff approval; and
- Residents take ownership of issues in their neighborhoods.

Disadvantages
- Effectiveness may be limited; and
- May create tension among neighbors.
NEIGHBORHOOD SIGN CAMPAIGN

The City provides yard signs to residents on a short-term basis to increase local awareness and encourage motorists to drive the speed limit. To increase effectiveness, residents can relocate the signs every few days.


Suitable for: Neighborhood Streets
All Terrains

Advantages
• Helps reinforce local speed limit;
• Requires neighborhood consensus, and therefore reaches a large audience; and
• Frequent relocation of signs helps keep message fresh.

Disadvantages
• May have limited effectiveness; and
• Potential for vandalism.
Description

Targeted police enforcement supports the traffic calming plan developed by residents and Public Works. Similar to Education, City staff is involved in the implementation process of Enforcement measures, however, formal approval is not required, and so these measures can be implemented quicker than higher level measures.

Enforcement measures include:

- Increased Police Force;
- School Safety Programs;
- Juvenile Traffic School Programs;
- Targeted Speed Enforcement;
- Radar Trailers;
- Pedestrian Sting Operations;
- Photo Enforcement; and
- Residential Speed Watch.
INCREASED POLICE FORCE

Adjacent jurisdictions can coordinate to share police force staff, allowing each jurisdiction to have a higher police presence. This can be done at specific times during the year to focus on anticipated issues such as drop-off activities at the beginning of the school year.

**Approximate Cost:** Varies – cost includes time to coordinate among jurisdictions

**Suitable for:** All Roadways All Terrains

**Advantages**
- Provides greater police force during specific times.

**Disadvantages**
- Requires coordination between adjacent cities.

SCHOOL SAFETY PROGRAM

Local schools can work with the Police Department to form Junior Safety Patrols where students from each of the schools volunteer to control pedestrian and vehicular traffic in and around their schools. Education is provided by the Police Department, and supervision is provided by parent volunteers.

**Approximate Cost:** Low cost. Includes in-kind City staff time to deliver education.

**Suitable for:** All Roadways All Terrains

**Advantages**
- Generates awareness among children and parents in the community; and
- Can be done on an ongoing basis without City Staff approval.

**Disadvantages**
- Requires funding to provide education component.
**Juvenile Traffic School Program**

Similar to traffic school for motor-vehicle drivers that do not obey laws in the vehicle code, juvenile traffic school provides classes on safe bicycling and walking for children who receive citations for such infractions as wrong-way bicycling, failing to yield right-of-way, and jay-walking.

**Approximate Cost:** Varies. Similar to Citywide education cost.

**Suitable for:** All Roadways
All Terrains

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**Targeted Speed Enforcement**

City Staff 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 generally 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:** In-kind City staff time

**Suitable for:** All Roadways
All Terrains
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:** $250 per radar trailer per day or $10,000 - $15,000 per trailer

**Suitable for:** All Roadways
All Terrains

PEDESTRIAN STING OPERATIONS

These operations target motor-vehicle drivers who violate pedestrian right-of-way, or those drivers who do not stop for a pedestrian when cars in the adjacent lane have stopped. Decoy pedestrians may be used.

**Approximate Cost:** Varies. In-kind City staff time.

**Suitable for:** All Roadways
All Terrains
PHOTO ENFORCEMENT

Photo enforcement can be used to photograph motor-vehicle drivers who enter an intersection after the signal has turned red, or drivers who are speeding. The photograph captures the license plate and sometimes the driver. Warning or citations can be sent to the offenders.

Approximate Cost: Varies depending on the number of locations. Generally leads to increased revenues if citations are issued. Hidden costs include additional traffic court caseload resulting from drivers challenging citations.

Suitable for: Major Roads Level Terrains

RESIDENTIAL SPEED WATCH

Residents deliver brochures to neighbors to raise awareness about traffic calming and local safety issues. Trained residents can then borrow radar guns from the City Police Department to conduct their own speed surveys. Residents can record the license plate numbers of the speed vehicles and send warning letters to those drivers stating where, when, and by how much they were exceeding the speed limit. Educational information can be included in the mailing.

Approximate Cost: Varies

Suitable for: Neighborhood Streets Level Terrains

Advantages
- Increase driver awareness;
- Helps reinforce good driver behavior; and
- Can improve pedestrian safety.

Disadvantages
- Requires budget for equipment, maintenance, and additional staff time.

Advantages
- Requires little City Staff time;
- Increases awareness in the neighborhoods; and
- Residents take ownership of solving local issues.

Disadvantages
- Warning letters may not be as effective as actual speeding tickets; and
- May create tension between neighbors.
Level 2 Measures

Non-Physical Engineering 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.

- Lane Striping;
- Speed Legends;
- Signage;
- Centerline or Edgeline Botts Dots;
- High-Visibility Crosswalk;
- Optical Speed Bars;
- Advanced Limit Lines; and
- Angled Parking.
LANE STRIPING ("LANE DIET")

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.

Approximate Cost: $2 per lineal foot
Suitable for: All Roadways
All Terrains

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
• Increases regular maintenance.

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 each
Suitable for: All Roadways
All Terrains

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.
SIGNAGE

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

- Speed Limit Signs;
- Stop Signs;
- Grade Signs; and
- Turn Restriction Signs.

Note that speed limit signs, to be eligible for radar enforcement, must be set using an appropriate engineering and speed study. Similar studies are needed to warrant Stop Signs.

**Approximate Cost:** $150 – $500 per sign

**Suitable for:** All Roadways
All Terrains

**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.
Botts dots and raised reflectors, or “raised pavement markers,” are small objects affixed to the roadway, usually lining the centerline or edgeline of a roadway or a lane marking. They are often used on curves where vehicles have a tendency to deviate outside of the proper lane, risking collision. Raised reflectors can also increase the nighttime visibility of the centerline or edgeline.

Another application of Botts dots is the rumble strip, in which the markers are arranged in a rectangular array across one or more lanes of the roadway causing a rumbling sensation to drivers as they cross. These can reduce travel speeds but also increase roadway noise considerably. Rumble strips are only placed in very low density areas because of the nose factor.

**Approximate Cost:** $5 per marker

**Suitable for:** All Roadways

**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.
High-visibility crosswalks use a combination of special marking patterns, raised reflectors, in-pavement flashers, and overhead lighting to increase the visibility of crosswalks, especially at night. In Benicia, a flashing crosswalk is used adjacent to Benicia High School to increase driver awareness at a location where there are high traffic volumes and high pedestrian crossing volumes. In the figure shown above, 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 - $100,000

**Suitable for:** All Roadways
All Terrains
**OPTICAL SPEED BARS**

Optical speed bars are a series of pavement markings spaced at decreasing distances. They have typically been used in construction areas to provide drivers with the impression of increased speed.

**Approximate Cost:** $1 per lineal foot  
**Suitable for:** All Roadways  
All Terrains

**ADVANCED LIMIT LINES**

Advanced limit lines are placed approximately seven to nine feet in advance of a marked crosswalk at a controlled location in order to prevent motorists from infringing on the pedestrian crossing. Advanced limit lines clearly delinate the pedestrian space and prevent the narrowing of the crosswalk due to motorists passing the first line of the crosswalk.

**Approximate Cost:** $50 - $100  
**Suitable for:** All Roadways  
Level Terrains

**Advantages**
- Inexpensive;  
- Reduction in 85th percentile speed;  
- Does not require time for design; and  
- Does not slow emergency vehicles.

**Disadvantages**
- Effectiveness diminishes after repeated use; and  
- Aesthetics.
**ANGLED PARKING**

Angled parking reorients on-street parking spaces to a 45 or 60-degree angle, increasing the number of parking spaces and reducing the width of the roadway available for travel lanes. Angled parking may work well in locations with high parking demand, such as multi-family residences, and high turnover rates, such as commercial and mixed-use areas.5

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**Approximate Cost:** $250 - $350 per stall  
**Suitable for:**  
All Roadways  
Level Terrains

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**Advantages**  
- Reduces speeds by narrowing travel lanes;  
- Increases the number of parking spaces;

**Disadvantages**  
- Precludes the use of designated 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.

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5 For more detailed information on angled parking, refer to the ITE Journal Article, *Changing On-Street Parallel Parking to Angle Parking* (February 2002) in Appendix F.
Level 3 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.
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 and provide additional pedestrian space at the intersection. 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.

### Measured Impacts

<table>
<thead>
<tr>
<th>Speed Impacts</th>
<th>Volume Impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduction in 85th Percentile Speeds between Slow Points</td>
<td>-7%</td>
</tr>
<tr>
<td>Reduction in Vehicles per Day</td>
<td>-10%</td>
</tr>
</tbody>
</table>


### 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.

### Approximate Cost:

$40,000 - $80,000 for four corners.

### Suitable for:

All Roadways
All Terrains
**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.

**Measured Impacts**

<table>
<thead>
<tr>
<th>Speed Impacts</th>
<th>Volume Impacts</th>
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</thead>
<tbody>
<tr>
<td><strong>Reduction in 85th Percentile Speeds between Slow Points</strong></td>
<td><strong>Reduction in Vehicles per Day</strong></td>
</tr>
<tr>
<td>-7%</td>
<td>-10%</td>
</tr>
</tbody>
</table>


**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;
- Potential loss of on-street parking; and
- Landscaping must be maintained by City or residents.

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

**Suitable for:** All Roadways

All Terrains
**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.

<table>
<thead>
<tr>
<th>Measured Impacts</th>
<th>Reduction in 85th Percentile Speeds between Slow Points</th>
<th>Reduction in Vehicles per Day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed Impacts</td>
<td>-14%</td>
<td>-20%</td>
</tr>
<tr>
<td>Volume Impacts</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

**Suitable for:** Neighborhood Streets Level Terrains

**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;
- Loss of on-street parking; and
- Landscaping must be maintained by City or residents.

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”.

<table>
<thead>
<tr>
<th>Measured Impacts</th>
<th>Reduction in 85th Percentile Speeds between Slow Points</th>
<th>-7%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed Impacts</td>
<td>Reduction in Vehicles per Day</td>
<td>-10%</td>
</tr>
</tbody>
</table>

**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;
- Potential loss of on-street parking; and
- Landscaping must be maintained by City or residents.

Approximate Cost: $6,000 - $15,000
Suitable for: All Roadways
All Terrains
Level 3 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. They are typically controlled by YIELD signs on all approaches. 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. A traffic circle exists in Benicia in front of the Library on 2nd Street.

<table>
<thead>
<tr>
<th>Measured Impacts</th>
<th>Reduction in 85th Percentile Speeds between Slow Points</th>
<th>-11%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed Impacts</td>
<td>Reduction in Vehicles per Day</td>
<td>-5%</td>
</tr>
<tr>
<td>Volume Impacts</td>
<td>Reduction in Average Annual Number of Collisions</td>
<td>-71%</td>
</tr>
</tbody>
</table>


**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.

**Approximate Cost:** $15,000 per location

**Suitable for:** Neighborhood Streets, Level Terrains
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: $120,000 - $400,000 per location
Suitable for: All Roadways
Level Terrains

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;
• Must be designed carefully to discourage drivers from deviating out of the appropriate lane; and
• Landscaping must be maintained by City or residents.
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: At least $10,000; varies by size of offset and length of transition.

Suitable for: All Roadways
Level Terrains

Advantages
• Moderates traffic speed on an arterial;
• 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.
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: $30,000 - $50,000 per series of three extensions.

Suitable for: All Roadways
Level Terrains

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:** $15,000 - $30,000

**Suitable for:** All Roadways

**Level Terrains**

**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.
Level Terrains Level 3 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. Vertical deflection devices are typically only used on level terrain, and on local streets. The vertical deflection devices in the toolbox include:

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

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Speed Impacts</td>
</tr>
<tr>
<td>Reduction in 85th Percentile Speeds</td>
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<tr>
<td>Reduction between Slow Points</td>
</tr>
<tr>
<td>Safety Impacts</td>
</tr>
<tr>
<td>Reduction in Average Annual Number</td>
</tr>
<tr>
<td>of Collisions</td>
</tr>
<tr>
<td>-18%</td>
</tr>
<tr>
<td>-13%</td>
</tr>
</tbody>
</table>


Approximate Cost: $1,500
Suitable for: Neighborhood Streets
Level Terrains

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.

Approximate Cost: $2,000 per lump
Suitable for: Neighborhood Streets, Level Terrains

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.

<table>
<thead>
<tr>
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<th>Reduction in 85th Percentile Speeds between Slow Points</th>
<th>-18%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed Impacts</td>
<td>Reduction in Vehicles per Day</td>
<td>-12%</td>
</tr>
<tr>
<td>Volume Impacts</td>
<td>Reduction in Average Annual Number of Collisions</td>
<td>-45%</td>
</tr>
<tr>
<td>Safety Impacts</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Approximate Cost:** $22,000 - $33,000 (basic materials)

**Suitable for:** Neighborhood Streets Level Terrains

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**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 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.

### Measured Impacts

<table>
<thead>
<tr>
<th></th>
<th>Reduction in 85th Percentile Speeds between Slow Points</th>
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</tr>
<tr>
<td>Volume Impacts</td>
<td>Reduction in Average Annual Number of Collisions</td>
<td>-45%</td>
</tr>
</tbody>
</table>


- **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.

**Approximate Cost:** $22,000 - $33,000 (basic materials)

**Suitable for:** All Roadways

Level Terrains
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.

<table>
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<tr>
<td>Speed Impacts</td>
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<tr>
<td>Reduction in 85th Percentile Speeds between Slow Points</td>
</tr>
</tbody>
</table>


Approximate Cost: $22,000 - $33,000 (basic materials)

Suitable for: All Roadways
Level Terrains

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.
Textured 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.

**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.

**Approximate Cost:** Varies by area and materials.

**Suitable for:**
- All Roadways
- All Terrains
**Level 4 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 may significantly increase emergency response time, therefore they must be reviewed and considered on a case-by-case basis in conjunction with the Benicia Fire Department. 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. In Benicia, a full closure was implemented on East K Street by means of back-to-back cul-de-sacs.

<table>
<thead>
<tr>
<th>Volume Impacts</th>
<th>Reduction in Vehicles per Day</th>
<th>-44%</th>
</tr>
</thead>
</table>


**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;
- May significantly increase emergency response times;
- May limit access to businesses; and
- Landscaping requires maintenance by City or residents.

Approximate Cost: $30,000 - $100,000.
Suitable for: Neighborhood Streets
            All Terrains
**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 a grid system 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.

<table>
<thead>
<tr>
<th>Speed Impacts</th>
<th>Volume Impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduction in 85th Percentile Speeds between Slow Points</td>
<td>-19%</td>
</tr>
<tr>
<td>Reduction in Vehicles per Day</td>
<td>-42%</td>
</tr>
</tbody>
</table>


**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.

**Approximate Cost:** $6,500 - $30,000

**Suitable for:** Neighborhood Streets
All Terrains
**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

<table>
<thead>
<tr>
<th>Speed Impacts</th>
<th>Volume Impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduction in 85th Percentile Speeds between Slow Points</td>
<td>Reduction in Vehicles per Day</td>
</tr>
<tr>
<td>-4%</td>
<td>-35%</td>
</tr>
</tbody>
</table>


### 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;
- May significantly increase emergency response times;
- Landscaping requires maintenance by City or residents; and
- May require reconstruction of corner curbs.

---

**Approximate Cost:** $15,000 - $40,000  
**Suitable for:** Neighborhood Streets, All Terrains
**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.

<table>
<thead>
<tr>
<th>Volume Impacts</th>
<th>Reduction in Vehicles per Day</th>
</tr>
</thead>
</table>

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

**Suitable for:** All Roadways  
All Terrains

**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; and
- Landscaping requires maintenance by City or residents.
**FORCED-TURN ISLAND**

Forced turn islands are raised islands that block certain movements on approaches to an intersection.

<table>
<thead>
<tr>
<th>Measured Impacts</th>
<th>Volume Impacts</th>
<th>Reduction in Vehicles per Day</th>
<th>-31%</th>
</tr>
</thead>
</table>


**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.

**Approximate Cost:** $5,000 - $20,000

**Suitable for:** All Roadways

All Terrains
2.2 Selecting Traffic Calming Measures

When selecting the most appropriate traffic calming device, one must narrow the field of devices to those that address the primary traffic issue. The major types of traffic calming issues 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 issue types. The appropriateness of each device is summarized in Table 1.

2.2.1 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 issue. If the traffic issue 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. Certain types of devices are appropriate in residential areas but not in non-residential areas. Furthermore, some devices are only applicable on level terrain. Table 2 indicates the locations where each traffic calming measure is applicable.
### Table 1. Traffic Calming Measures and Issue Types

<table>
<thead>
<tr>
<th>Types of Measures</th>
<th>Type of Traffic Issue</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Speeding</td>
</tr>
<tr>
<td><strong>Level 1 Measures</strong>: Education</td>
<td></td>
</tr>
<tr>
<td>Flyers and Brochures</td>
<td>●</td>
</tr>
<tr>
<td>Public Traffic Calming Classes</td>
<td>●</td>
</tr>
<tr>
<td>Neighborhood Pledge Program</td>
<td>●</td>
</tr>
<tr>
<td>Neighborhood Sign Campaign</td>
<td>●</td>
</tr>
<tr>
<td><strong>Level 1 Measures</strong>: Enforcement</td>
<td></td>
</tr>
<tr>
<td>Increased Police Force</td>
<td>●</td>
</tr>
<tr>
<td>School Safety Programs</td>
<td>○</td>
</tr>
<tr>
<td>Juvenile Traffic School</td>
<td>○</td>
</tr>
<tr>
<td>Targeted Speed Enforcement</td>
<td>●</td>
</tr>
<tr>
<td>Radar Trailer</td>
<td>●</td>
</tr>
<tr>
<td>Pedestrian Sting Operations</td>
<td>●</td>
</tr>
<tr>
<td>Photo Enforcement</td>
<td>●</td>
</tr>
<tr>
<td>Residential Speed Watch</td>
<td>●</td>
</tr>
<tr>
<td><strong>Level 2 Measures</strong>: Non-Physical Engineering Measures</td>
<td></td>
</tr>
<tr>
<td>Lane Striping</td>
<td>●</td>
</tr>
<tr>
<td>Speed Legends</td>
<td>●</td>
</tr>
<tr>
<td>Signage</td>
<td>●</td>
</tr>
<tr>
<td>Botts Dots/Raised Reflectors</td>
<td>○</td>
</tr>
<tr>
<td>High-Visibility Crosswalks</td>
<td>●</td>
</tr>
<tr>
<td>Optical Speed Bars</td>
<td>●</td>
</tr>
<tr>
<td>Advanced Limit Lines</td>
<td>○</td>
</tr>
<tr>
<td>Angled Parking</td>
<td>●</td>
</tr>
<tr>
<td><strong>Level 3 Measures</strong>: Narrowing Measures</td>
<td></td>
</tr>
<tr>
<td>Neckdowns</td>
<td>●</td>
</tr>
<tr>
<td>Two-Lane Chokers</td>
<td>●</td>
</tr>
<tr>
<td>One-Lane Chokers</td>
<td>●</td>
</tr>
<tr>
<td>Center Island Narrowings</td>
<td>●</td>
</tr>
<tr>
<td><strong>Level 3 Measures</strong>: Horizontal Measures</td>
<td></td>
</tr>
<tr>
<td>Traffic Circles</td>
<td>●</td>
</tr>
<tr>
<td>Roundabouts</td>
<td>●</td>
</tr>
<tr>
<td>Lateral Shifts</td>
<td>●</td>
</tr>
<tr>
<td>Chicanes</td>
<td>●</td>
</tr>
<tr>
<td>Realigned Intersections</td>
<td>●</td>
</tr>
<tr>
<td><strong>Level 3 Measures</strong>: Vertical Measures</td>
<td></td>
</tr>
<tr>
<td>Speed Humps</td>
<td>●</td>
</tr>
<tr>
<td>Speed Lumps</td>
<td>●</td>
</tr>
<tr>
<td>Speed Tables</td>
<td>●</td>
</tr>
<tr>
<td>Raised Crosswalks</td>
<td>●</td>
</tr>
<tr>
<td>Raised Intersections</td>
<td>●</td>
</tr>
<tr>
<td>Textured Pavement</td>
<td>●</td>
</tr>
<tr>
<td><strong>Level 4 Measures</strong>: Diversion Measures</td>
<td></td>
</tr>
<tr>
<td>Full Closures</td>
<td>●</td>
</tr>
<tr>
<td>Half Closures</td>
<td>●</td>
</tr>
<tr>
<td>Diagonal Diverters</td>
<td>●</td>
</tr>
<tr>
<td>Median Barriers</td>
<td>○</td>
</tr>
<tr>
<td>Forced Turn Islands</td>
<td>○</td>
</tr>
</tbody>
</table>

Key: ● = Strongly Appropriate, ○ = Indifferent, ¥ = Moderately Appropriate, √ = Inappropriate/Counterproductive, × = Inappropriate/Counterproductive
### Table 2. Traffic Calming Measures and Location Types

<table>
<thead>
<tr>
<th>Types of Measures</th>
<th>Terrain</th>
<th>Neighborhood Street</th>
<th>Major Road</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Midblock</td>
<td>Intersection</td>
<td>Boundary of Area</td>
</tr>
<tr>
<td><strong>Level 1 Measures: Education</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flyers and Brochures</td>
<td>All</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Public Traffic Calming Classes</td>
<td>All</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Neighborhood Pledge Program</td>
<td>All</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Neighborhood Sign Campaign</td>
<td>All</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td><strong>Level 1 Measures: Enforcement</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increased Police Force</td>
<td>All</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>School Safety Programs</td>
<td>All</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Juvenile Traffic School</td>
<td>All</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Targeted Speed Enforcement</td>
<td>All</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Radar Trailer</td>
<td>All</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Pedestrian Sting Operations</td>
<td>All</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Photo Enforcement</td>
<td>Level</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Residential Speed Watch</td>
<td>Level</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td><strong>Level 2 Measures: Non-Physical Engineering Measures</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lane Striping</td>
<td>All</td>
<td>●</td>
<td>○</td>
</tr>
<tr>
<td>Speed Legends</td>
<td>All</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Signage</td>
<td>All</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Botts Dots/Raised Reflectors</td>
<td>All</td>
<td>●</td>
<td>○</td>
</tr>
<tr>
<td>High-Visibility Crosswalks</td>
<td>All</td>
<td>●</td>
<td>Unsignalized Intersections</td>
</tr>
<tr>
<td>Optical Speed Bars</td>
<td>All</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Advanced Limit Lines</td>
<td>Level</td>
<td>○</td>
<td>●</td>
</tr>
<tr>
<td>Angled Parking</td>
<td>Level</td>
<td>●</td>
<td>○</td>
</tr>
<tr>
<td><strong>Level 3 Measures: Narrowing Measures</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neckdowns</td>
<td>All</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Two-Lane Chokers</td>
<td>All</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>One-Lane Chokers</td>
<td>Level</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Center Island Narrowings</td>
<td>All</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td><strong>Level 3 Measures: Horizontal Measures</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Traffic Circles</td>
<td>Level</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Roundabouts</td>
<td>Level</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Lateral Shifts</td>
<td>Level</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Chicanes</td>
<td>Level</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Realigned Intersections</td>
<td>Level</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td><strong>Level 3 Measures: Vertical Measures</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Speed Humps</td>
<td>Level</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Speed Lumps</td>
<td>Level</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Speed Tables</td>
<td>Level</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Raised Crosswalks</td>
<td>Level</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Raised Intersections</td>
<td>Level</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Textured Pavement</td>
<td>All</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td><strong>Level 4 Measures: Diversion Measures</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Full Closures</td>
<td>All</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Half Closures</td>
<td>All</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Diagonal Diverters</td>
<td>All</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Median Barriers</td>
<td>All</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Forced Turn Islands</td>
<td>All</td>
<td>●</td>
<td>●</td>
</tr>
</tbody>
</table>

**Key:** ● = Generally applicable. ○ = Not applicable except in some cases.

#### 2.2.2 Selecting Measures for the Street Environment

The second 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 summarizes the constraints on the use of traffic calming devices in these various environments.
<table>
<thead>
<tr>
<th>Types of Measures</th>
<th>Roadway Classification</th>
<th>Bus or Emergency Response Route</th>
<th>Other Considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Arterials</td>
<td>Collectors</td>
<td>Local Streets</td>
</tr>
<tr>
<td><strong>Level 2 Measures:</strong> Non-Physical Engineering Measures</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lane Striping/Botts Dots/Raised Reflectors</td>
<td>ADT &lt; 10,000; Speed Limit ≤ 35 mph</td>
<td>OK</td>
<td>(None)</td>
</tr>
<tr>
<td><strong>Level 3 Measures:</strong> Vertical Measures</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Speed Humps</td>
<td>No</td>
<td>ADT &lt; 3,000; Speed Limit ≤ 30 mph</td>
<td>No</td>
</tr>
<tr>
<td>Speed Lumps</td>
<td>No</td>
<td>Speed Tables</td>
<td>ADT &lt; 7,500; Speed Limit ≤ 35 mph</td>
</tr>
<tr>
<td>Raised Crosswalks</td>
<td></td>
<td></td>
<td>Raised Intersections</td>
</tr>
<tr>
<td>Raised Intersections</td>
<td></td>
<td></td>
<td>Textured Pavement</td>
</tr>
<tr>
<td><strong>Level 3 Measures:</strong> Horizontal Measures</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Traffic Circles</td>
<td>No</td>
<td>Daily Entering Volume &lt; 7,500; Speed Limit ≤ 35 mph</td>
<td>No</td>
</tr>
<tr>
<td>Roundabouts (Single-Lane)</td>
<td>Daily Entering Volume &lt; 18,000; Speed Limit ≤ 45 mph</td>
<td>No</td>
<td>Must design inscribed radius to be 100+ feet</td>
</tr>
<tr>
<td>Lateral Shifts</td>
<td>No</td>
<td>ADT &lt; 10,000; Speed Limit ≤ 35 mph</td>
<td>OK</td>
</tr>
<tr>
<td>Chicanes</td>
<td>No</td>
<td>ADT &lt; 5,000; Speed Limit ≤ 35 mph</td>
<td>OK</td>
</tr>
<tr>
<td>Realigned Intersections</td>
<td>No</td>
<td>Daily Entering Volume &lt; 5,000; Speed Limit ≤ 35 mph</td>
<td>OK</td>
</tr>
<tr>
<td><strong>Level 3 Measures:</strong> Narrowing Measures</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neckdowns</td>
<td></td>
<td>ADT &lt; 20,000; Speed Limit ≤ 35 mph</td>
<td>OK</td>
</tr>
<tr>
<td>Two-Lane Chokers</td>
<td>ADT &lt; 20,000; Speed Limit ≤ 35 mph</td>
<td>OK</td>
<td></td>
</tr>
<tr>
<td>Center Island Narrowings</td>
<td>ADT &lt; 20,000; Speed Limit ≤ 35 mph</td>
<td>OK</td>
<td></td>
</tr>
<tr>
<td>One-Lane Chokers</td>
<td>No</td>
<td>ADT &lt; 3,000; Speed ≤ 30 mph</td>
<td>No</td>
</tr>
<tr>
<td><strong>Level 4 Measures:</strong> Diversion Measures¹</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Full Closures</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Half Closures</td>
<td>No</td>
<td>ADT &lt; 5,000; &gt; 25% Non-Local Traffic</td>
<td>Public Works &amp; RT must review</td>
</tr>
<tr>
<td>Diagonal Diverters</td>
<td>No</td>
<td></td>
<td>No</td>
</tr>
<tr>
<td>Median Barriers</td>
<td>No</td>
<td></td>
<td>No</td>
</tr>
<tr>
<td>Forced Turn Islands</td>
<td>No</td>
<td></td>
<td>No</td>
</tr>
<tr>
<td><strong>Combined Measures</strong></td>
<td>Subject to Constraints of Component Measures</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes: ¹ Only if other measures are deemed unsatisfactory.
2.3 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.

2.3.1 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. The table below provides sample Midpoint speeds as a function of Actual speeds, Desired Slow speeds, and speed control spacing.

<table>
<thead>
<tr>
<th>Speed Limit (mph)</th>
<th>Actual 85th Percentile Speed (mph)</th>
<th>Desired 85th Percentile Slow Speed (mph)</th>
<th>Speed Control Spacing (feet)</th>
<th>Resulting 85th Percentile Midpoint Speed (mph)</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>33</td>
<td>20</td>
<td>200</td>
<td>24</td>
</tr>
<tr>
<td>25</td>
<td>33</td>
<td>20</td>
<td>400</td>
<td>26</td>
</tr>
<tr>
<td>25</td>
<td>33</td>
<td>20</td>
<td>600</td>
<td>27</td>
</tr>
<tr>
<td>30</td>
<td>40</td>
<td>25</td>
<td>100</td>
<td>28</td>
</tr>
<tr>
<td>30</td>
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</tr>
<tr>
<td>30</td>
<td>40</td>
<td>25</td>
<td>300</td>
<td>31</td>
</tr>
<tr>
<td>30</td>
<td>40</td>
<td>25</td>
<td>400</td>
<td>32</td>
</tr>
</tbody>
</table>

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.

2.3.2 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.

2.3.3 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.

2.4 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

<table>
<thead>
<tr>
<th>Types of Measures</th>
<th>Effectiveness</th>
<th>85th Percentile Speeds</th>
<th>Vehicles per Day</th>
<th>Average Annual Collisions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Before</td>
<td>After</td>
<td>Change</td>
</tr>
<tr>
<td><strong>Level 2 Measures</strong></td>
<td></td>
<td>I/D</td>
<td>I/D</td>
<td>I/D</td>
</tr>
<tr>
<td><strong>Level 3 Measures</strong>: Vertical Measures</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Speed Humps</td>
<td></td>
<td>35.0</td>
<td>27.4</td>
<td>-7.6</td>
</tr>
<tr>
<td>Speed Tables</td>
<td></td>
<td>36.7</td>
<td>30.1</td>
<td>-6.6</td>
</tr>
<tr>
<td>Raised Crosswalks</td>
<td></td>
<td>34.6</td>
<td>34.3</td>
<td>-0.3</td>
</tr>
<tr>
<td><strong>Level 3 Measures</strong>: Horizontal Measures</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Traffic Circles</td>
<td></td>
<td>34.2</td>
<td>30.3</td>
<td>-3.9</td>
</tr>
<tr>
<td><strong>Level 3 Measures</strong>: Narrowing Measures</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neckdowns</td>
<td></td>
<td>34.9</td>
<td>32.3</td>
<td>-2.6</td>
</tr>
<tr>
<td>Center Island Narrowings/ Pedestrian Refuges</td>
<td>33.4</td>
<td>28.6</td>
<td>-4.8</td>
<td>-14%</td>
</tr>
<tr>
<td><strong>Level 4 Measures</strong>: Diversion Measures</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Full Closures</td>
<td></td>
<td>I/D</td>
<td>I/D</td>
<td>I/D</td>
</tr>
<tr>
<td>Half Closures</td>
<td></td>
<td>32.3</td>
<td>26.3</td>
<td>-6.0</td>
</tr>
<tr>
<td>Diagonal Diverters</td>
<td></td>
<td>29.3</td>
<td>27.9</td>
<td>-1.4</td>
</tr>
<tr>
<td>Median Barriers</td>
<td></td>
<td>I/D</td>
<td>I/D</td>
<td>I/D</td>
</tr>
<tr>
<td>Forced Turn Islands</td>
<td></td>
<td>I/D</td>
<td>I/D</td>
<td>I/D</td>
</tr>
</tbody>
</table>

Notes: I/D = Insufficient Data

Source: Traffic Calming: State of the Practice (Ewing, 1999)
III. DESIGN GUIDELINES

This chapter identifies some physical design considerations and constraints associated with the traffic calming measures in the toolbox in the previous chapter.

3.1 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. These existing experimental measures and the exploration of new measures can be promoted through continuous dialogue between Public Works, the TPBSC, emergency services staff, and citizens of the community.

3.2 Vertical Deflection Measures

3.2.1 Ramp Profiles

Vertical deflection measures (e.g. speed hump, speed tables, and raised intersections) should use parabolic profiles on vehicular approach ramps 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 3 depicts the parabolic, trapezoidal, and sinusoidal ramp profiles.

3.2.2 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.
3.2.3 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.

3.3 Horizontal Deflection Measures

3.3.1 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.

3.3.2 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.
3.3.3 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 4 (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 4 (b). This method may require the acquisition of additional right-of-way.

![Figure 4. Traffic Circles at T-Intersections](image)

3.4 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.

3.5 Signing & Marking

Concurrent with the installation of traffic calming devices, device-specific symbol-based signs will be installed. At the discretion of City 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.

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.

3.6 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.

3.7 Roundabouts

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.

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 E can helpful in determining whether a
roundabout is a reasonable option to consider. Also, the following examples illustrate cases where a roundabout may be appropriate:

- **Minimizing Queues** – One case is a collector/arterial intersection located near an arterial/arterial intersection. A roundabout may be useful here because it can 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** – Another case is an intersection with greater than four approaches or with approaches that meet the intersection at irregular angles. 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.
IV. REFERENCES

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

4.1 Other Local Traffic Calming Programs


4.2 General Information on Traffic Calming


4.3 **Roundabouts**


Appendix A

Detailed Traffic Calming Process - Major Roads
Major Road Traffic Calming Process

The Major Road process includes 8 steps, summarized below.

Major Road Step 1: Staff Receives a Request

Initially, a citizen with a concern about pedestrian safety, speeding, or other traffic-related issue would contact a city staff person, who would then direct them to complete an Issue Reporting Form. A sample of the form is included in Appendix B. The form requires a few key pieces of information:

- A description of the nature of the issue, including location and boundary
- A contact name and number
- Signatures of at least ten other residents or business owners who agree that an issue exists

Once the form is complete, the resident submits it to the City, where it is circulated to Public Works and Police.

A sample Issue Reporting Form is shown in Appendix C.

Major Road Step 2: Initial Evaluation

The City Engineer makes a determination about the nature of the issue. For Major Roads, issues are a function of 85th percentile speed, average daily traffic volumes, and annual accident data. The Major Road segment is assigned a numerical score based on the scoring procedure shown below:

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Points</th>
<th>Basis for Point Assignment</th>
</tr>
</thead>
<tbody>
<tr>
<td>85th Percentile Speed</td>
<td>0-25</td>
<td>2 points for every mile-per-hour that the 85th percentile speed is greater than the speed limit</td>
</tr>
<tr>
<td>Average Daily Traffic Volume</td>
<td>0-25</td>
<td>1 point for every 1,000 vehicles</td>
</tr>
<tr>
<td>Annual Accident Data</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Property Damage: 1 point for every property damage accident</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Personal Injury: 3 points for every personal injury accident</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fatality: 5 points for every fatality</td>
</tr>
<tr>
<td>Other</td>
<td>25</td>
<td>Points distributed at discretion of city staff for other factors</td>
</tr>
<tr>
<td>Total Points Possible</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>

A total score greater than 25 qualifies a concern as an addressable issue.
Staff may make follow-up calls to the citizen who submitted the form or review existing data to get additional details. At this point, City staff can make three decisions:

- If no real issue exists, citizens can be informed that no further action will be taken by the City.
- If the issue poses an immediate safety risk (for example, sight lines are obstructed), then City staff takes action.
- If the issue is appropriate for traffic calming, the request moves to the next step.

If the issue did not qualify for traffic calming improvements, citizens may resubmit another Issue Report Form that will be placed at the back of the queue for review.

**Major Road Step 3: Data Collection**

Once staff determines that an issue is appropriate for traffic calming, the details of the issue are characterized: exactly where does it occur, and at what time(s) of day and day(s) of week? Is there a traffic control device (such as all-way stop control at an intersection) that does not seem to work?

Knowing the exact nature of the problem, staff may then 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.

**Major Road Step 4: Stakeholder Input and Setting Goals**

TPBSC staff arranges a meeting with interested stakeholders to form a Steering Committee to ensure that all stakeholder interests are represented during the project development process. At this meeting, the TPBSC will also share the results of the initial data collection. The public meetings should be publicized in a fashion to inform all potential stakeholders within the boundaries of the issue based on City staff’s knowledge of the area and the description provided in the Issue Reporting Form.

The purpose of this meeting is to familiarize the stakeholders with the City’s traffic calming toolbox, form a Steering Committee, and to review appropriate solutions. The meeting should be publicly noticed with special care taken to

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**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, and rates of unsafe driving practices (e.g. cutting corners or crossing the centerline).
- **Accident Data:** Statistics of the number of accidents by type, level of severity, location, and cause.
notify stakeholders immediately adjacent to the project boundaries. The following items should be considered when planning public meetings:

- Select an appropriate date - including day of week and time of day; be sensitive to cultural and religious holidays.
- Identify appropriate location - accessibility of building, availability and safety of parking, proximity to impacted community, size of room, and room amenities.
- Include all potential stakeholders i.e. nearby businesses, schools, other public facilities (hospitals, parks, post offices, churches) on mailing list.
- Provide proper advance notification (usually via post card and/or flyer, and/or posted on the City website, in the Benicia Herald, or on Public, Education, and Government (PEG) Channel 27, 10 - 14 days out).
- Does notification need to be bi (or multi) lingual?
- Establish and post an agenda for the meetings.
- Identify a moderator / facilitator.
- Prepare and distribute meeting summaries to attendees after the meeting.

At this meeting, the TPBSC and stakeholders will generate specific goals and objectives, and rank each in the order of importance. Quantitative objectives should be set for each traffic issue to help assess the success of the traffic calming plan in solving the issues. The objectives should be seen simply as rough yardsticks of success for use when reviewing the installed plan.

Major Road Step 5: Selecting Measures

To develop solutions to the traffic issue, the TPBSC and the Steering Committee must 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. Once 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.

The traffic calming measure toolbox (Chapter II) 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 affected residents and businesses and the City Council.

Education – Of the Level 1 measures, the first solutions to consider should always be the Education Measures, such as flyers, brochures, and traffic calming classes, since these can be most easily implemented and require little involvement with City staff.

Enforcement – Of the Level 1 measures, Enforcement Measures should be considered after or along with Education Measures. Enforcement Measures are typically successful, especially on a short-term basis, but require staff time from the Police Department.

Non-Physical Measures – These Level 2 measures include options such as signs and markings, and should be implemented after Education and Enforcement have been tried. Non-Physical Measures are preferred since they can be easily removed if unanticipated problems occur.

Narrowing Devices – The first of the Level 3 traffic calming measures (which include all but the Diversion Measures) considers 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, roundabouts, 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 and Diversion Devices, which are included in the toolbox, are not appropriate for Major Roads. Vertical Deflection Devices infringe on the ability of vehicles to travel at constant speeds, and Deflection Devices significantly limit vehicle mobility. These elements are included in the Neighborhood Streets section.

Major Road Step 6: Phase I Action Plan

The TPBSC and the Steering Committee first determine if the issue may be addressed through Education, Enforcement, or Non-Physical Engineering measures alone. If so, the TPBSC and the Steering Committee recommend a Phase I plan that might involve a combination of Education, Enforcement, and Non-Physical Engineering measures to target the root of the issue. This plan can be implemented on a temporary (at least three month) basis, after which new data is collected, and analyzed to determine if the issue has been abated.
If the issue has been abated according to the goals and objectives developed during Step 4, a survey is distributed to the affected residents and business owners to vote to permanently install the non-physical engineering components of the Phase 1 plan. A majority (51%) of responses in favor of the plan are necessary for approval. Either no further action will be taken, or the Phase 1 measures will be permanently installed.

The TPBSC and the Steering Committee can choose to bypass the temporary installation of the Phase 1 plan and can implement the plan components permanently if a consensus is met.

If the issue persists, the TPBSC and the Steering Committee may re-visit the issue and determine that Physical Engineering measures are warranted.

Major Road Step 7: Phase II Action Plan

If Phase I measures fail to solve the issue initially, the TPBSC and the Steering Committee may propose a Phase II (Physical Engineering) Action Plan. If there is consensus among all the TPBSC and Steering Committee members, the Phase II Action Plan is implemented. If consensus cannot be reached, a survey is distributed to the stakeholders to approve the plan. If the plan is approved with a two-thirds (67%) approval vote, the Phase II Action Plan is implemented.

The City Council votes to approve the project for inclusion in the prioritization process and eventually into the Capital Improvement Plan (CIP). All City Council decisions are considered final.

If the Phase II Action Plan was not successful, the TPBSC and the Steering Committee can reconvene to discuss alternative solutions.

Major Road Step 8: Project Prioritization

Since Phase II measures are more expensive, the project at this point needs to be prioritized and incorporated into the City of Benicia’s Capital Improvement Plan (CIP), so that funding can be allocated to the projects that are in most need of physical engineering traffic calming measures.

The prioritization process ranks each project based on traffic volumes, travel speeds, collision history, presence of schools and public facilities, presence of pedestrian and bicycle facilities, and if the roadway segment is along a transit route. A sample Prioritization Form is provided in Appendix D.
Appendix B

Detailed Traffic Calming Process - Neighborhood Streets
Neighborhood Street Traffic Calming Process

The Neighborhood Street process includes 8 steps, summarized below.

Neighborhood Streets Step 1: Staff Receives a Request

Initially, a citizen with a complaint about pedestrian safety, speeding, or other traffic related issue would contact a city staff person, who would then direct them to complete an Issue Reporting Form. A sample of the form is included in Appendix C. The form requires a few key pieces of information:

- A description of the nature of the issue, including location and boundary
- A contact name and number
- Signatures of at least ten other residents or business owners who agree that an issue exists

A sample Issue Report Form is shown in Appendix C. All signatures collected must be from residents and business owners from within the neighborhood boundaries as described on the Report Form.

Once the form is complete, the resident submits it to the City, where it is circulated to Public Works and Police.

Neighborhood Street Step 2: Initial Evaluation

The City Engineer makes a determination about the nature of the issue. For Neighborhood Streets, issues are a function of 85th percentile speed, average daily traffic volumes, and annual accident data. The Neighborhood Street segment is assigned a numerical score based on the scoring procedure shown below:

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Points</th>
<th>Basis for Point Assignment</th>
</tr>
</thead>
<tbody>
<tr>
<td>85th Percentile Speed</td>
<td>0-25</td>
<td>5 points for every mile-per-hour that the 85th percentile speed is greater than the speed limit</td>
</tr>
<tr>
<td>Average Daily Traffic Volume</td>
<td>0-25</td>
<td>1 point for every 200 vehicles</td>
</tr>
<tr>
<td>Annual Accident Data</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Property Damage</td>
<td>0-25</td>
<td>1 point for every property damage accident</td>
</tr>
<tr>
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<td>3 points for every personal injury accident</td>
</tr>
<tr>
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<td></td>
<td>5 points for every fatality</td>
</tr>
<tr>
<td>Other</td>
<td>25</td>
<td>Points distributed at discretion of city staff for other factors</td>
</tr>
<tr>
<td><strong>Total Points Possible</strong></td>
<td><strong>100</strong></td>
<td></td>
</tr>
</tbody>
</table>
A total score greater than 25 qualifies a concern as an addressable issue.

Staff may make follow-up calls to the citizen who submitted the form or review existing data to get additional details. At this point, City staff can make three decisions:

- If no real issue exists, citizens can be informed that no further action will be taken by the City.
- If the issue poses an immediate safety risk (for example, sight lines are obstructed), then City staff takes action.
- If the issue is appropriate for traffic calming, the request moves to the next step.

If the issue did not qualify for traffic calming improvements, citizens may resubmit another Issue Report Form that will be placed at the back of the queue for review.

**Neighborhood Street Step 3: Data Collection**

Once staff determines that an issue is appropriate for traffic calming, the details of the issue are characterized: exactly where does it occur, and at what time(s) of day and day(s) of week? Is there a traffic control device (such as all-way stop control at an intersection) that does not seem to work?

Knowing the exact nature of the issue, staff may then collect relevant information about the issue itself and about the environment of the issue. See the sidebar “Types of Traffic and Environmental Data” for some examples.

**Neighborhood Street Step 4: Neighborhood Input and Setting Goals**

Before any traffic calming measures are implemented, affected residents shall be consulted to evaluate their concerns and to determine what they would like to get out of implementing traffic calming in their neighborhood.

Working with the neighborhood contact, City staff arranges a meeting with affected residents in order to form a Neighborhood Committee. The public meetings should be publicized in a fashion to inform all potential stakeholders within the boundaries of the issue based on City staff’s knowledge of the area and the description provided in the Issue Reporting Form. The Neighborhood...
Committee should consist of residents and business owners from within the issue boundaries.

The purpose of the meeting is to share the results of the initial data collection; to familiarize residents with the City’s traffic calming toolbox; and to review appropriate solutions. The following items should be considered when planning public meetings:

- Select an appropriate date - including day of week and time of day; be sensitive to cultural and religious holidays.
- Identify appropriate location - accessibility of building, availability and safety of parking, proximity to impacted community, size of room, and room amenities.
- Include all potential stakeholders i.e. nearby businesses, schools, other public facilities (hospitals, parks, post offices, churches) on mailing list.
- Provide proper advance notification (usually via postcard and/or flyer, and/or posted on the City website, in the Benicia Herald, or on Public, Education, and Government (PEG) Channel 27, 10 - 14 days out).
- Does notification need to be bi (or multi) lingual?
- Establish and post an agenda for the meetings.
- Identify a moderator / facilitator.
- Prepare and distribute meeting summaries to attendees after the meeting.

The TPBSC and the Benicia Police Department shall be informed (via email) of all public meetings planned by the Neighborhood Committee.

At this meeting, the affected residents are asked to provide and rank specific goals and objectives. Goals should be stated to express, in qualitative terms, the kind of neighborhood the residents members desire to have. Quantitative objectives should be set for each traffic issue to help assess the success of the traffic calming plan in solving the issues. 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.

**Neighborhood Street Step 5: Selecting Measures**

To develop solutions to the traffic issues, the toolbox of traffic calming measures needs to be narrowed to include only those that will most closely target the key traffic issues, 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.

The traffic calming measure toolbox (Chapter II) 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.

**Education** – Of the Level 1 measures, the first solutions to consider should always be the Education Measures, such as flyers, brochures, and traffic calming classes, since these can be most easily implemented and require little involvement with City staff.

**Enforcement** – Of the Level 1 measures, Enforcement Measures should be considered after or along with Education Measures. Enforcement Measures are typically successful, especially on a short-term basis, but require staff time from the Police Department.

**Non-Physical Measures** – These Level 2 measures include options such as signs and markings, and should be implemented after Education and Enforcement have been tried. Non-Physical Measures are preferred since they can be easily removed if unanticipated problems occur.

**Narrowing Devices** – The first of the Level 3 traffic calming measures (which include all but the Diversion Measures) considers 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 Level 3 measures 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 and noise impacts.

**Diversion Devices** – Level 4 measures cannot be considered until measures from all other previous levels have been attempted and have failed to meet the
Neighborhood Committee’s goals. Consequently, they will generally not be considered simultaneously with the other types of measures.

**Neighborhood Street Step 6: Phase I Action Plan**

The Neighborhood Committee and City staff first determines if the problem may be addressed through Education, Enforcement, or Non-Physical Engineering measures alone. If so, staff assists the Neighborhood Committee recommend a Phase 1 plan that might involve a combination Education, Enforcement, and Non-Physical Engineering measures to target the root of the issue. This plan can be implemented on a temporary (at least three month) basis, after which new data is collected, and analyzed to determine if the issue has been abated.

If the issue has been abated according to the goals and objectives developed during Step 4, affected residents and business owners vote to permanently install the non-physical engineering solutions of the Phase I plan. A majority (51%) vote is necessary for approval. Either no further action will be taken, or the Phase 1 measures will be permanently installed.

The TPBSC and the Neighborhood Committee can choose to bypass the temporary installation of the Phase 1 plan and can install the plan components permanently if a consensus is met.

If the issue persists, the Neighborhood Committee may re-visit the issue and determine that Physical Engineering measures are warranted.

**Neighborhood Street Step 7: Phase II Action Plans**

When Phase I measures cannot fail to solve the issue initially, the Neighborhood Committee may propose a Phase II (Physical Engineering) Action Plan. The plan is presented to the TPBSC for review and approval. If the Phase II plan is not approved, the Neighborhood Committee can develop an alternative plan. If the plan is approved, the TPBSC and the Neighborhood Committee can choose to implement the Phase II Action Plan temporarily.

After the trial period, City staff collects data to evaluate if the measures have met the Neighborhood Committee goals and objectives. If the measures were successful during the trial period, the affected residents and business vote to approve permanent installation. With a two-thirds (67%) approval, the TPBSC shall review the Phase II plan for implementation.

If there is consensus among all the TPBSC and Neighborhood Committee members, affected residents and business can choose to approve permanent installation of the Phase II Action Plan without the temporary installation.

If acceptable, City Council votes to approve the project for inclusion in the prioritization process and eventually into the Capital Improvement Plan (CIP).
The City Council votes to approve the project for inclusion in the prioritization process and eventually into the Capital Improvement Plan (CIP). All City Council decisions are considered final.

If the Phase II Action Plan was not successful, the Neighborhood Committee can reconvene to discuss alternative solutions.

**Neighborhood Street Step 8: Project Prioritization**

Since Phase II measures are more expensive, the project at this point needs to be prioritized and incorporated into the City of Benicia’s Capital Improvement Plan (CIP), so that funding can be allocated to the projects that are in most need of physical engineering traffic calming measures.

The prioritization process ranks each project based on traffic volumes, travel speeds, collision history, presence of schools and public facilities, presence of pedestrian and bicycle facilities, and if the roadway segment is along a transit route. A sample Prioritization Form is provided in Appendix D.
Appendix C

Issue Report Form
Traffic Calming Issue Report Form

The purpose of this form is to enable residents of the City of Benicia to report an issue that may be resolved by means of the City Traffic Calming Program. This form is for major road and neighborhood street issues. The form must be filled out in its entirety and returned to the City of Benicia Public Works Department staff.

Name: ____________________________ Organization (if applicable) __________________________

Date: ___________ Daytime Tel. ___________ Evening Tel. __________________

Mailing Address _____________________________ City ________ Zip_________

E-mail _____________________________________

Type of Issue: Please indicate traffic issues that concern residents and business owners in your neighborhood/along your street:

___ Speeding
___ Traffic Volumes
___ Collision (Accidents)
___ Pedestrian/Bicycle Safety
___ Other:

________________________________________________________________________

Description of Issue: Please describe the traffic issues that concern residents and business owners in your neighborhood/along your street:

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

Location: Please describe the street or location of concern, as well as the limits of your neighborhood (street name and cross street or other information). Feel free to provide a sketch of any concerns on the backside of this sheet.

Street name _____________________________

(between _______________ and _________________)
Neighborhood Support: To complete this request, at least ten (10) residents/business owners from separate households/businesses within the boundaries described above must sign the petition below. Each resident must be at least 18 years of age. Each household (or housing unit) gets one vote.

By providing the information below, you indicate support for initiation of a traffic calming plan.

<table>
<thead>
<tr>
<th>Signature</th>
<th>Printed Name</th>
<th>Address</th>
<th>Phone Number (optional)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td></td>
<td></td>
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<tr>
<td>2.</td>
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<tr>
<td>3.</td>
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<tr>
<td>4.</td>
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<tr>
<td>5.</td>
<td></td>
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<tr>
<td>6.</td>
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<td>7.</td>
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<td>8.</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>9.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix D

Project Prioritization Form
TRAFFIC CALMING PROGRAM PRIORITIZE WORKSHEET

This worksheet will be completed by City of Benicia Staff in accordance with the City of Benicia’s Traffic Calming Plan. It will be used to prioritize the initiation of specific Major Roads and Neighborhood Street Phase II traffic calming processes.

Project Name: _______________________________________________________

1. **Traffic Volumes:**
   
   10 points for every 1,000 vehicles over 5,000 vehicles-per-day  
   ______

2. **Travel Speeds:**
   
   80% - 100% of traffic exceeds speed limit = 25 points  
   60% - 80% of traffic exceeds speed limit = 20 points  
   40% - 60% of traffic exceeds speed limit = 15 points  
   30% - 40% of traffic exceeds speed limit = 10 points  
   20% - 30% of traffic exceeds speed limit = 5 points  
   ______

3. **Collision History:**
   
   Greater than 5 annual collisions = 20  
   Between 2 and 4 annual collisions = 10  
   Less than 2 annual collisions = 5  
   ______

4. **School Presence:**
   
   10 points for every school on the study roadway segment  
   ______

5. **Public Facilities:**
   
   10 points for every public facility (such as parks, community centers)  
   ______

6. **Pedestrian Facilities:**
   
   10 points if there is discontinuous sidewalk on at least one side of the street  
   ______

7. **Bicycle Facilities:**
   
   10 points if the street is a designated bicycle route  
   ______

8. **Transit Presence:**
   
   5 points if the street is a designated transit route  
   ______

Total Score  ______
Appendix E  
**Checking Roundabout Compatibility**

When considering a roundabout for a particular intersection, both the expected traffic volumes and the available geometry must be taken into consideration.

**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 E-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:

\[
\begin{align*}
V_{EB,circ} &= V_{WB,LT} + V_{SB,LT} + V_{SR,TH} + V_{NR,U-turn} + V_{WB,U-turn} + V_{SB,U-turn} \\
V_{WB,circ} &= V_{EB,LT} + V_{NB,LT} + V_{SR,TH} + V_{WB,U-turn} + V_{EB,U-turn} + V_{NB,U-turn} \\
V_{NB,circ} &= V_{SR,LT} + V_{EB,LT} + V_{ER,TH} + V_{WB,U-turn} + V_{SB,U-turn} + V_{EB,U-turn} \\
V_{SR,circ} &= V_{NB,LT} + V_{WB,LT} + V_{WR,TH} + V_{EB,U-turn} + V_{NR,U-turn} + V_{WB,U-turn}
\end{align*}
\]

where \( V_{i,circ} \) = Circulatory flow immediately downstream of approach \( i \).

\( V_{ij} \) = 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 E-2 in combination with the Maximum Entry Flow to determine whether an Urban Single-Lane Roundabout could accommodate the traffic volume.
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 F

Institute of Transportation Engineers Angled Parking Journal Article
Changing On-Street Parallel Parking to Angle Parking

There is a "knee-jerk" reaction by many state highway officials and city traffic engineers to on-street angle parking—"no way-no where"—yet there are many existing low-volume streets with angle parking that are operating well within acceptable safety limits with low accident rates. With the struggle to revitalize traditional downtowns, there is a need to provide more convenient on-street parking in retail districts to support economic restructuring. In this feature, the first in a series on parking, the author summarizes the reasons why one should consider changing parallel on-street parking and the traffic and parking conditions under which such a change can be made.

MANY DOWNTOWNS ACROSS America are facing hard times and stiff competition from suburban shopping centers and "big box" retailers, most of which are not located in the traditional downtown, but are located in the suburbs or exurbs of urban areas. Beginning in the 1960s, the retail and retail-service segment of downtown have basically relocated to the suburbs in towns and cities with a population over 10,000. This has left vacant stores, reduced demand for central business district (CBD) floor space, devalued buildings and reduced assessed valuations. This has hit municipal governments where it hurts, in ad valorem taxes.

The reason for the relocation of the primary retail-trade segment to the suburbs has been stated many times and in many ways: some say the shift of population to the suburbs and exurbs, some say the improved accessibility provided to the market area by bypass and interstate roadways, some say the more convenient shopping offered by shopping centers with a wider selection of higher-quality goods and some say the lack of "adequate and convenient" parking downtown. This feature will address the adequate and convenient parking issue.

PARKING EXPECTATIONS

There is no question that "adequate and convenient" parking is important for commercial enterprises. All businesses that rely on customers coming to the establishment in a private vehicle recognize the importance of parking. In suburban areas, the provision of parking is relatively easy, land is available and surface parking can be provided adjacent to the buildings at low cost. In traditional downtowns, with narrow streets and zero lot-line development, the provision of adequate parking may be yet another matter. Herein lies the need to look at any and all strategies to provide additional parking.

It is interesting to note that the definition of convenient parking depends on "the eye of the beholder." Shoppers using traditional downtowns expect to be able to park in front of their destination or be able to at least see the destination, while shoppers at suburban shopping centers are willing to park at substantial distances from their primary destination and walk. Studies of average walking distances for shopping trips show longer walking distances for shopping centers than the CBD, especially for cities under a population of 500,000 (see Table 1), yet the perception by shoppers is that parking is more convenient in shopping centers as compared to traditional downtowns.

Numerous public-opinion surveys of downtown shoppers and merchants have been conducted in an effort to determine the perceptions of shoppers about the parking system. Almost universal, the lack of parking will be listed as a negative factor—frequently the most negative factor—of downtown. A national survey of municipal officials shows that the perceived lack of parking is the number one issue related to downtown business failure. Yet in over 75 downtowns where parking studies have been conducted, less than 25 percent had an actual shortage of parking. For the shopper and the merchant, on-street parking within sight of the destination is perceived as a requirement for successful retail operations.

ISSUES RELATED TO ON-STREET PARKING

If on-street parking is so important to retail and retail-service land uses, why not maximize the use of street space for parking? Transportation professionals know that angle parking will almost double the number of spaces over parallel parking—and these spaces are easy to use. Many women prefer angle parking to parallel parking—and women are the predominant shoppers in the household. Traffic
Table 1. Typical walking distances by trip purpose.

<table>
<thead>
<tr>
<th>Trip purpose</th>
<th>50,000 ft. or less</th>
<th>50,000 to 500,000 ft.</th>
<th>over 500,000 ft.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shopping-Central business district</td>
<td>200 to 300</td>
<td>300 to 400</td>
<td>500 to 600</td>
</tr>
<tr>
<td>Shopping center-Mall</td>
<td>400 to 500</td>
<td>500 to 700</td>
<td>500 to 700</td>
</tr>
<tr>
<td>Work trips</td>
<td>400</td>
<td>400 to 600</td>
<td>800 to 1,600</td>
</tr>
<tr>
<td>Business trips</td>
<td>400</td>
<td>500 to 600</td>
<td>600 to 800</td>
</tr>
<tr>
<td>Medical trips</td>
<td>200 to 300</td>
<td>300 to 400</td>
<td>300 to 400</td>
</tr>
<tr>
<td>Pay bills, tax, post office</td>
<td>100</td>
<td>200 to 300</td>
<td>200 to 300</td>
</tr>
</tbody>
</table>

Source: National Research Council, Transportation Research Board, Parking Principles, TRB Report #125, Table 2.11, p. 15.

Figure 1. Downtown San Marcos accident frequency from 1997. Source: San Marcos Police Department.

Area Type

Just as one would consider the type of area in the calculation of capacity or level of service, one must consider the area in the decision whether to change from parallel to angle parking. Traditional downtowns with closely spaced buildings, pedestrian activity on the street, low vehicle operating speeds and the general expectation of congestion are appropriate for angle parking; suburban areas or secondary strip districts on major traffic facilities are not.

Street Width

Perhaps the single most important factor is street width. With parallel parking, a typical minimum width in a business area is 38 feet (ft.) (two 8-foot parking lanes and two 11-foot driving lanes), assuming two-way operation. For angle parking in a business area, a typical minimum width to consider is 60 ft. curb-to-curb with two parking lanes and two driving lanes. In reality, a more comfortable minimum dimension is 68 to 70 ft. (two 18-foot parking lanes, two 16-foot driving lanes). With one-way streets, the above dimensions can be reduced to 51 to 52 ft. if the number of parking and driving lanes is reduced accordingly.

CHANGING PARALLEL TO ANGLE PARKING

The process of changing parallel to angle parking must consider a number of factors related to the particular street where the change is being considered. These considerations should include area type, the classification or type of facility, street width, current traffic volumes, pedestrian activity, the type of land use, the availability of parking, the impact on adjacent street segments, transit operations and the potential changes in accidents.
Curb overhang is somewhat related to street width and the parking angle. Sharp parking angles (approaching 90 degrees) will have front parking overhangs over 2.5 ft., while flatter angles are 2 ft. This may reduce the usable width of sidewalks or increase the driving width.

Parking Angles and Maneuvers
Just as parking angles have an impact on the effective sidewalk width and/or street width, impacts on parking and unparking maneuvers occur. Ninety-degree parking or angles approaching 90 degrees will encourage U-turns from lanes operating in the opposite direction, while flatter angles—45 degrees or less—discourage this type of traffic maneuver.

Another consideration related to parking angle is the time needed to park and unpark. It is reported that the average time for a “back-in” maneuver for a parallel space is 21 seconds, while the time for a “drive-in” or “back-in” maneuver for an angled space is only 11 to 12 seconds; thus parallel parking has the greatest potential for delaying traffic. This may be another consideration in the decision on conversion to angle parking.

A third consideration is the use of very flat angles (30 degrees or less) that may allow the front doors to swing free of the adjacent car. This can allow stall width of less than 8.5 ft. Highland Park, IL, USA, implemented 8-foot angle parking stalls at very flat angles, which appear to work well.

Traffic Volumes
Traffic volumes are an important criterion in the decision on parallel vs. angle parking. Streets with traffic volumes over 10,000 to 12,000 vehicles per day will rarely allow angle parking, due to the disruption of the traffic flow caused by parking maneuvers. Angle-parking maneuvers on streets less than 40 ft. wide will disrupt flow, creating congestion. If angle parking is interjected into streets with volumes in excess of 10,000 vehicles per day, parallel alternate routes should be designed. Figure 2 illustrates the diversion routes designated in Greenville, SC, USA, when angle parking was placed on Main Street.

Pedestrian Activity
One of the reasons for introducing angle parking is to provide a wider “buffer” between sidewalks and driving lanes. A parallel-parking lane provides 8 to 9 ft. of buffer, while an angle-parking lane provides 18 to 20 ft. This increased buffer results in reduced vehicle splash, reduced noise, reduced fumes and improved perception of safety for the pedestrian. With significant pedestrian volumes on the streets, the added buffer width can make a big difference in the walking environment.

Operating Speeds
High operating speeds on downtown streets are a significant deterrent to pedestrian activity. Speeds in excess of 30 mph are considered unsafe by pedestrians and are a negative factor in the revitalization of retail districts. Angle-parking maneuvers dictate lower operating speeds due to the limited sight distance involved in unparking from an angle-parking space. Therefore, posted and operating speeds must be lower. Posted speeds of 25 mph or less should be considered for streets with angle parking. This is consistent with desirable downtown operating conditions.
Table 2. Characteristics of downtowns with angle-parking conversions.

<table>
<thead>
<tr>
<th>City or town</th>
<th>Population</th>
<th>Gain of on-street parking</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Athol, MA</td>
<td>12,000</td>
<td>+10</td>
<td>Angle parking added on Traverse Street, relatively small impact</td>
</tr>
<tr>
<td>2. Hickory, NC</td>
<td>36,100</td>
<td>+46</td>
<td>Conversion to angle parking on 1st Avenue, 2nd Street and 3rd Street</td>
</tr>
<tr>
<td>3. Greenville, SC</td>
<td>180,000</td>
<td>+20</td>
<td>Conversion to angle parking, extensive streetscape treatment</td>
</tr>
<tr>
<td>4. Macon, GA</td>
<td>165,000</td>
<td>+28</td>
<td>Angle parking added on median on Cherry Street</td>
</tr>
<tr>
<td>5. San Marcos, TX</td>
<td>28,000</td>
<td>+120</td>
<td>Conversion to angle parking on several block faces</td>
</tr>
<tr>
<td>6. Seattle, WA</td>
<td>480,000</td>
<td>Over 200</td>
<td>Angle parking used on steep street grades to improve safety</td>
</tr>
</tbody>
</table>

Type of Land Use

The basic reason for changing parallel to angle parking is to make parking more convenient. Retail districts, with shopping and retail services as the primary use, are the areas where on-street parking is most important. The most successful changes from parallel to angle on-street parking have been where there are several contiguous blocks of primary retail use. Greenville, SC’s Main Street (see Figure 3) is a good example of what can happen when traffic is diverted and angle parking replaces parallel parking. The result has been significant revitalization of the retail district. In this example, parallel “diversion” routes took care of traffic movement and Main Street was converted from a through street to a “shopping street.”

Availability of Parking

The primary reason to convert from parallel to angle parking is to increase on-street parking availability; however, in downtowns where a surplus of parking exists, there is little reason to implement angle parking. Frequently, an area that appears to lack short-term parking is simply an area where enforcement activity is low and long-term parkers are using on-street parking spaces. Before changes are made from parallel to angle parking, a parking turnover survey should be done to determine the character of parking use. If short-term parking occupancy is less than 50 percent during the peak shopping hour, there is a question as to whether a conversion to angle parking will help, unless there is a comparable increase in time-limit enforcement.

Impact on Adjacent Street Segments

The introduction of angle parking will substantially reduce capacity on a street. If that segment is part of a continuous route that has significantly higher capacity in adjacent segments, then care must be taken to divert traffic in the higher capacity segments before the angle parking segment is reached. This will impose higher traffic volumes on parallel streets; therefore, one should be sure adequate capacity exists or can be developed. (See Figure 3 for an example of this concept.)

Transit Operations

In most traditional downtowns, transit operations are present on many of the downtown streets. In the conversion of parallel to angle parking, the presence of transit operations should be considered. This may affect transit operations in several ways: (1) It may increase route time due to additional congestion; (2) it may make the conversion of parallel to angle parking on narrow street widths unfeasible; and (3) the presence of transit stops may reduce the number of potential additional spaces that might be gained with angle parking.

Accident Frequency

As stated earlier, angle parking is usually associated with somewhat higher accident rates. While this may be statistically true, one must be careful not to overemphasize the accident potential because those accidents that do occur are likely to be minor in nature.

So, to do or not to do?

EXAMPLES OF ON-STREET CONVERSIONS

Many downtown areas utilize angle parking. Typically, the conversion of parallel parking to angle parking has been done to (1) increase on-street parking supply; (2) make parking safer (see case study on Seattle, WA, USA); and (3) improve the pedestrian environment. Table 2 summarizes the conditions under which the conversions and additions to angle parking were made. Typically, the conversions were done as a result of either parking studies or streetscape plans. The comments under each case study are based upon interviews with local planning, engineering and police officials.

- **Athol, MA, USA.** A traffic and parking study was performed in 1997 in this town of 12,000 in central Massachusetts. With only 291 on-street spaces, the addition of 10 angle spaces in the retail district was significant. These spaces were added on a side street, so no impact on major traffic flow has occurred. The adjacent YMCA building with no off-street parking generates high parking demands in the afternoon and evening, so the addition of parking spaces was well received.

- **Hickory, NC, USA.** Hickory, a city of 36,000 in the foothills of the Blue Ridge Mountains, had an ambitious program of parallel to angle parking conversions in 1999. Three street segments in the downtown area were converted, resulting in a 15 percent increase in parking. The local streets involved had daily traffic volumes of 2,000 to 5,000 vehicles per day. The wide streets and abutting retail uses made this an ideal situation for conversion. Accident rates have not changed and operating speeds were reduced to 22 mph. Figure 4 shows one of the converted streets.
• Greenville, SC, USA. Of all the case studies, this is the most radical design approach to a conversion to a shopping street—and probably the most successful, from an economic viewpoint. Main Street in Greenville carried over 12,000 vehicles per day and was a four-lane street with two lanes of parallel parking. The conversion was made to a two-lane street with angle parking with a curb width of 68 to 70 ft. as a part of a streetscape and a major redevelopment project in downtown that included a major hotel, office building, parking garage and conference center.

Traffic volumes on Main Street decreased after implementation to 5,000 to 8,000 vehicles per day. Accident frequency is very low (less than 20 per year) in the eight mid-block sections of the project. More importantly, retail sales, building assessments and tax collections have soared. Greenville has a healthy downtown again.

• Macon, GA, USA. The addition of angle parking in Macon was the result of a 1993 parking-management study. Cherry Street is a major retail street in Macon carrying 8,000 to 10,000 vehicles per day. Originally, a four-lane street with angle parking and a wide median, the revised design is a two-lane, two-way street with angle parking at the curbs and along the median as well. A high pedestrian area, operating speeds on Cherry Street range between 15 and 20 mph. Accident frequency is minimal, with 20 to 30 minor “fender-benders” in the eight-block section per year.

• San Marcos, TX, USA. This city of 28,000 persons is familiar with angle parking, having six streets in downtown with portions of each featuring angle parking. The addition of 120 angle parking spaces on-street was part of a streetscape program around “the Square,” as well as extensions of angle parking in the areas marked for parallel parking. These additional spaces can provide for long-term users in low-utilization areas as well. As indicated in Figure 1, the accident frequency in 1997 in mid-block locations were one to two per year, insignificant in terms of a serious accident potential.

• Seattle, WA, USA. Sometimes, angle parking is used for purposes other than simply the addition of on-street spaces. In Seattle, the problem of steep grades on some downtown streets has encouraged the use of angle parking. This occurs on Madison, Marion and Columbia Streets, all of which have steep grades (see Figure 5). In this case, the angle parking provides a safer way to park vehicles, as well as providing more convenient on-street parking. Traffic volumes on these street segments vary between 5,000 and 10,000 per day and operating speeds are 15 to 20 mph.

In summary, the examples indicate a variety of reasons and ways to implement angle parking on-street. In general, the implementation of angle on-street parking has occurred on retail streets with low volumes, high pedestrian movements, low speeds, in conjunction with streetscape improvements and for safety reasons. None of the examples have a problem with high accident frequency or rates. Concern about high accident potentials with angle parking seems to be overemphasized if other operational conditions are met.

What is the answer for the traffic engineer/transportation planner? On the one hand, there is the opportunity to increase convenient parking at little cost for the downtown retail district. On the other hand, there is a likely increase in congestion and a possible increase in accidents for that street segment that is the candidate for change.

These considerations should be kept in mind:

• Each candidate for change is an individual case. The concept of changing from parallel to angle parking is well proven in many case studies, but should not be universally applied without study.

• The minimum criteria of traffic volumes under 12,000 vehicles per day, unless diversion routes are provided; operating speeds of 15 to 20 mph; abutting retail and retail-service land
uses and minimum street widths should be kept in mind.

- It is unlikely that the change from parallel to angle will, by itself, stimulate downtown revitalization. It must be coupled with other programs, such as retail recruitment, marketing and downtown organization efforts.
- When a change is indicated, and is to be implemented, it should be coupled with an educational program, which will explain the pros and cons of the change.
- It would be helpful if before-and-after studies of accidents, congestion and the impact on retail trade were done. There is a lack of well-documented data on these aspects of parallel to angle-parking conversions.

Reference

1. Swanson, H.A. Unpublished research on parking maneuvers, Kelona, BC, Canada.

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JOHN D.
EDWARDS,
P.E., has been a nationally recognized expert in traffic engineering, transportation planning and intermodal transportation for over 40 years. He has promoted the development of transportation infrastructure and the redevelopment of downtowns through many articles and seminars on traffic circulation and parking. A graduate from North Carolina State University with a Bachelor of Science in Civil Engineering (1956) and a Master of Science in Civil Engineering (1958), he is most proud of his accomplishments on downtown revitalization in conjunction with many Main Street programs, including the National Main Street Center. Edwards has been active in ITE for a long time, and he is an Honorary Member of ITE.