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16. Abstract Speeding and speed control are often considered critical issues on residential and collector streets. Activities to reduce speed and volume on residential streets have recently been gathered under the term traffic calming. Speed management goes a step beyond traffic calming by looking at higher speed facilities such as arterials in addition to residential and collector streets. Integrating speed management techniques on residential, collector, and arterial streets can encourage traffic to use major roadways rather than residential streets and can address need on an areawide basis rather than for an isolated roadway or intersection. This <i>Handbook</i> provides practitioners with basic information regarding speed management techniques including descriptions, photographs, experiences of agencies that have used the techniques, and lessons that have been learned.			
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HANDBOOK OF SPEED MANAGEMENT TECHNIQUES

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DISCLAIMER

The contents of this report reflect the views of the authors, who are responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Texas Department of Transportation (TxDOT) or the Federal Highway Administration (FHWA). This report does not constitute a standard, specification, or regulation, nor is it intended for construction, bidding, or permit purposes. This report was prepared by Angelia H. Parham (TN-100,307) and Kay Fitzpatrick (PA-037730-E).

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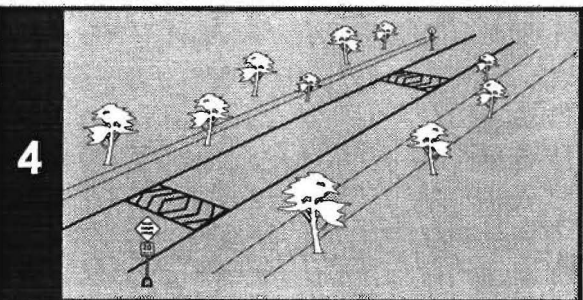
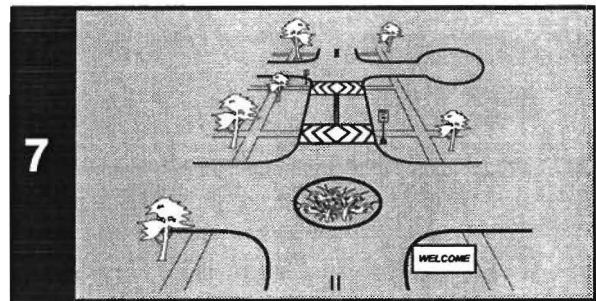
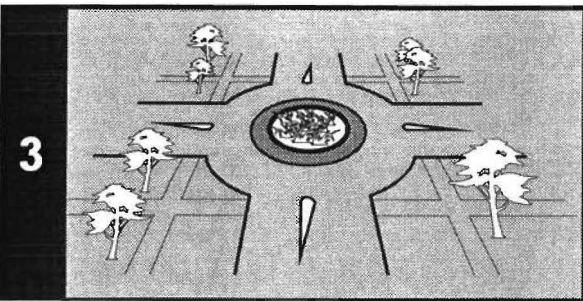
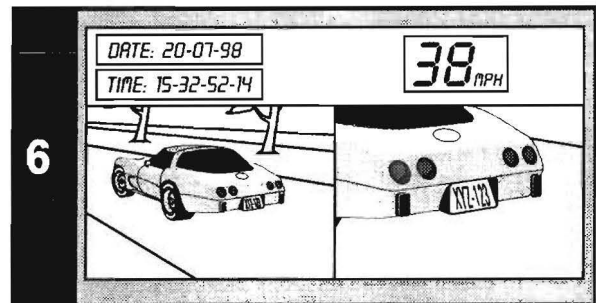
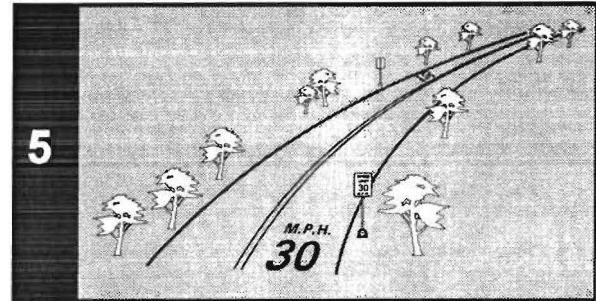
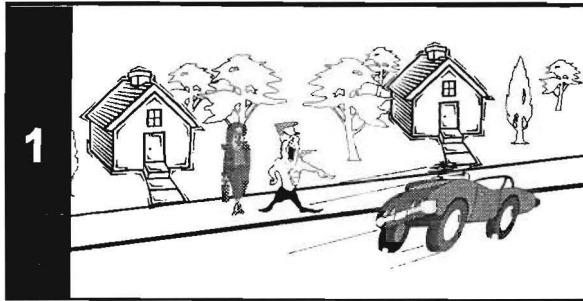
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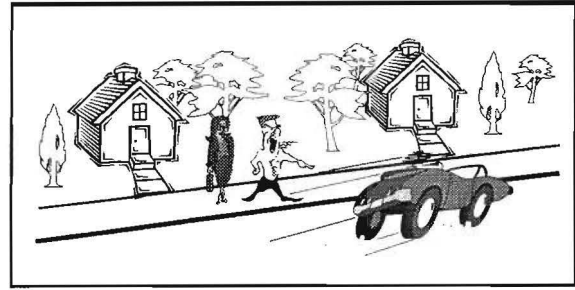
CHAPTER 1

INTRODUCTION



CHAPTER 1

INTRODUCTION



Speeding and speed control are often considered to be critical issues on residential and collector streets. In addition, speeding complaints are a continuing problem for traffic engineers and police departments. Indeed, speeding is a serious threat to the motoring public. In 1993, there were 53,343 drivers involved in fatal crashes in the United States. Of these drivers, 11,019 (20.7 percent) were reported to have been speeding. In the same year, 15.6 percent of Texas drivers involved in crashes were reported to have been speeding.⁽¹⁾

The idea of controlling speeds evolved out of the assumption that reducing speeds also reduces accidents, and indeed, speed is related to accident occurrence in three ways. First, speed influences the amount of time a driver has to respond to a problem in the roadway and to stop or avoid the problem. Second, the difference in speed between vehicles on the roadway or between vehicles and roadside objects such as pedestrians, parked cars, or obstructions directly influences the probability of accidents. Third, greater absolute speeds influence the severity of injuries and property damage in accidents.⁽²⁾

Residential and collector streets are intended to provide access and to distribute local traffic between neighborhoods and arterial street systems, and low operating speeds are desired to accommodate pedestrians, bicyclists, and local access. Observed operating speeds often exceed the posted speed limits or original design speeds.⁽³⁾ As a result, excessive speed is a frequent residential complaint. In some cases, the majority of the vehicles are speeding while in other cases there are only a few fast drivers. The negative reaction to speeding translates from concerns over safety and high noise levels. Vehicles driven at high speeds are seen as a threat to the peace, safety, and quality of life within a neighborhood.⁽⁴⁾

On arterial streets, the primary function of the road is to carry traffic. However, speed management is also needed on arterials due to concerns about pedestrian and cyclist safety, excessive speeds in residential areas, and pedestrian accessibility and parking availability in retail areas.⁽⁵⁾ The goal of managing speeds on arterials is safety related: maintaining mobility or capacity but increasing safety by managing speeds.

INTRODUCTION

CHAPTER

1

Speed Management Techniques

The issue of reducing speed, especially in residential areas, is currently one of the most popular topics in the areas of traffic and transportation. The use of traffic calming techniques is becoming widespread; in fact, traffic calming is one of the Institute of Transportation Engineers' (ITE) Hot Topics for 1998. ITE and the Transportation Research Board (TRB) have taken active roles in supporting residential traffic calming programs by city agencies. They have also established a network of professionals and committees to assess the state-of-the-practice of traffic calming in the United States and to sponsor technical sessions and papers at professional society meetings.

Traffic calming uses geometric changes or design to influence travel speed and to perhaps cause drivers to select another route for travel. It is intended to restore local streets to their intended function, providing more livable environments for residents. In most cases, problems on local streets are caused by through traffic, speeding, and/or noise. Traffic calming is site specific, and specific conditions must be considered in selecting appropriate traffic calming devices and measures.

Speed management goes a step beyond traffic calming by also looking at higher speed facilities, including collectors and arterials. Many of the typical traffic calming techniques used in residential areas to control volume and speed would be difficult to implement on these roadways; however, other techniques need only modifications or a different approach to be effective. Although this area has not had the same amount of attention as traffic calming on residential streets, managing speeds on higher speed roadways can be an effective part of a neighborhood traffic management plan. Integrating speed management techniques on local, collector, and arterial streets can encourage traffic to use major roadways rather than residential streets and can address needs on an areawide basis rather than for an isolated roadway or intersection. A need exists to identify treatments that would maintain mobility but decrease speed variance on collector and arterial facilities.

Many transportation professionals are concerned about the potential liability resulting from new devices on a road. These concerns are best addressed by designing devices to accepted standards, adequately signing devices, and regularly maintaining them. Additionally, transportation organizations are responding to the need for design standards. ITE recently developed a Recommended Practice for the design of speed humps and is currently completing a *National Traffic Calming Report - State-of-the-Art*.^(4,6) In addition, the Transportation Association of Canada is currently developing standards for traffic calming devices.⁽⁷⁾

CHAPTER
1

INTRODUCTION

Project Goals

The goals of the Texas Department of Transportation (TxDOT) project are to identify speed management techniques that are used throughout the country and to develop a handbook documenting these techniques. This project provides one of the first comprehensive approaches to dealing with speed management on collector and arterial roadways in addition to providing information about techniques used on residential streets. This document provides practitioners with basic information regarding the use of speed management techniques. No comprehensive effort has been undertaken to evaluate speed management on collector and arterial facilities, and this project provides an overview of the approaches being used to deal with collector and arterial speeds.

The *Handbook of Speed Management Techniques* includes descriptions of the techniques, photographs of the techniques, experiences of agencies that have used the techniques, and lessons that have been learned. The chapters of the *Handbook* discuss speed management techniques in four chapters: Roadway Design Techniques, Road Surface Techniques, Traffic Control Techniques, and Enforcement Techniques. Roadway design techniques include physical measures designed to alter the driver's path. Road surface techniques change the surface of the roadway by adding vertical elements such as speed humps, by narrowing the roadway, or by drawing the driver's attention through the use of pavement markings. Traffic control techniques, such as signs and beacons, are used to alert drivers of allowable speeds or to warn them of an approaching hazard or other traffic control device such as a traffic signal. Enforcement techniques remind drivers of speed limits and of the speed they are traveling through speed displays or additional enforcement. They may be used to issue warning letters or citations to those traveling above the speed limit if the state's legislation supports this. Figure 1-1 illustrates the categories of speed management techniques included in the report, and Figure 1-2 illustrates the use of the techniques on local and arterial streets.

Speed Management Techniques

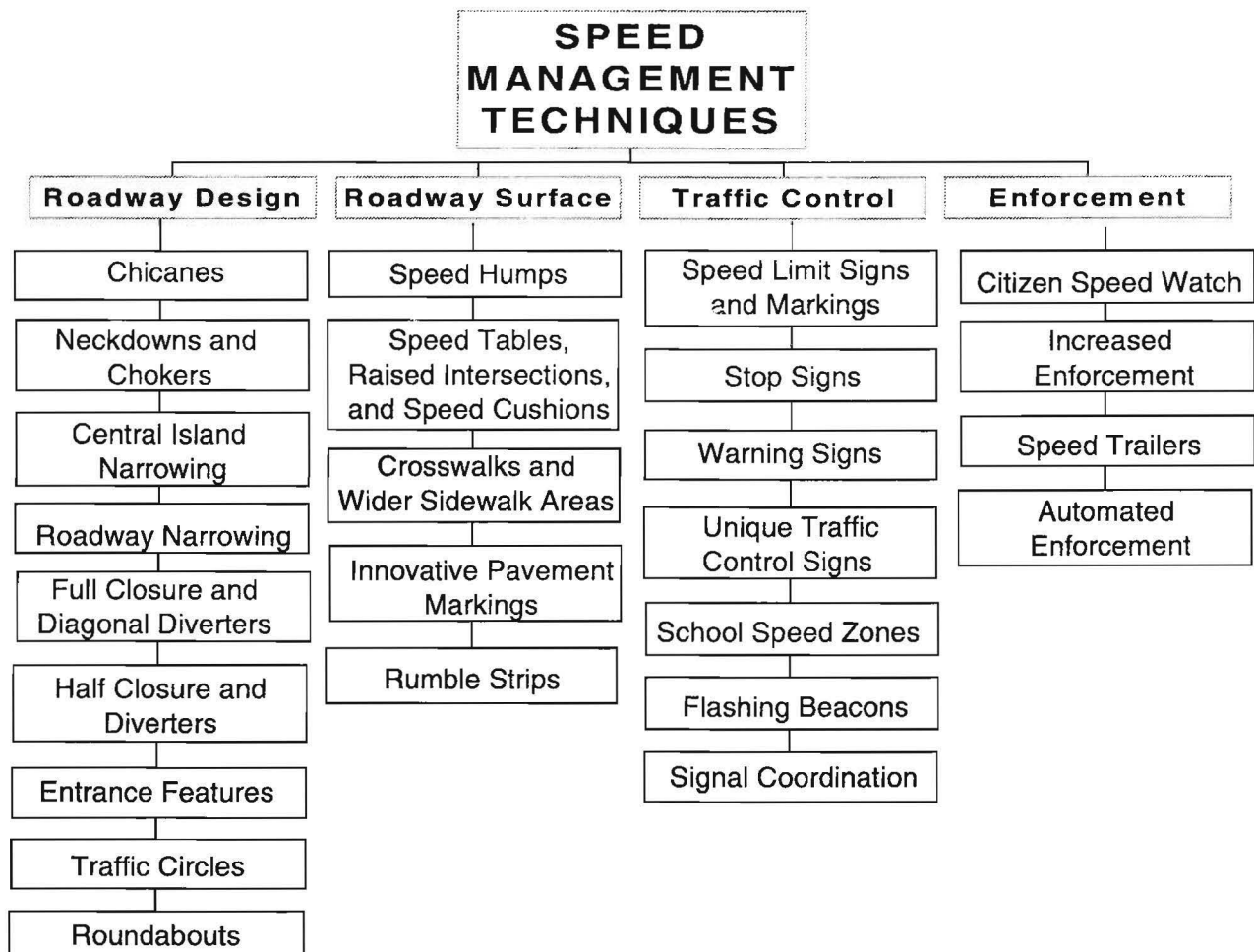


Figure 1-1. Speed Management Techniques.

Speed Management Techniques

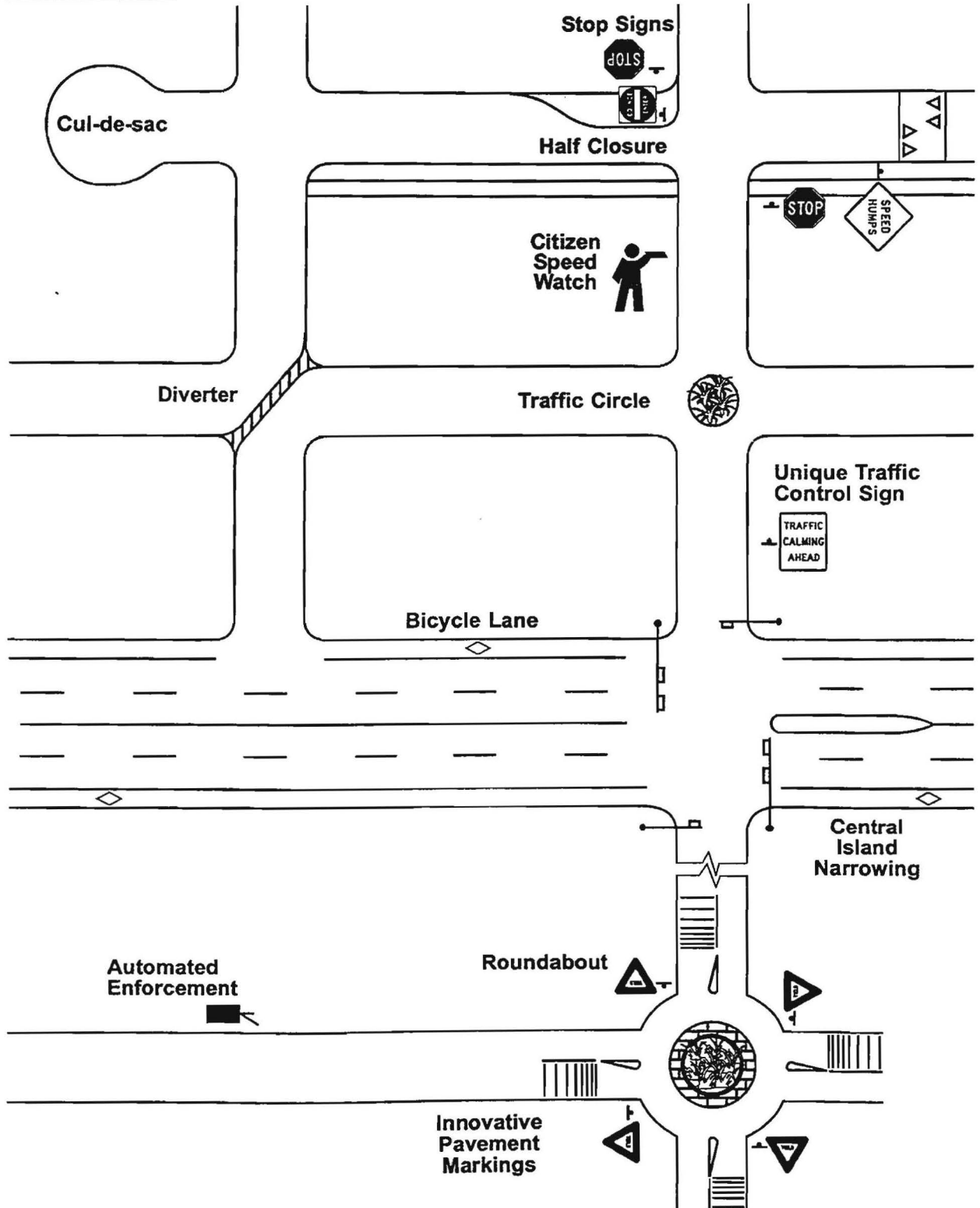


Figure 1-2. Illustration of Speed Management Techniques

INTRODUCTION

CHAPTER 1

Speed Management Techniques

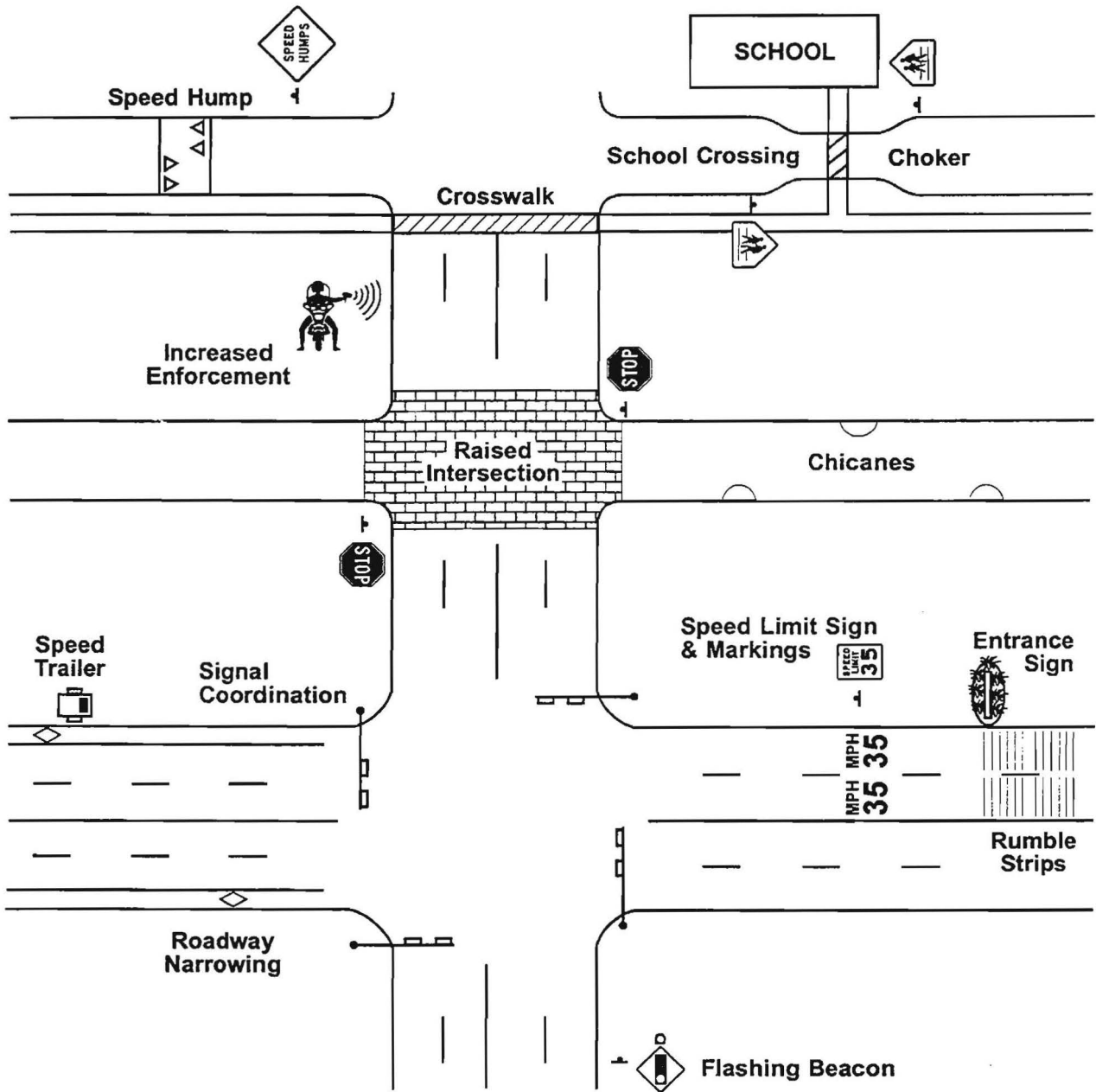
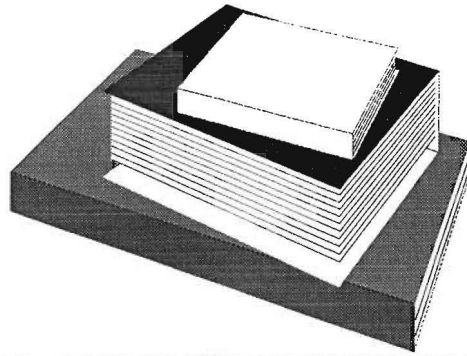


Figure 1-2. Illustration of Speed Management Techniques (continued).

CHAPTER 1

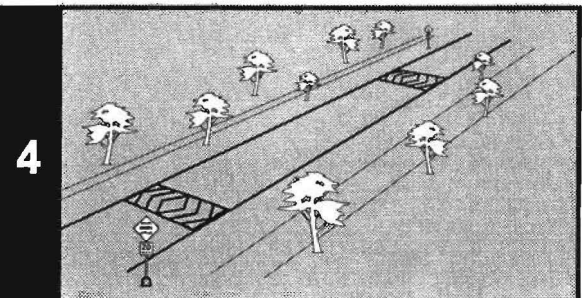
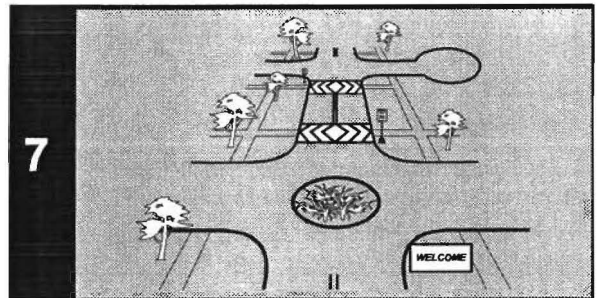
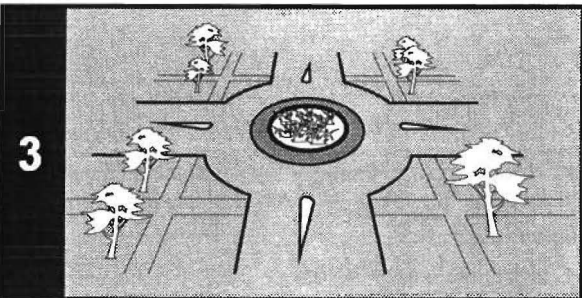
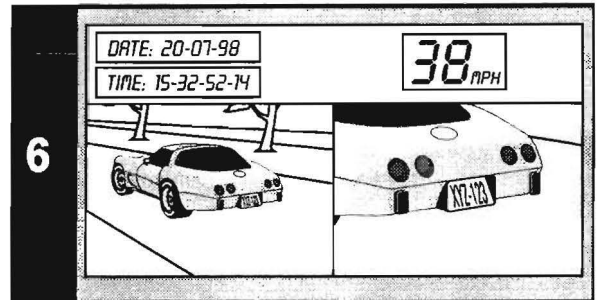
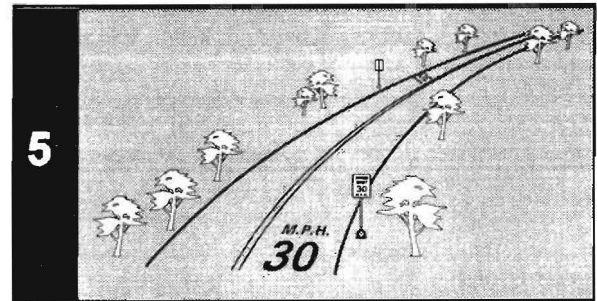
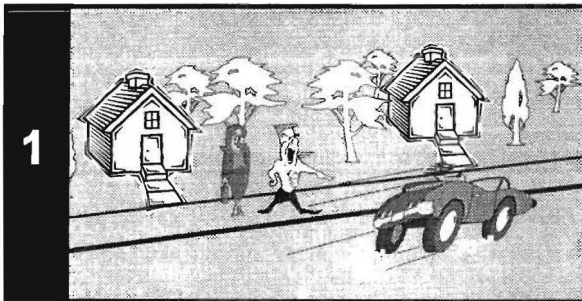
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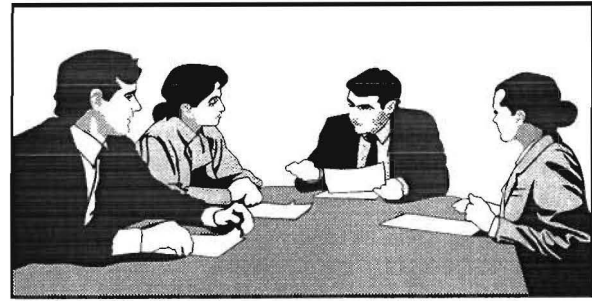
CHAPTER 2

PROGRAMS



CHAPTER 2

PROGRAMS



Speed management programs provide a process for identifying, evaluating, and addressing problems related to speeding, volumes, or overall concerns for safety. Speed management programs can involve strategic physical or operational changes to roadways to reduce speed variation on collector and arterial roadways and provide a more uniform traffic flow. They can also include enforcement efforts, traffic control devices, and activities of nearby residents and/or businesses. The speed management techniques are designed to encourage traffic to use major roadways rather than residential streets. Plans are most effective when they address an entire area rather than an isolated roadway or intersection so that the techniques are compatible with adjacent land uses.

Researchers conducted a mail-out survey to identify the types of techniques being used for speed management. Of the 400 surveys distributed to local and state agencies in the United States and Canada, 157 responses were received for a response rate of 39 percent. Approximately 40 percent of the respondents indicated that they had installed or considered speed management techniques on suburban arterials. The most frequently used techniques were increased enforcement, flashing beacons, and speed limit signing. Table 2-1 lists all the techniques in alphabetic order that were provided by the respondents.

Neighborhood traffic calming strategies are designed to improve safety, to provide a greater sense of security, and to increase neighborhood livability. In the United States, most efforts have focused on the residential streets. The traffic calming measures are generally focused on lowering vehicle speed and reducing traffic volumes, most often with physical or operational changes to the streets themselves. Although many traffic calming programs address only neighborhood concerns, they may be expanded to include higher speed and higher volume streets such as collector roadways or highways entering city limits where the speed limits are reduced. When expanded, however, the emphasis of reducing speeds or volumes could change to managing speed (e.g., reducing only the very high speeds), to increasing volume (e.g., to encourage the use of the arterials over residential streets), or to a specific focus on reducing crashes at a specific location. Implementation of traffic calming programs in several cities is discussed in the following paragraphs to provide the reader with an overview of existing programs and to illustrate ongoing activities.

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OVERVIEW

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Table 2-1. List of Techniques from Written Surveys.

Responses	Speed Management Technique	Responses	Speed Management Technique
22	Add signing (speed limit)	1	No passing zone pavement markings
2	Bike/pedestrian areas	1	Non-supervised radar equipment
1	Center line rumble strips	3	Oversized speed limitation signs
1	Change of legal speed	3	Oversized vehicle restrictions
1	Chokers	1	Pedestrians next miles
2	Crosswalk (brick)	1	Photo radar
2	Citizen speed watch	1	Raised sidewalks/lane restriction
3	Diagonal parking	4	Reduce speed limit signs, flasher, solid in strip
1	Diamond shape orange panels or speed limit signs	1	Restrictions of lanes
14	Display radar trailer	2	Roundabouts
1	Double fine zones	11	Rumble strips/undulations
1	Empty patrol cars	3	Safety corridor: enforce and public safety campaign
26	Enforcement (increased)	1	Separate cycle path/walkways
5	Flags on speed limit sign	1	"Slowdown" banner
23	Flashing beacon	2	Signal coordination
1	Four-way stop	6	Speed humps
1	Fluorescent strong yellow-green school crossing signs	2	Speed limit on pavement
3	Installation of medians	1	Speed table
1	Interurban warning with actuated flasher	1	Street lighting
1	Ladder style crosswalks	2	Traffic circle
1	Landscaping	4	Upstream signal coordination
4	Larger speed limit signs (36" x 48")	4	Variable message signs
1	Local blitz (media campaign)	4	Warning signs
2	Lower progression speed	1	Wider pavement
3	Narrow lanes	2	Wider pavement markings

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AUSTIN, TEXAS

In the fall of 1994, the city of Austin began a speed hump installation program with a budget of \$100,000 (see Figure 2-1). Approximately 115 speed humps were installed before the program was placed on hold in 1997. This allowed the city to conduct a more in-depth review of the issues involved and to develop a more comprehensive program. The new program uses an areawide approach, incorporating a combination of techniques into each area project. The new program has a budget of \$500,000, and the city has received resident approval in three of the five areas scheduled for improvements. (Ballots and detailed project information are sent to residents, property owners, businesses, and renters, and a household is counted as one vote. The city requires a 51 percent positive response rate from those residents who respond.) Implementation is scheduled to begin in the fall of 1998.



Figure 2-1. Speed Hump in Austin, TX.

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HOUSTON, TEXAS

The city of Houston uses a twofold traffic calming approach that includes a Neighborhood Traffic Program (NTP) and a Speed Hump Program. The NTP involves entire neighborhoods in the study, design, and installation of physical modifications to reduce or manage cut-through traffic on local streets. The program requires significant citizen participation, including at least three public meetings to review the process and select a citizen committee, to consider a proposed plan, and to review the results of mandatory temporary testing. In 1997, the program had completed projects in 13 neighborhoods with nine more under design and 34 at various stages of the process. The speed hump program is the city's most popular traffic initiative ever, winning a 90 percent approval rating in a recent survey. Mechanical traffic counts determine eligibility for speed hump construction, and a computerized matrix helps the city rank factors and make funding decisions. The program has reviewed over 1800 requests and constructed more than 900 speed humps on almost 300 separate street segments (see Figure 2-2 for an example of a speed hump in Houston). Houston is now developing a speed-reduction program with less intrusive approaches. Several strategies will be pilot tested, including raised pavement markings, signage, and citizen education.⁽²⁾

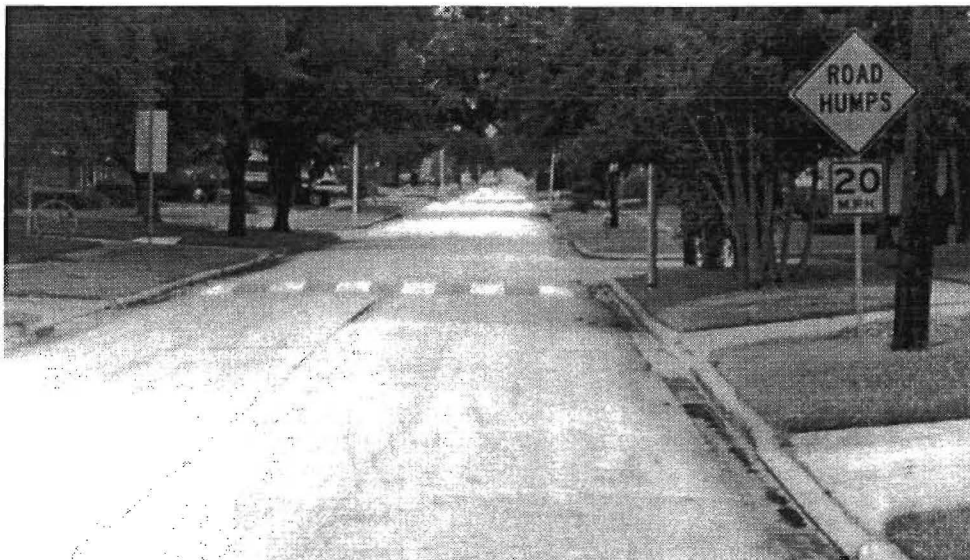


Figure 2-2. Speed Hump in Houston, TX.

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SAN ANTONIO, TEXAS

The city of San Antonio conducted a speed hump pilot program in 1995.⁽⁶⁾ Two to four speed humps were installed on each of 10 streets throughout the city. A 3.7 m (12 ft) width and 7.6 cm (3 in) high hump was used. The findings from the pilot program demonstrated that some sites experienced a reduction in traffic volumes while other sites found an increase in volume and that a spacing of 153 m (500 ft) will achieve an operating speed of about 48 km/h (30 mph) (the *prima facie* speed limit in Texas urban areas). A mail-out survey of affected residents revealed that the best thing about the speed humps is that they slow down traffic (67 percent), and the worst thing is that they are ineffective (13 percent). When asked if they wished to keep the speed humps, 75 percent responded positively. Based on these findings, the pilot program was deemed a success. At the conclusion of the analysis the city council adopted an annual program that provides for the construction of humps at numerous locations throughout the city. The policy includes extensive eligibility criteria, (e.g., 85th percentile speed, minimum daily volume, minimum street length, maximum number of lanes, 67 percent resident petition support, etc.). In addition, the city's policy includes a prorated cost sharing provision that allows for residents to expedite the installation of speed humps on their street if the eligibility criteria are met.

TORONTO, ONTARIO, CANADA

In Toronto, most traffic calming installations are on local or collector streets. A much discussed example is the treatment for Balliol Street.⁽⁴⁾ Local residents had been campaigning for many years to restrict speeds and traffic on the street. In October 1994, five raised and narrowed intersections and seven midblock road narrowings were installed (see Figure 2-3). In addition, decorative pavers in contrasting colors and increased vegetation were also installed. The speed limit was lowered from 40 to 30 km/h, and stop signs were removed at three T-intersections. The volume was slightly reduced (1,300 to 1,200 vehicles per day) while the 85th percentile speed was notably reduced from 47 to 36 km/h. In addition, the proportion exceeding 40 km/h was reduced from 54 to 9 percent.

While most of the traffic calming installations are on residential streets, some treatments have been implemented successfully on a number of arterial streets carrying up to 20,000 vehicles per day.⁽⁵⁾ In general, requests for traffic calming on these streets have been based on concerns about pedestrian and cyclist safety, excessive motor vehicle speeds, and pedestrian accessibility and parking availability in retail areas. Toronto arterial road traffic calming has relied on three main techniques: medians, road narrowing, and bicycle lanes — all of which involve narrowing the roadway. When a street is narrowed to two lanes, vehicle speeds are limited by the speed of the leading vehicle in a platoon. Toronto has several examples of converting four-lane roadways to two-lane roads by the addition of a median. In some cases, the median is raised with ground cover and trees planted, and in others, the median is flush to facilitate access to adjacent driveways. A prime purpose for a localized road narrowing is to improve the safety of pedestrian crossings. Another method for

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reducing a four-lane arterial is to allow parking on both sides, where it was previously prohibited. The roadway is typically widened to four lanes at the intersections to handle the high demands for turning movements. More than 20 km of Toronto's arterial roads have been equipped with bicycle lanes in the last five years. Typically, these streets have been four-lane roads carrying between 15,000 and 20,000 motor vehicles per day. With stripped bicycle lanes on each side, they become two-lane roads (for motor vehicles). When bicycle lanes are installed on these streets, parking is authorized on one side or both throughout the day, depending on the road width. If a particular street is being adapted to accommodate bicycle lanes, the speed limit is reduced to 40 km/h (25 mph) if it is not already. In general, the belief is that vehicle speeds have declined while pedestrian and cyclist safety and comfort have increased.



Figure 2-3. Example of Treatments on Balliol Street in Toronto, CAN.

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NASHVILLE, TENNESSEE

The city of Nashville adopted a traffic calming program in May 1998 with a budget of \$750,00.⁽¹⁾ The pilot program includes 30 techniques to be installed on local streets only. Support of 67 percent of those affected is required for a technique to be installed, and the city pays for the installations. The goal of the Nashville Neighborhood Traffic Management Program (NTMP) is to “establish procedures and techniques that will promote neighborhood livability by mitigating the negative impacts of automobile traffic in residential neighborhoods.”⁽¹⁾ The procedures typically considered for receiving, responding, and managing residents’ requests are:

- Step 1: Identification of Neighborhood Problem
- Step 2: Preliminary Analysis of Neighborhood Problem
- Step 3: Neighborhood Traffic Team Meeting
- Step 4: Neighborhood Workshop Meeting
- Step 5: Petition Process
- Step 6: Project Design and Implementation
- Step 7: Monitoring and Evaluation
- Step 8: Removal of an NTMP Project

SAN JOSE, CALIFORNIA

The city of San Jose reported that the city first applied a range of traffic calming devices to solve specific problems.⁽²⁾ These included lane striping, rumble strips, speed zones, temporary street closures, speed humps, and prohibiting signs. The efforts typically calmed residents but not traffic. Requests for Stop signs became very political, requiring formal appeal procedures. Next, the city tried programs to inform, rather than regulate, motorists. This program included a radar speed-display board and another program using local residents to record license plate numbers of vehicles they believed to be speeding. The results of the speed display board use were marginal at best, and the speed recording program had limited impact and was eventually suspended due to lack of resident interest. In the 1980s, San Jose moved from a case-by-case approach to collective, neighborhood-wide issues. A Neighborhood Traffic Management Program was established to improve quality of life in the city’s neighborhoods. The program engaged local residents in an in-depth study of traffic problems in their neighborhoods and in the development of neighborhood traffic plans. They set objectives; found consensus; installed, tested, and evaluated devices and design features; and adopted a final neighborhood traffic management plan. Typically, a plan recommended the use of several devices including traffic circles, chokers, diverters, closures, medians, and gateways. The process was long and controversial, and it was dropped in 1993 due to severe budget cuts. Today, the city is discovering that traffic calming is about strategy: enhancing arterial and freeway networks; rethinking land use and urban design; and using intelligent transportation systems (ITS) to better inform people of traffic conditions and travel alternatives and

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to monitor speeding vehicles. This strategy includes: (1) providing arterials and alternatives; (2) mitigating the impacts of new developments; (3) experimenting with new residential street designs (narrower streets and rotaries); and (4) penalizing the bad drivers and not the good ones. For example, the city is testing a Neighborhood Automated Speed Compliance Program (NASCO), where a van equipped with photo radar is dispatched to selected residential streets. Signs inform motorists that streets are subject to photo radar enforcement and encourage drivers to slow down and avoid traffic violations.⁽²⁾

MONTGOMERY COUNTY, MARYLAND

Montgomery County limits the speeds and access of vehicles in residential areas by using devices such as diverters, access-restriction controls, speed humps, traffic circles, chokers, raised crosswalks, and painted edge lines which narrow the streets and psychologically deter excessive speed. The Department of Public Works and Transportation works closely with neighborhoods to develop comprehensive traffic management plans that make communities more livable. The department requires a written request endorsed by the local citizens' group or traffic committee and an 80 percent majority vote by residents on affected streets. The speed hump is one of the most common devices. Two designs are used: a 3.7 m (12 ft) wide hump on most secondary residential streets, traversable at 24 km/h (15 mph); and a 6.7 m (22 ft) wide hump on primary residential streets, transit routes, and regularly used emergency vehicle routes (it is a flat-top design, traversable at 32 to 40 km/h [20 to 25 mph]). A recent evaluation indicated that the humps are lowering speeds on residential routes by as much as 48 percent as well as effectively reducing traffic volumes.⁽²⁾

TUSCON, ARIZONA

The city of Tuscon uses a wide variety of devices. Residents and government split the cost of implementing traffic controls, usually 50-50. Neighborhoods make the initial investment, and the city maintains the device. If a neighborhood decides to remove the devices, it has to pay the city to remove them. Most residents express enthusiasm about the program; the city council supports it, and more neighborhoods across the city are becoming interested.⁽²⁾

PORTLAND, OREGON

In 1984, the Portland city council adopted the Neighborhood Traffic Management Program (NTMP) to improve neighborhood safety and livability on Portland's local service streets. In 1993, city council adopted the Arterial Traffic Calming Program (ATCP) to improve neighborhood safety and livability on Portland's neighborhood collector streets. Because both programs were housed in the Bureau of Traffic Management (BTM) and as a result of budget reductions for fiscal year 1994-1995, the Bureau consolidated the two programs into the Traffic Calming Program (TCP).

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The mission of the Portland Traffic Calming Program is to “improve community safety and to preserve and enhance city of Portland neighborhoods by working with residents and businesses to design and implement solutions to the negative impacts created by automobile traffic on neighborhood streets.”⁽⁷⁾ The following are the objectives of the program:

- Enhance neighborhood livability and sense of community by reducing excessive speeding and excessive vehicle volumes on local service streets.
- Encourage reasonable and responsible driver behavior through education and emphasizing personal responsibility.
- Enhance traffic safety for pedestrians, providing special attention to the safety of children in school zones.
- Encourage alternative transportation options and the use of the arterial system for through traffic.
- Encourage broad citizen participation by providing service in a responsive, timely, and professional manner.

Examples of Portland’s traffic circles are shown in Figure 2-4.



Figure 2-4. Traffic Circles in Portland, OR.

EXAMPLES OF PROGRAMS

The program includes speed reduction devices (speed bumps, traffic circles, chicanes, and entrance treatments), pedestrian safety devices (pedestrian refuges/slow points, curb extensions, and raised crosswalks), and reduced traffic volume devices (diagonal diverters, semi-diverters, median barriers, cul-de-sacs, vehicle exclusion lanes, and choke points). Other speed-related activities include the city providing police enforcement, school safety programs, and stop and speed limit signs. Neighborhoods can also participate in the following: Speed Watch, SLOW DOWN Banners, Residential Speed Bump Purchase Program, Creative Approaches to Slowing Down Neighborhood Speeders (e.g., planting trees, encouraging all residents to leave their cars at home, and writing letters to the editor of the neighborhood and community papers), and Neighborhood Activities (e.g., a block party around the theme “Slow Down”). A summary of the policies that guide the TCP include:⁽⁷⁾

1. Through traffic should be encouraged to use higher classification arterials, as designated in the arterial streets classifications and policies.
2. A combination of education, enforcement, and engineering methods should be employed.
3. Emergency vehicle access should be accommodated in keeping within the existing Fire Bureau response standards.
4. Transit service access, safety, and scheduling should not be significantly impacted.
5. Reasonable automobile access should be maintained. Pedestrian, bicycle, and transit access should be encouraged and enhanced wherever possible and within budget limitations.
6. Parking removal should be considered on a project-by-project basis. Parking needs of residents should be balanced with the equally important functions of traffic, emergency vehicle access, transit, bicycle, and pedestrian movement.
7. Applications of the Traffic Calming Program shall be limited to those neighborhood collector streets that are primarily residential and to local service streets.
8. Traffic calming projects on neighborhood collector streets shall not divert traffic off the project street through the use of traffic diversion devices. As a result of a project on a neighborhood collector, the amount of traffic increase acceptable on a parallel local service street shall not exceed 150 vehicles per day.
9. Traffic may be rerouted from one local service street to another as a result of a traffic calming project.
10. To implement the Traffic Calming Program, certain procedures should be followed by the Office of Transportation in processing traffic calming requests in accordance with applicable codes and related policies and within the limits of available resources. At a minimum, the procedures shall provide for: submittal of project proposals; project evaluation and selection; citizen participation; communication of any test results and specific findings to project area residents and affected neighborhood organizations before installation of permanent traffic calming devices; and appropriate council review.

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PHOENIX, ARIZONA

Calming Phoenix Traffic recommends street designs that place citizens first. The report includes guidelines for controlling the speed of passenger cars on residential streets and enhancing the beauty, safety, and pedestrian friendliness of neighborhoods. The guidelines include:⁽²⁾

- Building local streets in curvilinear designs rather than grids.
- Restricting the maximum length of local streets to 275 m (900 ft) wherever possible.
- Using chokers, chicanes, and traffic circles to calm traffic on longer streets.
- Building sidewalks to a minimum width of 1.5 m (5 ft) with 1.5 m (5 ft) landscaped strips between the curb and sidewalk.

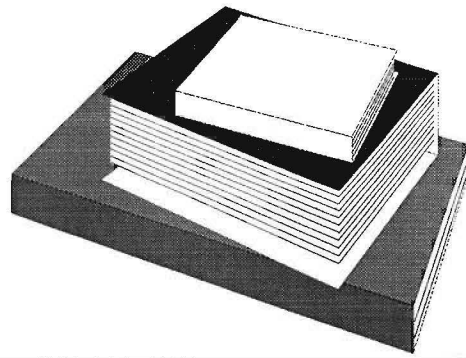
SUMMARY

The experiences of these programs emphasize the importance of adopting a “bigger picture” approach to speed management that reviews areawide rather than individual street conditions. A study of traffic management techniques in Europe summarized the following lessons learned in successfully implementing projects:⁽³⁾

- A high degree of public participation in planning is essential.
- Laws and regulations providing enhanced rights for pedestrians and bicyclists were an important foundation for the enforcement of automobile constraints.
- Public acceptance occurs over time when the benefits are clearly observable.
- Speed humps and traffic control devices are being used regularly as a means of controlling vehicle movement.
- Design of the street space is critical in emphasizing quality and human scale. (This may include bricks, paint, street furniture, and fencing.)
- Sophisticated visual guidance systems/kiosks can be used to provide information to visitors.
- Strong political commitment of community leaders is an essential ingredient of success.
- A stable and continuing maintenance fund is an important part of the financing strategy.
- Techniques are integrated with regional and local transit services.
- Zoning should be used to reinforce the types of land uses that are compatible with the pedestrian environment.

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References

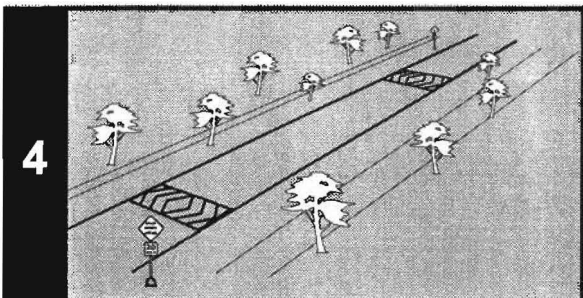
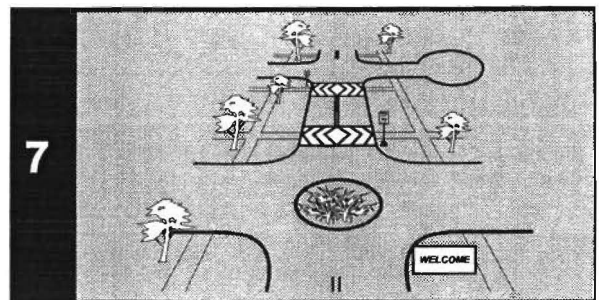
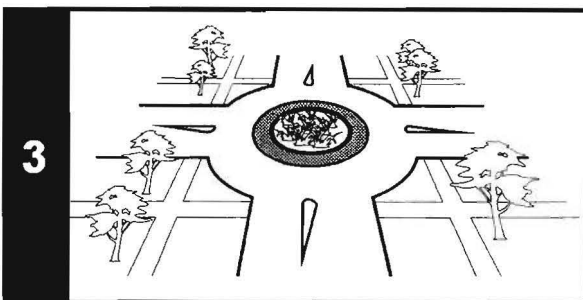
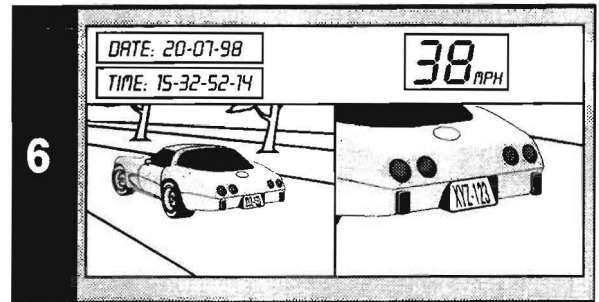
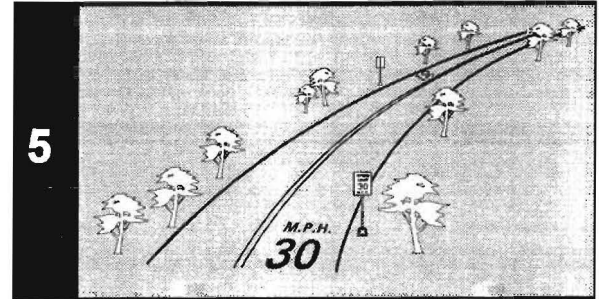
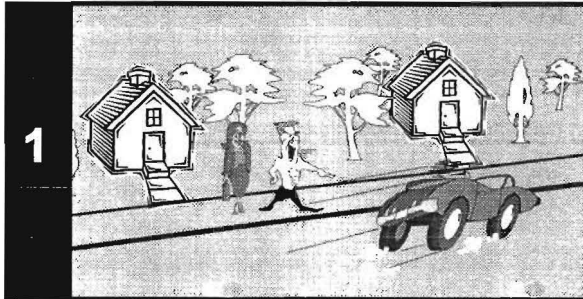


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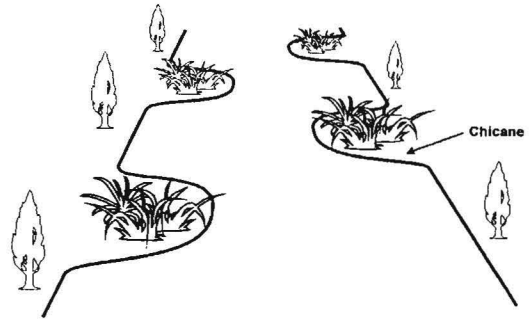
ROADWAY DESIGN

TECHNIQUES



CHAPTER 3 ROADWAY DESIGN TECHNIQUES

Chicanes



Chicanes are devices that alter the linear progression of a vehicle so that the driver must change paths in order to avoid an obstacle. This horizontal alignment change is accomplished by constructing the edge of the travel lane (typically curb extensions) laterally into the initial centerline of the roadway (see Figure 3-1). The alignment change forces a driver around the lateral “obstruction” at a slower speed. Chicanes are also referred to as offset slow points, deviations, serpentes, or reversing curves.

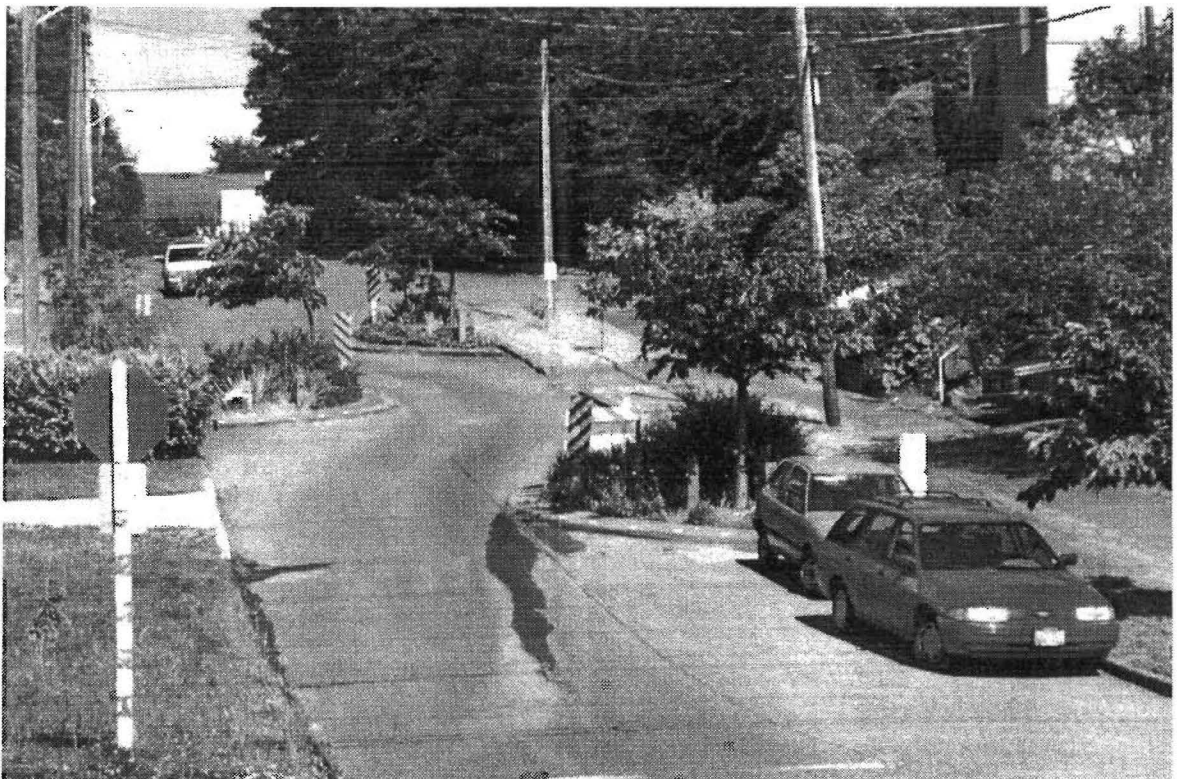


Figure 3-1. Chicanes in Seattle, WA.

Chicanes

CHARACTERISTICS

Chicanes are typically staggered on opposite sides of the street and placed at regular intervals, forcing the driver to shift directions around the chicane. Chicanes are often utilized on long, straight sections of roadways. They may also be used to alternate and separate parking as shown in Figure 3-2. Chicanes are more effective when used in pairs and placed approximately 153 m (500 ft) apart, but the distance may vary depending upon operating speeds and the desired speed reduction.⁽¹⁾

Devices used for construction may include curb extensions, raised pavement buttons, tree planters, barrels, delineators, fences, barricades, and striping. Features such as advance warning signs, object markers, arrow signs, street lighting, and elevated landscaping may be used to improve visibility (see Figure 3-3).



Figure 3-2. Chicane in Monterey, CA.

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ROADWAY DESIGN TECHNIQUES

Chicanes

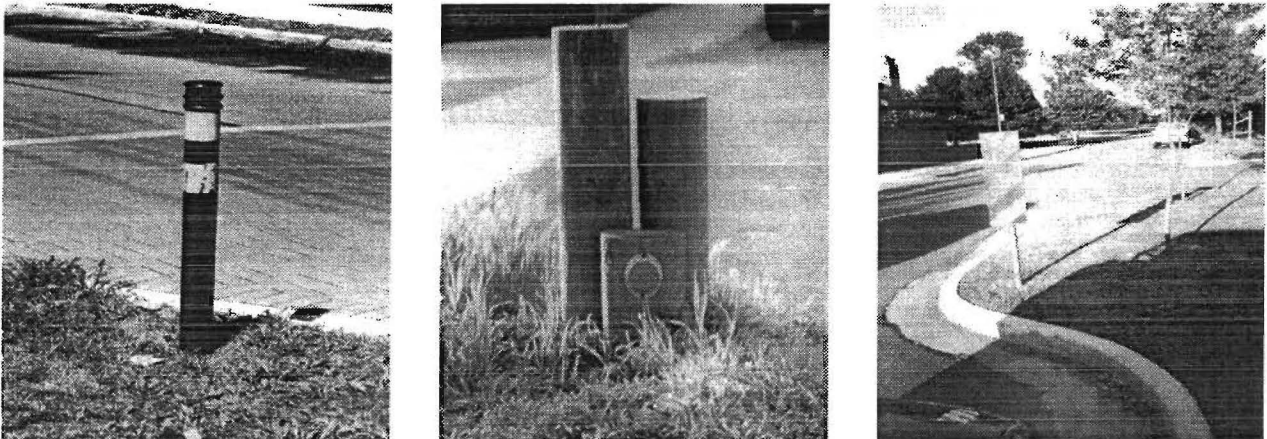


Figure 3-3. Examples of Features Used to Improve Visibility.

EXPERIENCES

The city of Arlington, Texas, installed chicanes on a residential roadway, primarily to reduce 85th percentile speeds below 56.3 km/h (35 mph). The chicanes were designed with raised pavement buttons, placed at approximately 22.9 to 30.5 m (75 to 100 ft) intervals. The impetus for the installation came from nearby residents. The chicanes were effective at reducing the number of vehicles traveling above 56.3 km/h (35 mph), as well as reducing the volume by 17 percent. The city also reported no crashes as a result of the chicanes. The chicanes, however, were subsequently removed due to noise of the vehicles traveling over the pavement buttons, complaints about the absence of sidewalks, the buttons not being aesthetically pleasing, and the regular maintenance required for the buttons.⁽²⁾

LESSONS LEARNED

Advantages of chicanes include:

- Can reduce speeds at the chicane location
- Can reduce speeds on the entire street length if used in series
- Can be installed for aesthetic purposes
- May reduce through-traffic volumes
- Can improve pedestrian safety

Chicanes

Disadvantages of chicanes include:

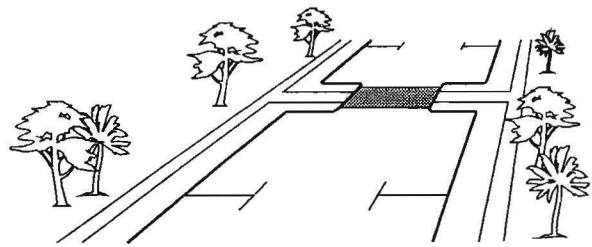
- May require high initial construction costs
- May be restrictive for emergency and service vehicles
- Create crash potential for drivers
- Violate driver expectancy if used in isolation
- Can force encroachment into opposing lane due to carelessly parked vehicles
- Are not appropriate for transit routes

DISCUSSION

Chicanes create a dramatic horizontal deflection in the travel path of a vehicle, and the most effective applications extend laterally out into the initial centerline of the roadway.⁽³⁾ The reduction of vehicle speeds over the entire street length requires the installation of a series of devices along the length of the street.⁽⁴⁾

CHAPTER 3 ROADWAY DESIGN TECHNIQUES

Neckdowns and Chokers



Neckdowns and chokers can decrease the crossing time for a pedestrian or can provide refuge during the crossing maneuver. Their presence also serves to inform drivers that pedestrian activity is present. Neckdowns and chokers are extensions of the curb to reduce the width of the traveled path. When at the intersection, the neckdowns are also called curb extensions, nubs, bulbouts, intersection narrowings, and corner bulges. When at the midblock, the chokers are also called pinch points, midblock yield points, and midblock narrowings. These devices can be employed to make pedestrian crossings easier and to narrow the roadway.

CHARACTERISTICS

Neckdowns and chokers are less dramatic approaches than chicanes, often employing symmetrical curb modifications to both sides of the roadway cross-section as shown in Figure 3-4. Neckdowns shorten the crossing distance between the curbs, increasing the number of opportunities to cross by allowing pedestrians to use shorter gaps in traffic. Pedestrians are still required to cross the same number of traffic lanes; therefore, while the exposure to traffic may decrease, the amount of information being processed and the decision of when crossing is safe does not greatly change. Neckdowns also bring pedestrians out from behind parked cars so they can see and be seen better. They require the elimination of one or more parking spaces on the corner near the intersection (or at the midblock in some situations), which is a difficult subject in some neighborhoods.

Neckdowns have been shown to improve pedestrian safety by shortening the length of the pedestrian crossing. Residents say they feel safer crossing the street at the neckdowns. In addition, they feel that the neckdown provides some protection for vehicles parked on the street.⁽⁵⁾ Neckdowns may have a small effect on speed and volume, but their psychological effect may be their most important attribute. A 1997 ITE survey of neighborhood traffic management performance data indicated that out of 32 studies of neckdown use, the average speed reduction was 5.3 km/h (3.3 mph). The survey also indicated volume changes from 45 vehicles per day to 4100 vehicles per day, with an average of 597 vehicles per day. Public satisfaction was 79 percent.⁽⁶⁾

Neckdowns and Chokers



Figure 3-4. Neckdown with Brick Crosswalks, Landscaping, and Parking in Westminster, MD.

Neckdowns and chokers may be used in combination with other speed management techniques such as speed humps or speed tables. They can also be used to define the entrance to a neighborhood and to provide landscaping opportunities (see Figure 3-5). When used at transit stops, service is enhanced because riders can step directly from the sidewalk to the bus door, or there is additional room for patron amenities such as a bus shelter.⁽⁷⁾ Figure 3-6 shows a neckdown used as a bus stop. These configurations are called bus bulbs, curb extensions, and/or nubs by the transit agencies. A disadvantage of the neckdown is that it may occupy street area otherwise available for parking.

Cost per installation for typical concrete curb and gutter installations is approximately \$5,000 to \$10,000.⁽⁸⁾ This cost can increase significantly if drainage design requirements are necessary or if landscaping is provided.⁽⁵⁾

CHAPTER
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ROADWAY DESIGN TECHNIQUES

Neckdowns and Chokers

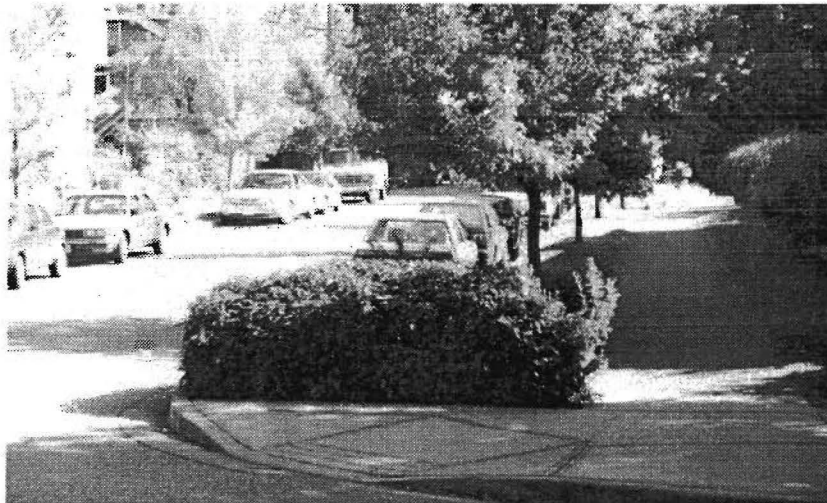
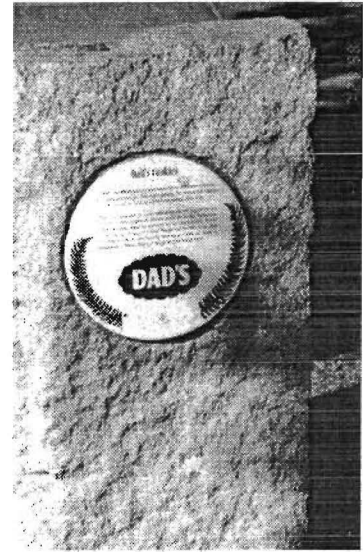


Figure 3-5. Neckdowns with Bench, Historical Marker, and Landscaping in Vancouver, CAN.

Neckdowns and Chokers



Figure 3-6. Bus Stop at a Neckdown (also known as a Bus Bulb) in Seattle, WA.

EXPERIENCES

In Columbia, Maryland, chokers are used on residential and collector streets to narrow school pedestrian crossings. Figure 3-7 illustrates a collector roadway crossing which was narrowed from 11 to 7 m (36 to 23 ft) by installation of brick and concrete curb extensions.

As illustrated in Figure 3-8, chokers may also be used to narrow pedestrian crossings in commercial areas. In Westminster, Maryland, chokers are used in combination with on-street parking, tree planters, textured crosswalks, and high-visibility crosswalks to provide a pedestrian-friendly environment in a downtown shopping area.

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ROADWAY DESIGN TECHNIQUES

Neckdowns and Chokers



Figure 3-7. Choker at Pedestrian Crossing in Montgomery County, MD.



Figure 3-8. Choker at Pedestrian Crosswalk in Monterey, CA.

Neckdowns and Chokers

LESSONS LEARNED

Advantages of neckdowns and chokers include:

- Create shorter pedestrian crossings
- Make pedestrian crossings more visible to drivers
- Opportunity to visually enhance the street with landscaping
- May reduce speed slightly
- Do not slow emergency vehicles
- Allow signs to be placed closer to a driver's cone of vision
- Can be used as a bus stop and the extra sidewalk space can be available for patron amenities such as a shelter

Disadvantages of neckdowns and chokers include:

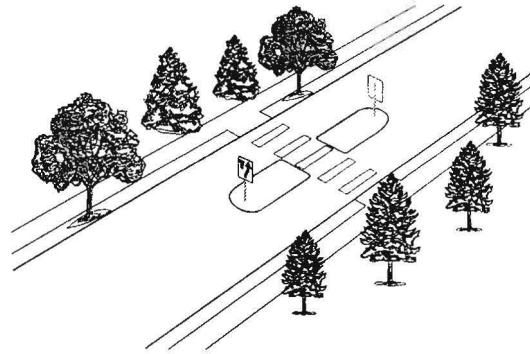
- May require some parking removal
- Create potential crash obstacles for drivers
- May make it difficult to accommodate full bicycle lanes
- May require drainage revisions
- May impede legitimate truck movements

DISCUSSION

Neckdowns and chokers physically narrow the street but may have little effect on reducing traffic volumes or speeds. However, they have been shown to improve pedestrian safety by reducing crosswalk widths, and public satisfaction with them appears to be high.

CHAPTER 3 ROADWAY DESIGN TECHNIQUES

Central Island Narrowing



Central island narrowings are small islands in the middle of the road which narrow the roadway available to a driver, provide a visual cue to drivers that they are in a pedestrian area, and provide a refuge for pedestrians so they can cross a street one-half at a time, if desired.

CHARACTERISTICS

Central island narrowings (also called pedestrian refuge islands) are defined as the areas within an intersection or between lanes of traffic where pedestrians may safely wait until vehicular traffic clears, allowing them to cross a street. These islands provide a resting area for pedestrians, particularly those who are wheelchair-bound, elderly, or otherwise unable to completely cross an intersection within the provided signal time. The islands are built in the center of the roadway, often at marked crosswalks as shown in Figures 3-9 and 3-10. The widths of the islands vary with the width of the street but are usually 1.8 to 2.4 m (6 to 8 ft) wide with standard 15 cm (6 in) curbs, and they may include landscaping. The islands provide a physical barrier in the middle of the street to protect the pedestrian, allowing them to concentrate on one direction of traffic before continuing across the second half of the street.⁽⁹⁾

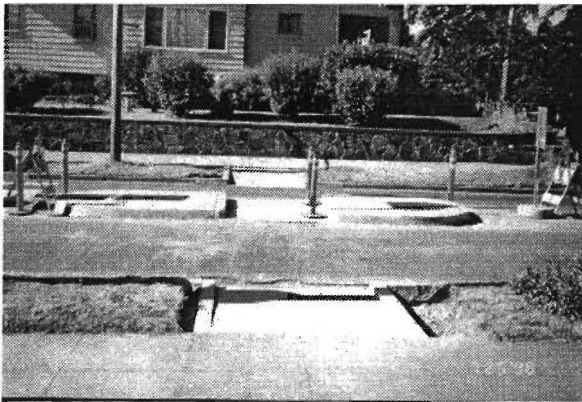


Figure 3-9. Central Island Narrowings in Portland, OR.

Central Island Narrowing



Figure 3-10. Central Island Narrowing with Landscaping and Artwork in Vancouver, CAN.

Pedestrian refuge island design guidelines are provided by *AASHTO* policy and *MUTCD* requirements.^(10,11) Design considerations include the following:⁽⁹⁾

- Islands would be beneficial at traffic signals where the total length of crosswalk cannot be readily traveled in one pedestrian phase. Special consideration should be given to intersections where a large number of elderly pedestrians and/or persons with disabilities will be present. Special consideration also should be given to complex or irregularly shaped intersections where islands could provide a pedestrian with the opportunity to rest and become oriented to the flow of oncoming traffic.
- Islands should be used on wide (four lanes or more) streets with high-traffic volumes.
- There should be no obstruction to visibility through the use of features such as foliage, barriers, or benches.
- The curbs should be raised with cut-through ramps at pavement level or curb ramps for wheelchair users.
- The width of the island should be 1.8 m (6 ft) wide from face-of-curb to face-of-curb, and the length should not be less than 3.7 m (12 ft) long or the width of the crosswalk, whichever is greater. The minimum island size should be 4.7 m² (50 ft²).

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ROADWAY DESIGN TECHNIQUES

Central Island Narrowing

- An approach nose, offset from the edge of the traffic lane, appropriately treated to provide motorists with sufficient warning of the island's presence should be present. This can be achieved through various considerations such as illumination, reflectorization, marking, signing, and/or size.

EXPERIENCE

Pedestrian refuge islands are used to enhance pedestrian crossing points and provide a visual narrowing along the roadway. Depending on their location, they may also result in small to moderate traffic speed reductions. A 1993 study for the Federal Highway Administration found that streets with raised medians in both central business districts and suburban areas have lower pedestrian crash rates compared to streets with a painted two-way left-turn lane or undivided streets.⁽⁹⁾ Pedestrian refuges cost approximately \$8,000 to \$15,000.⁽⁷⁾

Figure 3-11 illustrates the use of a neckdown and a pedestrian refuge island at an intersection in Portland, Oregon. The painted crosswalk continues at street grade through the pedestrian refuge island.



Figure 3-11. Central Island Narrowing and Neckdown in Portland, OR.

Central Island Narrowing

LESSONS LEARNED

Advantages of central island narrowing include:

- Allow pedestrians to cross half of the street at a time, stopping in the island before crossing the other half of the street
- Make pedestrian crossings more visible to drivers
- May reduce vehicle speeds because of the narrowing effect
- Provide a location for traffic control and utility pole installations
- Can be used to load or unload transit riders (although curbside locations are better)

Disadvantages of central island narrowing include:

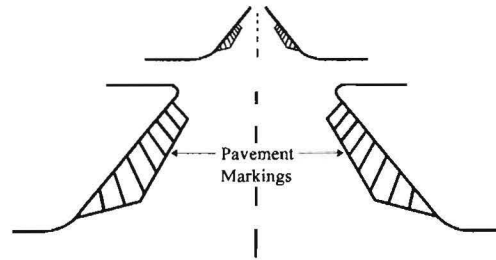
- May require some parking removal
- May give pedestrians a false sense of security
- May create potential crash obstacles for drivers
- May require additional right-of-way
- May create problems for street-sweeping or snow plowing efforts
- Are more expensive than flush islands

DISCUSSION

Central island narrowing physically narrows the street but may have little effect on reducing traffic volumes or speeds. The islands are typically used to supplement pre-existing crosswalks rather than to create a new crosswalk location.⁽⁷⁾

CHAPTER 3 ROAD DESIGN TECHNIQUES

Roadway Narrowing



Roadway narrowing (or lane narrowing) may be created by geometric features (curb modifications) or traffic control materials (pavement striping or buttons) that effectively reduce the roadway width. Roadway narrowing techniques are different than neckdowns/chokers, central island narrowings, or chicanes in that the roadway cross-section generally remains constant for a continuous length of that roadway.

CHARACTERISTICS

Roadway narrowing techniques can be implemented on two- and four-lane roadways, typically reducing travel lanes to no less than 3.1 m (10 ft) in width. Lanes may be narrowed by adding wider pavement markings, pavement markers or buttons, bike lanes, parking areas, tree planters or bulb-outs, painted or raised medians, or other unique techniques. Compliance with the *Manual on Uniform Traffic Control Devices (MUTCD)* is needed for line widths and colors. Pavement markings are likely the least expensive method of channelization, costing approximately \$0.20 to \$0.50 per linear foot to install. Physical channelization, such as curb extensions, can be much more expensive during installation, costing approximately \$50.00 per linear foot.⁽⁵⁾ Lane narrowing may be an optimal solution where citizens request agency action and little justification or budget exists for costly and/or intrusive treatments.⁽¹²⁾

Most studies of narrower lanes have shown minimal speed changes of 1.6 to 3.2 km/h (1 to 2 mph) and very little effect on volumes. However, most residents feel safer due to the narrower streets.⁽⁵⁾ Pedestrian safety may be improved slightly due to shorter crossing times, but there is also the possibility of reduced pedestrian safety if parked vehicles obscure the presence of pedestrians. Bicycle safety could also be compromised if the bicycle path is not continuously traversable.⁽⁵⁾

EXPERIENCES

The city of Arlington, Texas, has narrowed a 48 km/h (30 mph) minor collector roadway approaching a horizontal curve by using a combination of roadway striping and pavement markers. As shown in Figure 3-12, the roadway striping and reflectors transition from a zero-width to approximately a full-lane width to narrow the roadway approaching the horizontal curve. Figure 3-13 illustrates the sign that proceeds the narrowing. A painted median is also used to gradually narrow the roadway approaching the curve on the opposite approach (see Figure 3-14). Spot speed

Roadway Narrowing

studies indicate that 85th percentile speeds before roadway narrowing were 62 to 64 km/h (39 to 40 mph), and speeds after the installation were 50 to 52 km/h (31 to 32 mph).

The city of Garland, Texas, has implemented a lane narrowing technique called a “parking shelf” on a four-lane divided major collector with a 64 km/h (40 mph) posted speed limit. The primary purpose of installing this technique was to manage speeds or prevent excessive speeding along the roadway. The 3.1 m (10 ft) wide non-traversable parking shelf was installed on the right side of the roadway; it is a curb-delineated shoulder which allows residential parking along the length of the roadway. The parking shelf is depicted in Figure 3-15. Perceptions of the parking shelf are that it does not effectively reduce speeds, but it does accomplish speed management by decreasing excessive speeds along this section.



Figure 3-12. Roadway Narrowing in Arlington, TX.



Figure 3-14. Painted Median to Indicate Roadway Narrowing.

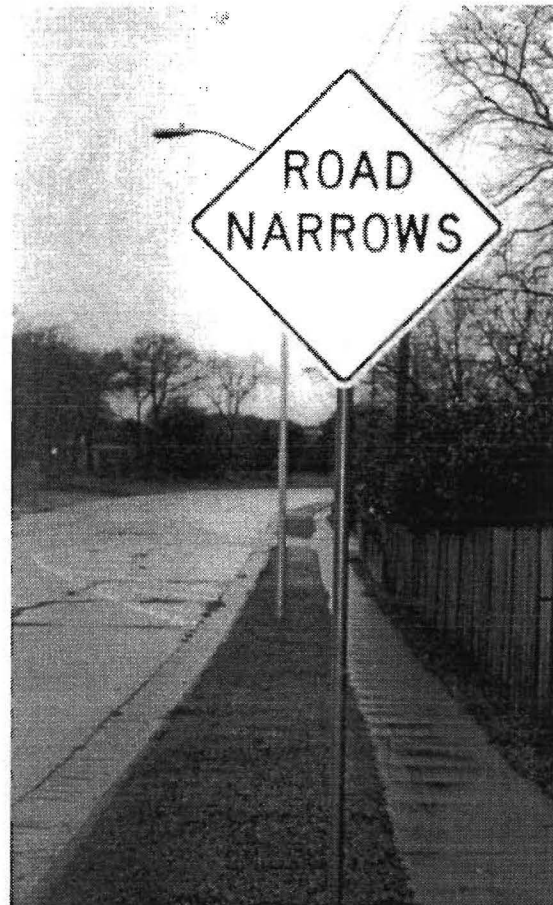


Figure 3-13. Sign That Proceeds the Narrowing.

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ROADWAY DESIGN TECHNIQUES

Roadway Narrowing

The city of Plano, Texas, used reflective pavement markings to add a parking lane and narrow a 48 km/h (30 mph) residential collector as shown in Figure 3-16. Additionally, raised ceramic markers are placed in a semi-circular pattern near intersections and at approximately 122 m (400 ft) intervals to remind drivers that the lane is not a traffic lane. The roadway is a four-lane, divided section with curb and gutter and a center median. Traffic lanes are 3.6 m (12 ft) wide, and the parking lanes are 3.6 to 4.3 m (12 to 14 ft) wide.

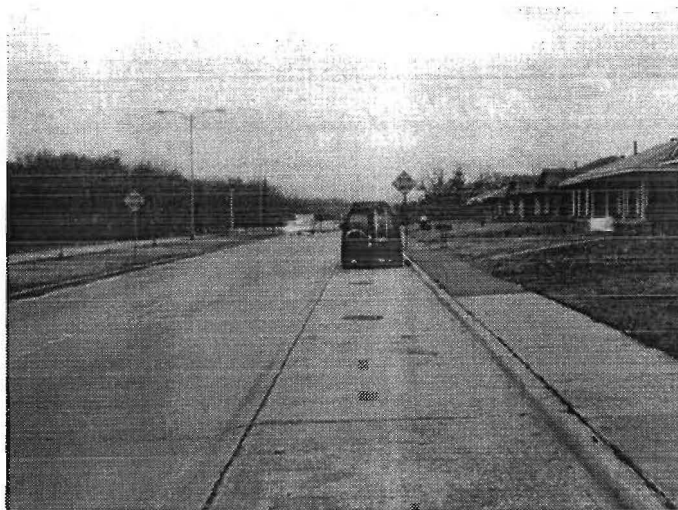


Figure 3-15. Roadway Narrowing (Parking Shelf) in Garland, TX.



Figure 3-16. Roadway Narrowing in Plano, TX.

Roadway Narrowing

Toronto, Ontario, Canada, has several examples of narrowing four-lane roadways to two-lane roads by the addition of a median. In some cases, the median is raised with ground cover and trees, and in others, the median is flush to facilitate access to adjacent driveways. Another method for reducing a four-lane arterial is to allow parking on both sides, where it was previously prohibited (see Figure 3-17). The roadway is typically widened to four lanes at the intersections to handle the high demands for turning movements. More than 20 km (12.4 mi) of Toronto's arterial roads (with between 15,000 and 20,000 motor vehicles per day) have been equipped with bicycle lanes. Figure 3-18 illustrates St. George Street in Toronto. The roadway was narrowed by extending the sidewalk, and bike lanes were added. Colored brick is used to emphasize the high pedestrian and bicycle activity associated with the neighboring university and the desired low speeds. A different color brick is used to mark the centerline and bike lane. If a particular street is being adapted to accommodate bicycle lanes, the speed limit will typically be reduced to 40 km/h (25 mph) if it is not already so. In general, the belief in Toronto concerning road narrowings is that motor vehicle speeds have declined while pedestrian and cyclist safety and comfort have increased.⁽¹³⁾

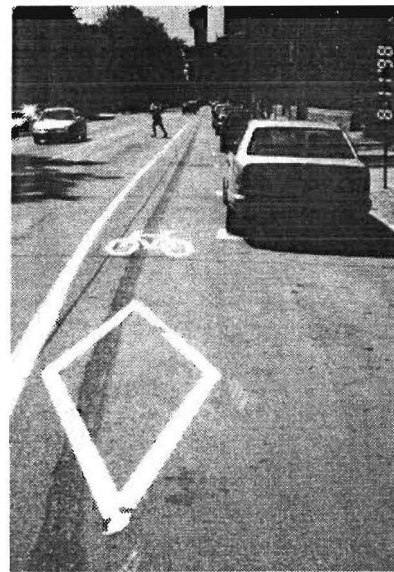


Figure 3-17. Parking and Bike Lanes Examples in Toronto, CAN.

Roadway Narrowing

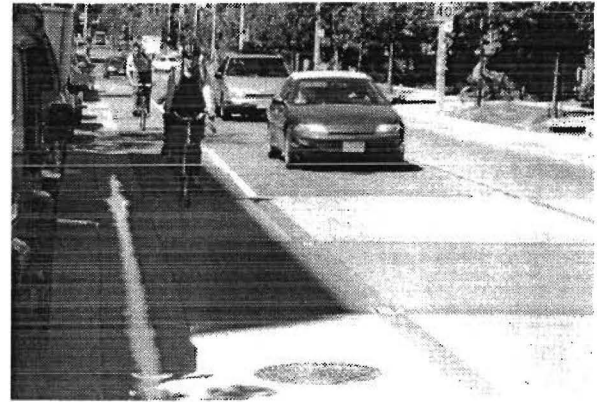
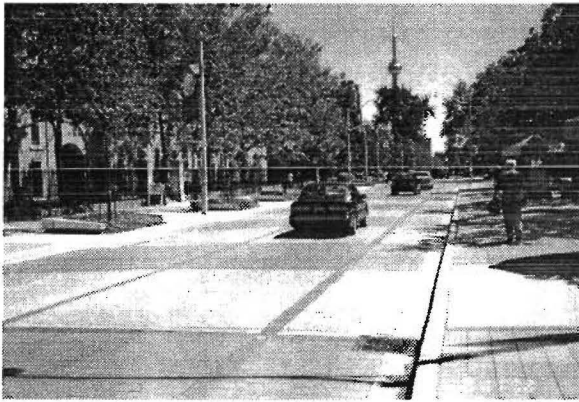


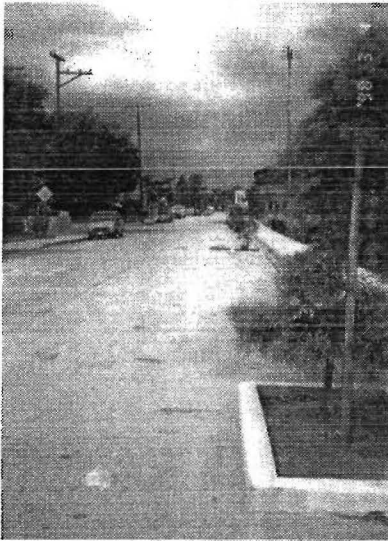
Figure 3-18. St. George Street in Toronto, Ontario, CAN.

Another method to narrow the roadway is with tree planters (see Figure 3-19). The city of Santa Barbara, California, installed tree planters to narrow Wentworth Street, as illustrated in Figure 3-19. The planters are placed adjacent to the gutter on the two-lane roadway, and 40 km/h (25 mph) pavement markings also remind drivers to slow down. The city of Monterey, California, installed bulbouts with trees on their main downtown street as shown in Figure 3-19. The bulbouts are used in combination with wide brick sidewalks and decorative street lighting with banners to create a pedestrian-friendly environment.

On Shaker Drive in Columbia, Maryland, pavement markings are used to visually narrow the two traffic lanes, as shown in Figure 3-20. Figure 3-20 also shows a wide, shared parking and bicycle lane to narrow a wide collector street in Ventura, California. Offset center turn lanes also add to the narrowed effect.

The city of Madison, Wisconsin, has created visually narrow streets through the use of wider pavement markings in conjunction with parking lanes that are converted to travel lanes during peak periods (see Figure 3-21). The lanes were formerly four 3.4 m (11 ft) lanes with 10 cm (4 in) lane lines and a 10 cm (4 in) skip centerline. The markings now include a 61 cm (24 in) centerline and 15 cm (6 in) edge and lane lines. City officials report that the pavement markings give people the feeling that something is being done.⁽⁵⁾

Roadway Narrowing



Santa Barbara, CA



Monterey, CA

Figure 3-19. Tree Planter Examples.



Columbia, MD



Ventura, CA

Figure 3-20. Pavement Marking Examples.

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ROADWAY DESIGN TECHNIQUES

Roadway Narrowing



Figure 3-21. Pavement Markings in Madison, WI.

The Minnesota Department of Transportation narrows very wide streets as part of road construction or reconstruction projects. Many older streets are very wide and became even wider when angle parking was removed. During a project, a sidewalk or boulevard section may be added.

LESSONS LEARNED

Advantages of narrowing roadways include:

- Provide continuous, visual channelization
- Can be inexpensive to install, depending upon the technique used
- Can be quickly implemented, depending upon the technique used
- Create shorter pedestrian crossing distances
- Do not negatively affect emergency response times
- Provide space for on-street parking and/or landscaping

Roadway Narrowing

Disadvantages of narrowing roadways include:

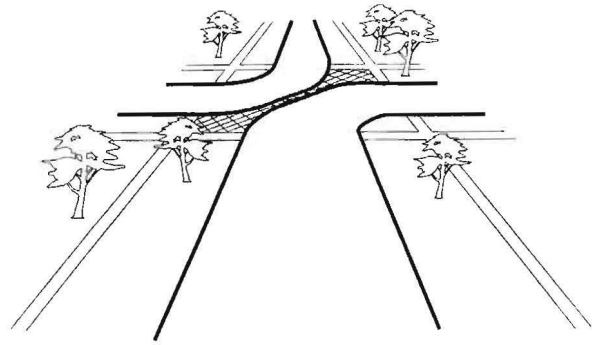
- Require regular maintenance of narrowing devices
- May be unfriendly to cyclists unless designed to accommodate bicycles
- Increase cost of roadway resurfacing
- May be expensive to install, depending upon technique used

DISCUSSION

Roadway narrowing can be achieved physically by making part of the pavement surface unusable or achieved psychologically by using pavement markings that indicate narrow travel lanes. Physical narrowing may be implemented in conjunction with a street beautification program, which provides landscaping and/or wider sidewalks. These types of programs are perceived in a positive way by pass-through drivers and residents of the neighborhood. Pedestrian safety may be improved slightly due to shorter crossing times, but there is also the possibility of reduced pedestrian safety if parked vehicles obscure the presence of pedestrians. Bicycle safety could also be compromised if the bicycle path is not continuously traversable.⁽⁵⁾

CHAPTER 3 ROADWAY DESIGN TECHNIQUES

Full Closures and Diagonal Diverters



Full closures completely close the roadways to through traffic. Other names for full closures include cul-de-sacs and dead ends. Diagonal diverters are barriers placed diagonally across an intersection to block through movements. The goal of these treatments is to eliminate undesired through traffic and to reduce the speed of the remaining traffic.

CHARACTERISTICS

Full closures have a dramatic impact on speed because speeds are reduced to speeds associated with dead-end residential streets. Effects on volume are also dramatic because volume is generated only by the abutting properties. Closures must be clearly marked to prevent confusion by unfamiliar drivers. Also, sufficient capacity on the alternative route is needed for the closure to be effective.⁽⁵⁾

Cul-de-sacs

Cul-de-sacs provide roadway closure to through traffic in either direction. They are intended to completely block access from one end of a street while allowing adequate turnaround for most vehicles. A 15.2 m (50 ft) right-of-way is desirable so that trucks can turn around. Cul-de-sacs are often included in new subdivision designs to help prevent cut-through traffic in the neighborhood. They can also be retrofitted to an existing street at an intersection or at a midblock location. Like diagonal diverters, cul-de-sacs restrict emergency vehicle access but can be designed to allow emergency access.⁽⁷⁾ Cul-de-sacs cost approximately \$20,000 to install.

Signing

Roads may also be closed by installing prohibitive “Road Closed” signing. However, this technique is not nearly as prohibitive or self-enforcing as are diagonal diverters and cul-de-sacs.

Diagonal Diverters

Diagonal diverters place a barrier diagonally across an intersection to disconnect the legs of the intersection. Diagonal diverters force drivers to make a sharp turn but do not allow for other movement, interrupting the continuity of a through street. They are usually used in groups of two or

Full Closures and Diagonal Diverters

more to create a maze within a neighborhood, eliminating cut-through traffic. Diagonal diverters make travel through a neighborhood difficult without actually preventing it.

Diagonal diverters can be designed to allow emergency vehicle access (traversable barriers) using bollards and traversable curbs, but this limits the prohibitive value of diverters. Diagonal diverters may be constructed of concrete, brick, landscaped areas, or by using barriers, bollards, or planters. Aesthetically pleasing diagonal diverters typically cost between \$15,000 and \$35,000. Visibility of diverters is important and can be addressed using advanced warning and/or reflectors, lighting, or elevated landscaping.⁽⁷⁾

EXPERIENCES

Diagonal diverters are used in residential areas in Portland to reduce speeds and eliminate cut-through traffic, as shown in Figure 3-22. Figure 3-23 shows a pedestrian or bicycle access within a diverter so as not to restrict those type of movements.

The city of Austin, Texas, installed a temporary diagonal diverter which was paid for by residents. The diverter was later removed due to citizen requests because of traffic that was shifting to other streets and because the diverter was affecting emergency response times.

Cul-de-sacs are used extensively in Columbia, Maryland. Many of the cul-de-sacs also have small traffic circles to further reduce speeds and provide landscaping opportunities (see Figure 3-24).



**Figure 3-22. Diagonal Diverter
in Portland, OR.**

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ROADWAY DESIGN TECHNIQUES

Full Closures and Diagonal Diverters

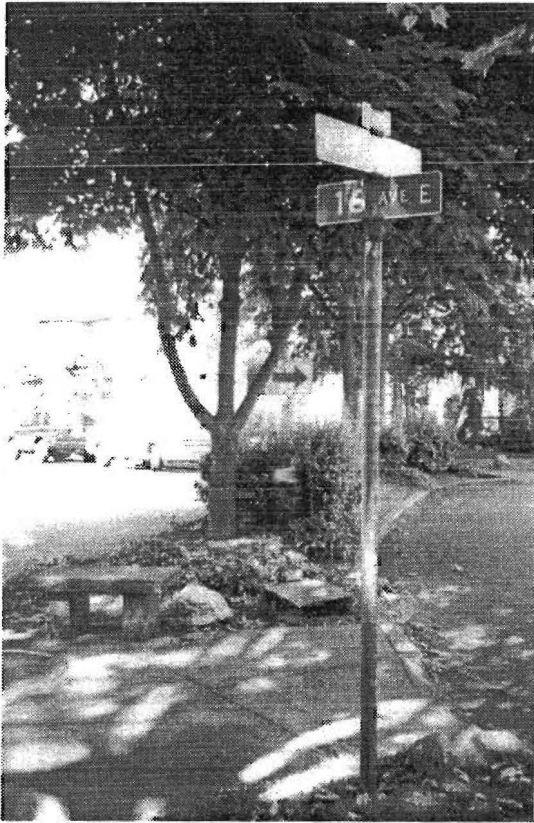


Figure 3-23. Close-up of Pedestrian/Bicycle Access in the Diagonal Divorter in Portland, OR.



Figure 3-24. Cul-de-sacs in Columbia, MD.

In College Station, Texas, a residential street which has had increasing cut-through traffic has been temporarily closed to through traffic using signs on one end and temporary barricades on the other end (Figure 3-25). The neighborhood street has been the subject of a significant amount of controversy and political debate. A former six-month trial period of partial closure was followed by installation of speed humps and Stop signs. The speed humps and Stop signs will remain in place during the trial period of full closure. Additionally, a 28-member committee has been appointed to study the situation and make recommendations to city council.

Full Closures and Diagonal Diverters

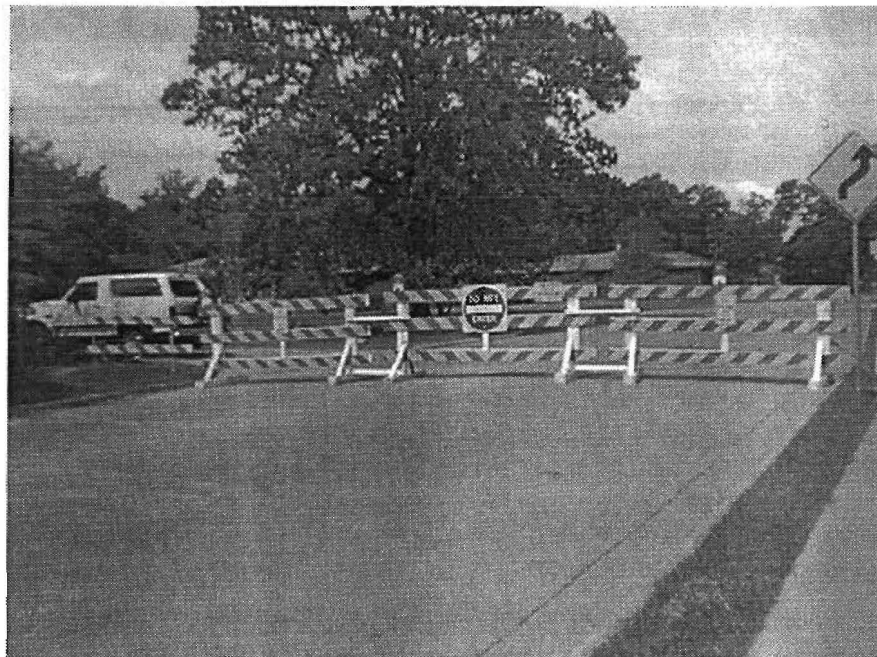
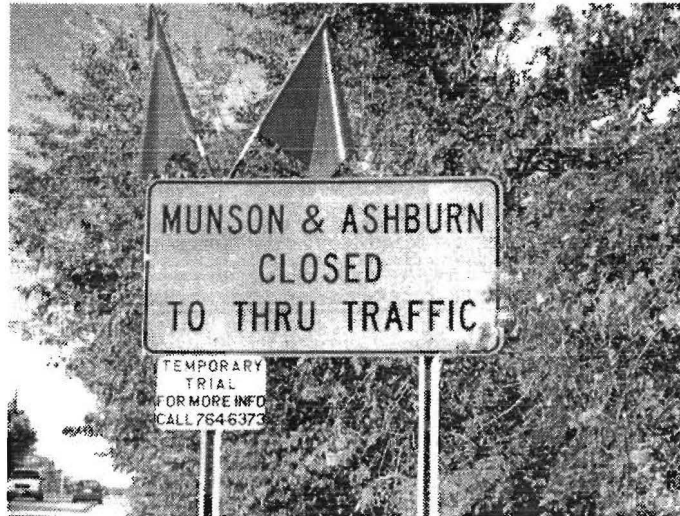


Figure 3-25. Road Closed Signs and Barricades in College Station, TX.

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ROADWAY DESIGN TECHNIQUES

Full Closures and Diagonal Diverters

LESSONS LEARNED

For preventing cut-through traffic, street closures are commonly used; however, they are also very controversial. Table 3-1 summarizes closure policies for selected communities. In general, closures are opposed and are only used after other measures have failed. Issues with closures include their effects on emergency response and the quantity of traffic moved to parallel local streets.

Advantages of full closures include:

- Reduce traffic volume and conflict points
- Restrict vehicle access
- Can still allow bicycle and pedestrian access while increasing safety
- Provide landscaping areas

Disadvantages of full closures include:

- Restrict emergency vehicle and transit access
- Prohibit or limit access and movement
- Divert traffic to other streets
- May increase trip length
- Can be unsightly if barricades or a proliferation of signs are used

DISCUSSION

Full closures can be an effective element as part of an overall network and are most successful when used in groups of two or more to provide a maze effect. Diagonal diverters and cul-de-sacs are effective in reducing cut-through traffic and volumes.

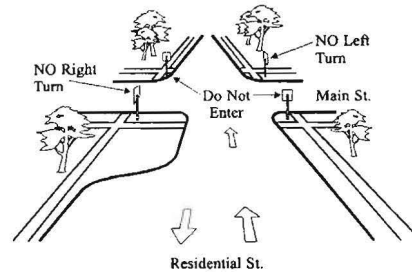
Full Closures and Diagonal Diverters

Table 3-1. Street Closure Policies and Procedures.⁽¹⁴⁾

Location	Policies and Procedures
Austin	closures discouraged but not ruled out as part of neighborhood-wide plans
Bellevue	closures considered only on residential streets with 20% or more cut-through traffic and at least 3,000 vpd
Boulder	closure discouraged but listed among program options—barriers occasionally erected without abandoning street right-of-way
Charlotte	closures not listed among program options—barriers occasionally erected without abandoning street right-of-way
Ft. Lauderdale	permanent closures discouraged—two public hearings and super majority of resident support required—temporary closures allowed for crime prevention
Gainesville	closures discouraged
Gwinnett County	neutral
Howard County	unofficial ban on street closures
Montgomery County	closures difficult to effect under county code
Phoenix	closures discouraged but listed among program options— street abandonment process inhibited by a filing fee, public hearing, and likelihood of no action—residents redirected to other options
Portland	closures discouraged but listed among program options
San Diego	closures discouraged
San Jose	closures discouraged
Sarasota	closures not listed among program options—considered only as a last resort, if an alternate route exists
Seattle	closures discouraged but listed among program options—larger impact area from which petition signatures must be obtained for volume controls than for speed controls
West Palm Beach	moratorium in effect

CHAPTER 3 ROADWAY DESIGN TECHNIQUES

Half Closures and Diverter



Half closure of or limited access to or from a roadway can be accomplished using semi-diverters, median barriers, exclusion lanes, or forced-turn barriers. Half-closures or semi-diverters are physical blockages of one direction of traffic on a two-way street that physically prevent drivers from entering or exiting certain legs of an intersection. Diverters are islands that prevent left turns from the through street and prevent left turns and through movements from the cross street. Exclusion lanes limit access to a particular class of vehicle, excluding all others. Forced-turn barriers restrict traffic movement using small traffic islands.

CHARACTERISTICS

Half Closures

Half closures are barriers to traffic in one direction of a street that permits traffic in the opposite direction to pass through. They are used to prohibit mainline left and right turns onto the side street.⁽⁵⁾ Half closures physically reinforce regulatory “Do Not Enter” signs and are usually installed in conjunction with these signs as well as by turn prohibition signs on the crossing street. Half closures are less restrictive than one-way operations, allowing two-way travel on the remainder of the street, but they have many of the same benefits as one-way streets. Visibility is an important issue because half closures are potential crash objects.⁽⁷⁾ When two half closures are placed across from one another at an intersection, the result is a semi-diverter.

Half closures can help to convey a sense of community privacy by narrowing the entry to the intersection. They are very effective in reducing volumes, and they allow a higher degree of emergency access than cul-de-sacs or diagonal diverters. Half closures may affect curbside parking opportunities opposite the device to permit emergency vehicle access and are typically only considered on non-transit streets. Half closures cost between \$5,000 and \$20,000.

Median Barriers

Median barriers are concrete curbs or islands that are located in the centerline of the street, continuing through the street’s intersection with a given cross street. They prevent left turns from the through street and left turns and through movements from the cross street. Median barriers are very effective in reducing traffic volumes when strategically placed.

Half Closures and Diversers

Median barriers are not typically used when they block a fire response route. They may also prevent transit services on the cross street. Median barriers may not significantly affect curbside parking opportunities, but some parking may need to be prohibited to accommodate the remaining turning movements or to install a wider median barrier. Median barriers cost approximately \$10,000 to \$20,000.

Exclusion Lanes

Exclusion lanes limit access to a particular class of vehicle and exclude all others. Examples of exclusion lanes are bus-only, bicycle, and car pool/diamond lanes. The effectiveness of exclusion lanes varies with location; they are most effective when there are clear alternatives that are easier than violating the lane restrictions.

Emergency response vehicles are generally not affected by exclusion lanes. Exclusion lanes may impede transit service or scheduling, but the lanes are often constructed for their benefit.

Forced-Turn Islands

Forced-turn islands are small traffic islands at intersections that channel turning movements. They restrict access by preventing exiting left-turn movements and by forcing vehicles to reduce speeds upon entry. They are also known as right-turn islands. Forced-turn islands may be aesthetically pleasing if landscaped and can be inexpensive to install depending upon the design.

EXPERIENCES

A semi-diverter installation in Seattle uses a curb extension to block entry on one side of the street. The curb extension is curbed and is planted as a grassy area, as shown in Figure 3-26. Do Not Enter and No Left Turn signs reinforce the turn prohibition.

A semi-diverter was installed in the small community of Grayson, Georgia (see Figure 3-27). The semi-diverter restricts entrance to a rural residential area from a 88.5 km/h (55 mph) roadway. The semi-diverter is considered very successful by county staff. A similar semi-diverter installation in Glendale, California, is shown in Figure 3-28.

An exclusion lane in Portland allows only buses to enter, as illustrated in Figure 3-29. An example of a forced-turn island is shown in Figure 3-30.

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ROADWAY DESIGN TECHNIQUES

Half Closures and Diverters



Figure 3-26. Partial Closure in Seattle, WA.



Figure 3-27. Semi-diverter in Grayson, GA.

Half Closures and Diverters



Figure 3-28. Semi-diverter in Glendale, CA.

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Half Closures and Diverters

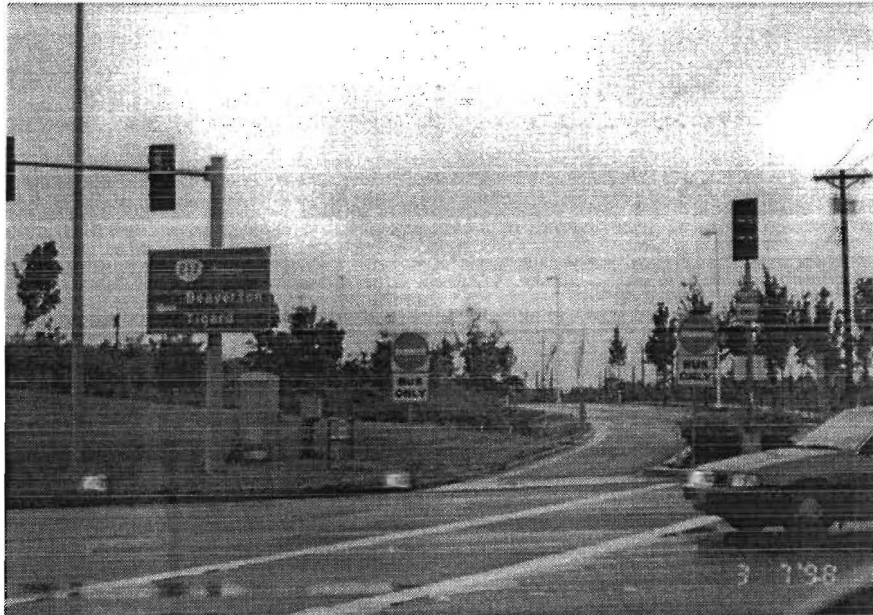


Figure 3-29. Exclusion Lane in Portland, OR.



Figure 3-30. Forced-Turn Island in Montgomery County, MD.

Half Closures and Diverters

When drivers routinely went around narrow barriers at its intersections, Ft. Lauderdale built a half closure that extends 9.1 m (30 ft) upstream of an intersection. Drivers are reluctant to travel in the wrong direction for such a distance. Ft. Lauderdale also began to angle its barriers for right turns out of the neighborhood, making turns into the neighborhood awkward.⁽¹⁴⁾

In Ventura, California, a median barrier is used to prevent left turns to and from a residential area (Figures 3-31 and 3-32). The median barrier also reduces pedestrian conflicts at the crosswalk in a school zone.

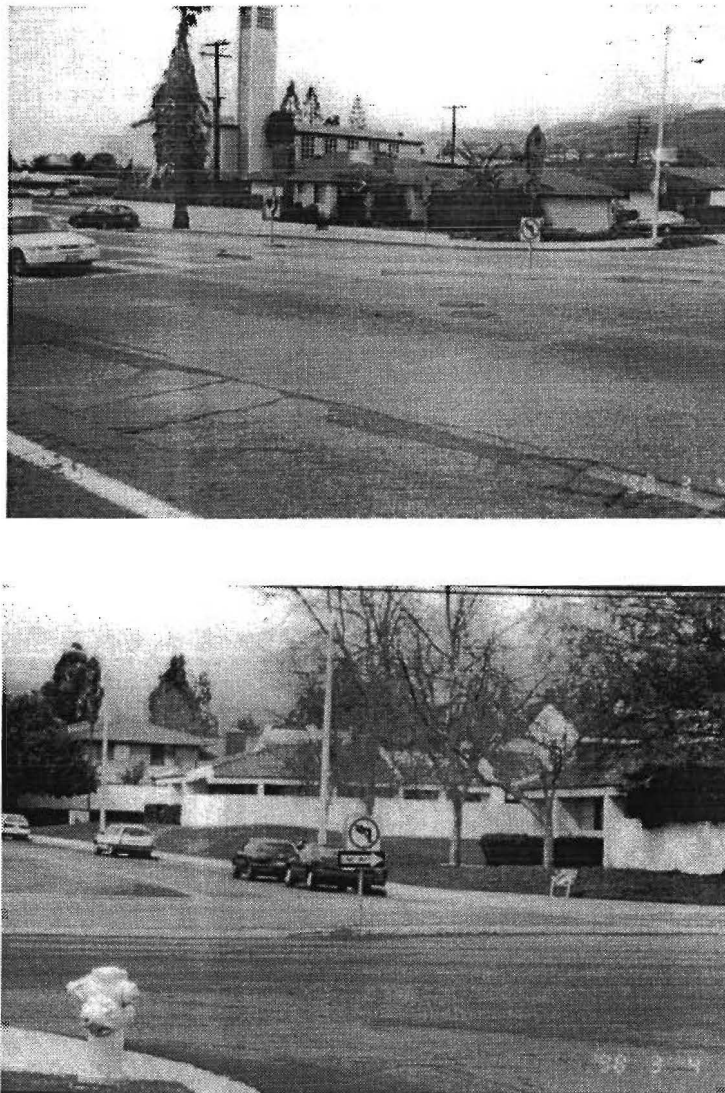


Figure 3-31. Channelization and Turn Restrictions in Ventura, CA.



Figure 3-32. Turn Restrictions in Ventura, CA.

LESSONS LEARNED

Advantages and disadvantages of half closures and limited access techniques are listed in Table 3-2.

DISCUSSION

Half closures are effective in restricting vehicle access and movements, thereby reducing volumes. Because they are not complete closures, they can be evaded by motorists, and compliance rates are not 100 percent. Temporary installations can be used to test the effectiveness of these techniques at a particular location, but care should be taken to ensure that the temporary devices are operationally safe and aesthetically pleasing.

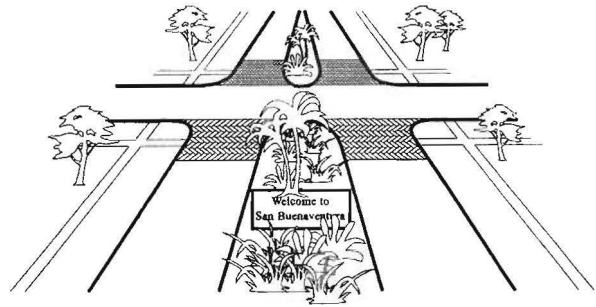
Half Closures and Diverseters

Table 3-2. Advantages and Disadvantages of Partial Closures and Limited Access Techniques.

Technique	Advantages	Disadvantages
Semi-diverters	<ul style="list-style-type: none"> • Reduce through traffic in one direction and possibly in the other direction • Allow two-way traffic on the remainder of the street • Provide shorter crossing distance for pedestrians • Can be designed to provide two-way access for bicycles • Can provide for bicycles • Provide landscaping opportunities 	<ul style="list-style-type: none"> • Reduce access for residents • Limit access for emergency vehicles, but they can drive around with care • Do not provide 100% compliance • May increase trip length for some residents • Add maintenance responsibility if landscaped • Can be evaded because they block only half the street
Median Barriers	<ul style="list-style-type: none"> • Separate opposing vehicle travel lanes • Can be designed to provide pedestrian refuge • Can improve safety by limiting access • Can visually enhance the street if landscaped 	<ul style="list-style-type: none"> • Prohibit or limit access and movement from driveways • May require parking removal • May have a negative impact on emergency services due to limited access • Add maintenance responsibility if landscaped
Exclusion Lanes	<ul style="list-style-type: none"> • Do not generally impede emergency response vehicles • Restrict volume by limiting access 	<ul style="list-style-type: none"> • May require some parking removal • May impede transit services but are often constructed for their use • May be easier to violate than physical barriers
Forced-Turn Barriers	<ul style="list-style-type: none"> • May reduce cut-through traffic • Can be attractive if landscaped 	<ul style="list-style-type: none"> • May increase trip length • May increase emergency response time • Add maintenance responsibility if landscaped

CHAPTER 3 ROADWAY DESIGN TECHNIQUES

Entrance Features



Entrance features are used to create a sense of community or neighborhood identity. Entrance features may consist of textured and colored pavements, curb extensions, raised crosswalks or speed tables, landscaping, and entry signage at key entry ways into neighborhoods or small towns. Entrance features that narrow the roadway may also be referred to as gateways. Entrance treatments create visual and/or audible cues to tell drivers that they are entering a local residential area or that the surrounding land uses are changing.⁽⁷⁾ One intent of the entrance treatment is to reduce speed.

CHARACTERISTICS

Entrance features vary depending upon the classification and speed of the roadway, the desired speed upon entry, and the theme of the feature in providing cues to drivers. On an approach into a small town, roadway cross-section elements and other visual cues can effectively reduce travel speeds prior to entry. The cross-section can transition from a wide, median-divided roadway to an undivided roadway with traversable medians to an undivided roadway with no medians. Speed limit transitions, driveway density, landscaping, lighting, and traffic signals or beacons also provide cues for speed reduction. Typical signing practices include city limit signing, radar enforcement signing, and speed limit signing.

Entrances to residential areas typically include roadway narrowing and a landscaping theme, along with textured and colored pavements, raised crosswalks, and/or speed tables. Entry signing may also be used to regulate and guide drivers through the area.

Entrance features have minimal influence on drivers' routine behavior. The city of Portland officials believe that overall speeds and total volumes are not influenced but that drivers are made more aware of the environment in which they are driving and that they are more considerate of pedestrians.

EXPERIENCES

Entrance features vary widely in design and cost. The city of Portland estimates that entry treatments cost approximately \$5,000 to \$20,000. Following are different examples of entrance features:

Entrance Features

- Figure 3-33 shows a sign on State Route 395 at the entrance to Kettle Falls, Washington.
- Entrance features for the town of Williamsburg, Virginia, add an historic atmosphere to the area while alerting drivers of a different type of environment (see Figure 3-34).
- When entering the town of Caldwell, Texas, the cross-section changes from a four-lane divided highway to a five-lane non-divided section (see Figures 3-35 and 3-36). Other visual cues for speed reduction include a welcome sign, additional lighting, and reduced speed limit signing (reduced from 112.7 to 88.5 km/h [70 to 55 mph] at the city limit and then reduced from 88.5 to 56.3 km/h [55 mph to 35 mph] in 8 km/h [5 mph] increments).
- A sign and landscaped center island mark the entrance to San Buenaventura, California, as shown in Figure 3-37.
- Figure 3-38 illustrates the entrance to Marshall, Texas.
- The Navy Post Graduate School Entrance in Monterey, California, uses a guard house and other treatments to communicate to drivers that they are entering a different facility (see Figure 3-39).



Figure 3-33. Entrance Sign in Kettle Falls, WA.

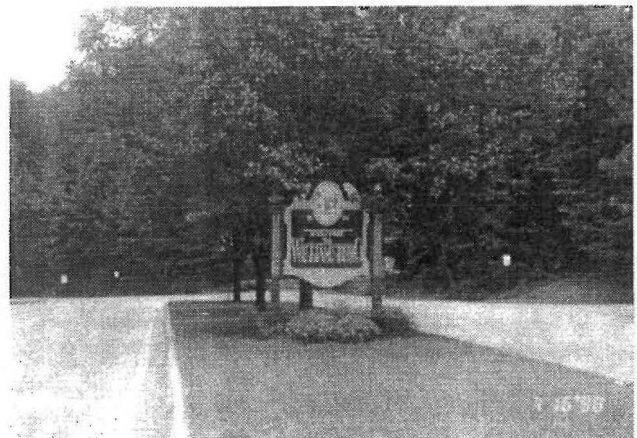


Figure 3-34. Entrance Sign in Williamsburg, VA.

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ROADWAY DESIGN TECHNIQUES

Entrance Features

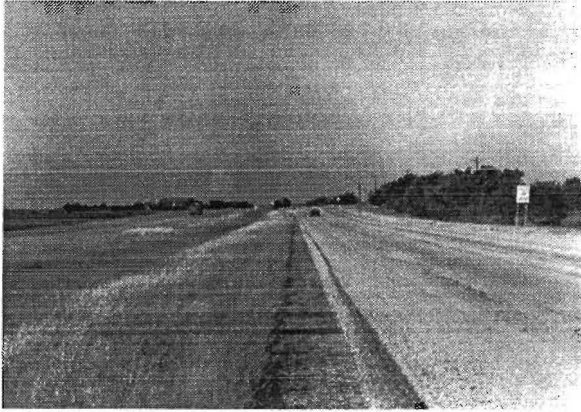


Figure 3-35. Four-Lane Divided Highway Approaching Caldwell, TX.

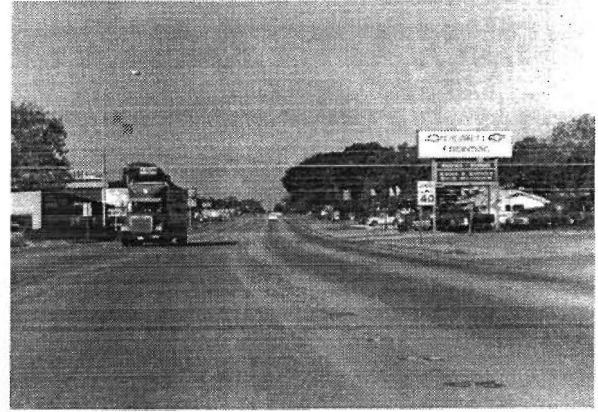


Figure 3-36. Five-Lane with Two-Way Left-Turn Lane Approaching Caldwell, TX.

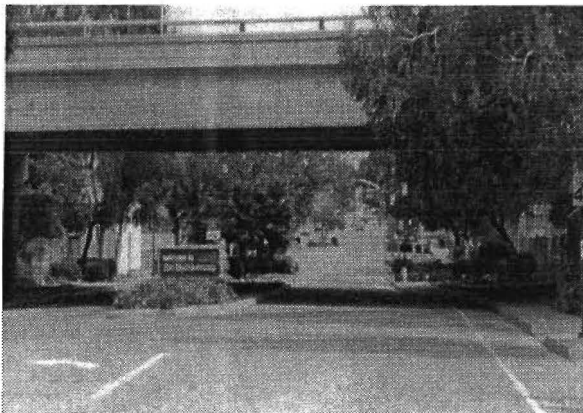


Figure 3-37. Entrance Features in San Buenaventura, CA.



Figure 3-38. Welcome Sign in Marshall, TX.

Entrance Features

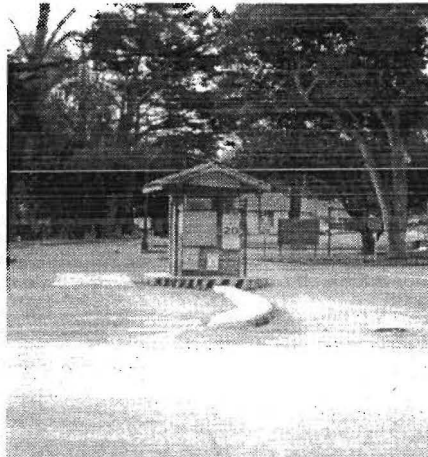


Figure 3-39. Guard House Entrance in Monterey, CA.

LESSONS LEARNED

Advantages of entrance features include:

- Provide an indication of a change in environment
- Help to create a neighborhood identity
- Can reduce entry speed
- May reduce pedestrian crossing distance
- Create additional areas for landscaping and monuments
- Can discourage truck entry (residential areas)
- May allow signs to be placed closer to a driver's cone of vision

Disadvantages of entrance features include:

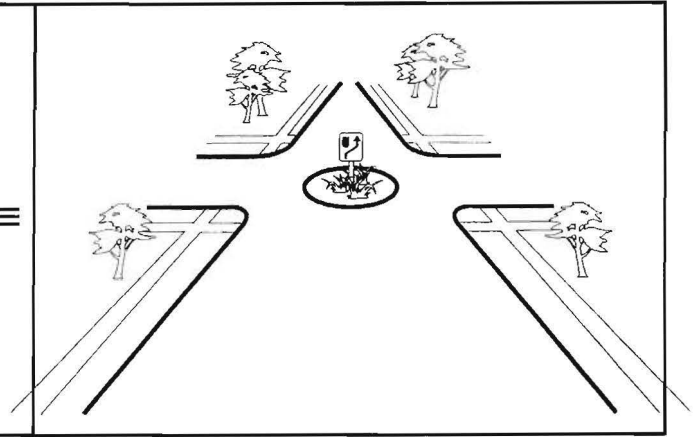
- Are not uniform from one location to another
- May increase landscape maintenance costs

DISCUSSION

Entrance features use a variety of visual and physical features to communicate the message that a driver is entering a different environment. Entrance features are different for high-speed and low-speed entrance areas, and entrances to small towns may require much larger speed reductions than neighborhood entrances. Signs, narrowing intersections, and landscaping features may be used separately or in combination to create this effect.⁽³⁾

CHAPTER 3 ROADWAY DESIGN TECHNIQUES

Traffic Circles



Traffic circles are small circular islands placed in the center of existing local street intersections, often planted with shrubbery, trees, or flowers, as shown in Figure 3-40. The islands require drivers to slow down to go around them and break the line of sight down a street. A primary benefit of traffic circles is reducing the number of turning and angle collisions.



Figure 3-40. Traffic Circle in Monterey, CA.

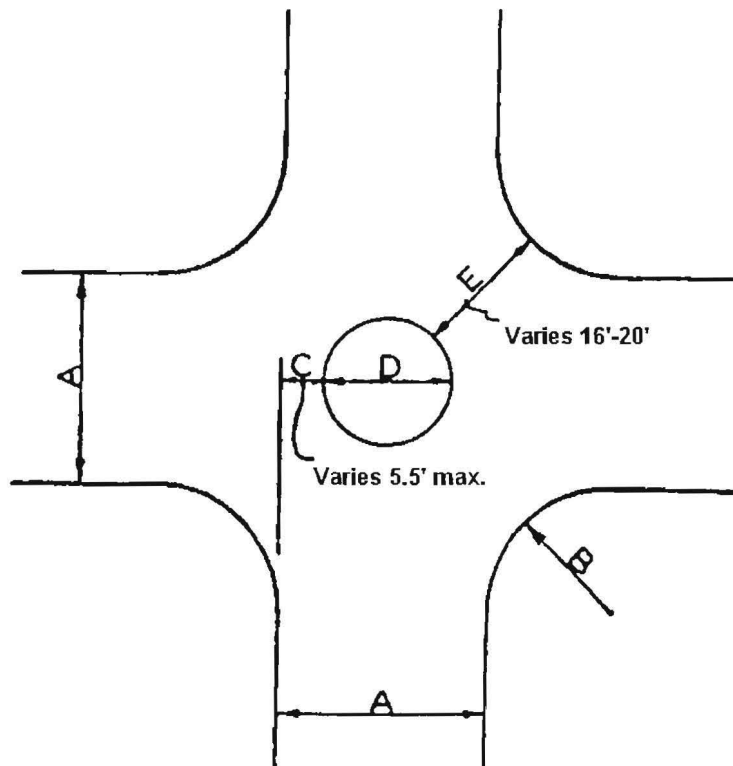
CHARACTERISTICS

A typical traffic circle is 6.1 m (20 ft) in diameter, with roadway approach widths of 9.1 m (30 ft) or more.⁽⁵⁾ A minimum of 9.1 m (30 ft) of curbside parking must be prohibited on the through street at the corner of the intersection. Traffic circles are less effective at T-intersections and difficult to design for offset intersections.

The city of Seattle design criteria are summarized below in conjunction with the diagram in Figure 3-41.

- The distance between a traffic circle and the street curb projection (off-set distance) is a maximum of 1.7 m (5 ½ ft) (dimension “C”).

Traffic Circles



Legend:

- A. Street Width
- B. Curb Return Radius
- C. Offset Distance
- D. Circle Diameter
- E. Opening Width

OPTIMUM CRITERIA

Offset Distance	Opening Width
5.5' max	16' min
5.0'	17'±
4.5'	18'±

Figure 3-41. Seattle's Traffic Circle Design Criteria.⁽⁷⁾

- The width between a traffic circle and the curb return is 4.9 to 6.1 m (16 to 20 ft) (dimension "E").
- As the offset distance decreases from the maximum 1.7 m (5 ½ ft), the opening width increases from the minimum 4.9 m (16 ft).

Speeds near the intersection are reduced so that vehicles can avoid the traffic circle, and this is especially true of right- and left-turning vehicles. However, speed in the middle of the block may increase as some drivers try to make up for lost time. If right-angle accidents are a problem, these accidents may be reduced by the installation of a traffic circle. If there are few right-angle accidents or there is existing stop control at the intersection, there will probably be little effect on accidents. Additionally, there may be some confusion over the correct method for making a left turn.⁽⁵⁾ Some jurisdictions allow left-turning vehicles to turn in front of the circles. Others, such as Boulder,

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ROADWAY DESIGN TECHNIQUES

Traffic Circles

Colorado, install a sign indicating that the vehicle is to drive around the circle to turn left.⁽⁷⁾ Additionally, traffic circles can operate with stop or yield controls. Effect on volume is minimal, although some vehicles may be diverted to adjacent collector or arterial streets to avoid the traffic circle.⁽⁵⁾

Buses and fire trucks can maneuver around traffic circles at slow speeds, provided vehicles are not illegally parked near the circles. The city of Portland has performed extensive studies on delay to emergency vehicles indicating a delay of 1.3 to 10.7 sec per circle.⁽¹⁵⁾ A well done traffic circle can be expensive to install. Conversely, traffic circles may also be installed with very little cost. Some jurisdictions may use tires, planters, pipes on end, guard rails, or wooden barricades when experimenting with traffic circles on a trial basis.⁽⁷⁾ The cost of a typical traffic circle with concrete curb and gutter and landscaping can approach \$5,000.⁽⁵⁾ The city of Portland reports that traffic circles may cost as much as \$5,000 to \$15,000 each.

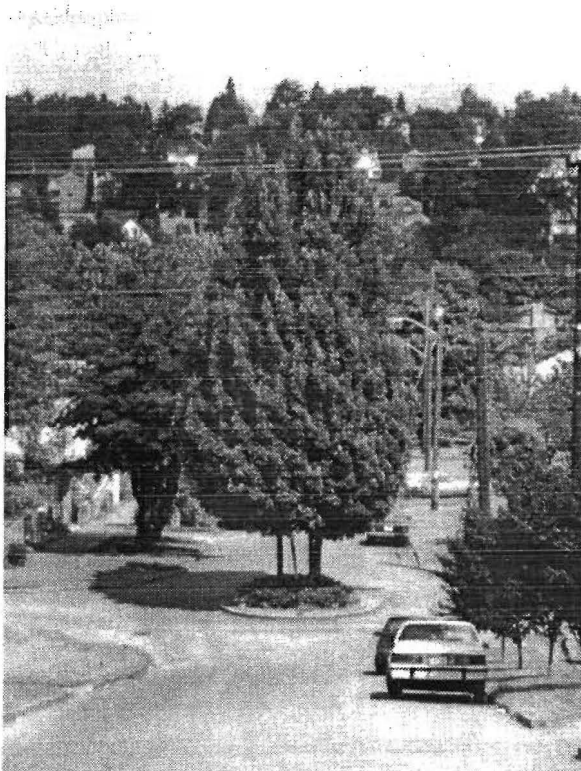
Maintenance concerns include whether to landscape the traffic circle, who will maintain the landscaping if installed, the slowing of snow plowing efforts due to the presence of the traffic circle, and maintenance of signs and markings.⁽⁵⁾ It is important to mark traffic circles well for nighttime visibility. This may be done with illumination, reflector buttons on the street surface, or reflectors on the sides of the concrete or on low signs.⁽⁷⁾ If well maintained, traffic circles can be very attractive. However, there are also several traffic control signs and pavement markings associated with traffic circles that are not very attractive. Noise impacts are minimal. However, there may be some noise related to vehicles decelerating and accelerating near the circle.

EXPERIENCES

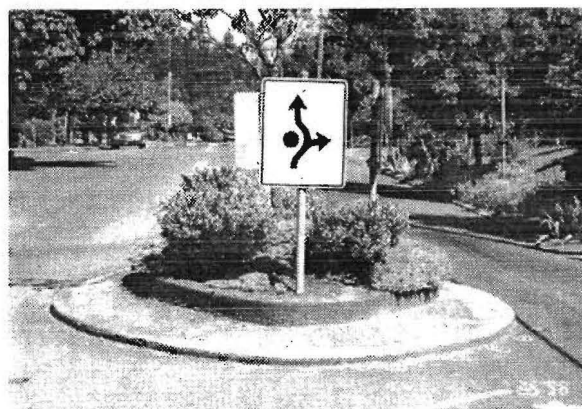
Portland, Oregon

Traffic circles are widely used in Portland.⁽⁷⁾ The city of Portland has experience with two different types of traffic circles. The older type is a simple, raised circular island, as shown in Figure 3-42. The new type consists of a slightly larger circular outer lip with a concentric ring/curb, as illustrated in Figure 3-43. This new design also results in the middle of the island being higher than the older design. Portland's experience with the older islands indicated that some drivers were not turning sharply enough, causing the vehicle's tires to rub into the island. The purpose of the newer design is to make the circle more conspicuous and to make it more difficult for an errant vehicle to mount the traffic circle island. Also, if a vehicle strikes the outer curb, the vehicle is better redirected along its path and away from the center of the circular island.⁽⁷⁾

Traffic Circles



**Figure 3-42. Older Traffic Circle
Located in Seattle, WA.**



**Figure 3-43. Newer Design Traffic
Circle in Portland, OR.**

For one installation in Portland, traffic circles were constructed on a six-block segment of NW 25th Avenue in 1989. This street is 11 m (36 ft) wide, functions as a collector street, and has regular bus service at 10-minute headways during peak travel times. There were two lanes of travel, and parking was allowed on both sides. Volumes were approximately 8000 vpd.

Three traffic circles were constructed and spaced at 152 m (500 ft) intervals at alternating intersections. The circles' diameters vary from 5.8 to 7 m (19 to 23 ft) and were designed with the intent of requiring vehicles to reduce their speed as they negotiate the intersections. The landscaping included small trees and was designed to provide a visual interruption of the corridor. The posted speed is 40.2 km/h (25 mph). Speed distribution studies prior to the installation showed 85 percent of the vehicles traveling at or below 51.5 km/h (32 mph). After the traffic circle installations, the 85th percentile speed dropped to 43.4 km/h (27 mph) between the circles, and lower speeds were observed at the circles. The geometry of the circles allows buses and emergency vehicles to negotiate the devices; however, they must travel at relatively low speeds.⁽¹⁵⁾

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Traffic Circles

Seattle, Washington

A representative of the city of Seattle notes that traffic circles have proven to be the most effective of all the neighborhood traffic control devices used in Seattle for solving traffic concerns with a minimum of controversy (see Figure 3-44). Between 1993 and 1997, more than 600 traffic circles were constructed, with the staff receiving about 700 requests each year.



Figure 3-44. Traffic Circle in Seattle, WA.

Potential traffic circle locations are identified through community requests of identification of high accident locations. Each request is investigated, and an initial assessment is made to determine if a traffic circle is feasible. A priority point system is used to rank the locations where traffic circles are requested in order to ensure that funding is allocated to the locations with the greatest need. The ranking is based on the number of accidents that have occurred at the intersection in the past three years, the 85th percentile speed, and traffic volume. Funding is allocated starting with the location with the worst combination of problems and proceeds as far as funding allows. The cost of each circle ranges from \$3,000 to \$6,000, and residents are required to submit a petition with signatures representing 60 percent of the households within one block of the proposed traffic circle in order to compete for funding. Each traffic circle is designed to fit the individual intersection without having to modify the street width or corner radii. Most of Seattle's local streets are 7.6 m (25 ft) in width (or less), so the traffic circles are usually 3.7 to 4.9 m (12 to 16 ft) in diameter. The design vehicle

Traffic Circles

is a single unit truck with a 13.7 m (45 ft) turning radius to ensure that fire trucks can pass by the circle without running over the curbs. All potential traffic circle intersections are reviewed by the fire department and are field tested if there is a specific concern. Traffic circles are also designed with a 0.6 m (2 ft) wide mountable curb so that larger vehicles can run over the mountable curb without damaging the vehicle or the traffic circle.

Landscaping is used to make the traffic circles more attractive and to change the character of the street so that it is less appealing to drive at high speeds. Local residents are required to maintain the landscaping, consisting of ground cover and one to three trees. Residents may add their own low-growing plants.

Accident reduction is the greatest benefit of traffic circles. A total of 119 traffic circles were constructed between 1991 and 1994; there was a 94 percent reduction in accidents in the calendar year following the traffic circles' construction compared to the year before their construction. Injuries dropped from 153 in the year before construction to one injury in the year following construction. This reduction continued in subsequent years for locations where the traffic circles had been in place long enough to provide data.

Traffic circles have also been effective in reducing vehicle speeds, although the reduced speed effect is less at the middle of the block than at the intersection. Traffic circles have not significantly reduced traffic volumes, but this minimal impact on volume allows traffic circles to be used as spot safety devices without having to address the impacts of diverted traffic. After more than 20 years experience using traffic circles, the city of Seattle considers them an effective device for controlling neighborhood traffic and improving the safety of residential streets.⁽¹⁶⁾ Operational features of traffic circles are discussed further in the Roundabout section.

Columbia, Maryland

In the Macgil's Commons area of Columbia, traffic circles are used in combination with forced-turn islands, pavement markings, and speed humps to reduce speeds on a collector street. The traffic circles are constructed of concrete, as shown in Figure 3-45. Small landscaped traffic circles are used on cul-de-sacs in the same neighborhood (Figure 3-46).

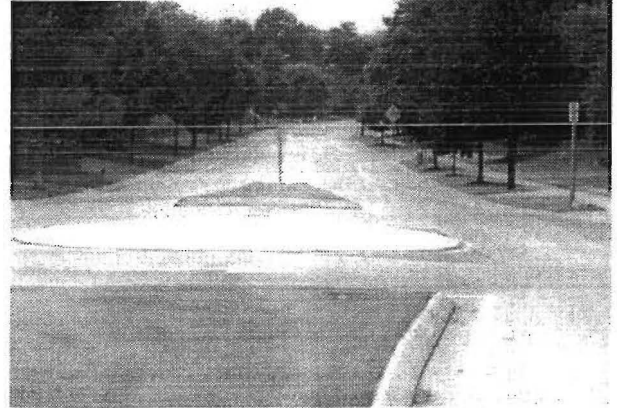


Figure 3-45. Concrete Traffic Circle in Montgomery County, MD.

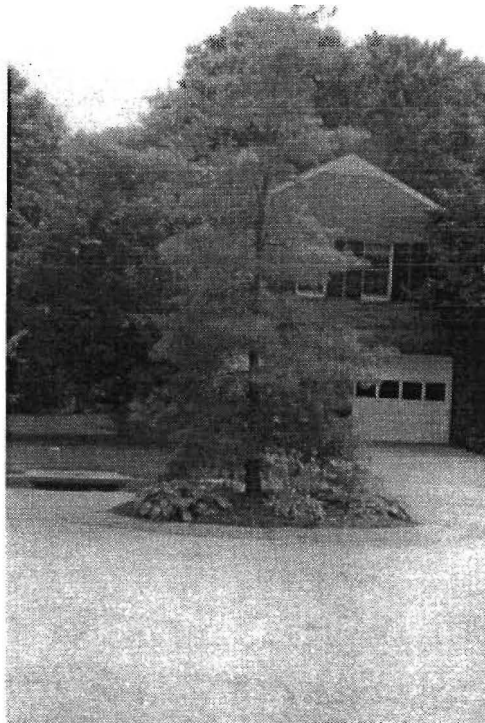


Figure 3-46. Traffic Circle in Cul-de-sac in Montgomery County, MD.

Traffic Circles

LESSONS LEARNED

Advantages of traffic circles include:

- Effectively reduce vehicle speeds
- Improve safety conditions
- Can be visually attractive when landscaped and maintained

Disadvantages of traffic circles include:

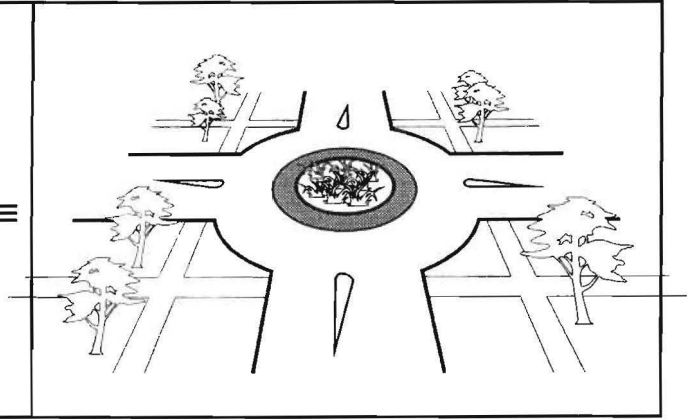
- Add a potential hazard to the middle of the roadway
- Require some parking removal
- Can cause bicycle/vehicle conflicts at intersections due to narrowed travel lanes
- Can restrict emergency or transit vehicle movement if vehicles are parked illegally near the circle
- Can increase emergency vehicle response times

DISCUSSION

Traffic circles have proven to be effective in reducing speeds and accidents at the intersections of local streets. Community reaction regarding traffic circles is mixed; some drivers express concern about an unnecessary obstruction and potential hazard, and there are some complaints regarding noise, air quality, or energy consumption. Additionally, there are varying opinions regarding aesthetic value, depending upon the type of construction and landscaping.⁽⁵⁾

CHAPTER 3 ROADWAY DESIGN TECHNIQUES

Roundabouts



Roundabouts are growing in popularity as a form of traffic control in North America. Roundabouts guide traffic flow with a raised island constructed in the center of an intersection to create a one-way circular flow of traffic, as shown in Figure 3-47. When a roundabout is placed in an intersection, vehicles may not travel in a straight line. Roundabouts have been used to reduce crash frequency by reducing the number of conflict points, to lower travel speeds, and as an alternative to traffic signal installation.

CHARACTERISTICS

Comparison with Traffic Circles

Roundabouts are similar to traffic circles, but they have design and operational characteristics that result in better performance. The key operational feature of roundabouts is that traffic must yield at entry to the traffic that is already within the roundabout. Roundabouts and traffic circles are compared as follows:⁽¹⁷⁾



Figure 3-47. Roundabout in Santa Barbara, CA.

Roundabouts

- Vehicles entering a roundabout on all approaches are required to yield to vehicles within the circulating roadway. *Traffic circles sometimes employ stop or signal control to give priority to entering vehicles.*
- The circulating vehicles are not subjected to any other right-of-way conflicts, and weaving is kept to a minimum. This provides the means by which the priority is distributed and alternated among vehicles. A vehicle entering as a subordinate vehicle immediately becomes a priority vehicle until it exits the roundabout. *Some traffic circles impose control measures within the circulating roadway or are designed with weaving areas to resolve conflicts between movements.*
- The speed at which a vehicle is able to negotiate the circulating roadway is controlled by the location of the central island with respect to the alignment of the right entry curb. This feature is responsible for the improved safety record of roundabouts. *Some large traffic circles provide straight paths for major movements or are designed for higher speeds within the circulating roadway. Some small traffic circles do not achieve adequate deflection for speed control because of the small central island diameter.*
- No parking is allowed on the circulating roadway. Parking maneuvers prevent the roundabout from operating in a manner consistent with its design. *Some larger traffic circles permit parking within the circulating roadway.*
- No pedestrian activities take place on the central island. Pedestrians are not expected to cross the circulating roadway. *Some larger traffic circles provide for pedestrian crossing to, and activities on, the central island.*
- All vehicles circulate counterclockwise, passing to the right of the central island. *In some smaller traffic circles (sometimes called “mini-traffic circles”), left-turning vehicles are expected to pass to the left of the central island.*
- Roundabouts are designed to properly accommodate specified design vehicles. *Some smaller traffic circles are unable to accommodate large vehicles, usually because of right-of-way restraints.*
- Roundabouts have raised splitter islands on all approaches. Splitter islands are an essential safety feature, required to separate traffic moving in opposite directions and to provide refuge for pedestrians. They are also an integral part of the deflection scheme. *Some smaller traffic circles do not provide raised splitter islands.*

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ROADWAY DESIGN TECHNIQUES

Roundabouts

- When pedestrian crossings are provided for the approach roads, they are placed approximately one car length back of the entry point. *Some traffic circles accommodate pedestrians in other places, such as the yield point.*
- The entry deflection is the result of physical features of a roundabout. *Some traffic circles rely on pavement markings to promote deflection.*⁽¹⁷⁾

Safety

Roundabouts reduce the severity and frequency of intersection accidents by the nature of their design. Roundabouts resolve vehicle conflicts by means of priority control: entering vehicles yield to the circulating traffic. Traffic interactions are based on gap acceptance; entering traffic must wait for a gap in the traffic stream to enter.

Roundabouts eliminate left turns at intersections, reducing the opportunity for collisions. Roundabouts contain only four merging conflict points, compared with 24 merging/crossing conflict points at intersections controlled by Stop signs or traffic signals (see Figures 3-48 and 3-49). The driver needs to decide when to enter the circulating stream, when to leave the circulating stream, and how fast to travel while circulating so that other drivers may enter the circulating stream without causing a conflict or accident.

Roundabouts are used extensively throughout Europe and Asia. Figure 3-50 summarizes the safety of roundabouts worldwide.⁽¹⁸⁾ The introduction of the roundabout to America has raised many questions about potential safety and operational problems of this intersection design. In the U.S., a recent study confirms the safety benefits of roundabouts. An investigation of six sites in Florida, Maryland, and Nevada revealed that the conversion of T and X intersections (stop controlled and signalized) to roundabouts decreased accident frequency. The reduction was statistically significant.⁽¹⁹⁾

A study of roundabouts in Florida and Maryland focused on characterizing safety performance by evaluating the number and type of traffic conflicts. Many of the accidents in the before period were severe, including one fatality. Accidents that occurred at the roundabouts were less severe and had very few, if any, injuries associated with them compared with the previous intersection configuration. Rear-end and weave conflicts occur most often at the roundabouts, and the cause of the majority of this type of accident at roundabouts is failing to yield. Overall, the average accident rate at these five intersections was reduced from an average of 5.0 accidents/year to an average of 2.4 accidents/year, or greater than a 50 percent reduction. Average accident cost decreased from \$119,788 (before roundabout construction) to \$84,125 (after roundabout construction).⁽²⁰⁾

Roundabouts

In Great Britain, roundabouts have reduced the number of slight injury accidents by 34 percent and serious injury and fatalities by 46 percent when compared to previous intersection designs.⁽²¹⁾ The Netherlands achieved a 95 percent reduction in injuries to vehicle occupants at locations where roundabouts were installed.⁽²¹⁾ A large study conducted in Victoria, Australia, on 73 roundabouts before and after their installation, found a 74 percent reduction in casualty accident rates after roundabouts were installed.⁽²²⁾ Because of four fatalities involving cyclists riding along a marked bike lane and striking exiting trucks at roundabouts in the Netherlands, considerations are being made to eliminate bike lanes within the circulating roadways.⁽²²⁾

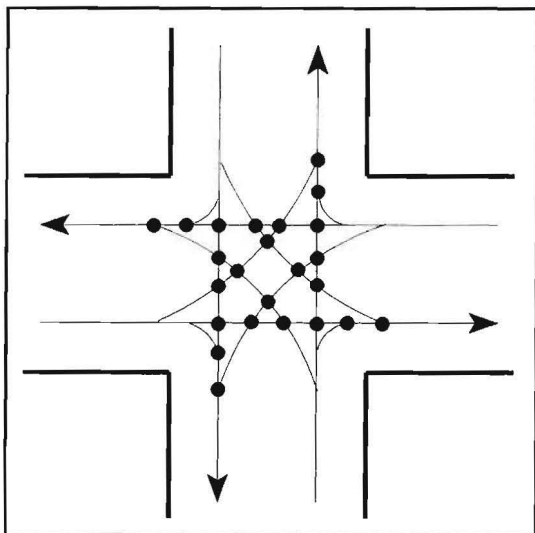


Figure 3-48. Conflict Points at Traditional Four-Way Intersection.

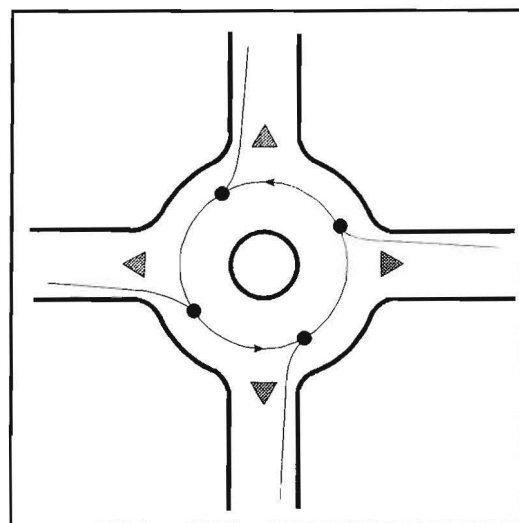


Figure 3-49. Conflict Points at Four-Way Roundabout.

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Roundabouts

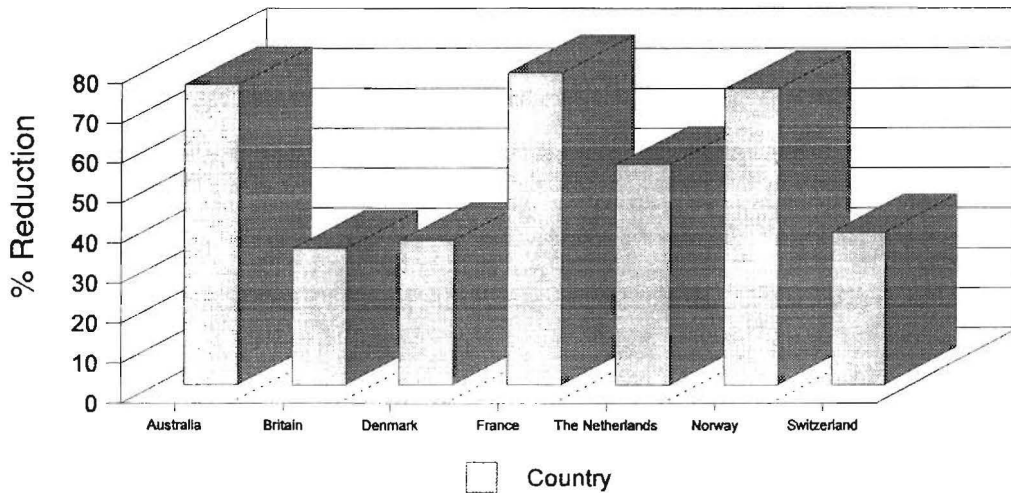


Figure 3-50. Injury Accident Reductions: Conversion of Conventional Intersection to Roundabout.

EXPERIENCES

The Maryland State Highway Administration (MSHA) decided to build a roundabout in 1991. They produced a videotape to explain what roundabouts are, how they work, and what they can do. Maryland's first roundabout site was the intersection of MD-144 and MD-94 in Lisbon, as shown in Figure 3-51. The two-way stop-controlled rural crossroad had a history of serious injury accidents. The citizens demanded a traffic signal, but the intersection did not meet signal warrants. MSHA proposed a roundabout and offered to remove it if the citizens did not like it. After installation, the local government overwhelmingly approved it, and MSHA made it permanent. With complete before and after crash data, crashes are down 70 percent; injury crashes are down more than 90 percent, and measured delay is less than a signal. This early success has led to the construction of eight more roundabouts in Maryland, and MSHA has accepted roundabouts as a standard intersection type. Another Maryland roundabout is shown in Figure 3-52.

Roundabouts can be designed in other than circular shapes. For example, an oval-shaped roundabout may keep the overall size of the roundabout to a minimum while providing access to all approach legs. An oval roundabout may also be used where one intersecting street is considerably wider than the other and/or where a wide median exists. An oval roundabout is under construction in Towson, Maryland, as illustrated in Figure 3-53.

Roundabouts

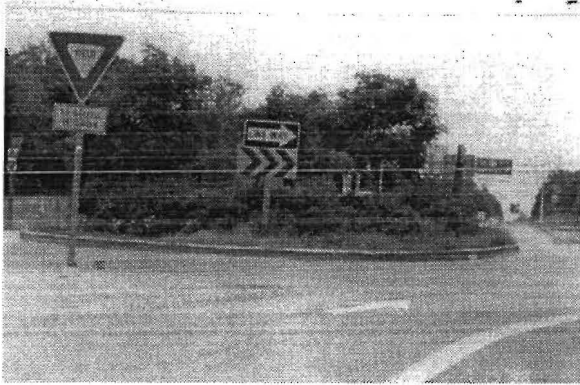


Figure 3-51. Roundabout in Lisbon, MD.



Figure 3-52. Roundabout West of Westminster, MD.



Figure 3-53. Oval Roundabout Under Construction in Towson, MD.

Figures 3-54 and 3-55 illustrate roundabout warning signs approaching two roundabouts in Maryland. The sign in Figure 3-54 states "CIRCLE AHEAD" while the sign in Figure 3-55 is supplemented by a Yield sign informing drivers to the yield condition at the roundabout.

Roundabouts at interchange ramp termini may result in less delays and accidents and may be less costly when compared to other conventional interchange designs. A modern roundabout interchange is a freeway-to-street interchange or a street-to-street interchange that contains at least one roundabout. Unlike interchanges regulated by traffic signals, modern roundabout interchanges do not require long storage and turning lanes over or under a bridge, which is an expensive element of the interchange.

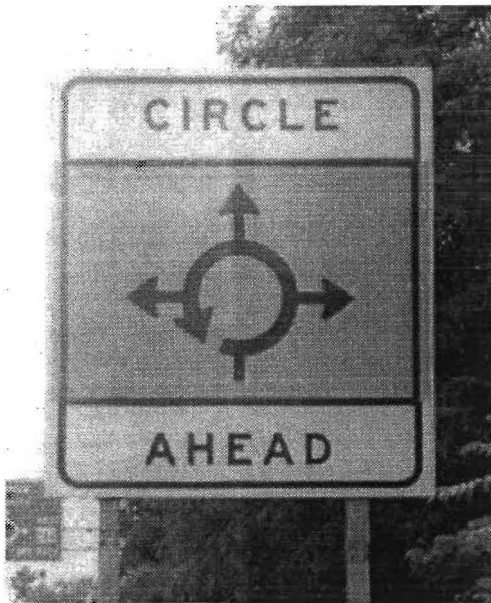


Figure 3-54. Warning Sign in Lisbon, MD.

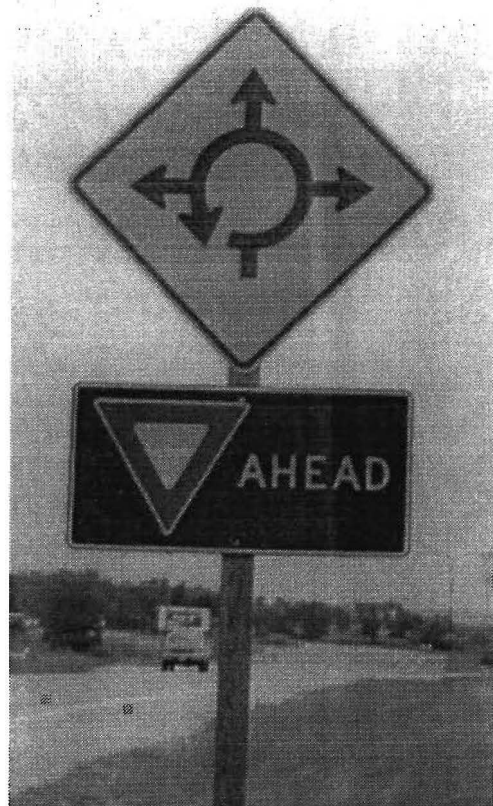


Figure 3-55. Warning Sign in Westminster, MD.

Roundabouts

The Department of Transportation in Jackson, Mississippi, installed a roundabout at the intersection of two four-lane divided highways (an arterial and a state route) in 1998. The roadway speed limits are 72.4 km/h (45 mph). The roundabout is right turn only with only one lane entering the roundabout. The initial public relations information provided by the Department of Transportation received both positive and negative comments. The intersection has experienced an overall reduction in delay since the installation of the roundabout. More roundabout installations are planned. The roundabout is a circle with a concrete apron, and the installation cost was approximately \$60,000 including one-third of the cost in signage.⁽²⁴⁾

The town of Vail, Colorado, built their first modern roundabout interchange at I-70/Vail Road in 1995. Closely spaced ramp and frontage road intersections, formerly regulated by Stop signs, have been replaced by two roundabouts. As shown in Figure 3-56, one is a five-leg, 36.6 m (120 ft) raindrop-type roundabout north of the freeway, and the other is a six-leg, 61 m (200 ft) roundabout south of the freeway. The two frontage road entries to the south roundabout flare to three lanes at the yield line from two upstream lanes. All other roundabout entries flare to two lanes at the yield line from one upstream lane. Since the 10 m (36 ft) wide undercrossing was not widened, the total cost of the project was only \$2.8 million, compared to \$5 million if the bridge had been widened. The project also saves the town \$85,000 on traffic direction officers whose services are no longer needed.⁽²¹⁾ Before the roundabout project, the interchange was so overloaded that traffic was directed to other interchanges. Now traffic is directed toward the interchange, which has reserve capacity (see Table 3-3). Additionally, long queues of traffic used to extend back onto the freeway. Now, queues rarely exceed 10 vehicles. Crash rates are slightly lower but are not statistically significant. Also, the project received an average rating of 4.4 on a scale of 1 to 5 in a survey of residents' opinions measuring the acceptance of the modern roundabout interchange, which is a high approval rating for a public works project. In addition to improved traffic performance, residents expressed appreciation of the beautiful entry statement to their world-class resort.⁽²¹⁾

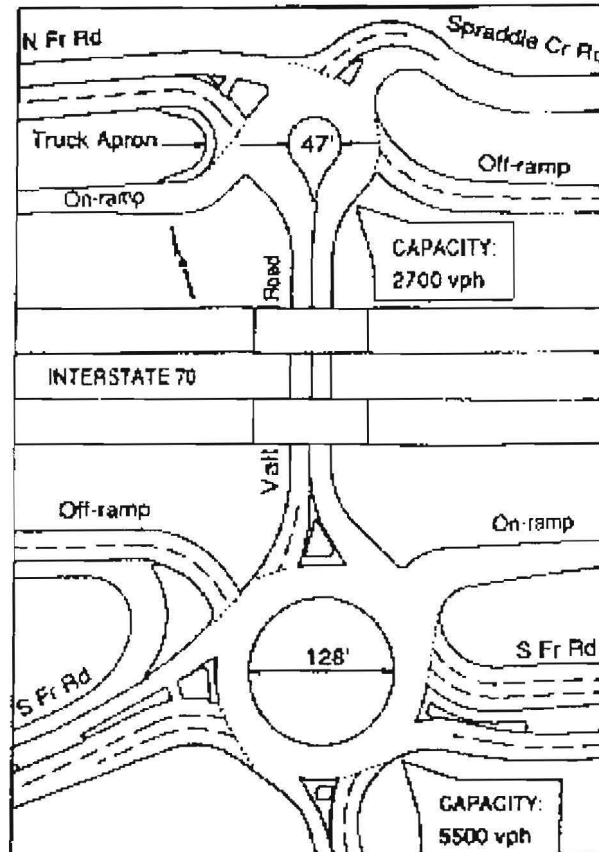


Figure 3-56. Modern Interchange Roundabout in Vail, CO. ⁽²¹⁾

Table 3-3. Capacity Comparisons for Roundabout Interchange. ⁽²¹⁾

	North	South
Former intersection capacity	1700	3200
Highest roundabout count	1884	3412
Roundabout capacity	2700	5500

Roundabouts

LESSONS LEARNED

Advantages of roundabouts include:

- Can noticeably reduce speeds
- Reduce accident potential
- Can increase capacity
- Can be used instead of Stop signs
- Reduce the number of conflict points at an intersection
- Provide an orderly and continuous flow of traffic
- Clarify priority and simplify decision making
- Increase conspicuity at the intersection
- Provide landscaping opportunities
- Are effective at multi-leg intersections

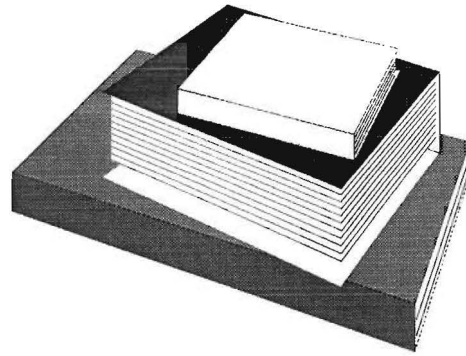
Disadvantages of roundabouts include:

- May be restrictive for some larger service and emergency vehicles unless mountable
- May lose some aesthetic quality due to required safety signing
- Require pedestrians and bicyclists to adjust to less traditional crossing patterns
- May require some parking removal on approaches to accommodate vehicles' deflected paths
- May increase accidents until drivers become accustomed to change
- May increase noise due to extra gear changing
- Require additional maintenance if landscaped

DISCUSSION

Roundabouts perform best at intersections with similar traffic volumes on each approach leg and at intersections with heavy left-turning volumes. By eliminating left turns and by reducing the number of intersection conflict points from 24 to four, roundabouts have reduced both the number of and severity of accidents in the United States and throughout Europe and Asia. In Great Britain, roundabouts have reduced the number of slight injury accidents by 34 percent and the number of serious injury accidents by 46 percent when compared to previous intersection designs. In Florida and Maryland, greater than a 50 percent reduction in average accident rates was achieved. Average accident costs also decreased by approximately 30 percent after roundabout construction.

CHAPTER 3



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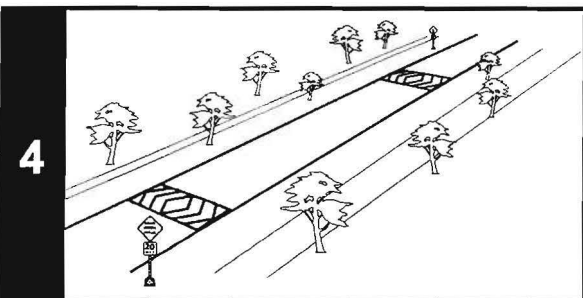
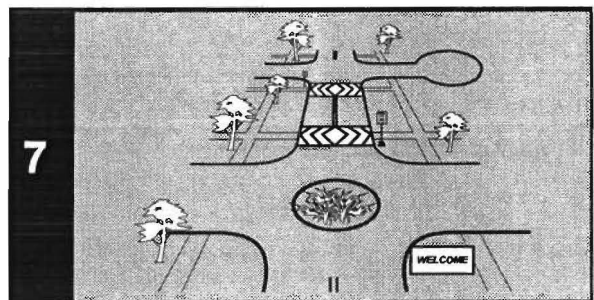
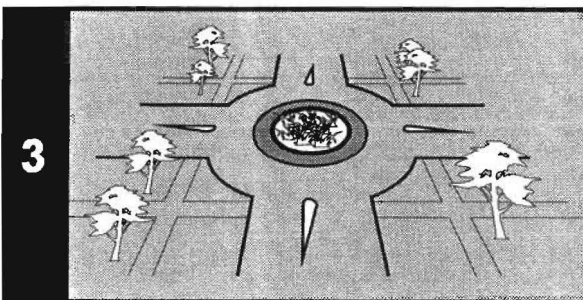
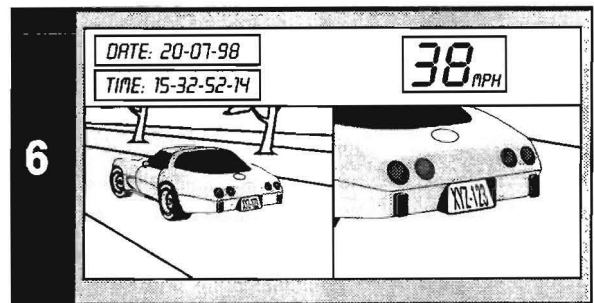
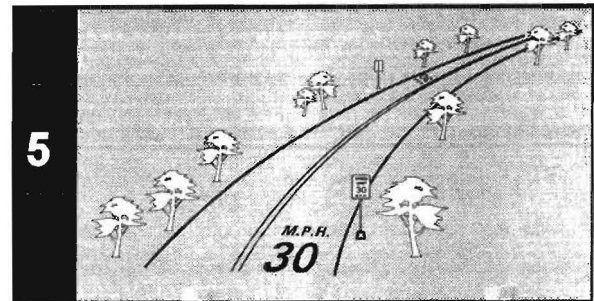
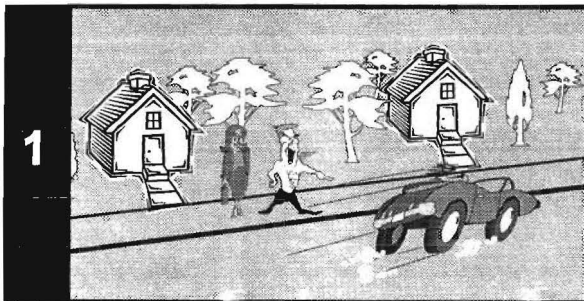
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CHAPTER 4

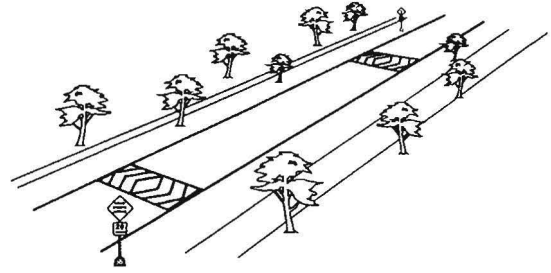
ROADWAY SURFACE

TECHNIQUES



CHAPTER 4 ROADWAY SURFACE TECHNIQUES

Speed Humps



A speed hump is a raised area in the roadway pavement surface extending transversely across the travel way, perpendicular to the traffic flow. The humps are constructed of paving materials to the height and width specified by local standards. Speed humps are typically installed in a series of at least two humps, spaced at a minimum interval to provide continuity in speed reduction. Where designed and installed with proper planning and engineering review, speed humps have generally been found to be effective at reducing vehicle speeds without increasing accident rates. Speed humps have the advantage of being largely self-enforcing and of creating a visual impression, real or imagined, that a street is not intended for speeding or through traffic.

The extent to which a series of speed humps will reduce the street's speed is affected by several factors, including the space between humps, the individual driver's perception of comfort, and the type of vehicle being driven. Speed humps' greatest effect is on drivers exceeding the posted speed limit by more than 16 km/h (10 mph). The trade-off is that they affect all drivers, even those drivers who obey the speed limit. Longer and heavier vehicles like buses, garbage trucks, and larger fire vehicles will need to go slower over speed humps than automobiles. Also, there may be an increase in noise when these larger vehicles travel over the speed humps. Speed humps are easily constructed and are relatively low cost.⁽¹⁾

CHARACTERISTICS

Speed humps are much flatter than speed bumps, which are typically used to reduce speeds in parking lots and on private streets. Speed bumps are typically 8 to 15 cm (3 to 6 in) high and are 0.3 to 0.9 m (1 to 3 ft) long while speed humps are typically 8 to 10 cm (3 to 4 in) high and approximately 3.7 m (12 ft) wide (longer than the wheel base of an automobile) (see Figure 4-1). From an operational standpoint, humps and bumps have critically different impact on vehicles. Within typical residential speed ranges, humps create a gentle vehicle rocking motion that causes some driver discomfort and results in most vehicles slowing to 24 km/h (15 mph) or less at each hump and to 40 to 48 km/h (25 to 30 mph) between properly placed humps in a system. At high speeds, the hump can act as a bump and jolt the vehicle's suspension and its occupants or cargo. A bump, on the other hand, causes significant driver discomfort at typical residential speeds and generally results in vehicles slowing to 8 km/h (5 mph) or less at the bump.

Speed Humps

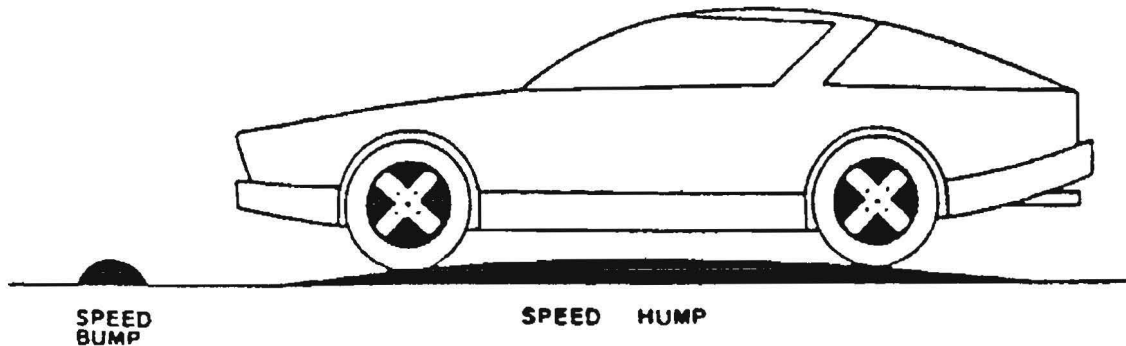


Figure 4-1. Example of Speed "Bumps" and Speed "Humps".⁽³⁾

Within the United States, speed bumps of varying designs have been routinely installed on private roadways and parking lots without the benefit of proper engineering study regarding their design and placement. Speed humps, however, have evolved from extensive research and testing and have been designed to achieve a specific result on vehicle operations without imposing unreasonable or unacceptable safety risks. NOTE: The terms "speed hump" and "speed bumps" are sometimes used interchangeably to refer to the speed humps as defined in this chapter. As illustrated in the photographs in this chapter, signing also varies and may include the terms humps or bumps to indicate speed humps.

Speed humps are typically 0.9 to 1.2 cm (3 to 4 in) in height at their highest point. Some are rounded so that the highest point is only at the center of the hump, while some humps are more square in shape. In either case, speed humps should be constructed so that there is a smooth transition for vehicles traveling at the posted speed. Speed humps are typically 3.7 to 4.3 m (12 to 14 ft) in width, allowing for a much smoother transition than that provided by speed bumps. Speed humps generally have a continuous effect on vehicle speeds if spaced 76 to 244 m (250 to 800 ft) apart. If spacing exceeds 244 m (800 ft), speed reduction occurs only at the hump itself.⁽²⁾ Most jurisdictions require a minimum of two speed humps on any given street to consider installation. Examples of various speed humps are shown in Figure 4-2 and in Figures 2-1 and 2-2.

CHAPTER
4

ROADWAY SURFACE TECHNIQUES

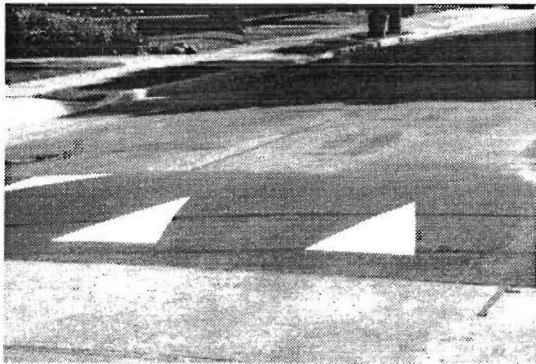
Speed Humps



Santa Barbara, CA



Montgomery County, MD



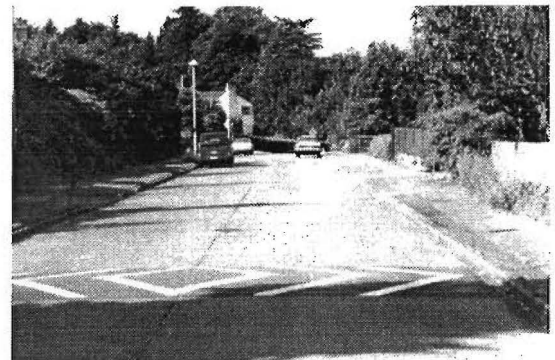
Toronto, CAN



Gwinett County, GA



Oakland, CA



Seattle, WA

Figure 4-2. Examples of Markings on Speed Humps.

Speed Humps

Portland, Oregon, uses two different shapes of speed humps according to the needs and conditions of a given street. On residential streets where speeds of 40 km/h (25 mph) are desired, 4.3 m (14 ft) speed humps that ramp up to a height of 7.6 cm (3 in) might be used. On streets where speeds of 48 km/h (30 mph) are desired, 6.7 m (22 ft) speed humps may be used. On streets that are used by transit vehicles, that are considered primary fire response routes by the Portland Fire Bureau, or that have exceptionally high volumes, the 6.7 m (22 ft) hump may be selected instead of the 5.3 m (14 ft) speed bumps.

Warning signs to inform motorists of the presence of speed humps vary; however, the signs should be consistent within a city or jurisdiction so that they are easily recognized. Figure 4-3 illustrates different warning signs. Additionally, several patterns of pavement markings exist for delineating the speed humps themselves. At this time, there are no established standards for signs or pavement markings within the MUTCD.

Impacts on maintenance activities such as snow plowing and street sweeping are minimal. The city of Austin, Texas, uses thermoplastic pavement markings in order to reduce the frequency of reapplication of the markings.

Speed humps can be constructed for \$1,000 to \$2,000. Additional funding is also needed for proper inspection and maintenance of the humps and supporting devices. The city of Brentwood, Tennessee, requires 60 percent resident funding for speed hump installation. The city of San Antonio, Texas, uses cost sharing between the city and the residents according to how much the measured speed exceeds their speed criteria (8 km/h [5 mph] over the street's legal speed limit). Cost sharing information is given in Table 4-1.

Table 4-1. Cost Sharing in San Antonio, TX.

85 th PERCENTILE SPEED	RESIDENTS' COST SHARE
56.3 to 57.9 km/h (35 to 36 mph)	100%
59.5 to 61.1 km/h (37 to 38 mph)	67%
62.8 to 64.4 km/h (39 to 40 mph)	33%
>64.4 km/h (40 mph)	0%

Notes: For a street located in a Community Development Block Grant (CDBG) area, the cost responsibility of the residents is zero percent, regardless of how much the measured speed exceeds the speed criteria. The cost for transportation engineering studies and maintenance of the speed hump is the responsibility of the city.

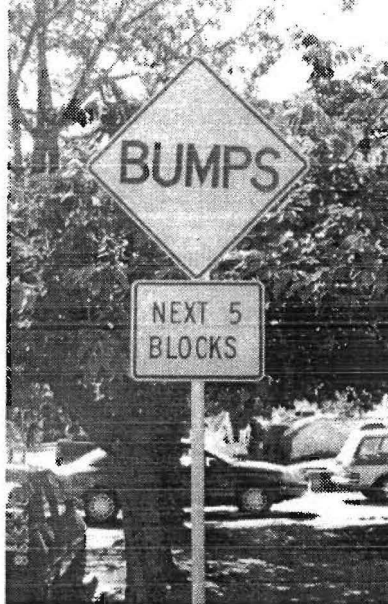
CHAPTER
4

ROADWAY SURFACE TECHNIQUES

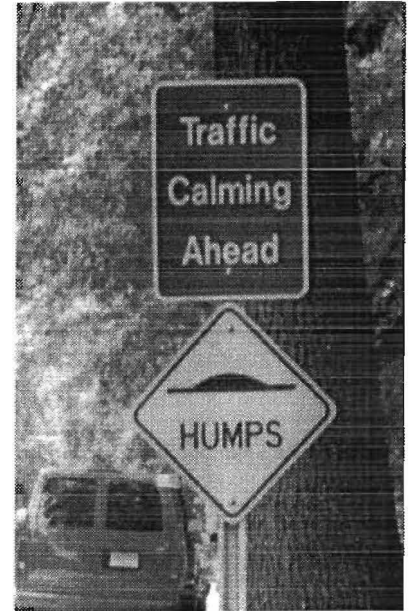
Speed Humps



Vancouver, CAN



Portland, OR



Columbia, MD



College Station, TX

Figure 4-3. Examples of Speed Hump Warning Signs.

Speed Humps

EXPERIENCES

Houston, Texas

The city of Houston, Texas, has installed 1700 speed humps to date. Requests for speed humps are evaluated by a weighted matrix system. Houston's process now includes an application by area groups only, a request for support throughout the affected area, a codified process, multiple public meetings, and justification for the installation.

Appleton, Wisconsin

A series of three speed humps were installed on Homestead Drive in Appleton, Wisconsin. The speed humps were effective in reducing the 85th percentile speed from 54.7 to 41.9 km/h (34 to 26 mph). However, the speed humps were removed 17 months after their installation based upon survey results of residents directly abutting the street where the speed humps were installed. The presence of the speed humps did not create any unusual street maintenance problems during the two winters of maintenance. After the speed humps were removed, vehicle speeds returned to the higher speeds measured prior to the installation of the speed humps.⁽²⁾

Austin, Texas

The city of Austin, Texas, began an aggressive speed hump installation program in the fall of 1994 with a total program budget of \$100,000. During the first two years of the program, approximately 115 humps were installed. After this initial period, the city staff recognized the need for a more comprehensive program using a more widespread approach to traffic calming. They are now in the process of implementing three new neighborhood plans which include traffic circles, speed cushions, textured surfaces, angled slow points, and semi-diverters in addition to speed humps. The new program has a total budget of \$500,000.

Conroe, Texas

The city of Conroe, Texas, has installed speed humps in seven locations within the city. The city has very strict policies for installation, requiring 80 percent of signatures on petitions in addition to signatures on forms regarding the location of the speed hump installation. Speed humps are installed only on residential streets.



ROADWAY SURFACE TECHNIQUES

Speed Humps

Santa Barbara, California

The city of Santa Barbara, California, reports an average of an 11.3 km/h (7 mph) reduction in speeds for speed humps installed within their city. Their hump design is 6.6 or 6.8 cm (2.6 or 2.7 in) high instead of the 7.6 or 10.1 cm (3 or 4 in) height used by many agencies. This lower height seems to cause less diversion to other streets. They use a series of humps spaced 61 to 92 m (200 to 300 feet) apart. This has been successful in reducing overall speeds by 8 to 11 km/h (5 to 7 mph) and has been sustained over time. Also, traffic diversion has been very minimal. Affected residents are defined by an area drawn by the city and varies by project. Renters (apartment) were previously included in the vote for approval; they are now informed but not included in the vote due to previous lack of response.

Kirkland, Washington

The city of Kirkland, Washington, currently has two speed humps on collector streets. They have changed their 3.7 m (12 ft) width to a 4.3 m (14 ft) width on these streets because it is less jarring and just as effective. The city requires a 70 percent approval from affected residents.

Portland, Oregon

The city of Portland Bureau of Traffic Management undertook a study of speed bumps (humps) in 1991. As the result of two years of testing, speed bumps became a standard tool for addressing the problem of speeding on Portland's residential streets. The 4.3 m (14 ft) speed bump was adopted for local service streets that do not have transit or are not on a primary fire response route. The 6.7 m (22 ft) speed bump was adopted for streets with high volumes of traffic and those that are transit or primary fire response routes. The Traffic Calming Program has been installing speed bumps since 1992 and installed more than 100 new speed bumps in 1995-1996.⁽⁴⁾

With so many bumps installed and so many more streets on the waiting list, the Fire Bureau and the Bureau of Traffic Management became concerned about the cumulative effect of how several speed bump streets along any emergency route could impact emergency response time. The goal of the Portland Bureau of Fire and Emergency Services is a response time of four minutes or less on 90 percent of emergency calls. A study found that the amount of increase in time due to speed bumps was dependent upon the type of vehicle and the type of traffic calming. Rescue vehicles were not slowed over the 6.7 m (22 ft) bumps, while trucks and engines were slowed as much as nine seconds per bump. It was decided that an "emergency response route" street classification system needed to be developed before any more traffic slowing devices could be placed on emergency response routes. The process of developing this system and policy is a long and detailed task that could take several

Speed Humps

years to complete. All projects planned for streets currently used as primary routes by the Fire Bureau were put on hold until the classification process was completed.⁽⁴⁾

In the meantime, the Traffic Calming Program needed a device that would accommodate the Fire Bureau vehicles and still slow speeding motorists, so they developed the split hump, as shown in Figure 4-4. The split hump divides at the roadway centerline, allowing emergency vehicles to go around the hump rather than across it. The split hump was tested as a temporary measure at the Fire Bureau Training Center using the vehicle with the least maneuverability; the truck was 11.9 m (39 ft) long and 2.5 m (8 ft, 4 in) wide with a wheel base of 5.6 m (18 ft, 6 in). The device was also tested in two on-street installations, and modifications to the distances between the bumps were made as suggested by the Fire Bureau (the distance was increased from 8.5 to 15.2 m [28 to 50 ft]). The split speed bump was found to effectively slow traffic speeds without delay to emergency vehicles. This was especially evident on high-volume streets where drivers showed no tendency to cross over the center line to avoid the bump. The removal of on-street parking was necessary for the devices to operate well on the street widths tested (11 to 12.8 m [36 to 42 ft]). Therefore, the advantages of slower vehicle speeds versus the need for on-street parking need to be considered for this speed bump application. The test devices have been removed; no split humps are in place at this time.⁽⁴⁾

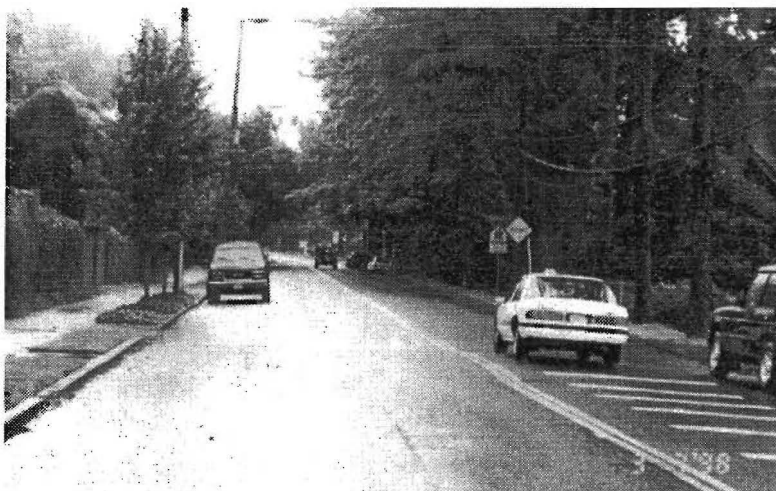


Figure 4-4. Speed Hump in Portland, OR.

CHAPTER
4

ROADWAY SURFACE TECHNIQUES

Speed Humps

Sarasota County, Florida

In June 1998, the Circuit Court in and for Sarasota County, Florida, ruled that the city of Sarasota must remove speed humps and speed tables erected on various streets. The court agreed with arguments made by two city residents that speed humps and speed tables were traffic control devices that must comply with the *Manual on Uniform Traffic Control Devices* (MUTCD) as directed by Florida statutes. The court's review of MUTCD revealed that it does not address speed humps or speed tables; therefore, the court ruled that the traffic calming devices do not conform to the MUTCD and are in violation of Florida law. The court rejected arguments by experts testifying on the city's behalf that speed humps and speed tables are not traffic control devices. The city of Sarasota is "permanently enjoined" from erecting speed humps or speed tables and "permanently and mandatorily enjoined" to remove all speed humps and speed tables previously erected and to "restore the effected streets and highways to the condition they were prior to the construction of the speed humps and speed tables."⁽⁵⁾ The county is appealing the decision.

LESSONS LEARNED

Advantages of speed humps include:

- Reduce speed
- May shift traffic to arterial streets and reduce through traffic in neighborhood
- Allow on-street parking
- Relatively inexpensive to install
- Do not affect intersection operations

Disadvantages include:

- May shift traffic to parallel residential streets
- Can slow emergency vehicles and affect emergency response times
- Can jar vehicle contents
- May increase noise levels from braking and acceleration at speed hump

To enhance aesthetic considerations, speed humps can be constructed of special materials such as brick pavers or specially treated concrete asphalt (rather than typical asphalt installations) to enhance their appearance. However, consideration should be given to street maintenance requirements in the area and to whether special materials can be properly maintained by the responsible agency.

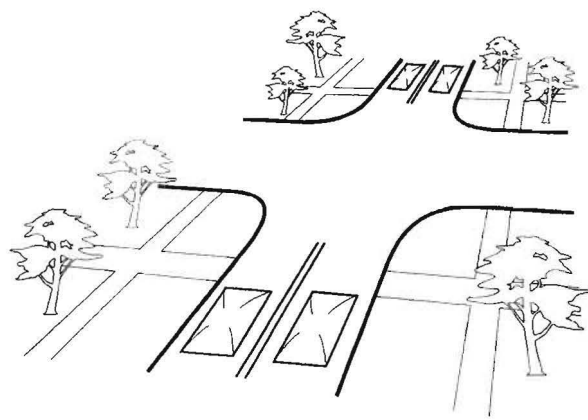
Speed Humps

DISCUSSION

Extensive research and use throughout Great Britain, Australia, the United States, and other countries indicate that the use of properly designed speed humps or speed hump systems can be useful in managing traffic speed on roadways intended to serve as local residential streets. Speed humps have also been used successfully on some collector streets. Speed humps have been found, in general, to reduce traffic speeds, volumes, and accidents depending on the site-specific circumstances of the installation. In addition, they discourage through traffic from using a local street as an alternative route to inconvenient or congested arterial and collector systems. The safety of speed humps and their ability to perform their intended use is directly contingent upon their proper design and application.⁽⁴⁾

CHAPTER 4 ROADWAY SURFACE TECHNIQUES

Speed Tables, Raised Intersections, and Speed Cushions



Vertical changes in roadway surface (in addition to speed humps) include speed tables, raised intersections, and speed cushions. Speed tables are basically extended speed humps consisting of a longer flat section in the center and ramps on each side. Raised intersections, or intersection humps, elevate an entire intersection area above the normal roadway surface. Speed cushions, or pillows, are smaller raised areas within a traffic lane which cannot be easily avoided by a vehicle.

CHARACTERISTICS

Speed tables are elevated plateaus in the roadway with a descending ramp on each side. They may be constructed of asphalt or of distinctive materials such as pavers or tiles, and they may be installed at intersections or midblock. Speed tables may also serve as raised crosswalks and are also known as raised pavements because they raise the road level to the level of the bordering footway. Speed tables typically have a 1.8 m (6 ft) parabolic approach transition rising to 7 to 10 cm (3 to 4 in) above the nominal pavement surface. The flat section of the table is usually 3 to 3.7 m (10 to 12 ft) wide and is striped in accordance with *Manual on Uniform Traffic Control Devices* standards for crosswalks if used as a pedestrian crosswalk. Speed tables may also be used in place of speed humps, providing a longer and smoother transition for vehicles.⁽⁶⁾

Raised intersections (also known as raised humps or plateaus) elevate the entire intersection above street grade to reinforce the character of the area. Raised intersections are used more often in commercial areas with high-pedestrian volumes, and they are typically constructed of bricks, pavers, or other textured material to draw attention and to provide a change in roadway surface. The plateaus are generally about 10 cm (4 in) higher than the surrounding streets.⁽⁶⁾

Speed cushions or speed pillows are similar to speed humps but cover only a portion of a traffic lane rather than extending across the entire roadway. Speed cushions are designed to limit the vertical deflection of vehicles with wide track widths by allowing these vehicles to straddle the cushions. Vertical deflection for vehicles with smaller track widths is maintained as these vehicles are forced to ride over the cushions with at least one set of wheels. On multi-lane roadways, speed cushions are typically installed parallel to each other in adjacent lanes. Speed cushions may be constructed of asphalt, rubber, brick, pavers, concrete, or other materials. A study of speed cushion installations as part of 34 traffic calming schemes in England indicated that speed cushions are effective as a speed-reducing measure but not quite as effective as speed humps. The overall average mean and 85th percentile speeds at the cushions were 3.2 to 11.2 km/h (2 to 7 mph) higher than those measured

Speed Tables, Raised Intersections, and Speed Cushions

at speed humps. Reactions from both emergency services and bus operators were generally positive. However, there was some evidence to suggest that residents may prefer speed humps. Maintenance items that had to be addressed during the study included: sheared bolts on molded rubber cushions; deformation of molded rubber cushions; partial lifting of molded rubber units; repairs of block paved cushions; and modifications of concrete units. No maintenance was required for asphalt cushions.⁽⁷⁾

EXPERIENCES

A series of eight speed tables has been installed on Winn Drive in Gwinnett County, Georgia, as shown in Figure 4-5. The speed limit is 40 km/h (25 mph), and the eight speed tables are installed over a 1.3 km (0.9 mi) section of roadway. The speed tables function as extended speed humps, providing a more gradual change in elevation for approaching vehicles.

A speed table has been constructed on Eliots Oak Road in Columbia, Maryland, as shown in Figure 4-6. It is constructed of asphalt and marked with chevron-style pavement markings to add visibility. The speed table may also be considered a raised intersection because it raises the elevation of the T-intersection with Broken Oak Lane. The speed table is used in conjunction with other speed management techniques including speed humps, chokers, and high-visibility crosswalks.



Figure 4-5. Car on Speed Table in Gwinnett County, GA.

CHAPTER
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ROADWAY SURFACE TECHNIQUES

Speed Tables, Raised Intersections, and Speed Cushions

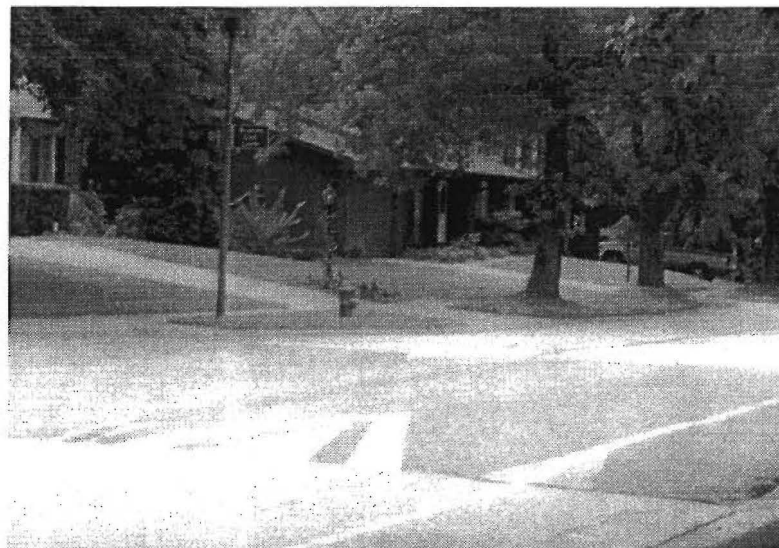
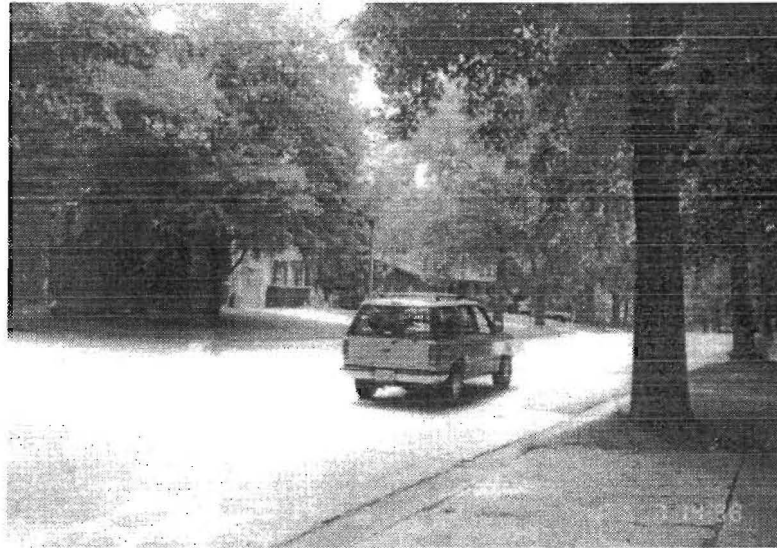


Figure 4-6. Speed Table in Columbia, MD.

Speed Tables, Raised Intersections, and Speed Cushions

The city of Hampton, Virginia, recently constructed a raised intersection in a high-pedestrian area, as illustrated in Figure 4-7. The raised intersection was constructed in conjunction with a new traffic signalization plan and is constructed of contrasting colors of brick pavers using diamond patterns. The raised intersection is located on a 56 km/h (35 mph) arterial with an ADT of approximately 18,000 to 20,000 vehicles per day.

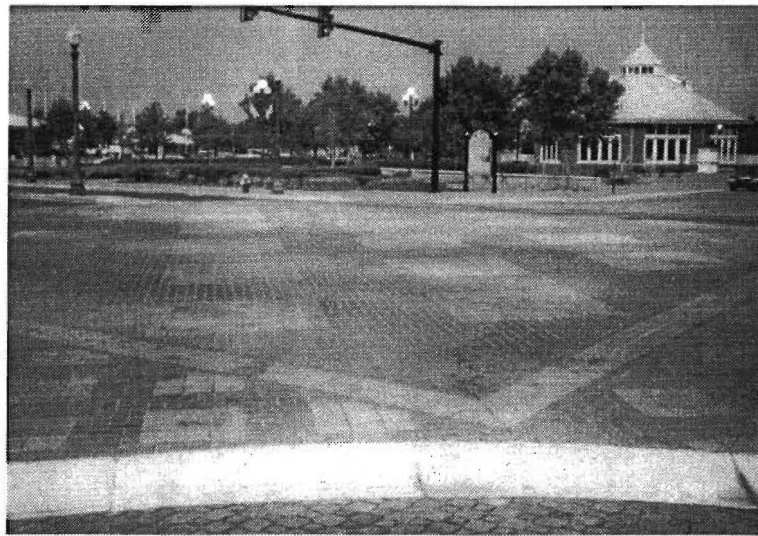


Figure 4-7. Raised Intersection in Hampton, VA.

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Speed Tables, Raised Intersections, and Speed Cushions

The city of Austin, Texas, recently installed temporary speed cushions to test sizes and locations for future installations. The dimensions used in the test were wide enough so that a passenger car had to cross the cushion, but the back tires of emergency vehicles also had to traverse the cushion which creates concerns with the truck loads on the pavement. The emergency services officials were still more comfortable with the cushion than with speed humps. Photographs of similar speed cushions installed in Germany are included in Figure 4-8.

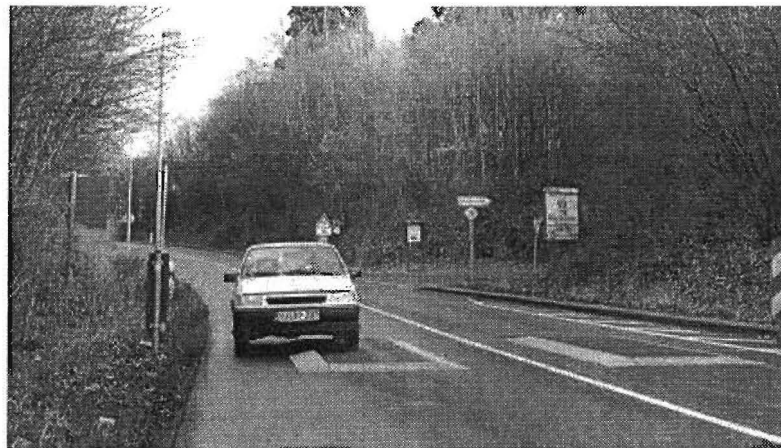


Figure 4-8. Speed Cushions in Germany.

ROADWAY SURFACE TECHNIQUES

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Speed Tables, Raised Intersections, and Speed Cushions

LESSONS LEARNED

Advantages of speed tables, raised intersections, and speed cushions are:

- Reduce speeds
- Draw attention to intersection and pedestrian areas
- Can be used on higher or lower volume streets
- Can be aesthetically pleasing

Disadvantages include:

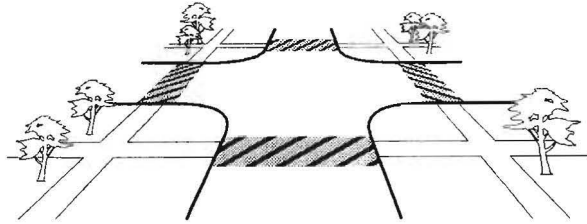
- May be expensive to construct and maintain
- May affect emergency vehicle response times
- Require additional signage and driver education

DISCUSSION

Speed tables, raised intersections, and speed cushions are vertical techniques used to reduce speeds. These measures are less severe than speed humps but are still effective in reducing speeds.

CHAPTER 4 ROADWAY SURFACE TECHNIQUES

Crosswalks and Wider Sidewalk Areas



The sharing of the roadway between pedestrians and motor vehicles is a difficult task. Vehicles, which are the more predominate users of the roadways, are larger, heavier, and operate at higher speeds. These characteristics make the use of the roadway by pedestrians a challenging effort. Accommodating pedestrians within the roadway, however, is imperative if a shift from automobiles to walking is to be achieved and the collision rate between vehicles and pedestrians is to be reduced. Attention can be drawn to pedestrians through the use of high-visibility crosswalks or wider sidewalk areas. In both of these cases, the objective is to inform drivers of the presence of pedestrians so that drivers will reduce speed in the area.

CHARACTERISTICS

A crosswalk is generally defined as the portion of roadway designated for pedestrians to use in crossing the street. The standard crosswalk consists of two parallel white lines; however, diagonal or longitudinal lines may be added for increased visibility. Higher visibility crosswalks have been implemented to increase driver recognition through the use of the following techniques: raising the crosswalk to a grade higher than the roadway, designing the crosswalks with paving blocks or contrasting color concrete, or painting the crosswalks with zebra or ladder stripes between the outer boundary stripes. Figures 4-9 to 4-12 illustrate techniques used to increase the visibility of a crosswalk. Installation costs vary from \$1,000 to \$5,000 depending upon the treatment type selected.

Raised crosswalks are constructed 7.6 to 10.1 cm (3 to 4 in) above the elevation of the street and are typically at least 6.7 m (22 ft) wide. Raised crosswalks are intended to reduce vehicle speeds specifically where pedestrians will be crossing a street. Raised crosswalks may generate noise from vehicles decelerating and accelerating. Consideration for visually impaired persons dictates not placing a raised crosswalk at the same elevation as the sidewalk because a pedestrian should be able to tell when he is entering an area shared with vehicles.⁽⁸⁾ Experience shows that raised crosswalks shouldn't impede transit service or scheduling. However, in Portland, Oregon, the Fire Bureau reviews all raised crosswalks that are proposed on their primary response routes.

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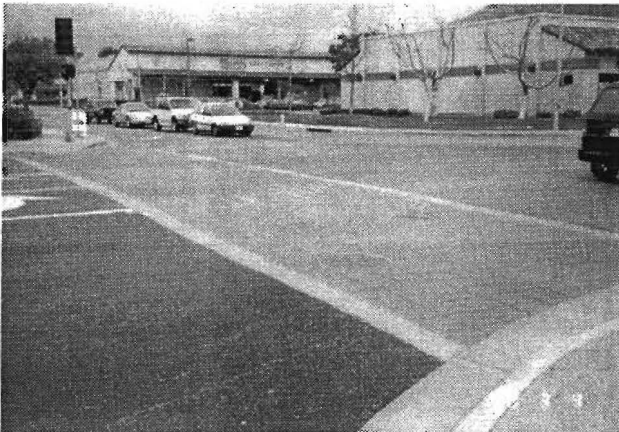
Crosswalks and Wider Sidewalk Areas



**Figure 4-9. Zebra Pattern
in a Crosswalk in Santa Barbara, CA.**



**Figure 4-10. Lattice Crosswalk Markings
in Oakland, CA.**



**Figure 4-11. Brick Pavers in
a Crosswalk in Ventura, CA.**



**Figure 4-12. Ladder Style High-
Visibility Crosswalk in Santa Barbara, CA.**

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ROADWAY SURFACE TECHNIQUES

Crosswalks and Wider Sidewalk Areas

Wider sidewalk areas can provide additional space for pedestrians, street furniture, or landscaping that provides a more pedestrian-friendly area. The pedestrian areas may also be constructed of contrasting materials to draw attention to the area, as shown in Figures 4-13 to 4-17. Enhancing the pedestrian area alongside the roadway can alert drivers of the likelihood of pedestrian activity.

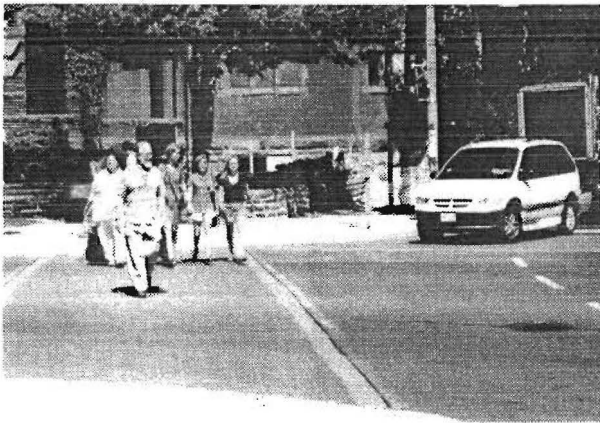


Figure 4-13. Crossing with Brick Pavers in Toronto CAN.

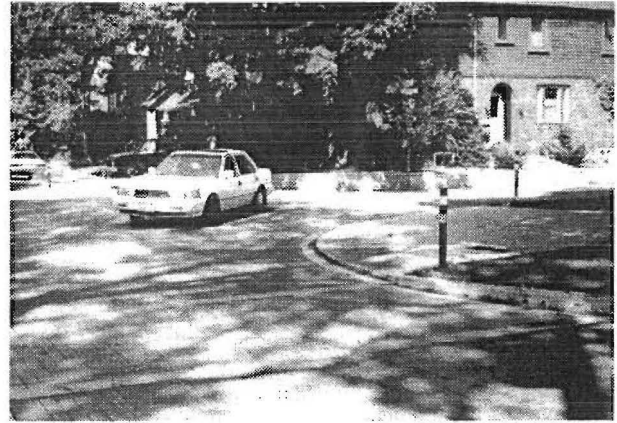


Figure 4-14. Crossing with Contrasting Pavers in Toronto, CAN.

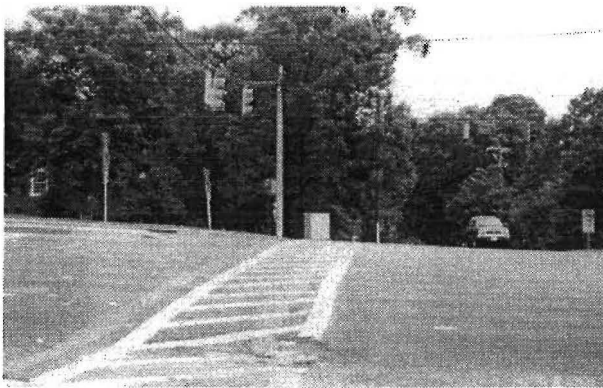


Figure 4-15. High-Visibility Crosswalk in Greenbelt, MD.

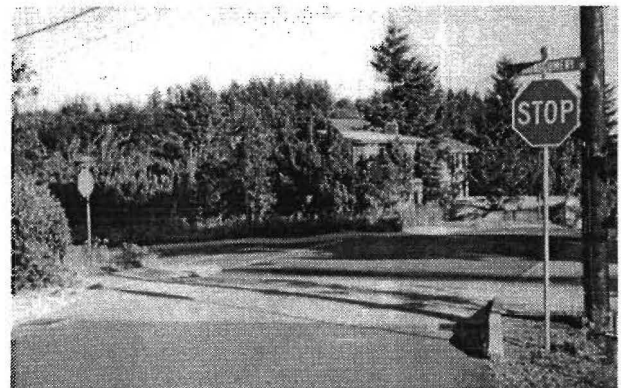


Figure 4-16. Raised Crosswalk in Portland, OR.

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Crosswalks and Wider Sidewalk Areas



Figure 4-17. Example of Enhancing the Pedestrian Area with Landscaping, Toronto, CAN.

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ROADWAY SURFACE TECHNIQUES

Crosswalks and Wider Sidewalk Areas

EXPERIENCES

An ITE survey on the state-of-the-practice survey found that most agencies reported a conservative use of marked crosswalks. Fifty-eight percent stated they did not use a high-visibility crosswalk design (defined in the survey as being longitudinal or diagonal markings). Of those agencies who did use a high-visibility design, most keep this use to a very small percentage of their total marked crosswalks (less than 5 to 10 percent). Factors considered to warrant the use of high-visibility crosswalk markings included one or more of the following: high-vehicle speeds, high-pedestrian volumes, school crossings, midblock crosswalks, unexpected crossing locations, and engineering judgment.⁽⁸⁾

In the downtown University of Texas area in Austin, Texas, the city has removed a left-turn lane and added wider pedestrian and bicycle areas. The wider area provides safety for bicyclists, additional parking for shopping, and wider sidewalks and safer areas for pedestrians (Figure 4-18). This is a unique project which is a cooperative effort involving the city of Austin, The University of Texas, and Capital Metro (the local transit agency). The first phase of the project proved to be so successful that a second phase was approved and is under construction.

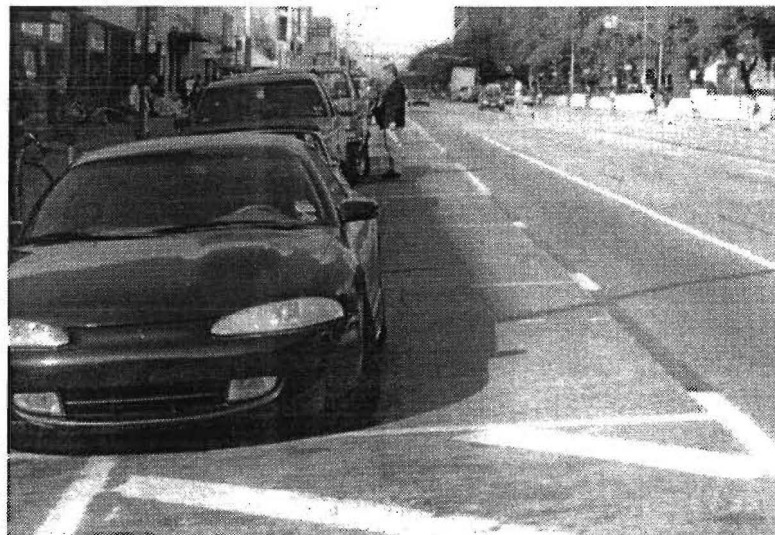


Figure 4-18. Wide Pedestrian/Parking Area in Austin, TX.

Crosswalks and Wider Sidewalk Areas

LESSONS LEARNED

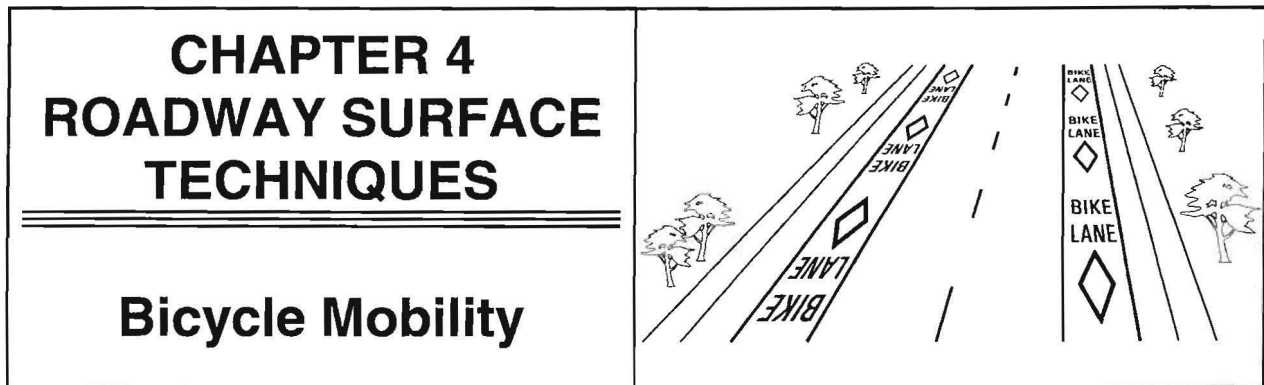
The advantages and disadvantages of higher visibility crosswalks and wider pedestrian areas are listed in Table 4-2.

Table 4-2. Advantages and Disadvantages of Crosswalks and Wider Sidewalks.

	Advantages	Disadvantages
Crosswalks	<ul style="list-style-type: none"> • Indicate the preferred crossing location to pedestrians • Provide more visibility to drivers than traditional crosswalks • Alert drivers of pedestrian activity in an area where pedestrians may not be expected to cross (e.g., mid-block crossings) • Attract pedestrians to cross within the markings 	<ul style="list-style-type: none"> • May provide an increased false sense of security to pedestrians that the higher visibility markings will limit driver's speed • May require more maintenance than traditional crosswalks • Are more expensive to install than traditional crosswalks • Haven't proved to be safer than traditional crosswalks • Require consideration of the effect of additional marking materials (e.g., diagonal or longitudinal lines) on vehicle tire paths and the slipperiness of the surface where wet weather or snow conditions exist
Wider Sidewalks	<ul style="list-style-type: none"> • Provide additional space for pedestrian movement • Add potential for street furniture to be located in the area • Can improve the aesthetics of the area 	<ul style="list-style-type: none"> • Increase construction and maintenance costs

DISCUSSION

Higher visibility crosswalks and wider pedestrian areas draw attention to pedestrian crossing areas to reduce speeds and inform drivers of the potential for pedestrians in these areas. Differences in texture, highly visible pavement markings, and streetscaping measures can make drivers more aware of pedestrian activity.



According to the Bicycle Institute of America, nearly 100 million people in the United States own bicycles; however, the Bicycle Federation of America estimates that fewer than 5 percent are classified as experienced bicyclists.⁽⁹⁾ Impacts on bicycling are often overlooked when speed management programs are implemented; however, bicycling and traffic calming can be compatible. Many bicyclists prefer streets with few cars and slower traffic, which are qualities of a traffic-calmed street.

CHARACTERISTICS

Bicycle traffic may be accommodated by shared roadways, wide outside lanes, bike lanes, separate bike paths, or with a bicycle route. A shared roadway is any roadway where a bicycle lane is not designated and which may be legally used by bicycles; the standard shared lane is 3.7 m (12 ft) wide. A shared roadway may have a wider outside lane to assist in accommodating bicyclists and is usually at least 4.2 m (14 ft) wide; however, this area is not specifically marked for bicyclists' use. A bike lane is a portion of a roadway which has been designated by signing and pavement markings for the preferential or exclusive use of bicyclists. A separate bike path is physically separated from motorized vehicular traffic by an open space or barrier and may be either within the highway right-of-way or within an independent right-of-way. A bike route is designated with appropriate directional and informational markers. Additionally, bicycles often use the roadway shoulder. They may also be prohibited from specific streets through local ordinances and regulatory signing.

EXPERIENCES

Figure 4-19 illustrates a separate bicycle lane in Ventura, California. The lane is signed with pavement markings indicating its exclusive use for bicyclists.

An example of a bicycle path crossing a collector street is shown in Figure 4-20. This crossing is constructed with red pavers, wide pavement markings, and bicycle symbols which make it more visible to motorists. The bicycle path also connects to a bicycle/pedestrian trail and has a unique flashing beacon with the image of bicycle in yellow (Figure 4-21).

Bicycles are prohibited from using Texas Avenue in College Station, Texas. Regulatory signs on streets intersecting Texas Avenue alert cyclists that they are not allowed to use the major arterial street. Bicycles near Greenbelt, Maryland, share the roadway with motor vehicles, as indicated by the sign in Figure 4-22.

Bicycle Mobility



Figure 4-19. Bicycle Lane in Ventura, CA.



Figure 4-20. Bicycle Crossing in Monterey, CA.



Figure 4-21. Bicycle Crossing Sign with Flashing Bicycle Indication in Monterey, CA.



Figure 4-22. Share the Road Bike Sign in Greenbelt, MD.

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Bicycle Mobility

Figure 4-23 illustrates how bicycles and pedestrians can be accommodated by speed management techniques with proper planning. The recently installed diagonal diverter provides a pedestrian/ bicycle crossing to allow access.

Traffic calming can also be implemented specifically to encourage bicycling with a *bicycle priority street*. As originally conceived in Palo Alto, California, a bicycle priority street is a roadway where bicycle traffic has right-of-way priority over intersecting streets, and periodic full-width barriers discourage through motor vehicle traffic. Bicycle priority streets provide bicyclists with three advantages that usually do not exist simultaneously in the current street network: a low-volume traffic alternative where bicycles and motor vehicles can share the roadway without conflicts; significantly reduced travel time since bicyclists on the route are granted the right-of-way at as many intersections as possible (usually accomplished by converting four-way stops to two-way stops or by switching two-way stops to stop the cross street rather than the bicycle priority street); and a route where two or more bicyclists can safely ride side-by-side, increasing the attractiveness to families and other cyclists who enjoy conversing while riding.⁽¹⁰⁾ Figure 4-24 shows an example of priority given to bicyclists on a roadway.

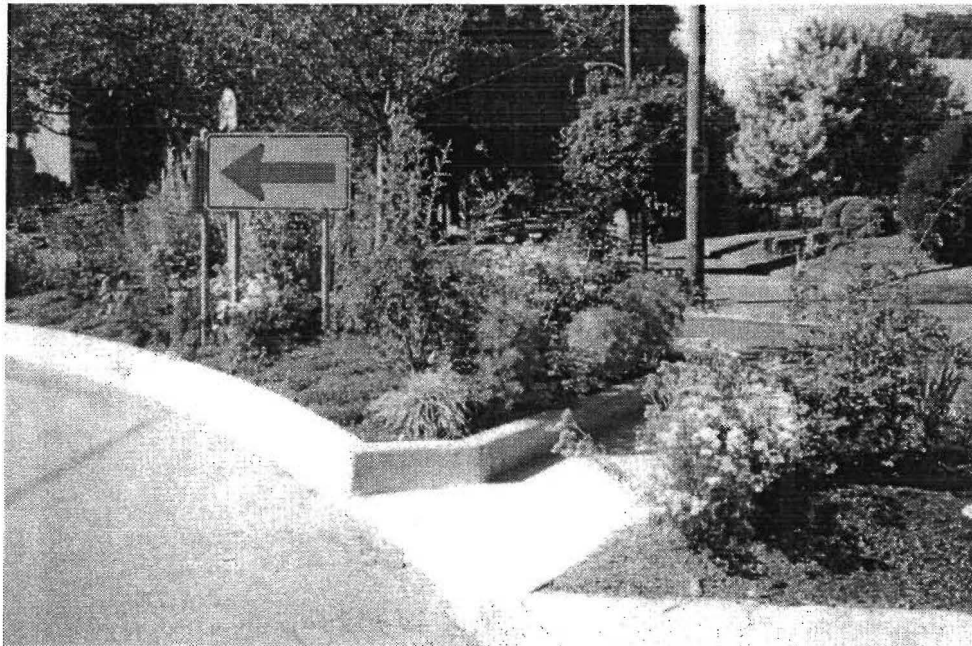


Figure 4-23. Access Through Diverter in Portland, OR.

Bicycle Mobility



Figure 4-24. Example of Bicycle Priority in Toronto, CAN.

LESSONS LEARNED

“Traffic calming has improved bicyclists’ safety. Both the incidence and severity of crashes involving bicyclists have been reduced, primarily through the reduction in speed of motor vehicles. Bicycle use has also increased through traffic calming measures.”⁽¹¹⁾

Speed management techniques can be compatible with bicycle use when the techniques are carefully planned. The most bicycle-compatible traffic calming techniques and their benefits are:⁽¹⁰⁾

- Speed humps, speed tables, and raised intersections: produce small but consistent speed and volume reductions but only in their immediate vicinity.
- Traffic circles on streets with fairly low volumes: moderately effective in reducing both speed and volume.

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ROADWAY SURFACE TECHNIQUES

Bicycle Mobility

- Road closures (traffic barriers): most effective of all traffic calming measures for bicycle traffic.
- Half closures: less intrusive, offer greater flexibility in placement, and allow emergency vehicles to pass.
- Forced turn channelization: can be highly effective if existing geometry permits it to be used and is less coercive than road closures. It is a good substitute for diagonal diverters.
- Median barriers: prevent through vehicular movements but can be configured to permit other movements. If there is significant uncontrolled cross traffic, the median can include a bicycle refuge.
- Traffic signals: can be coordinated for a speed suitable to bicycle travel (e.g., 13 to 24 km/h [8 to 15 mph]).
- Textured surfaces: have little effect by themselves and are most useful as a visual cue to reinforce more restrictive design features.
- Reduced corner radii: slow traffic, thereby improving safety at intersections.

The following measures are not recommended as traffic calming techniques for use with bicyclists in general, as other measures can provide the same effects:

- Meandering roadways: tend to cause erratic movements by motorists and increased travel distances for bicyclists.
- Chicanes: tend to force motorists and bicycles into a narrow space; they are appropriate only where volumes are very low (< 1000 vpd).
- Stop signs used as traffic calming devices: dramatically increase delay to bicyclists unnecessarily.
- Rumble strips: cause a very uncomfortable ride for bicyclists which can lead to steering difficulties, loss of control, and falls.

Bicycle Mobility

The following techniques may be used under the conditions noted:

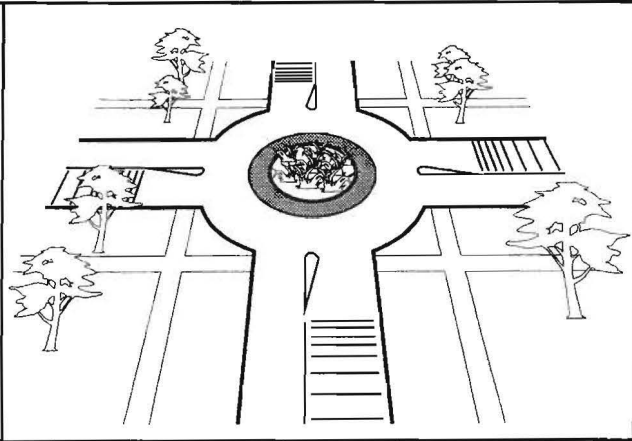
- Curb extensions or bulbouts: usually narrow the roadway to two narrow lanes resulting in less room for motorists and bicyclists to share but benefits pedestrians by reducing crossing widths and increasing visibility. Curb extensions are acceptable as long as 4.3 m (14 ft) of the travel lane remains for bikes and motorized vehicles to share.
- Median islands: used to provide a refuge for pedestrians and/or reduce roadway width. By continuing a median through an intersection, median islands also restrict access to a street. By retaining adequate curb lane width (4.3 m [14 ft] minimum) and providing curb cuts, they can be compatible with bicycling.
- Turn restrictions: usually used to prevent motor vehicle traffic from diverting onto side streets during peak hours or from increasing the congestion at a certain intersection. In either case, bicyclists should be exempted from turn restrictions as long as a turn can be made safely.

DISCUSSION

Since bicyclists are permitted on all roadways except designated freeways in most states, speed management techniques should always be safe for bicyclists (at a minimum). Bicyclists can benefit from speed management projects, and some techniques can be implemented specifically to encourage bicycling. It is reasonable to treat bicyclists differently than motorized vehicle traffic when designing speed management techniques because most residents do not consider bicycle traffic on their streets a nuisance or hazard, many bicyclists prefer to ride on streets where traffic is light, and many cities would like to actively promote bicycle travel as an environmentally sound method of transportation.⁽¹⁰⁾

CHAPTER 4 ROADWAY SURFACE TECHNIQUES

Innovative Pavement Markings



Drivers sometimes fail to realize that the speeds at which they are traveling are too fast for the existing highway environment. Also, drivers who have traveled at a relatively high rate of speed for an extended time may underestimate the degree to which they are lowering their speed when they approach an intersection, traffic circle, bridge, horizontal curve, or construction zone. Illusion-creating pavement markings have been developed to reduce traffic speeds and traffic crashes that result from driver inattention and habituation to high-speed driving.⁽¹²⁾ Pavement markings and/or reflectors and buttons may also be used to create the illusion of narrowed or narrowing lanes, to add a parking lane, or to develop on-street parking, particularly on collector and arterial streets.

CHARACTERISTICS

The markings discussed in this section include the converging chevron pavement marking pattern, the transverse bar pavement marking pattern, and markings used to give the illusion of a narrower roadway.

The Transverse Bar Pavement Marking Pattern

The transverse bar pattern consists of a series of stripes or bars placed across the roadway perpendicular to the path of traffic. The first bars encountered are widely spaced; subsequent bars in the pattern are placed closer and closer together so that drivers encounter the bars at an increasing rate. When this pattern works as intended, drivers perceive that they are failing to reduce their speed as rapidly as they should as they proceed through the pattern (see Figure 4-25). This pattern has been used at the approaches to roundabouts that are preceded by long stretches of highway on which drivers could maintain higher speeds. Other applications of this pattern are approaches to intersections, horizontal curves, construction areas, and freeway off-ramps. Figure 4-26 illustrates the lengths and number of bars contained in five different studies as well as the spacing between the bars. The visual patterns presented to drivers traversing the five patterns depicted in this figure are quite different.

Innovative Pavement Markings

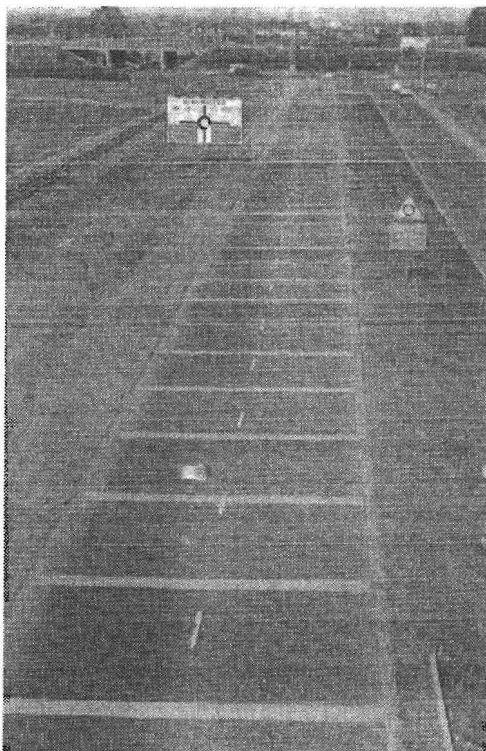


Figure 4-25. Transverse Bar Pattern at the Approach to a Roundabout in England.⁽¹²⁾

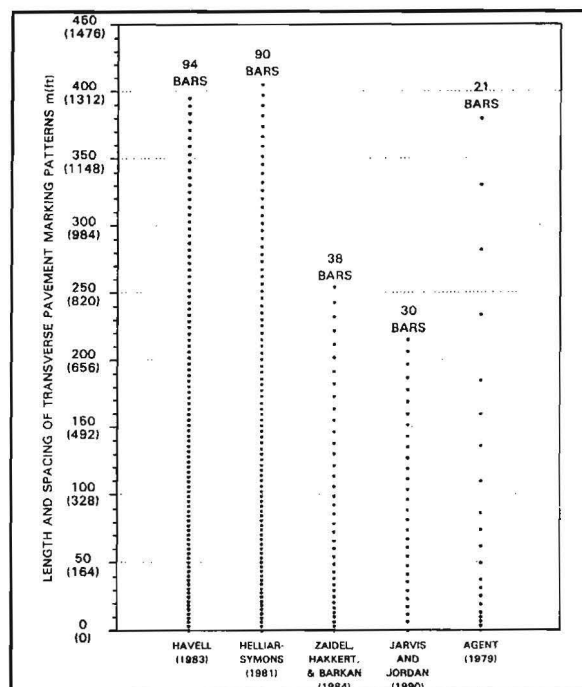


Figure 4-26. Interbar Spacings Employed in Five Different Transverse Bar Patterns.⁽¹²⁾

Speed studies for these projects provided the following results, which are not too surprising with the variations in patterns, traffic, geography, and climate:⁽¹²⁾

- Most studies indicated that traffic speeds could be reduced by application of transverse bar markings. Reductions in average speed were typically less dramatic than reductions in 85th percentile speeds.
- Some studies show reductions in speed variability associated with transverse bars; others show no appreciable effect on speed variability.
- Some studies suggest that the speed-reduction effectiveness of the patterns can be maintained for many months; others suggest the benefits of the markings are quite transitory and fade within a matter of days or weeks.

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Innovative Pavement Markings

- When transverse markings were used in conjunction with rumble strips, speed reduction was enhanced, but speed variability tended to increase.
- Speed reductions associated with transverse bar markings may be more pronounced during the day than at night.
- Transverse bar markings may reduce traffic speeds for reasons other than those originally proposed. Rather than creating the illusion that drivers are driving too fast, the patterns may simply function as warning signals indicating to drivers they should reduce their speeds.

The cost of installing transverse pavement markings depends upon several variables, including the number of bars in the pattern, material from which the bars are constructed, and labor costs. In 1973 and early 1974, the cost of a typical transverse pavement marking project consisting of 90 bars of yellow thermoplastic was \$985. The cost of that same pattern in the mid 1990s would be approximately \$3,275, and it could be expected to have a useful service life of five years. Another pattern consisting of 30 bars constructed of reflective tape cost \$609 in 1975, and the effective service life of this project was estimated to be about one year.

The Converging Chevron Pavement Marking Pattern

The converging chevron pattern is a more recently developed pattern from Japan. This pattern is characterized by a set of chevrons on the pavement surface that are placed progressively closer together so that the space between adjacent chevrons decreases as a driver travels through the pattern. Each chevron extends across one lane of traffic, and traffic flow is in the direction indicated by the chevrons (see Figure 4-27). The intent of this pattern is to create the illusion that drivers are traveling faster than they really are and to give the impression of narrowing traffic lanes.

Individual chevrons are divided into the two categories of standard and anti-skid. The standard chevron is a white painted or thermoplastic “V” that points in the direction of travel. At the start of the pattern, the width of the “legs” or lines forming the chevron is 150 cm (59 in). The leg width is gradually narrowed in later chevrons, and chevrons near the end of the pattern have leg widths of 30 cm (12 in). The angle formed by the legs is 60 degrees (see Figure 4-28). Anti-skid chevrons are formed from two to 10 narrow, 15 cm (6 in) wide stripes with 5 cm (2 in) gaps between them. The first anti-skid chevron in a pattern is formed from 10 stripes, and the last is formed from two stripes. The angle formed by the legs is 60 degrees as it is for the standard chevron.

Innovative Pavement Markings



Figure 4-27. Converging Chevron Pattern on Route 371, Kawachinago Bypass, Japan. ⁽¹²⁾

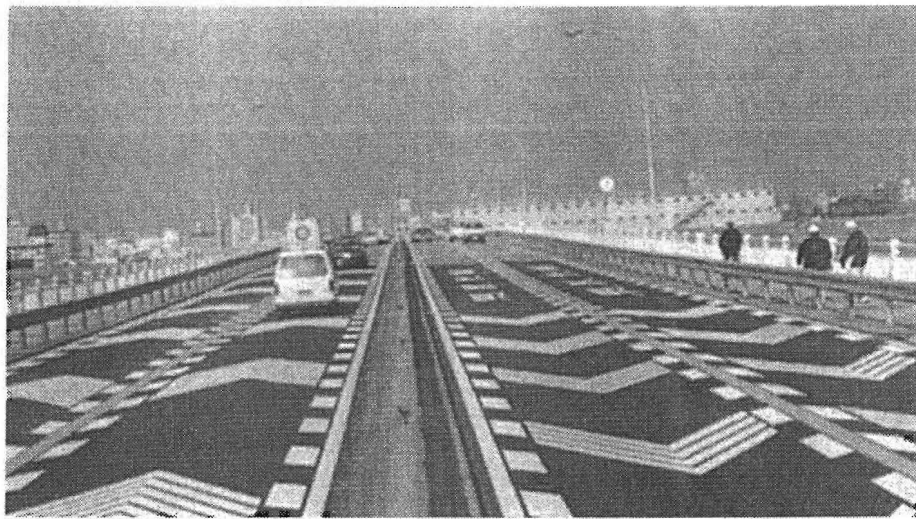


Figure 4-28. Converging Chevron Pattern on Route 2, Yodogawa River Bridge, Japan. ⁽¹²⁾

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The length of an individual chevron pattern is based on assumptions, including the initial speed of vehicles entering the pattern, the desired speed upon leaving the pattern, reaction time, and constant deceleration once the brakes are applied. Once the length of the pattern has been defined, the spacing between adjacent chevrons must be arranged so that a vehicle undergoing constant acceleration traverses a fixed number of chevrons per unit of time, typically about two per second.

In conjunction with the converging chevrons, the Japanese use white painted “dashes” to delineate traffic lanes. Each dash is in the shape of a parallelogram and is 30 cm (12 in) wide and 100 cm (40 in) long. The dashes are placed 100 cm (40 in) apart.

In 1995, construction costs of the converging chevron patterns for projects in Japan varied from \$15,000 to \$90,000. The estimated service life for the pavement markings is four to six years, depending upon traffic volumes.

EXPERIENCES

Transverse Bar Pavement Marking

The transverse bar pattern has been applied in many different forms in several countries including Great Britain, Israel, South Africa, Australia, the United States, and Canada. The transverse bar pattern has been installed on approaches to speed humps in Oregon and Maryland, as shown in Figures 4-29 and 4-30.

A study in England utilized transverse bar pavement markings on opposing, minor approaches to a two-lane rural intersection with and without rumble strips. Speeds were measured before and one month after the transverse markings and rumble strips were applied. Both approaches experienced speed reductions following the installation, but the effect was much more pronounced for the approach with rumble strips. Much of the speed reduction occurred before or just after entering the pattern. When speeds were monitored one year after marking installation, the small speed reductions associated with the transverse marking had disappeared, but the transverse markings combined with rumble strips maintained their speed-reducing effects.

Innovative Pavement Markings

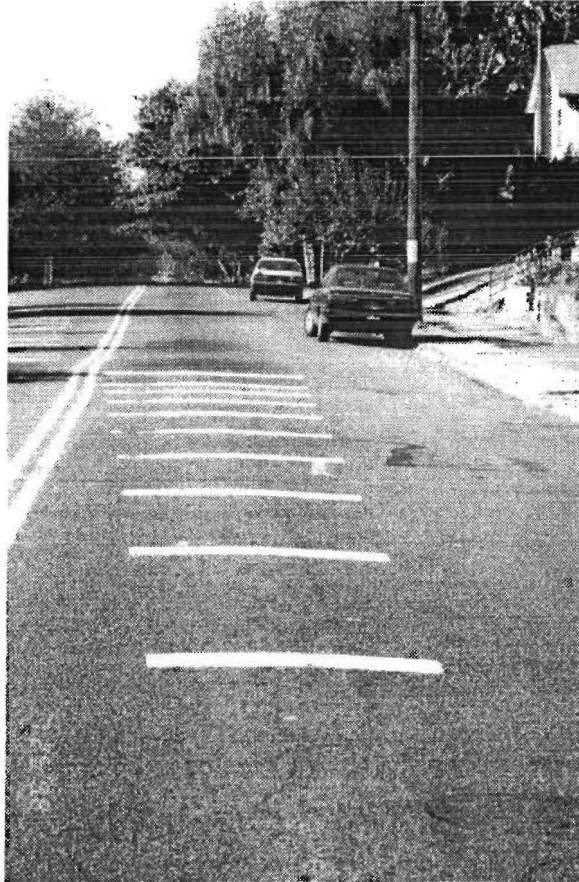


Figure 4-29. Transverse Pavement Markings in Portland, OR.

The most extensive evaluation of crash-reduction effectiveness of transverse bar patterns was performed in a study in England where transverse markings were applied on one approach to each of 42 traffic circles. The markings were strips of yellow thermoplastic material which were 0.6 m (2 ft) in width. The markings were applied in late 1973 and early 1974, and injury crashes were recorded at and near the treatment sites for a period of two years before and two years after the pavement markings were installed. The markings were found to reduce relevant crashes by 35 to 70 percent, suggesting that the transverse bar pattern may reduce total crashes by about 5 percent.⁽¹²⁾

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Innovative Pavement Markings

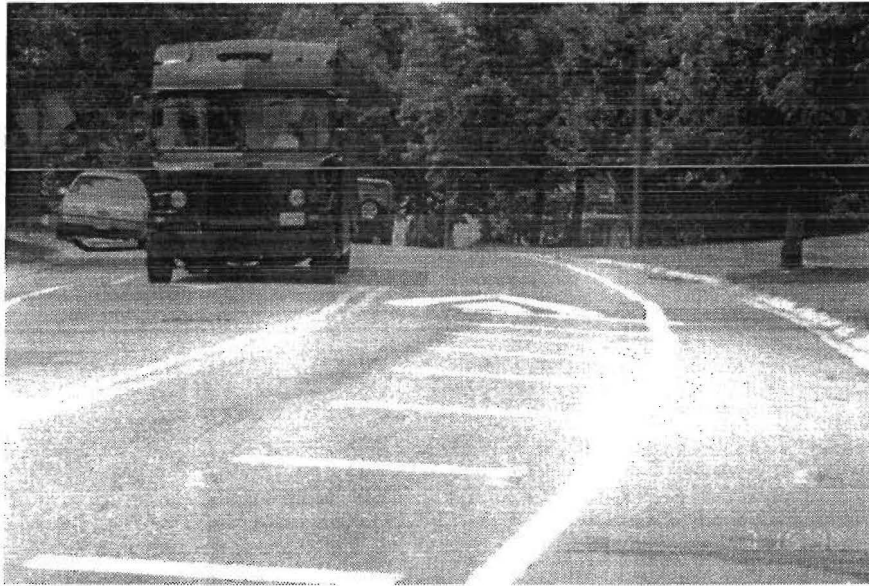


Figure 4-30. Transverse Pavement Markings in Montgomery County, MD.

Converging Chevron Marking Pattern

Most of the work on converging chevron marking patterns comes from Japan. Study sites include a bypass, a railway overpass, a coastal city road, and a bridge deck. The Yodogawa River Bridge deck has converging chevron markings on all four lanes in addition to Chinese characters which say “Beware of rear-end collision” (see Figure 4-28).

Three of the six treatment locations experienced a significant reduction in crashes following application of the converging chevron patterns. Before and after studies of six locations in Japan showed estimates of crash reductions from 14.3 to 74.7 percent. It should be noted that the crash reduction effectiveness of the chevron markings is not homogeneous or consistent from location to location.

LESSONS LEARNED

Lessons learned in the studies where these innovative pavement markings have been installed include the following:⁽¹²⁾

Innovative Pavement Markings

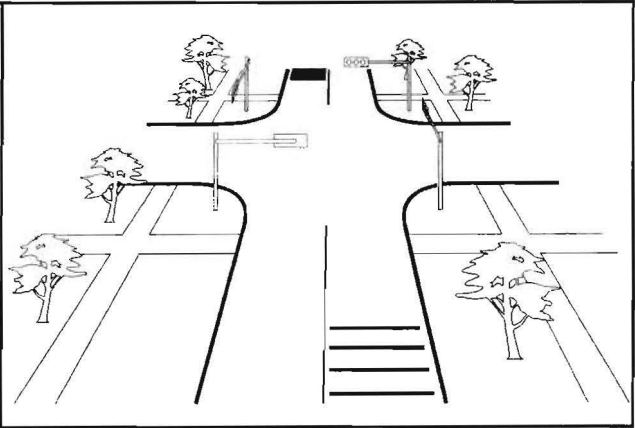
- The transverse bar marking pattern may serve to reduce traffic speeds and crashes by 1) warning or alerting drivers to an upcoming situation and 2) by causing drivers to perceive that they are traveling too fast.
- Various patterns of transverse bar patterns have been used; they are highly variable in terms of length, number of bars, and the rate at which inter-bar spacings are reduced.
- Case studies suggest that transverse bar markings used in combination with rumble strips may be more effective in reducing speeds than installations with only transverse bar pavement markings.
- The converging chevron pattern applied in Japan includes a wide dashed edge line. This edge line may promote the perception that the traffic lane is narrower than it actually is.
- Even if the innovative pavement markings do not dramatically reduce vehicle speeds, they may still alert drivers to a heightened sense of awareness in which they are better prepared to avoid a crash.

DISCUSSION

The potential benefits associated with transverse bar and converging chevron pavement markings and the relatively low cost of these patterns suggest that more research using these patterns is justified.

CHAPTER 4 ROADWAY SURFACE TECHNIQUES

Rumble Strips



Rumble strips are pavement undulations placed across the driving lane, causing the vehicle to “rumble” or vibrate when crossing them.⁽¹³⁾ Rumble strips can be an effective attention-getting device where a particular situation exists that warrants alerting the approaching driver. They are generally used in advance of a downstream traffic control device or hazardous or unique condition.

CHARACTERISTICS

Rumble strips can be treatments on top of the pavement surface including asphalt strips, patterned sections of rough pavement, traffic buttons or dots glued to the pavement, brick paving blocks, or layers of thermoplastic striping material. Rumble strips may also be installed by making grooves in the pavement, as shown in Figure 4-31. Rumble strips can be effective in drawing attention to unexpected situations, such as a stop sign or traffic signal ahead. Rumble strips have had some applications for speed control in residential areas, but the noise generated by vehicles crossing the rumble strips tends to create more protests from residents than the speeding problems they were intended to solve. Advance warning signs are often installed upstream of rumble strips, and a sign indicating the purpose of the rumble strip may be placed adjacent to the rumble strip.⁽¹⁴⁾

EXPERIENCES

Rumble strips have been placed on U.S. 290 north of Houston, Texas, at a high-speed approach to an isolated signalized intersection (see Figure 4-31). They have also been used in Atlanta, Lubbock, and Austin, Texas, at approaches to rural signalized intersections. The rumble strips and warning signs alert motorists of the approaching signal and are spaced to provide adequate time to reduce speed. Several cities in California use rumble buttons which are ceramic markers (see Figure 4-32).

The Texas Department of Transportation in Atlanta, Texas, uses rumble strips as a temporary installation for new stop sign installations and for changes from two-way to four-way stops. Permanent installations are used in advance of high-accident locations. The rumble strips are thick pavement markings made of several layers of thermoplastic that create a small rumble effect. A series of six or seven of the pavement marking rumble strips has been installed at the end of a long road ending in a T-intersection.

Rumble Strips



Figure 4-31. Rumble Strips on U.S. 290 North of Houston, TX.



Figure 4-32. Rumble Dots in Monterey, CA.

Rumble strips are used on the approach to a roundabout in Taneytown, Maryland (Figure 4-33).

Rumble strips are also installed at a school crossing near Greenbelt, Maryland (Figure 4-34). The roadway is a six-lane facility, and the school is located across this roadway from a residential area. The rumble strips are placed at 2.7 m (9 ft) intervals in the first grouping and then at 1.5 m (5 ft) intervals approaching the pedestrian crosswalk. The rumble strips are constructed of layers of yellow thermoplastic striping material, and the word "SCHOOL" is also painted on the pavement.

In Catonsville, Maryland, rumble strips have been installed on both approaches to a high-accident horizontal curve in addition to warning signs and a hazardous indication beacon (Figure 4-35). The rumble strips are constructed of thermoplastic materials.

CHAPTER
4

ROADWAY SURFACE TECHNIQUES

Rumble Strips

In East Texas, rumble strips are used on the approach to a sharp curve to encourage drivers to slow down when approaching the curve. The rumble strips are constructed of layers of thermoplastic material and are installed at 1.4 m (4.5 ft) spacings (see Figure 4-36). The rumble strips are used in conjunction with curve warning signs, advisory speed plates, and speed limit pavement markings.

Rumble strips are relatively inexpensive to install, starting at approximately \$500 per installation. Maintenance costs vary depending on the type of rumble strips installed.



Figure 4-33. Rumble Strips in Taneytown, MD.

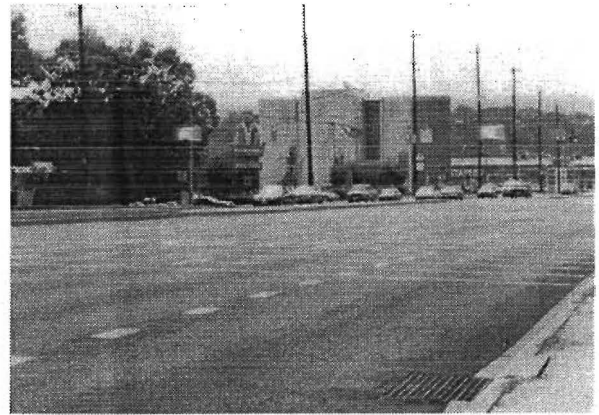


Figure 4-34. Rumble Strips in School Zone in Greenbelt, MD.



Figure 4-35. Rumble Strips in Catonsville, MD.

Rumble Strips

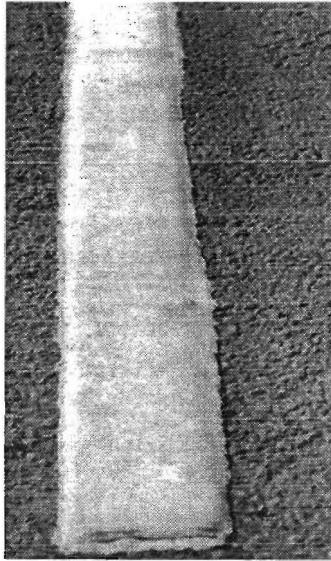


Figure 4-36. Rumble Strips Approaching Curve in East Texas.

LESSONS LEARNED

Advantages of rumble strips include:

- May reduce speeds up to 8 km/h (5 mph)
- Create driver awareness to increase safety
- Are inexpensive to install and may be removed or changed as necessary when created with thermoplastic materials

Disadvantages include:

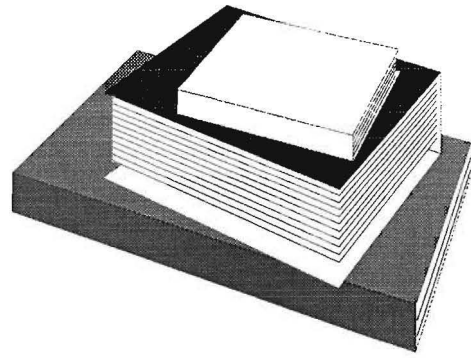
- May require high maintenance to reattach dots to the pavement
- May adversely impact bicyclists
- May be ineffective in reducing vehicle speeds
- Are noisy by design and may not be appropriate for neighborhood settings

DISCUSSION

Rumble strips may improve safety and reduce speed by calling attention to other traffic control devices or hazards. They should be carefully considered for residential areas due to the noise created by vehicles crossing the rumble strips.

CHAPTER 4

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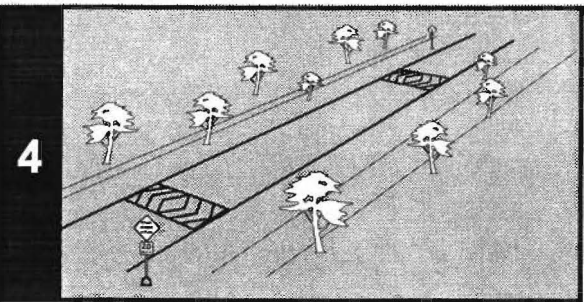
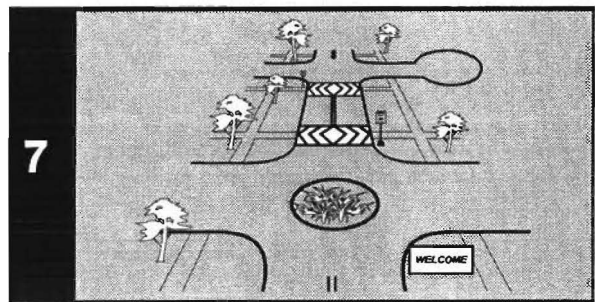
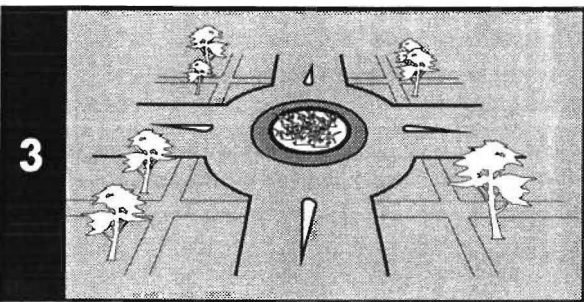
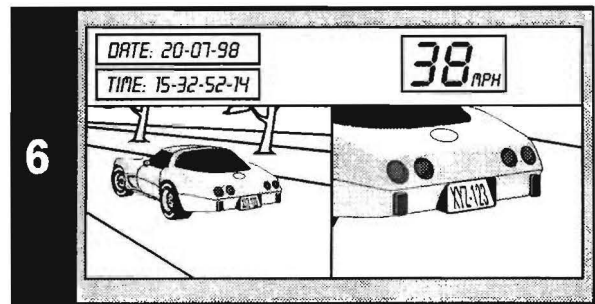
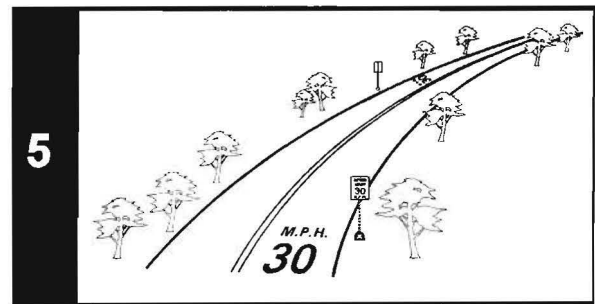
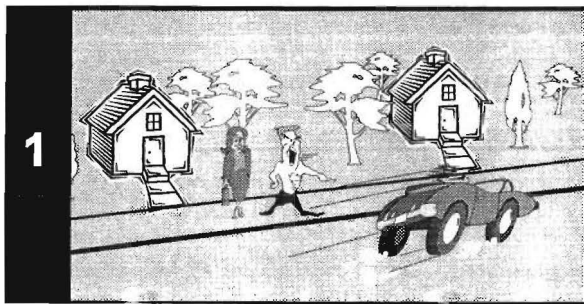
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CHAPTER 5

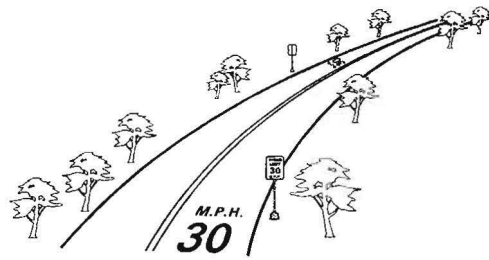
TRAFFIC CONTROL

TECHNIQUES



CHAPTER 5 TRAFFIC CONTROL TECHNIQUES

Speed Limit Signs and Markings



Speed limit signs are the most commonly used technique to achieve a desirable reduction in speed, although signing alone does little for mitigation. Although not as common, speed limits may also be marked on the pavement to reinforce the posted speed limit.

CHARACTERISTICS

Speed limit signs display the speed limit established by law or by regulation. However, drivers generally ignore posted speed limits and travel at speeds which they consider reasonable, comfortable, convenient, and safe under the existing conditions.⁽¹⁾ Therefore, speed limits are most effective when established by an engineering study of the roadway section involved, considering the 85th percentile speed, horizontal and vertical alignment, sight distance, development, parking and pedestrian activity, and accident history. Separate speed limits may be posted for buses and trucks.⁽²⁾

Speed limit signs may be supplemented by pavement markings which also indicate the legal speed limit. An example of a speed limit marking is shown in Figure 5-1. Figure 5-2 illustrates a roundel, which is a horizontal sign application used in England. Roundels are elongated circles with the speed limit in the center of the circle, and they are supplemented with traditional vertical signing. Roundels are commonly used as an entrance feature to a small town or residential area. The roundels are spaced at 200 to 300 m (700 to 1100 ft).⁽³⁾

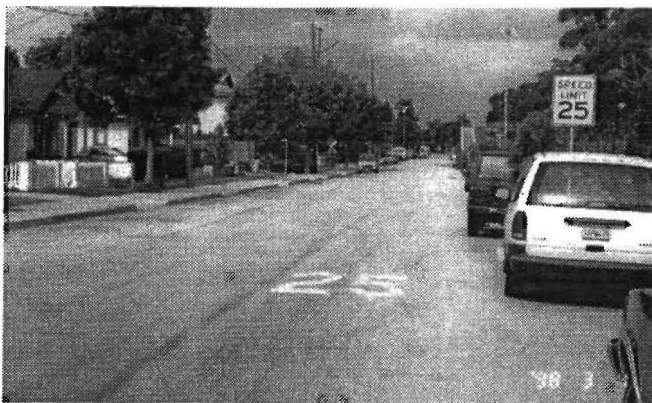


Figure 5-1. Speed Limit Sign and Markings in Santa Barbara, CA.



Figure 5-2. Roundel in England.

TRAFFIC CONTROL TECHNIQUES

CHAPTER

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Speed Limit Signs and Markings

Speed limits or speed zoning signs are typically posted at the city limits, as shown in Figures 5-3 and 5-4.

Other horizontal pavement markings, such as arrows or specific words such as STOP AHEAD, may also be used to provide speed reduction when approaching another traffic control device or unique situation (see Figure 5-5).

Figure 5-6 illustrates the use of pavement markings to reinforce the advisory speed for a horizontal curve. Figures 5-7 and 5-8 illustrate speed limit signs in Oregon and Maryland.

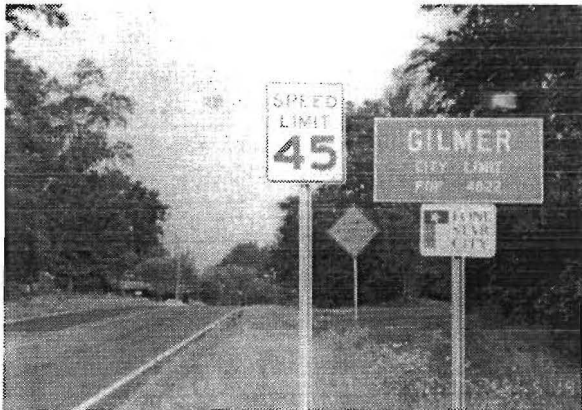


Figure 5-3. Speed Limit Sign Entering Gilmer, TX.



Figure 5-4. Speed Limit Sign Entering Huntington, TX.

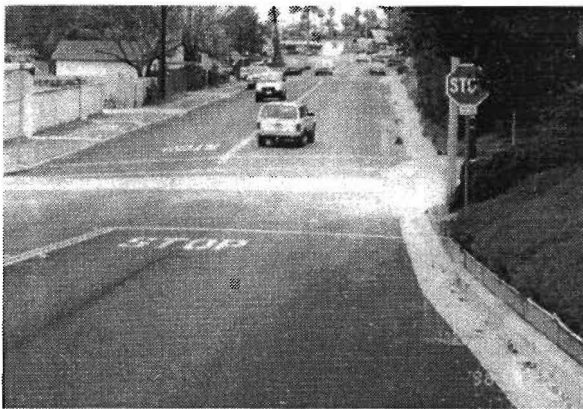


Figure 5-5. 'Stop' on Pavement in Ventura, CA.

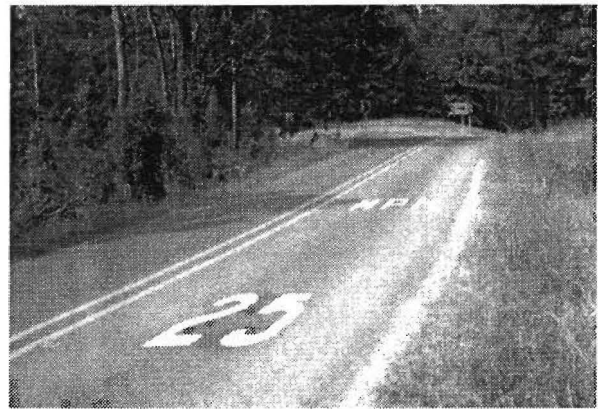


Figure 5-6. Speed Limit Pavement Markings in East Texas.

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5

TRAFFIC CONTROL TECHNIQUES

Speed Limit Signs and Markings

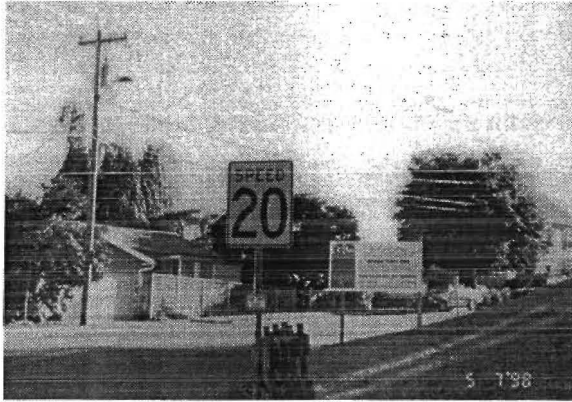


Figure 5-7. Speed Limit Sign in Portland, OR.



Figure 5-8. Speed Limit Sign in Montgomery County, MD.

EXPERIENCES

Speed limit signing may reduce traffic speeds if used in conjunction with regular enforcement. Officials at the Minnesota Department of Transportation report that larger speed limits signs (91.4 m by 121.9 m (36 in by 48 in) are more effective when used along with increased enforcement and in locations where normal speed limit signs are being missed.

Researchers with the Insurance Institute for Highway Safety (IIHS) conducted studies to determine if specially designed pavement markings were effective at reducing excessive speeds on rural and suburban two-lane roadways with sharp horizontal curvatures. These pavement markings consisted of the words SLOW and a left-curve arrow painted on the roadway. Marginal speed reduction results of about 7 percent were attributable to the pavement markings, and little use of such markings exists in the U.S.⁽⁴⁾

In England, roundels are typically applied in the center of the travel lane with thermoplastic. The location is selected to minimize any friction loss that may result from vehicle braking maneuvers on that surface. Similar to the arrow pavement markings, the roundels did not appreciably reduce travel speeds during a before-and-after study period.⁽⁵⁾

A regulatory speed-zone configuration and lighted warning signs were found to be more effective than more traditional unlighted warning signs in reducing motorists' speeds in the vicinity of a rural intersection and increasing their awareness of both the signs and the conditions at the intersection.⁽⁶⁾ A study of rural high-speed intersections found that providing the driver adequate warning of the intersection is of primary importance for this type of intersection.⁽⁷⁾

Speed Limit Signs and Markings

LESSONS LEARNED

Advantages include:

Speed Limit Signs

- Are well recognized and understood
- Are inexpensive to install
- Can reduce speeds with regular enforcement

Pavement Markings

- Reinforce speed limit signs
- Are inexpensive to install

Disadvantages include:

Speed Limit Signs

- Have significant non-compliance rates

Pavement Markings

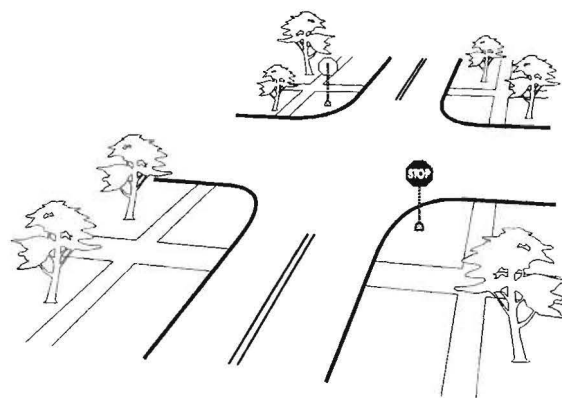
- Are not proven to be effective
- May cause concern regarding conspicuity and legibility

DISCUSSION

Studies of reducing speed limits on all types of roadways show little or no effect in reducing speeds. Drivers react more to roadway geometrics, other traffic, and the immediate environment than to a posted speed limit. However, speed limits are important from an enforcement standpoint and for indicating the perceived safe speed for unfamiliar drivers.

CHAPTER 5 TRAFFIC CONTROL TECHNIQUES

Stop Signs



OVERVIEW

Stop signs are the most frequently requested traffic control device in residential areas. Residents often believe that the installation of stop signs, or a series of stop signs, at previously uncontrolled intersections will reduce both the speed and volume of cut-through traffic. Unfortunately, this is not usually true.⁽⁸⁾

CHARACTERISTICS

Stop signs are used to assign the right-of-way at intersections with *significant* traffic volumes or crash frequencies. The *Manual on Uniform Traffic Control Devices (MUTCD)* provides guidelines for stop sign installation and warrants for two-way and four-way stop sign installations.⁽⁸⁾ The warrants discourage the use of stop signs at low-volume residential intersections except in cases of high speed, restricted view, or serious accident record. Numerous studies have indicated that stop signs are not effective at reducing speeds or volumes in residential areas. In fact, the use of stop signs solely to regulate speed may cause negative traffic safety impacts (non-compliance with the signs and more crashes). Stop signs can have beneficial safety effects in residential areas by reducing crashes at previously uncontrolled intersections.

Stop signs may often seem like a good solution to neighborhood speeding, but traffic studies and experience show that using stop signs to control speeding doesn't necessarily work. When stop signs are installed to slow down speeders, drivers may actually increase their speed between signs to compensate for the time they lost by stopping. Too many stop signs can cause drivers to ignore the right-of-way rule, or some drivers may simply choose to ignore the stop sign. The city of Santa Barbara reports four-way stop locations with violation rates of 30 percent. Also, studies show that speeds are affected only about 30.5 - 45.7 m (100 - 150 ft) before and after the stop sign.⁽²⁾

Costs of installation are approximately \$200-\$300 per sign installation, and enforcement costs of non-compliance can be significant for a law enforcement agency. Also, more stop signs in a neighborhood can result in higher levels of pollution and more noise. Examples of stop signs are shown in Figures 5-9 through 5-11.

Stop Signs



Figure 5-9. Stop Sign in Seattle, WA.

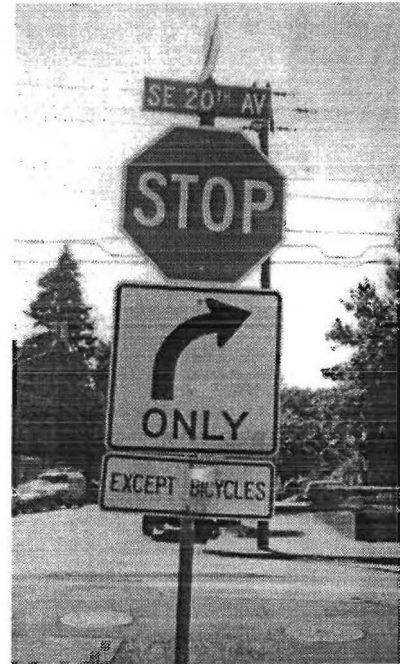


Figure 5-10. Stop Sign with Bicycle Exception in Portland, OR.



Figure 5-11. Multi-way Stop Signs in Garland, TX.

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TRAFFIC CONTROL TECHNIQUES

Stop Signs

EXPERIENCES

A study of nine residential two-way stop sign installations in Portland, Oregon, indicated that stop signs are not very effective in reducing speeds. Before-and-after studies on all 36 legs of the intersections indicated that the 85th percentile speeds remained the same on 19 legs (53 percent), increased by 3.2 km/h (2 mph) or more on four legs (11 percent), and decreased by 3.2 km/h (2 mph) or more on 13 legs (36 percent). A study of two residential collector streets in San Antonio, Texas, indicated slightly greater reductions in 85th percentile speeds and that speeds were reduced as far as 91.5 and 152.5 m (300 and 500 ft) from the stop signs on the respective collectors.⁽⁹⁾ A study of 50 two-way and four-way stops on residential streets in Chicago found a 69 percent reduction in accident rates after stop signs were installed at previously uncontrolled intersections.⁽⁸⁾ Stop signs may reduce some existing shortcutting through traffic; however, the alternative route is often an adjacent residential street so that traffic is actually moved rather than eliminated.⁽¹⁾ These studies indicate that stop signs may be effective as a safety measure on residential streets but are less effective for controlling speeds or volumes.⁽⁸⁾

The Portland Bureau of Traffic Management considers where to place stop signs to provide the best benefit for the neighborhood. Drivers may seek new routes to avoid stop signs, which can lead to new traffic problems in adjacent neighborhoods. Also, installing a stop sign on one street may result in higher speeds on the intersecting streets. The city developed a systematic approach for installing stop signs at uncontrolled intersections within residential neighborhoods where streets are arranged in a grid pattern. This application establishes a pattern of stopping traffic on every other block throughout the entire neighborhood. Because this pattern eliminates uncontrolled through streets, it encourages an even traffic distribution throughout the neighborhood. The program is intended to provide a rational traffic control plan rather than to reduce speeds.⁽⁸⁾

In 1993, the city of Brentwood, Tennessee, developed procedures to rationally address the increasing number of requests for multi-way stop sign installations. The city staff hoped that such a policy would help to avoid the excessive and arbitrary use of multi-way stop signs. The primary goals of the multi-way stop sign policy are to limit the number of multi-way stop sign installations within the city, avoid multi-way stop signs at adjacent intersections, and avoid installations at very low-volume intersections. The volumes specified in Brentwood's policy are much lower than in the *MUTCD*. Also, Brentwood's criteria include the consideration of sight distance restrictions at intersections, the number of intersection approaches, and the proximity to other multi-way stop sign installations; the *MUTCD* does not include any of these factors. In the three years prior to the adoption of the policy, 44 percent of the requests for multi-way stop signs were granted. In the three years after the adoption of the policy, 17 percent of requests for multi-way stop signs have been granted. Based on this information, as well as the response from city staff and from residents, the multi-way stop sign

Stop Signs

policy is considered a useful and successful tool for managing Brentwood's residential traffic concerns.⁽⁹⁾

LESSONS LEARNED

Advantages of stop signs include:

- Are well recognized and understood
- Provide positive public perception of reduced speeds and volumes if installed
- Are inexpensive to install
- Are easy to install
- Can improve safety at previously uncontrolled intersections

Disadvantages include:

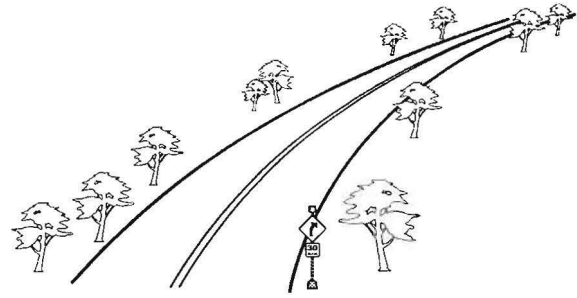
- Can breed disrespect and non-compliance if used excessively
- May cause poor public perception if agency rejects installation request
- Have warrants for installation that may be difficult to meet
- Are not effective in reducing speed or volume

DISCUSSION

When traffic problems become noticeable in neighborhoods, stop or yield signs may be the first measure requested by local residents to slow speeders or reduce cut-through traffic. However, numerous studies have indicated that stop signs are not effective devices to reduce speed or volume.⁽⁸⁾

CHAPTER 5 TRAFFIC CONTROL TECHNIQUES

Warning Signs



Warning signs are used to warn drivers of existing or potentially hazardous conditions on or adjacent to a highway or street. Warning signs are intended to encourage drivers to be cautious, to be aware of possible reductions in speed, to be prepared to make maneuvers in the interest of their safety, and to be aware of other drivers and pedestrians.

CHARACTERISTICS

Adequate warning signs greatly assist drivers and are valuable in safe-guarding and expediting traffic. However, their unnecessary use can cause disrespect for warning signs and other traffic control signs.⁽²⁾

Locations and hazards which may result in the use of warning signs include:

- Changes in horizontal alignment
- Intersections
- Advance warning of control devices
- Converging traffic lanes
- Narrow roadways
- Changes in highway design
- Grades
- Roadway surface conditions
- Railroad crossings
- Entrances and crossings
- Miscellaneous⁽²⁾

The *MUTCD* has an entire chapter covering warning signs, and it addresses special warning signs for highway construction, school areas, railroad grade crossings, and bicycles in other parts of the *Manual*.

EXPERIENCES

Warning signs used as part of speed management techniques are illustrated in Figures 5-12 through 5-17. The applications are discussed in the following paragraphs.

Warning Signs

Figures 5-12 through 5-14 are curve warning signs in Texas. Figure 5-12 shows the direction of the curve in addition to the approximate location of intersecting streets. This sign is supplemented by an advisory plate to warn drivers of traffic entering the curve and by a flashing beacon. Figure 5-13 warns of two turns in opposite directions. Chevron signs, a large arrow sign, and painted speed limit pavement markings are used in the horizontal curve as shown in Figure 5-14.

Figures 5-15 through 5-17 illustrate various pedestrian warning signs.

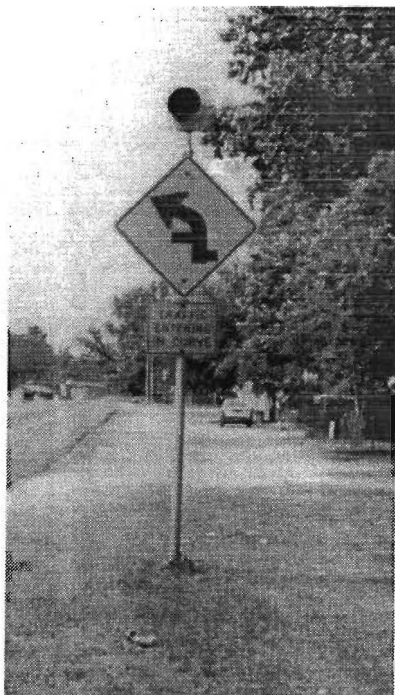


Figure 5-12. Curve Sign with Flashing Beacon in East Texas.



Figure 5-13. Curve Sign in East Texas.



Figure 5-14. Curve with Signs and Pavement Markings in East Texas.

Warning Signs



Figure 5-15. Pedestrian Crossing Sign in Towson, MD.



Figure 5-16. Pedestrian Sign in Oakland, CA.



Figure 5-17. Seniors' Pedestrian Sign in Oakland, CA.

Warning Signs

A 1980s study in Ohio examined the effectiveness of advisory speed signs used in conjunction with curve warning signs.⁽¹⁰⁾ The results of the test-driver study indicate that drivers, on the average, look about two times at a warning sign (fixation duration 0.5 to 0.6 sec). Based upon the findings from 40 test drivers, the author concluded that advisory speed signs are not more effective in causing drivers to reduce their speeds through the curves than curve and turn signs alone.

LESSONS LEARNED

Advantages of warning signs include:

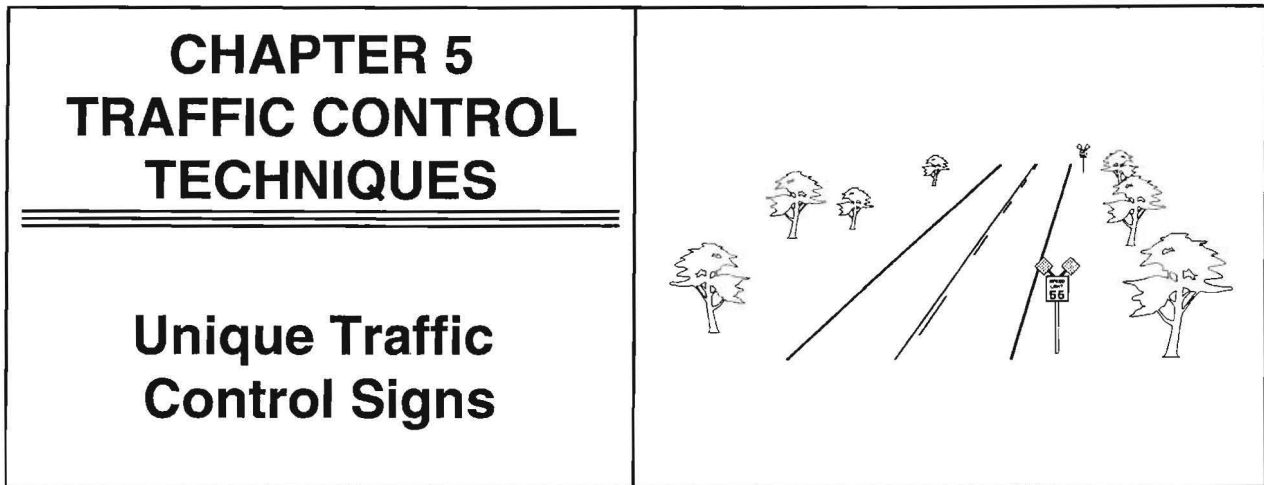
- Are easily recognizable
- Alert drivers of approaching hazards or unique conditions
- Can be supplemented with advisory speeds to provide drivers with additional guidance
- Can be supplemented with flashing beacons

Disadvantages include:

- Can cause disrespect for signs if used unnecessarily
- Can be an additional fixed object along the roadside

DISCUSSION

Warning signs are intended to inform drivers of hazardous or unique situations that may require additional action or attention. Warning signs may be supplemented with speed plates, flashing beacons, or other signs to provide additional information to drivers.



Agencies use many unique signs in an attempt to inform drivers of upcoming devices or existing conditions. Examples of some of these devices are illustrated and discussed in this section.

CHARACTERISTICS

Unique traffic control signs include regulatory, informational, warning, and guide signs. Such signs are typically designed for a unique situation believed to warrant special attention; however, they are to follow the basic signing principles:

1. Place the sign adequately in advance of the action point.
2. Provide sufficient time to respond appropriately (either by increasing sign size or locating it farther upstream or both).
3. Provide redundant information.
4. Avoid areas of high driver workload.

This section is not intended to endorse or to be critical of the devices herein but to present them for informational purposes only, noting that traffic control devices are required to conform to the colors, shapes, sizes, and placement as specified in the *MUTCD*.⁽²⁾

EXPERIENCES

Several signs have been developed for different purposes. Figure 5-18 illustrates the use of orange metal flags to draw attention to a speed limit sign. Figures 5-19 and 5-20 warn drivers that they are approaching a speed hump. Figures 5-19 through 5-23 are guide signs providing directional information when approaching roundabouts in Maryland. Notification of speed control devices is illustrated in Figure 5-24, while Figures 5-25 and 5-26 show signs that inform drivers that they are entering a traffic calming area.

Unique Traffic Control Signs



Figure 5-18. Orange Metal Flags on Speed Limit Signs in Rochelle, TX.

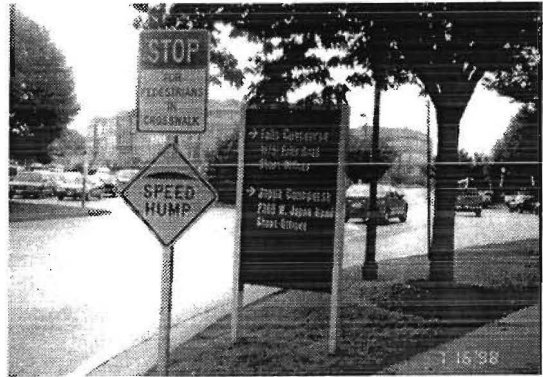


Figure 5-19. Speed Hump Sign in Brooklandville, MD.

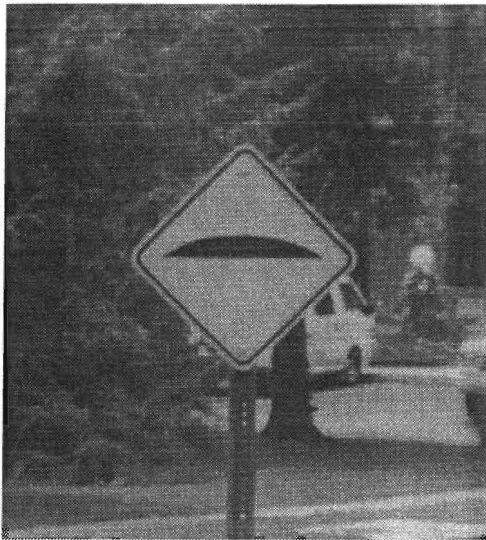


Figure 5-20. Speed Hump Sign in Columbia, MD.

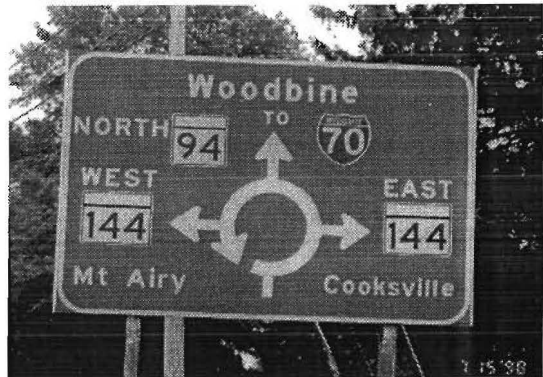


Figure 5-21. Roundabout Directional Sign in Lisbon, MD.

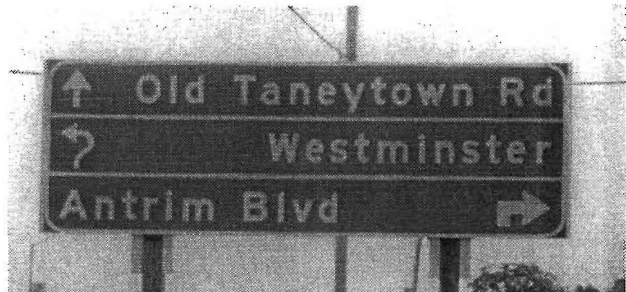


Figure 5-22. Roundabout Directional Sign in Taneytown, MD.

CHAPTER
5

TRAFFIC CONTROL TECHNIQUES

Other Unique Traffic Controls

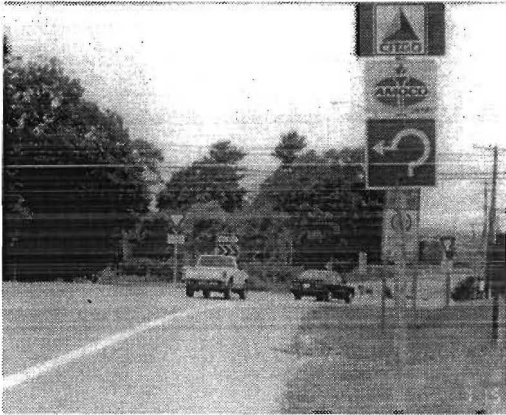


Figure 5-23. Directional Sign at Roundabout in Lisbon, MD.



Figure 5-24. Informational Sign About Speed Humps in Gwinnett County, GA.



Figure 5-25. Traffic Calming Sign in Montgomery County, MD.

The school zone crossing signs in Figure 5-27 are used as temporary speed calming measures for a preschool. The signs alert drivers to watch for children who are moving from one building to another.

DISCUSSION

Agencies use a variety of signs to try to inform drivers of what to expect. As stated previously, this section is not intended to endorse or to be critical of the devices herein but to present them for informational purposes only, noting that traffic control devices are required to conform to the colors, shapes, sizes, and placement as specified in the *MUTCD*.⁽²⁾

Unique Traffic Control Signs

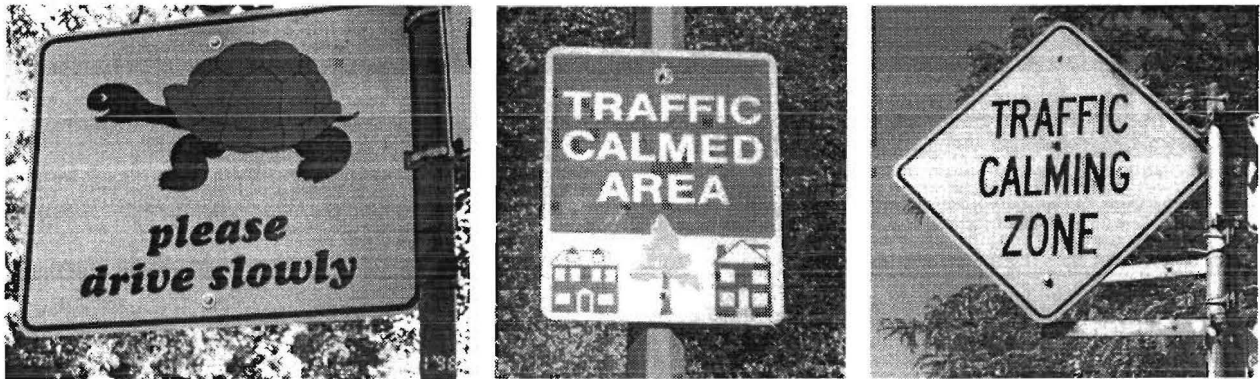


Figure 5-26. Examples of Traffic Calming Signs in CAN.

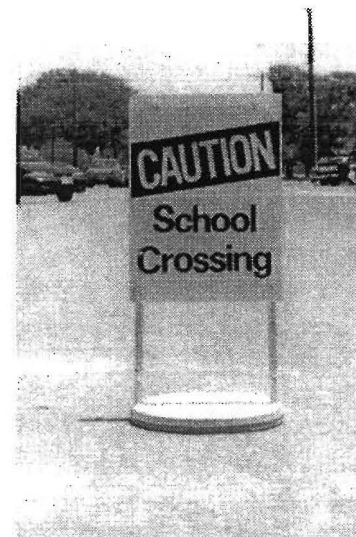


Figure 5-27. Temporary School Crossing Signs in College Station, TX

CHAPTER 5 TRAFFIC CONTROL TECHNIQUES

School Speed Zones



School speed zones provide a vital means of maintaining safety for children by alerting drivers to reduce speeds and to watch for children. School speed zones reduce speed limits for specific morning and afternoon time periods while school is in session. Warning signs, crosswalks, other pavement markings, flashing beacons, and traffic signals are used to alert drivers of the school zone and to inform them of the beginning and end of the reduced speed area.

CHARACTERISTICS

According to the *Manual on Uniform Traffic Control Devices (MUTCD)*, traffic control devices in school areas are a critical subject for public agencies, school officials, and parents. All entities involved expect a significant degree of safety and for drivers to fully understand all devices within the area of a school. The *MUTCD* sets forth specific standards for school zone traffic control devices, including all speed limit devices.⁽²⁾

The type of school area traffic control used relates to the volume and speed of traffic, street width, and the number of children crossing; traffic controls necessary for school areas on a major highway aren't needed in a residential area away from heavy traffic. However, a uniform approach must be used to promote uniform behavior by drivers and pedestrians.⁽²⁾

The School Speed Limit sign is used to indicate speed reductions in established school zones. Various devices can supplement the School Speed Limit sign; the most effective may be the Speed Limit Sign beacon which flashes during the periods when the school speed limit is enforced. Other traffic control devices used in school zones include marked crosswalks and crosswalk warning signs; the words "SCHOOL" or "SCHOOL ZONE AHEAD" painted on the pavement; and End School Zone or a regulatory speed limit sign informing the driver of the end of the school zone.

Examples of various school speed zones and traffic control devices are illustrated in Figures 5-29 through 5-34.

EXPERIENCES

School speed limits are critical, especially at midblock crosswalks that may not be controlled by the presence of a stop sign or traffic signal. The city of San Antonio, Texas, has studied crosswalks in school speed limit zones throughout the city to determine locations that could benefit from the addition of flashing beacons to supplement the 32 km/h (20 mph) reduced speed limits. The intent

School Speed Zones

of the study was to identify and prioritize locations where flashing beacons would provide the most safety benefit.

Approximately 200 schools throughout the city were selected based on the uncontrolled, midblock crosswalks not already controlled by a stop sign or traffic signal. Crosswalks located at stop signs and traffic signals are preferred locations for students to cross the road as vehicles are required to stop. Furthermore, most crosswalks at traffic signals are equipped with pedestrian indicators.

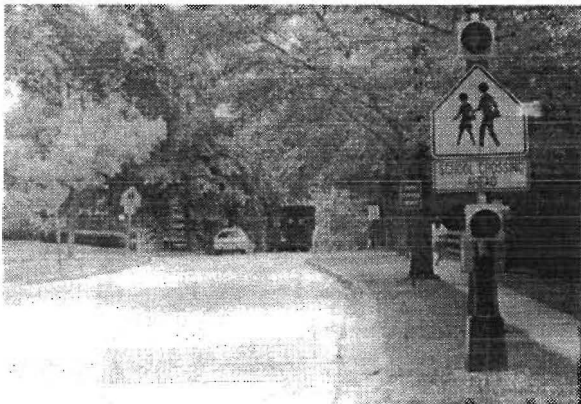


Figure 5-28. School Crossing Sign in Columbia, MD.

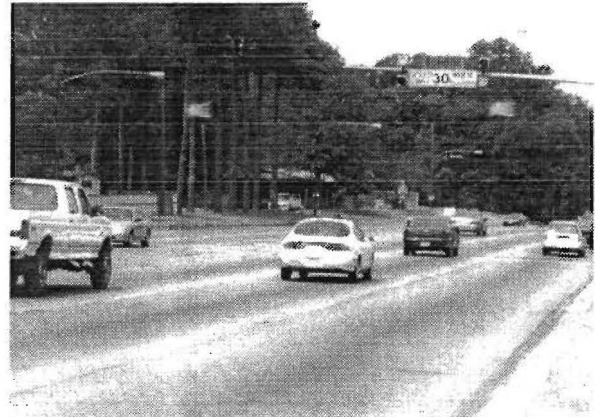


Figure 5-29. School Crossing Sign in Tyler, TX.



Figure 5-30. School Zone in Ventura, CA.



Figure 5-31. School Zone in Hollywood, CA.

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TRAFFIC CONTROL TECHNIQUES

School Speed Zones

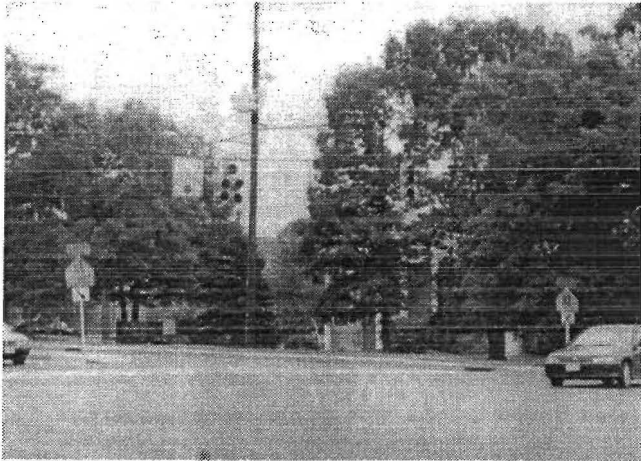


Figure 5-32. Signalized Crossing in Greenbelt, MD.

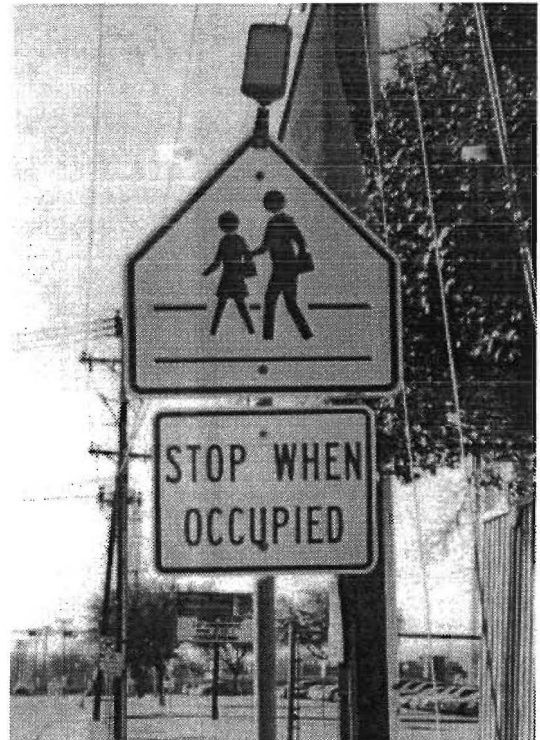


Figure 5-33. School Crossing Sign with Strong Yellow-Green Color in Carrollton, TX.

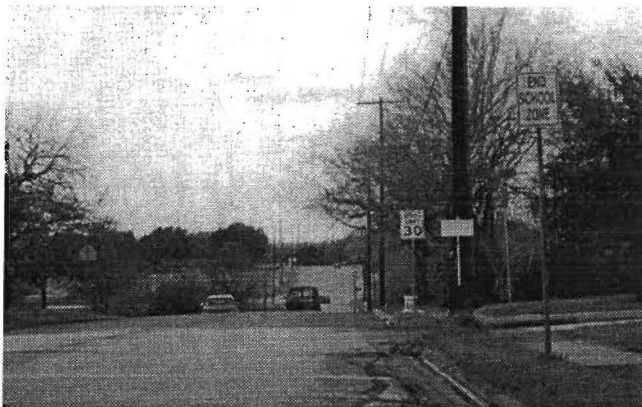


Figure 5-34. End School Zone Sign in Carrollton, TX.

School Speed Zones

Many jurisdictions establish special speed limits on streets adjacent to or in the vicinity of schools during certain hours of the day. A West Virginia study indicated that the most significant factors influencing speeds in school zones were the approach speed limit, the distance of school buildings from the roadway edge, traffic volumes, and the length of the school zone.⁽¹¹⁾ Research also suggests that to be effective, school speed limits should be reasonable and consistent with drivers' perception of the need for caution in these zones.⁽¹²⁾ School speed zones which designate a lower speed limit at specific times or when a flashing beacon is operating have been found to be the preferred methods of implementation, although some studies have found the effectiveness of these devices to be lacking unless heavy enforcement is provided. Conversely, having school speed zones active only WHEN CHILDREN ARE PRESENT is not recommended due to poor driver compliance.⁽¹²⁾

LESSONS LEARNED

Advantages of school speed zones include:

- Alert drivers of possible pedestrian presence
- Use uniform colors and symbols for easy recognition
- Reduce speed limits for specified hours only

Disadvantages include:

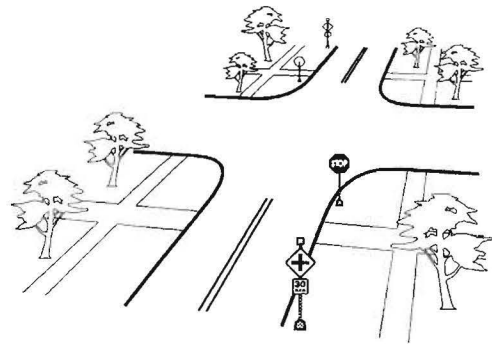
- Can be costly to implement
- Can be costly to enforce
- May cause confusion if non-uniform devices or enforcement procedures are used

DISCUSSION

Pedestrian safety depends upon public understanding of accepted methods for efficient traffic control. Neither school children nor drivers can be expected to move safely through school zones unless they understand the need for traffic controls and how these traffic controls function for their benefit. Analyses show that school crossing controls requested by parents, teachers, and other citizens are unnecessary in many locations. Such controls are also costly and tend to lessen the respect for controls that are warranted. Non-uniform procedures and devices cause confusion, prompt wrong decisions, and can contribute to accidents. It is important to achieve uniformity by treating comparable school traffic situations in the same manner.⁽²⁾

CHAPTER 5 TRAFFIC CONTROL TECHNIQUES

Flashing Beacons



Flashing beacons are used to attract drivers' attention and to make them aware of right-of-way conditions and/or potential hazards in the roadway. The beacons are typically used with warning signs and are intended to reduce vehicle speeds prior to an intersection, potential hazard, or unique condition.

CHARACTERISTICS

Beacons are used as an effective attention-getting device for particular situations that warrant alerting the approaching driver. They are generally used in advance of a downstream traffic control device or hazardous or unique condition. They are often used with warning signs to alert drivers that they are entering a school zone, as shown in Figure 5-35.

Issues to consider for beacon installation include:

- Volume- and crash-based conditions
- Percentage of repeat users on the roadway
- Beacon type
- Placement on post (hardware mounting) and lateral placement
- Power requirements (for solar options)
- Flash rate
- Maintenance requirements

Flashing beacons are most applicable on roadways where a high percentage of drivers are not repeat users so that the uniqueness of the beacon is more likely to have the desired effect.

Flashing beacons may be used on vertical posts or on mast arm posts. A variety of flashing beacons are shown in Figures 5-35 through 5-44. Costs of beacon installations vary due to the variety of configurations available.

Flashing Beacons

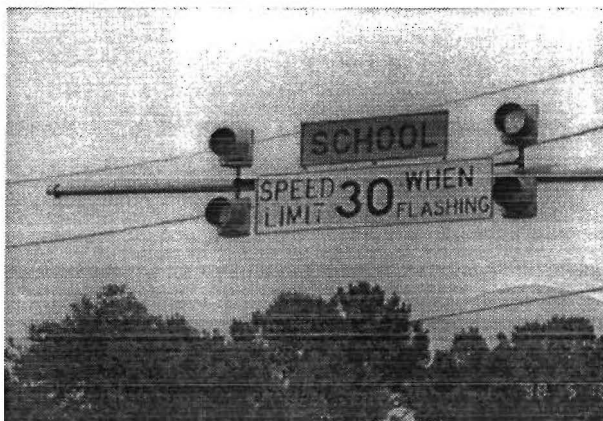


Figure 5-35. School Speed Limit and Wig Wag on Overhead Mast in Tyler, TX.

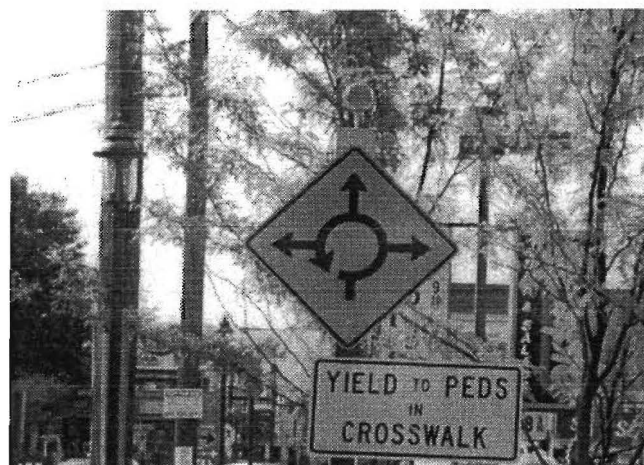


Figure 5-36. Roundabout Signs in Towson, MD.



Figure 5-37. Wigs Wags in Longview, TX.

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TRAFFIC CONTROL TECHNIQUES

Flashing Beacons

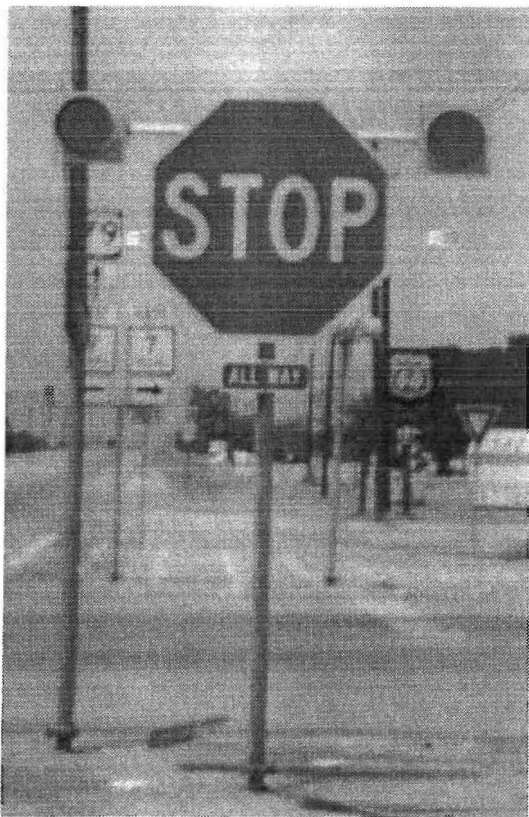


Figure 5-38. Flashing Beacons on Oversize Stop Sign in Marquez, TX.



Figure 5-39. Signal Ahead Sign with Four Wig Wags in Longview, TX.



Figure 5-40. Flashing Bicycle Beacon in Monterey, CA.

Flashing Beacons



**Figure 5-41. Flashing Beacon
near Westminster, MD.**



**Figure 5-42. School Crossing Sign
with Wig Wags in Tyler, TX.**

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TRAFFIC CONTROL TECHNIQUES

Flashing Beacons

EXPERIENCES

The city of Arlington, Texas, installed flashing sign beacons to reduce vehicle speeds on a 72.5 km/h (45 mph) section of four-lane, divided minor arterial roadway in advance of an intersection on the crest of a vertical curve (see Figures 5-43 and 5-44). The city was concerned about sight distance for motorists on the minor approach of the intersection and motorists' ability to safely make left and right turns from a stopped position. The major street volume (uncontrolled) is approximately 20,000 vehicles per day, and the minor street volume is significantly less than required to warrant a traffic signal.

The beacons were installed above 91.4 cm (36 in) Cross Road signs on each major street approach at approximately 152.5 m (500 ft) in advance of the intersection. Each sign and beacon installation were supplemented by a 48.3 km/h (30 mph) speed plate (60.9 × 76.2 cm [24 × 30 in]).

The city's decision to install the flashing beacons was based on numerous complaints from residents traveling through the intersection on a daily basis. Once the beacons were installed, the agency experienced a significant decline in complaints and received positive feedback from residents.



Figure 5-43. Warning Sign and Beacon in Arlington, TX.



Figure 5-44. Close-up of Warning Sign and Beacon in Arlington, TX.

Flashing Beacons

Flashing devices can improve the visibility of an unsignalized intersection. A study in Ohio examined 82 intersections, each of which was controlled by a flashing device.⁽¹³⁾ The results indicated that there is a reduction in accident rate with the installation of a flashing device. The evaluation of the different types of flashing beacons revealed that intersections had a significant reduction in total accidents when equipped with the following types of flashing devices: 1) standard stop sign on the side of the road with one or two flashing beacons attached to the support post; 2) a single unit placed overhead in the center of the minor approach roadway and displaying two beacons flashing alternately; and 3) two units placed overhead, each centered over a lane on the minor road, each unit consisting of one beacon. When intersection type was investigated, only one group had a significant reduction in accident rate—four-leg intersections with two-lane main and minor approaches.

The characteristics of traffic flow at rural, low-volume intersections controlled by stop signs and by intersection control beacons in conjunction with stop signs were examined.⁽¹⁴⁾ The study found that intersection control beacons generally reduced vehicular speeds in the major directions, particularly at intersections with inadequate sight distance. The intersection control beacons had, in general, little or no impact on accepted or rejected gaps. A large proportion of drivers (40 to 90 percent) violated stop sign laws by not completely stopping at the intersections. The intersection control beacons were not necessarily effective in reducing stop sign violations or accidents. Guidelines for installation of intersection control beacons are included in the report.

LESSONS LEARNED

Advantages of flashing beacons include:

- May be a low-cost solution
- Require low maintenance
- Are effective at drawing attention to potential hazards

Disadvantages include:

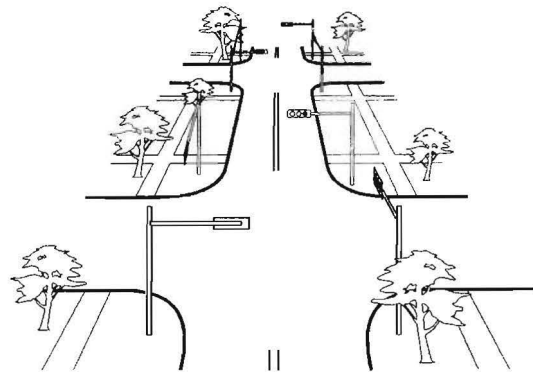
- May become overused
- Effectiveness may diminish over time if there is a high percentage of repeat users

DISCUSSION

Flashing beacons may improve safety and reduce speed by calling attention to other traffic control devices or hazards. However, the effect may diminish quickly for repeat users.

CHAPTER 5 TRAFFIC CONTROL TECHNIQUES

Signal Coordination



Traffic signal coordination allows a platoon of vehicles to progress through a series of intersections at a specified speed. This technique may be used for speed management and reducing speed variation.

CHARACTERISTICS

Closely spaced traffic signals may have their green times coordinated so that vehicles move more efficiently through the set of signals. This helps to prevent drivers held at one signal from watching wasted green time at the downstream signal and arriving just as the signal turns red.⁽¹⁵⁾

Vehicles released from a traffic signal often maintain their grouping for well over 305 m (1000 ft). Common practice is to coordinate traffic signals less than 0.8 m (0.5 mi) apart on major streets and highways.⁽¹⁵⁾ Figure 5-45 shows the speeds that can be expected with a given cycle length and signal spacing. Closely spaced signals 0.40 km (.25 mi) apart on streets that have signal cycle lengths of 100 seconds or more result in travel speeds of 32 km/h (20 mph) or less (see Figure 5-46). A signal spacing of 0.8 km (0.5 mi) optimizes two-way traffic flow on streets where longer cycle lengths are necessary. Keeping the number of signal phases to a minimum can improve the capacity of a corridor by increasing green band width by 20 seconds.⁽¹⁶⁾

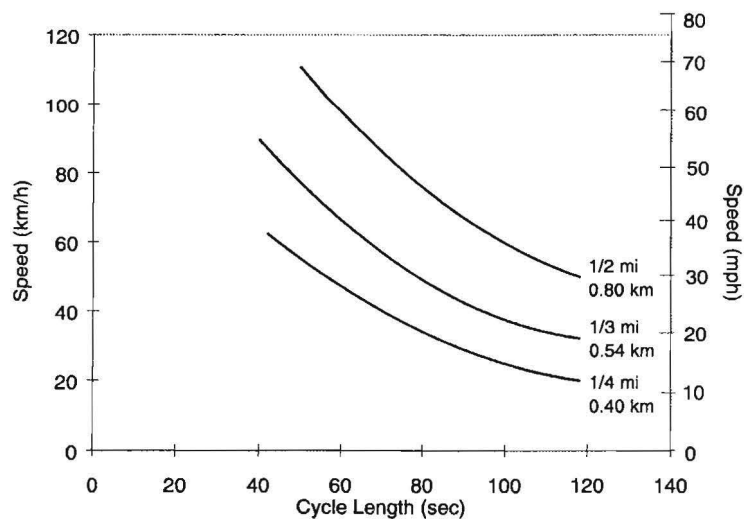


Figure 5-45. Optimum Signal Spacing as a Function of Speed and Cycle Length on Two-Way Streets.⁽¹⁶⁾

Signal Coordination

There are four major areas of consideration for signal coordination: benefits, purpose of signal system, factors lessening benefits, and exceptions to the coordinated scheme. These four areas are discussed briefly in the following paragraphs.

1. Benefits - The prime benefit of coordination is improvement of service provided, usually measured in terms of stop and delay. For a platoon of vehicles leaving one intersection and passing through another, the effect of allowing a poor offset to exist can result in delays of up to 30 seconds per vehicle and 10 stops per cycle. This is illustrated in Figure 5-46.

Another benefit of signal coordination is the maintenance of a preferred speed. The signals can be set to encourage a certain speed, and only vehicles going much faster than this speed will have to stop frequently.

Sending vehicles through successive intersections in moving platoons is also a benefit. In a well-formed platoon, the time headway between successive vehicles is somewhat shorter than the headway achieved when vehicles start from a complete stop.

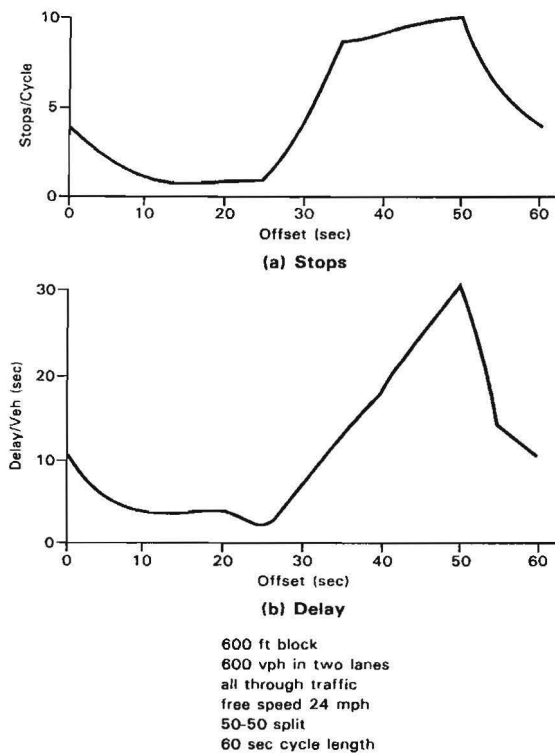


Figure 5-46. Illustration of the Effect of Offset on Stops and Delays.⁽¹⁵⁾

It is also possible to stop fewer vehicles using signal coordination. This is especially important if there is not sufficient storage available.

Keeping vehicles moving as smoothly as possible at efficient speeds also helps to conserve fuel and to reduce air pollution.

2. Purpose of signal system - The type of signal system and the movements to be progressed are important considerations. Another important consideration is the purpose for coordinating the signals. Common objectives include maximum green times for platoons, minimum delay, minimum stops, and minimum combinations of stops and delay.
3. Factors lessening benefits - Factors limiting the benefits of signal coordination

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TRAFFIC CONTROL TECHNIQUES

Signal Coordination

include inadequate roadway capacity; substantial side friction including parking, loading, double parking, and multiple driveways; complicated intersections with multi-phase control; wide variability in traffic speeds; very short signal spacing; and heavy turn volumes.

4. Exceptions to the coordinated scheme - There are intersections which make it difficult to coordinate all signals within a system. There may be an intersection within the system which requires a longer cycle length than all of the others, or there may be a critical intersection (one which cannot handle the volumes delivered to it at any cycle length). These situations require careful consideration and may require changing the purpose for which the progression is being designed.⁽¹⁵⁾

Traffic signal coordination and interconnection are estimated to cost between \$5,000 and \$13,000 per signal.⁽¹⁷⁾

EXPERIENCES

Downtown streets in Portland, Oregon, are coordinated at low speeds (19 to 29 km/h [12 to 18 mph]) and are coordinated for pedestrian speeds in certain directions. This slow speed works well for bicycles as well.

The city of Oakland, California, informs drivers that 11th Street's signals are not timed in an effort to divert traffic to Franklin Street, as shown in Figure 5-47.

Experience has shown that traffic signals can decrease the number and severity of right-angle collisions but may increase the number of rear-end collisions. However, the cost effectiveness of improved signal timing is significant due to the reduced delay at intersections. Several studies have indicated the level of these benefits. Texas implemented a statewide signal synchronization program; after 26 projects and \$1.7 million in expenditures, there was a 19.4 percent reduction in delay, 8.8 percent reduction in the number of stops, and 13.3 percent reduction in fuel consumption. The overall benefit/cost ratio was 38:1. In Tucson, Arizona, a regional program to improve traffic signals resulted in 14 to 29 seconds in average delay per signal cycle. An aggressive program of signal timing optimization applied to 3172 signals in California yielded a 58:1 benefit cost ratio. The program resulted in a 15 percent reduction in vehicular delays and 16 percent reduction in stops over a three-year period. Overall travel times dropped by 7.2 percent, and the 8.6 percent reduction in fuel expenditures alone produced savings almost 18 times the total cost of implementing the signal project.⁽¹⁷⁾

Signal Coordination



Figure 5-47. Sign Encouraging Use of Alternate Street in Oakland, CA.

LESSONS LEARNED

Advantages of signal coordination include:

- Can reduce number of stops
- Can reduce delay
- Can encourage a preferred speed
- Can send vehicles through intersections in platoons, reducing time headways
- Can stop fewer vehicles
- Can conserve fuel and minimize air pollution

Disadvantages include:

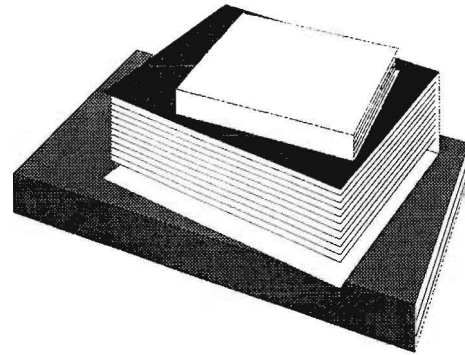
- May be difficult to include all intersections within a corridor
- May be difficult to optimize both directions

DISCUSSION

Traffic signal coordination allows vehicles to progress through a series of signals at a specified speed, providing improved service in terms of stops and delay.

CHAPTER 5

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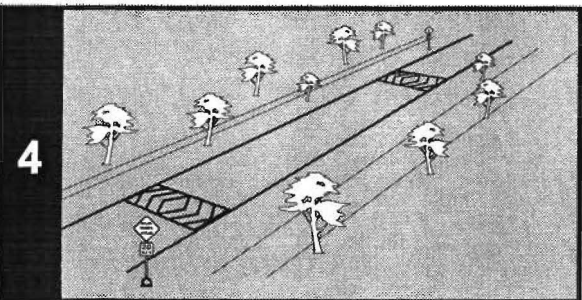
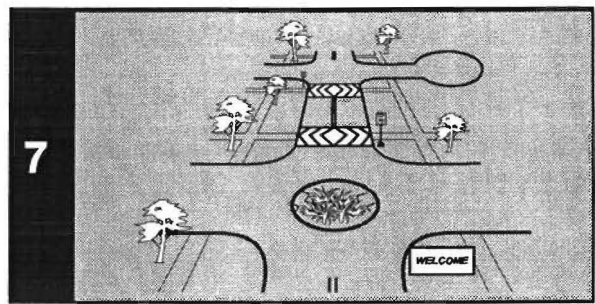
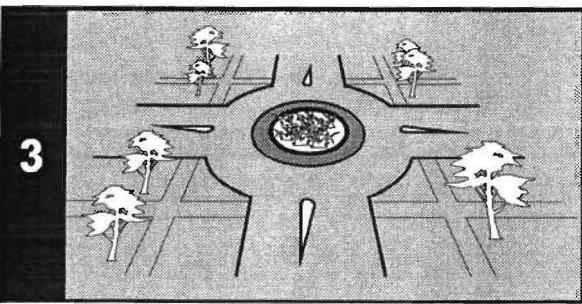
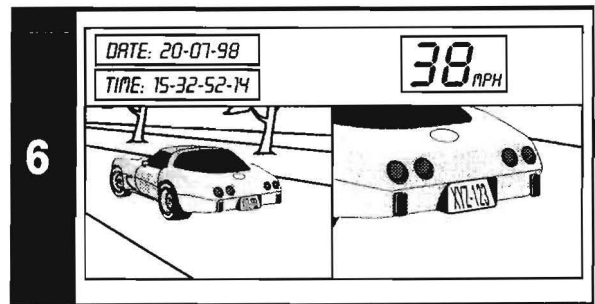
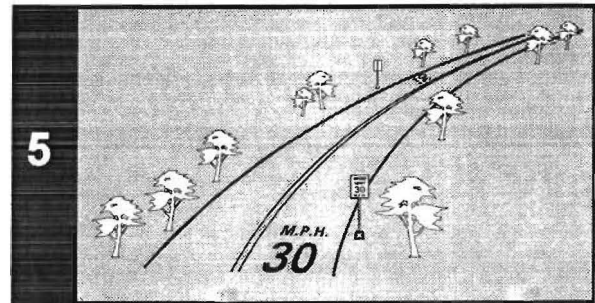
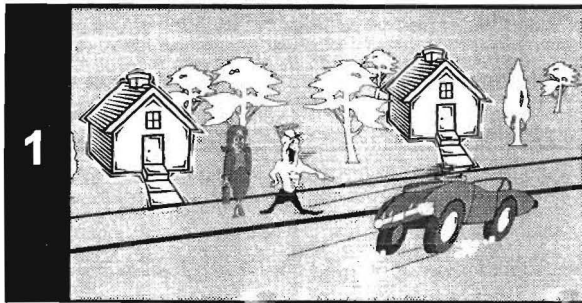
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CHAPTER 6

ENFORCEMENT

TECHNIQUES



CHAPTER 6 ENFORCEMENT TECHNIQUES

Citizen Speed Watch Programs



Citizen speed watch programs are public awareness programs that involve a cooperative effort among concerned residents, city or county staff, and motorists. The key to the success of the programs is that most drivers who speed through neighborhoods are unaware of the effects their actions have on the peace and safety of the neighborhood. Residents observe and record vehicle speeds on their streets and notify the owners of these vehicles when and where they were observed speeding.⁽¹⁾

CHARACTERISTICS

In many jurisdictions, speed watch programs are the first measure used when complaints are received about speeding traffic on residential streets. One reason is that neighbors are involved in the solution.

Neighborhood speed watch programs have been initiated in several locations nationwide. Although program specifics vary, the basic premise of the program is for citizens living in a given area to monitor and identify vehicles they observe speeding in their neighborhoods. A personalized letter may be sent to local residents asking for their cooperation, and personal visits by neighborhood committee members may include an appeal for cooperation if a self-contained subdivision is involved. Signs may be erected to make drivers aware of the program.⁽²⁾

In most areas, citizens are trained to use a radar gun by local law enforcement agencies. One citizen operates the equipment and another records the vehicle and speed information. License plates are matched by the local police department or the Department of Public Safety. The local traffic or police department could then send letters to speeders informing them that their speeding is inconsistent with standards adopted by their neighbors and asking speeders to avoid speeding through the neighborhood. If the vehicle is owned by someone in the neighborhood, the neighborhood association or similar group may handle the driver notification process.⁽²⁾

ENFORCEMENT TECHNIQUES

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Citizen Speed Watch Programs

EXPERIENCES

Neighborhood speed watch programs are a very low-cost approach to providing additional neighborhood enforcement. The equipment may be borrowed from the local traffic or police department, whose representative also trains the citizens to perform the work. Citizen groups may also purchase a radar device for a few hundred dollars, however, additional funds may be needed for training. Citizen time is voluntary, and minimal costs are associated with initial and follow-up mailings to introduce the program and generate resident interest.

Speeds are typically reduced during the time a speed watch is conducted but may increase after the speed watch. In some cases, however, citizens may find that no significant problem exists.

In two Gwinett County, Georgia, subdivisions, the 85th percentile speeds were reduced from 72.4 - 56.3 km/h (45 - 35 mph), and the total number of vehicles exceeding 80.5 km/h (50 mph) was reduced from 56 to 13 vehicles daily.⁽³⁾ Although the program was canceled in 1991-1992, city staff stated that benefits of the program still exist due to newsletters and to residents “preaching to each other” to slow down. The biggest problem with the program was that it was very labor intensive.

In Portland, Oregon, the Speed Watch Program trains residents to use radar in their neighborhoods and provides equipment for a week. The information gathered by the volunteers is matched with the Driver and Motor Vehicle Service (DMV) records. The bureau then sends a letter to the vehicle’s registered owner advising the owner their vehicle was seen speeding. The letter appeals to the owner and drivers to slow down on neighborhood streets.

Because speeding can result from habit, not from an intentional decision to break the law, short-term reminders to slow down may be an effective way to inform people to change their driving behaviors. Banners are used in Portland to alert drivers to check their speeds. Neighborhood associations or other community groups are asked for \$100 to help defray some of the costs of hanging the banner. The group also receives bumper stickers with the “Slow Down” message to distribute throughout the neighborhood. When a neighborhood completes a successful Speed Watch, the city installs a banner in the area reminding people to slow down (see Figure 6-1). The Speed Watch and Banner programs in Portland are now on hold due to budget cuts.

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ENFORCEMENT TECHNIQUES

Citizen Speed Watch Programs



Figure 6-1. Slow Down Banner in Milwaukee, OR.

LESSONS LEARNED

Support of neighborhood residents is essential to the success of a citizen speed watch program. One agency requires at least 50 percent of local residents to indicate their desire for the initiation of a speed watch program before it is implemented. Some neighborhood groups actually restrict violators from using neighborhood amenities or publicize the offender's name in the neighborhood newsletter.⁽²⁾

Advantages of neighborhood speed watch programs include:

- Temporary effect on speeders within sight distance of the radar gun
- Long-term effects possible as neighbors become more aware of who is speeding and interact with each other in social settings

Citizen Speed Watch Programs

- Possible speed reduction during short intervals when the radar gun is in use
- Effective public relations and educational tool
- Neighbors feel they are part of the solution

Disadvantages of Neighborhood Speed Watch Programs include:

- Very labor intensive
- Not an enforcement tool
- Not effective on multi-lane roadways that have significant volumes because it is difficult to differentiate between approaching vehicles.⁽⁴⁾

DISCUSSION

Citizen or neighborhood speed watch programs rely on citizen participation to create awareness and help control speeds in neighborhoods. The programs have been perceived positively by most neighborhoods, even in areas where significant speed reductions were not measurable. In the Georgia subdivisions cited earlier, residential speed complaints virtually ceased after the speed watch program was enacted.

CHAPTER 6 ENFORCEMENT TECHNIQUES

Increased Enforcement (Conventional)



Increased enforcement involves the effective use of public safety and/or police personnel to encourage reduced speeds. Enforcement usually involves the use of radar to identify speeders and the subsequent ticketing of the violators.⁽³⁾

CHARACTERISTICS

Increased enforcement may be handled on a citizen request basis, by a program of alternating locations for added enforcement, or by specific programs funded particularly for this purpose.

Studies have shown that appreciable speed reductions result from enforcement operations. However, speeds are usually reduced only as long as the enforcement is maintained. While speeds are reduced, the number of accidents is generally reduced, and overall safety is improved.⁽³⁾

A concern of increased enforcement is that enforcement must be long term in order to be effective, which results in a significant investment of personnel and funds. Use of personnel for speed enforcement is typically not a high priority for police departments.

EXPERIENCES

The city of Madison, Wisconsin, uses annual 402 Highway Safety Funds to provide increased enforcement through overtime hours for law enforcement officers. One officer uses a radar gun to monitor speeds and then calls ahead with license plate numbers to approximately five other officers who are stationed downstream. Warning signs are installed in targeted areas to notify the public of the "Speed Wave." The signs were intended to be temporary, but some were left permanently. The program started with the traffic engineering department but was later turned over to the police department. The Speed Wave was originally used at higher-speed accident locations, but locations are now also determined by citizen requests during the year.

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Increased Enforcement (Conventional)

In Texas, the Speed Selective Traffic Enforcement Program (Speed STEP) is used to provide additional enforcement using funds from the Texas Highway Traffic Safety Program (Federal 402 funds). The project description is: "Selective traffic enforcement and information projects designed to bring motorists into compliance with all posted speed limits in order to reduce risk-taking behavior by motorists." For fiscal year 1997, the city of College Station, Texas, received a \$15,000 grant which was used to target speeders on six roadways in College Station. Citizens were notified of the increased enforcement through an article in the local newspaper. Results of the speed study are shown in Table 6-1.

Table 6-1. Effect of Increased Enforcement in College Station, TX.

STEP Location	Speed Limit	Percentage Exceeding Speed Limit (Start of Grant)	Percentage Exceeding Speed Limit (End of Grant)
Holleman (Taurus to FM 2154)	56.3 km/h (35 mph)	80%	48%
University Drive (FM 2154 to Discovery)	64.4 km/h (40 mph)	93%	93%
FM 2818 (Dowling Road to north city limits)	88.5 km/h (55 mph)	72%	68%
FM 2818 (300 Blocks)	64.4 km/h (40 mph)	74%	76%
SH 30 (Kyle South to SH 6 Bypass)	64.4 km/h (40 mph)	73%	70%
Southwest Parkway (Texas Avenue to Welsh Street)	56.3 km/h (35 mph)	77%	87%

150 observations were made at each site using a stationary radar device.

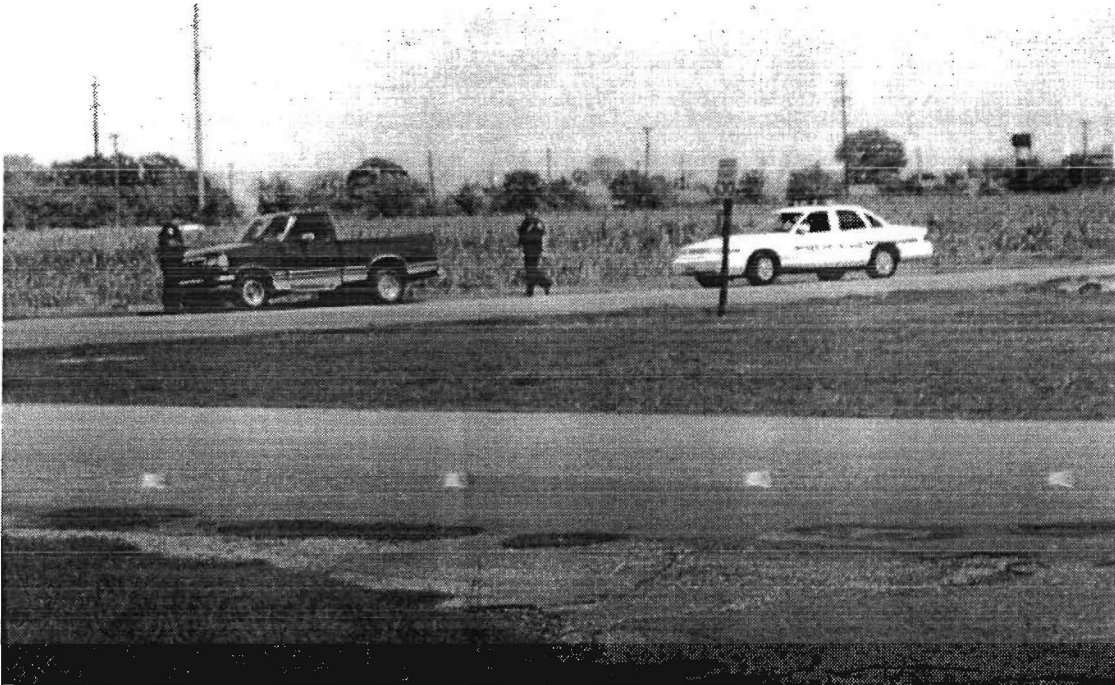
Overall results of the 1997 STEP program in College Station indicated a 5 percent reduction in vehicles exceeding the speed limit from the start of the grant. A total of 516 enforcement hours were spent at the six sites, and an average of three arrests or citations were made/issued per enforcement hour.

Figure 6-2 illustrates conventional enforcement and typical regulatory signs advising drivers that their speeds are being monitored.

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6

ENFORCEMENT TECHNIQUES

Increased Enforcement (Conventional)



**RADAR
ENFORCED**

**SPEED
CHECKED
BY
RADAR**

**UNMARKED
POLICE CARS
PATROLLING**

Figure 6-2. Examples of Conventional Enforcement and Signage.

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Increased Enforcement (Conventional)

LESSONS LEARNED

Residents support and encourage enforcement on their street; however, there is often a negative reaction if enforcement results in citations to local residents.

Advantages of increased enforcement include:

- Reduces speed
- Increases driver awareness about speeding on residential streets
- Increases safety
- Makes response quick and effective⁽⁵⁾
- Good temporary public relations tool

Disadvantages of increased enforcement include:

- Requires regular periodic enforcement to gain long-term benefits
- Is costly for law enforcement agency⁽⁵⁾

DISCUSSION

Surveys have shown that police enforcement for speed reduction is a widely accepted and effective method nationwide and is accepted positively by the general public. However, enforcement must be administered continuously for long terms in order to be effective.⁽³⁾

CHAPTER 6 ENFORCEMENT TECHNIQUES

Speed Trailers



Speed trailers are mobile roadside devices that use radar to measure the speed of approaching vehicles by recording and displaying the speed to passing drivers in an effort to decrease speed. The portable units post the legal speed of the roadway and display the current speed of the approaching vehicle. Speed trailers are also known as speed display boards or mobile radar trailers and were developed in the late 1980s. Usage has grown quickly since that time; in 1991, 90 devices were reported in the United States. In late 1998, 500 devices were in operation. Speed trailers have been used as an enforcement tool in some areas when police officers enforce the speeds; however, they are mainly used as a public relations measure to inform motorists of their speeds in the hope that the speeding motorists would voluntarily reduce their speed.⁽⁵⁾

Speed trailers are also used for automated enforcement in a few states, where speeds and license plate numbers are recorded by hidden cameras, and citations are issued by the local law enforcement agency.

CHARACTERISTICS

Speed trailers include a radar device to detect the speed of approaching vehicles, an LCD to display this speed, and a speed limit sign posting the legal speed limit of the roadway. These items are mounted on a trailer which can be pulled from one location to another. Equipment to collect traffic volumes may also be used within the speed trailer (see Figure 6-3).

Speed trailer costs vary from \$2,000 to \$12,000 per unit depending upon their sophistication and whether a traffic counting computer unit is included. The cost for a typical day of operation is approximately \$10 for 12 hours of operation. An enforced radar trailer is estimated at \$92 for 12 hours of operation, which includes two hours of police enforcement.⁽⁶⁾

Speed trailers are very useful for educational purposes. They may be used by communities to educate citizens on how fast they are traveling or to illustrate to school groups how actual speeds vary from legal speeds. The three Es of speed trailer use are defined as:

Speed Trailers

- Education - can be used in neighborhoods, schools, and work zones as a public relations tool and for educational purposes
- Engineering - to collect speed and volume data
- Enforcement - to provide an aid in speed enforcement⁽⁵⁾

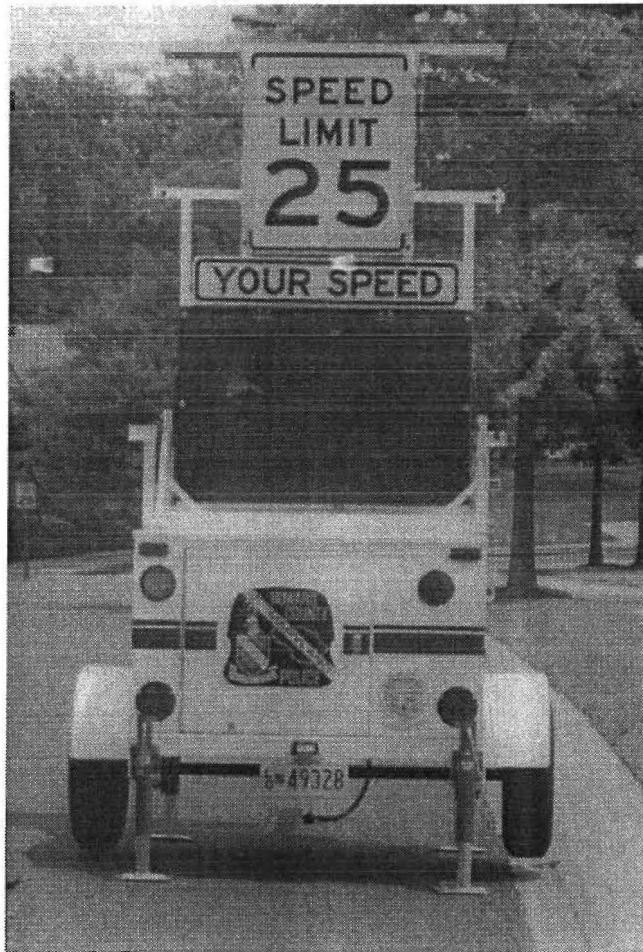


Figure 6-3. Speed Trailer in Montgomery County, MD.

EXPERIENCES

A research study in Bryan, Texas, confirmed that speed trailers *are* effective in reducing speeds and the proportion of speeders on low-speed urban roadways for speeders downstream of the trailer (see Figure 6-4). However, the same research study showed that speed trailers *do not* appear effective

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Speed Trailers

in reducing speeds and the proportion of speeders *after* the trailer is removed.⁽⁵⁾ A study in Riverside, California, demonstrated that speed trailers used with enforcement have a carryover effect both alongside and downstream of the device one week after its removal. Speeds alongside the trailer were reduced by 10.6 km/h (6.6 mph), and speeds downstream of the trailer were reduced by 7 km/h (4.4 mph) one week after the trailer was removed. Other studies in Orange County and Santa Barbara, California, and in North Carolina have also demonstrated positive effects on vehicle speeds. The Santa Barbara study found that speeds were reduced by 10 percent alongside the device and by 7 percent downstream for a distance of up to 0.8 km/h (0.5 mi).⁽⁶⁾

The city of San Jose, California, has two radar message boards (RAMBO units) which are operated by the police department. They are generally used with enforcement further down the road or with enforcement within a few days of the board's presence. The display boards are used on all classes of streets but more often on residential streets and collectors. The police department noted that the display boards were far more effective during a 13-month period of photo radar testing, probably because drivers didn't know whether or not their photograph was being taken.

The city of Madison, Wisconsin, has a portable speed board program which is volunteer driven. Volunteers are responsible for the operation of the portable speed board, and it is used as a periodic reminder to watch speeds. The portable speed trailer has an impact for a short time.

The Minnesota Department of Transportation suggests using portable speed displays for requests for speed reduction measures. In one school zone, the speed display was used to make drivers aware of the change from a 96.6 km/h (60 mph) to a 48.3 km/h (30 mph) speed zone. The speed display unit is handled by the police department.



Figure 6-4. Speed Trailer in Bryan, TX.

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Speed Trailers

LESSONS LEARNED

Advantages of speed trailers include:

- Make the public aware of posted and excessive speeds in given locations
- Provide efficiency for police officers
- Can be used for neighborhood speed watches
- Are claimed to be advantageous for traffic engineers
- May result in increased safety
- Are easily moved from one location to another
- Are a good educational and public relations tool
- Are especially useful in school and construction zones where spot speed reduction is important

Disadvantages include:

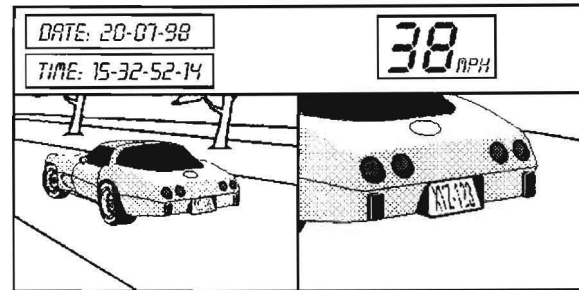
- Provide limited use for multi-lane roadways due to limited ability to differentiate between two or more approaching vehicles
- Do not appear effective in reducing speeds and proportion of speeders *after* the trailer is removed
- Have limited effect without the combined use of speed trailers and enforcement (automated or traditional)

DISCUSSION

Speed trailers are most useful in public awareness and education and for maintaining a high profile of concerns for local roadways. In general, they are not effective in modifying long-term habits or modifying a driver's perception of safe, reasonable speeds. In order to obtain results, selective enforcement should take place after the trailer is removed. The enforcement, though short-term, may curtail speed violations for a period of time.

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Automated Enforcement



Automated enforcement may be defined as “the use of image capture technology to monitor and enforce traffic control laws, regulations, or restrictions. Where enabling legislation authorizes the use of automated enforcement, the image capture technology negates the need for a police officer to directly witness a traffic offense.”⁽⁷⁾ Automated enforcement programs include enforcement of speed limits, red-light running, high-occupancy vehicle/bus lanes, railroad-highway grade crossings, and electronic toll collections. Speed limit enforcement is an automated enforcement technique which may be used to manage speeds on various roadway types as an alternative to conventional enforcement methods.

CHARACTERISTICS

Automated enforcement equipment typically consists of a radar device, a processing unit to determine if the vehicle is in violation, and a camera. When the processing unit determines that the vehicle is exceeding a preset speed, a photograph is taken. The camera records the vehicle license plate, the date and time of the exposure, the location, the vehicle speed, and sometimes the driver’s face. Information from the license plate is used to identify the owner of the vehicle, and the photograph may be used to identify the individual committing the violation. A warning or citation may then be mailed to the owner or driver of the vehicle.

Photo radar equipment may be installed on a tripod, in a stationary vehicle (see Figure 6-5), or in a bullet-proof cabinet attached to a pole. Photo radar is much harder to detect by common, commercially available radar detectors than conventional radar; the vehicle is caught by the radar beam with virtually no advance warning so that the driver cannot slow down quickly enough to avoid having the camera take the snapshot.

EXPERIENCES

Photo radar has produced mean speed reductions of 8.2 km/h (5.1 mph) at the operating device and mean speed reductions of 6.6 km/h (4.1 mph) downstream. However, effects of photo radar are even greater on excessive speeds (10 mph or more over the legal speed limit). Photo radar reduced excessive speeds by 30.2 percent at the device and by 33.5 percent downstream. While speeds are reduced significantly, the effects are typically short-lived after the devices are removed.⁽⁶⁾ A before

Automated Enforcement



Figure 6-5. Automated Enforcement in San Jose, CA.

and after study of 64 test sections in Norway found a 20 percent reduction in the number of injury accidents and a 12 percent reduction in the property-damage-only accidents.⁽⁶⁾

Cost estimates for a 12-hour day of deployment are \$220 for equipment and personnel when the equipment is purchased by the police department and \$155 for police personnel with equipment provided by an outside vendor. Cost per exposed driver is estimated to be \$0.55 for equipment and personnel purchased by the police department and \$0.39 for police personnel with equipment provided by an outside vendor.⁽⁶⁾

Pasadena, California, had a successful pilot program in 1987 which has led to regular use of the equipment. In three years of using photo radar, a Pasadena police lieutenant says they have issued 40,278 tickets; 50 of these tickets were contested in court, with only 10 percent of these cases

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Automated Enforcement

favoring the driver. The production of 40,278 speeding tickets is over six times what a full-time police officer issues.⁽⁸⁾

The city of San Jose, California, implemented a photo radar test program for speeding over a two-year period in 1996-1997. Photo radar was tested in two phases over a two-year period: four months of enforcement, nine months of non-enforcement, and nine months of enforcement. This program used a turn-key lease for equipment and was used only on residential streets by citizen request. Applications were mailed to 300 neighborhood associations, and the program was also announced through public service announcements. If a neighborhood association did not exist, petitions were used to request the enforcement. The petitions included the street requesting the enforcement and intersecting side streets and required a 51 percent approval rate.

The system was tested on 18 residential streets at the rate of one AM and one PM enforcement period each month (two hours each) for a total of four hours per month per street. Accidents dropped about 40 percent. Average and 85th percentile speeds dropped a few miles per hour; however, speeds that were more than 16 km/h (10 mph) over the speed limit dropped by about 40 percent. Residual effects were close to 100 percent; the decreases in speeding held for the entire nine months of non-enforcement. Marginal results were obtained on streets that did not have at least 15 to 20 percent of the drivers exceeding the limit by at least 16 km/h (10 mph). The test program's process and procedures were developed with a task force involving the police department, the courts, the DMV, and affected city departments. The program was run by non-sworn personnel who used a photo radar-equipped van and who had to be present to witness and document the speeder. Testimony was used in addition to the field sheets and photographs to document the speeder. No legislative problems were encountered other than passing the necessary city ordinance to allow non-sworn personnel to enforce speeds. An extensive public relations campaign took place prior to enforcement. The program received approximately 90 percent support from those who expressed opinions.

The results of San Jose's photo radar test experience may be summarized as follows:

The program is neighborhood driven; only neighborhood streets are targeted.

- 1) Many requests for enforcement were going unanswered because of the emphasis placed on collector and arterial streets. This program was enacted in lieu of placing road bumps.
- 2) The data shows success if 15 to 20 percent of the vehicles are exceeding the speed limit by 16 km/h (10 mph) or more.

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Automated Enforcement

The program proved to be successful and was approved for funding by the city council. The full-time program will begin in the fall of 1998. The city will hire a consultant to do the necessary follow-ups, mailouts, and matching.

LESSONS LEARNED

Based on a review of automated enforcement programs worldwide, three elements were found to be critical in successful automated enforcement programs: public education and awareness, involvement of local judiciary, and passage of enabling legislation.

Favorable public opinion and public acceptance have been named most often as the aspect that can make or break an automated enforcement program, and numerous agencies have discontinued programs due to public or political disapproval. Public safety campaigns explain why the program is being implemented, the safety issues that are being addressed, advantages over conventional enforcement methods, and how revenues will be used. The Federal Highway Administration developed a "Red Light Running Campaign Strategic Planning Guide" to assist local agencies with public education and awareness, and many examples of public education materials can be found on the World Wide Web.⁽⁷⁾

Another critical step in developing an automated enforcement program is early involvement of the local judiciary. Legal issues vary among different states and municipalities, including whether the state constitution contains an explicit or implicit right to privacy, whether the "silent witness" theory applies, and whether "service" by mail is allowed. Anchorage, Alaska's photo radar program was struck down at the local judicial level; the program had not been tested in the courts prior to initiation of the program.⁽⁷⁾

In most areas of the United States and elsewhere, explicit enabling legislation is necessary prior to initiation of an automated enforcement program. Attorney generals in several states have ruled that a combination of current laws and court rulings in effect prohibit automated enforcement. There are several open questions concerning implementation, such as whether photos will be taken of drivers in addition to vehicle license plates; whether the owner or driver of the vehicle will be ticketed; and whether the ticket will be a moving violation or the equivalent of a parking ticket. These issues must be addressed by the community in which the program is being implemented.

Advantages of photo radar include:

- Detecting and recording information about a large number of speeders
- Reducing the number of police pursuits and resulting confrontations
- Improving traffic flow by reducing rubbernecking at the ticketing site

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Automated Enforcement

- Making law enforcement officer time more efficient
- Providing enforcement in areas where roadway geometry makes it difficult
- Increasing traffic safety by reducing accidents and fatalities
- Targeting speeders objectively

Disadvantages of photo radar include:

- The violator caught on film is essentially guilty until proven innocent
- Impaired drivers or unsafe vehicles remain on the road because no traffic stop is made
- The violator may forget the details of the event due to the lag time between processing the photo and issuing the citation
- An officer cannot give discretion for an emergency situation
- May be a less effective learning tool than if the violator were stopped and given a citation immediately
- May be considered an invasion of privacy by some citizens
- People who purposely fail to register their vehicle cannot be sanctioned by this system

The use of automated enforcement has met with opposition in some locations. Opposition has centered around issues such as privacy, distribution of ticket revenues, ticketing procedures, and effectiveness of automated enforcement.

Legal experts have concluded that automated enforcement does not violate a citizen's legal right to privacy. However, most people have the perception of privacy while driving in their vehicle and feel that they are giving up this perceived privacy if they drive in an area of automated enforcement. Steps which can be taken to lessen the threat to privacy include photographing vehicles from the rear to show only the rear license plate along with not mailing the photograph with the citation sent in the mail.

It is also critical to decide whether the driver or registered owner of the vehicle will be ticketed for violations detected by automated enforcement systems. This may be dependant upon provisions in state or local enabling legislation. If tickets issued by an automated enforcement system are not moving violations and are the equivalent of a parking ticket, it becomes much less important for the system to identify the driver of the vehicle. On the other hand, it would be impractical to issue a moving violation to the registered owner of a vehicle when it could not be determined conclusively that the person actually committed the violation.

Automated Enforcement

DISCUSSION

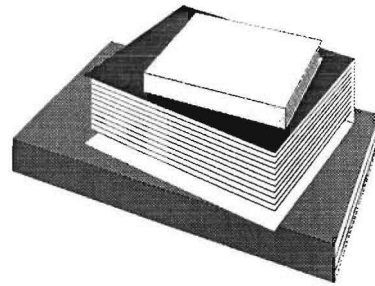
One National Highway Traffic Safety Administration study concluded that automated enforcement could be highly cost effective, even with its relatively high initial cost. Several locations in the United States are using photo radar in one form or another, and many others would like to use it but have had either public objections or legal disagreements regarding its implementation.⁽⁹⁾ However, public acceptance of this technique varies widely; some areas have high acceptance rates, while others have captured photos of drivers and occupants trying to destroy the photo radar equipment. A 1989 study indicated that 58 percent of those asked either approved or strongly disapproved of photo radar use. The study also found that almost half of the respondents said they drove slower because they were aware of the possibility of the presence of photo radar in their area.⁽¹⁰⁾

An ITE Traffic Engineering committee is currently gathering information on the use of automated enforcement, with an emphasis on red light, speed limit, and railroad-highway grade crossings. The committee is also investigating applications with high-occupancy vehicle and bus lanes, electronic toll collections systems, and weigh-in-motion stations. The committee findings should be published in an ITE Informational Report in 1999. Table 6-2 summarizes the information gathered to date.⁽⁷⁾

Table 6-2. Automated Speed Limit Enforcement Programs Worldwide.⁽⁷⁾

Programs in Operation	Test, Demonstration, or Discontinued Programs
Paradise Valley, Arizona Campbell, California Pasadena, California National City, California Riverside, California San Jose, California Garland, Utah Sandy City, Utah Wellington, Utah West Valley, Utah Washington State British Columbia Alberta, Canada Victoria, Australia Germany Norway Switzerland Finland	Anchorage, Alaska (discontinued) Peoria, Arizona (discontinued) Danville, California (discontinued) Folsom, California (discontinued) Pasadena, California (discontinued) Roseville, California (discontinued) Beaverton, Oregon Portland, Oregon Huntington, Utah Ontario, Canada (discontinued)

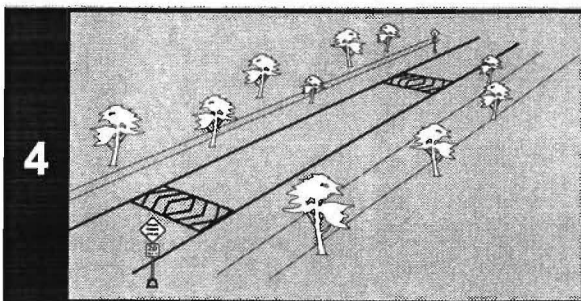
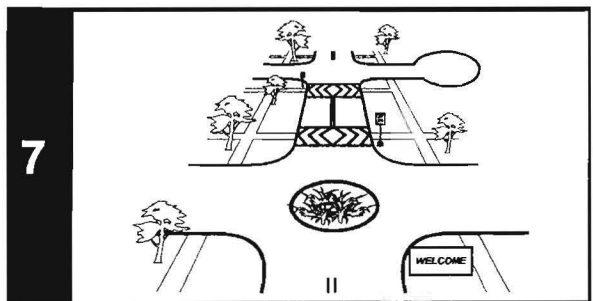
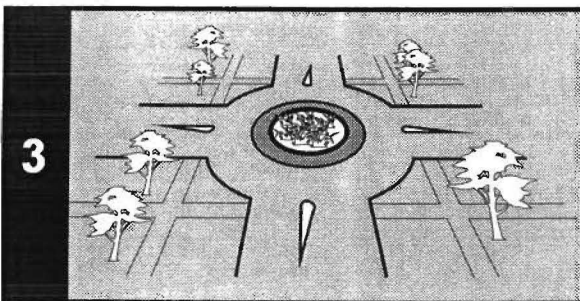
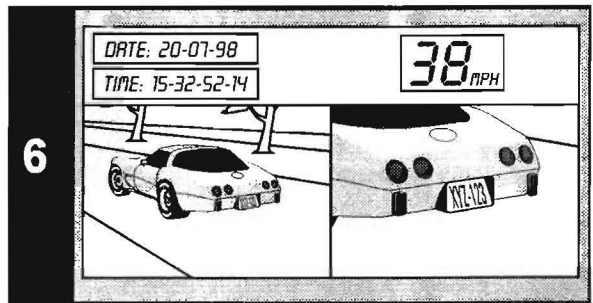
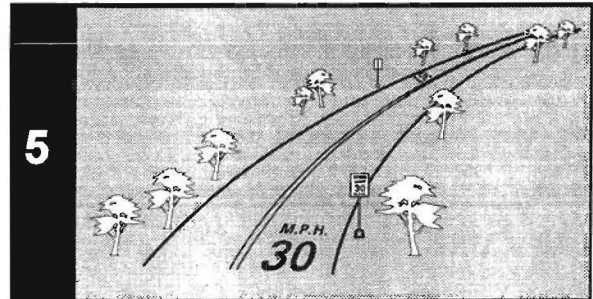
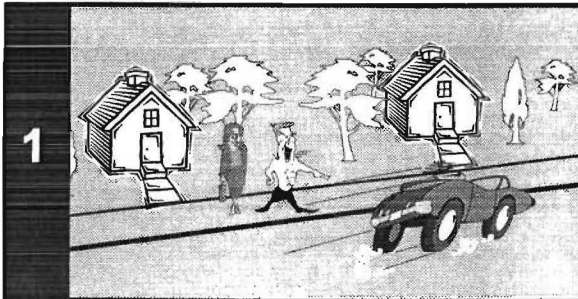
CHAPTER 6 ENFORCEMENT TECHNIQUES



References

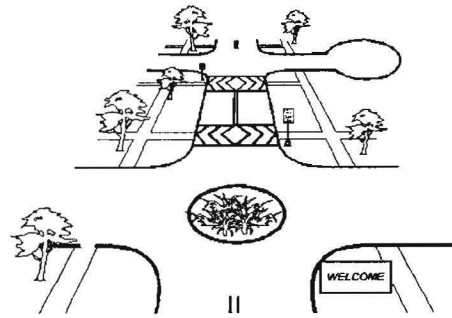
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CHAPTER 7 SUMMARY



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Use of Techniques



Speed management includes both residential areas (typically gathered under the term traffic calming) and higher speed facilities such as collectors and arterials. (It would also include freeways; however, freeways were not included in this project.) Managing speeds on arterials can be an effective part of a neighborhood traffic management plan; integrating speed management techniques on local, collector, and arterial streets can encourage traffic to use major roadways rather than residential streets and can address needs on an areawide basis rather than for an isolated roadway or intersection. Table 7-1 indicates those techniques which are suitable for higher speed roadways such as collectors and arterials as well as those that are appropriate for residential streets.

Table 7-1. Technique Use by Street Type.

TECHNIQUE	Appropriate on Local Residential Streets	Appropriate on Collectors and Arterials
ROADWAY DESIGN TECHNIQUES		
Chicanes	✓	
Neckdowns/Chokers	✓	✓
Central Narrowing Islands	✓	✓
Roadway Narrowing Techniques	✓	
Full Closures	✓	
Half Closures	✓	
Entrance Features	✓	
Traffic Circles	✓	
Roundabouts		✓

SUMMARY

CHAPTER

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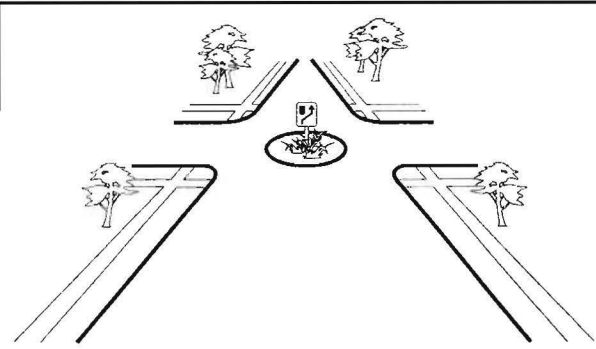
Use of Techniques

Table 7-1. Technique Use by Street Type (continued).

TECHNIQUE	Appropriate on Local Residential Streets	Appropriate on Collectors and Arterials
ROADWAY SURFACE TECHNIQUES		
Speed Humps	✓	
Speed Tables, Raised Intersections, Speed Cushions	✓	
Crosswalks Wider Sidewalk Areas	✓	✓
Bicycle Mobility Techniques	✓	✓
Innovative Pavement Markings	✓	✓
Rumble Strips		✓
TRAFFIC CONTROL TECHNIQUES		
Speed Limit Signs and Pavement Markings	✓	✓
Stop Signs	✓	
Warning Signs	✓	✓
Unique Traffic Control Signs	✓	✓
School Speed Zones	✓	✓
Flashing Beacons		✓
Signal Coordination		✓
ENFORCEMENT TECHNIQUES		
Citizen Speed Watch Programs	✓	✓
Increased Enforcement (Conventional)	✓	✓
Speed Trailers	✓	✓
Automated Enforcement	✓	✓

CHAPTER 7 SUMMARY

Roadway Design Techniques



The speed management techniques investigated in this project are summarized in the following tables. Each table includes the name of the technique, description, and the key advantages and disadvantages of each.

Table 7-2. Summary of Roadway Design Techniques.

TECHNIQUE / Description	Key Advantages	Key Disadvantages
<p>CHICANES are devices that alter the linear progression of a vehicle so that the driver must change paths to avoid the device.</p>	<ul style="list-style-type: none"> • Can reduce speeds at the chicane or on the entire street length if installed in series • Can reduce cut-through volumes 	<ul style="list-style-type: none"> • May require high initial costs • Are restrictive for emergency and service vehicles • Create potential crash obstacles for drivers
<p>NECKDOWNS/CHOKERS are constrictions of the roadway to reduce the width of the traveled path.</p> <p>CENTRAL NARROWING ISLANDS are used in the center of the roadway to provide refuge to pedestrians during the crossing maneuver.</p>	<ul style="list-style-type: none"> • Can shorten the crossing time for pedestrians • Create a refuge so pedestrians can cross half the street at a time • Both can make pedestrian crossings more visible to drivers • Neither slow emergency vehicles 	<ul style="list-style-type: none"> • Both may require some parking removal • Both may give pedestrians a false sense of security • Both create potential crash obstacles for drivers
<p>ROADWAY NARROWING TECHNIQUES narrow the roadway for a continuous length using geometric features, pavement markings, or landscaping.</p>	<ul style="list-style-type: none"> • Provide continuous, visual channelization • Can be inexpensive to install • Can be quickly implemented • Do not affect emergency response times 	<ul style="list-style-type: none"> • Require regular maintenance • Increase cost of roadway resurfacing • May be expensive to install, depending upon technique

Roadway Design Techniques

Table 7-2. Summary of Roadway Design Techniques (continued).

TECHNIQUE / Description	Key Advantages	Key Disadvantages
FULL CLOSURES completely close the roadway to through traffic at one end or at a mid-block location using diverters, cul-de-sacs, or signing.	<ul style="list-style-type: none"> • Reduce traffic volume and number of conflict points • Can still allow bicycle and pedestrian access 	<ul style="list-style-type: none"> • Restrict emergency vehicle and transit access • May increase trip length • Can be unsightly
HALF CLOSURES limit access to or from a roadway through the use of semi-diverters, median barriers, exclusion lanes, or forced-turn barriers.	<ul style="list-style-type: none"> • Reduce through traffic • Can provide for bicyclists and pedestrians • Can be attractive if landscaped 	<ul style="list-style-type: none"> • May increase emergency response time • Do not provide 100 percent compliance • May add landscape maintenance
ENTRANCE FEATURES use textured pavements, curb extensions, raised crosswalks, landscaping, or entrance signs to create a sense of neighborhood or community.	<ul style="list-style-type: none"> • Provide an indication of a change of environment • Help to create a sense of identity • Create additional areas for landscaping and monuments 	<ul style="list-style-type: none"> • Are not uniform from one location to another • May add additional landscape maintenance costs
TRAFFIC CIRCLES are small circular islands placed in the center of existing local intersections.	<ul style="list-style-type: none"> • Reduce vehicle speeds • Improve safety conditions • Can be visually attractive when landscaped and maintained 	<ul style="list-style-type: none"> • Add a potential hazard to the middle of the roadway • Can increase emergency vehicle response times • Unfamiliar drivers may not know how to drive them, especially when making a left turn
ROUNDABOUTS are raised islands that create a circular one-way flow of traffic.	<ul style="list-style-type: none"> • Can noticeably reduce speeds • Reduce the number of conflict points at the intersection • Can increase capacity • Provide an orderly and continuous flow of traffic • Are effective at multi-leg intersections 	<ul style="list-style-type: none"> • May be restrictive for some larger emergency and service vehicles unless mountable • Require pedestrians and bicyclists to adjust to less traditional crossing patterns • May have reduced aesthetic value due to safety signage

CHAPTER 7 SUMMARY

Road Surface Techniques

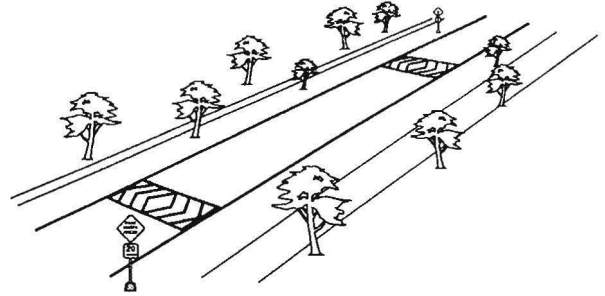


Table 7-3. Summary of Roadway Surface Techniques.

TECHNIQUE / Description	Key Advantages	Key Disadvantages
<p>SPEED HUMPS are raised areas in the roadway pavement perpendicular to the traffic flow.</p>	<ul style="list-style-type: none"> • Reduce speed • Are inexpensive to install • Do not affect intersection operations 	<ul style="list-style-type: none"> • Can increase emergency vehicle response times • May shift traffic to parallel streets
<p>SPEED TABLES are elevated plateaus in the roadway with descending ramps on each side. RAISED INTERSECTIONS elevate the entire intersection above the normal roadway surface. SPEED CUSHIONS are smaller raised areas within a traffic lane.</p>	<ul style="list-style-type: none"> • Reduce speed • Draw attention to intersection and pedestrian areas • Can be used on higher or lower volume streets • Can be aesthetically pleasing 	<ul style="list-style-type: none"> • May be expensive to construct and maintain • May affect emergency vehicle response times • Require additional signage and driver education
<p>CROSSWALKS are portions of roadways designated for pedestrians to use in crossing the street. WIDER SIDEWALK AREAS provide additional pedestrian space and streetscaping space off of the roadway.</p>	<ul style="list-style-type: none"> • Crosswalks indicate the preferred crossing location to pedestrians • Higher visibility crosswalks provide more visibility to drivers than standard crosswalks • Wider sidewalks provide additional space for pedestrians and street furniture • Wider sidewalks can improve the aesthetics of the area 	<ul style="list-style-type: none"> • Higher visibility crosswalks may provide a false sense of security to pedestrians • Higher visibility crosswalks require consideration of the effect of the materials on vehicle tires paths and the slipperiness of the surface where wet weather or snow conditions exist • Both may require increased construction and maintenance costs

Road Surface Techniques

Table 7-3. Summary of Roadway Surface Techniques (continued).

TECHNIQUE / Description	Key Advantages	Key Disadvantages
<p>BICYCLE MOBILITY TECHNIQUES are used to accommodate bicyclists. They include shared lanes, bike lanes, bike paths, or bicycle routes.</p>	<ul style="list-style-type: none"> • Encourage non-motorized travel • Better define where bicyclists are expected 	<ul style="list-style-type: none"> • Could create additional conflicts between vehicles and bicycles
<p>INNOVATIVE PAVEMENT MARKINGS are used to create the illusion of narrowed or narrowing lanes, to add a parking lane, or to develop on-street parking, particularly on collector and arterial streets.</p>	<ul style="list-style-type: none"> • May serve to reduce traffic speeds and crashes by warning or alerting drivers to an upcoming situation and by causing drivers to perceive that they are traveling too fast • Even if the innovative pavement markings do not reduce vehicle speeds, they may still alert drivers to a heightened sense of awareness in which they are better prepared to avoid a crash 	<ul style="list-style-type: none"> • More research is needed to verify the use of these patterns • Expensive to maintain the complex patterns
<p>RUMBLE STRIPS are pavement undulations across the driving lane causing a vehicle to rumble or vibrate when crossing them.</p>	<ul style="list-style-type: none"> • May reduce speeds • Create driver awareness to increase safety • Are inexpensive to install 	<ul style="list-style-type: none"> • May require high maintenance (depending upon the type installed) • May adversely impact bicyclists • Are noisy and may not be appropriate for neighborhood areas

CHAPTER 7 SUMMARY

Traffic Control Techniques

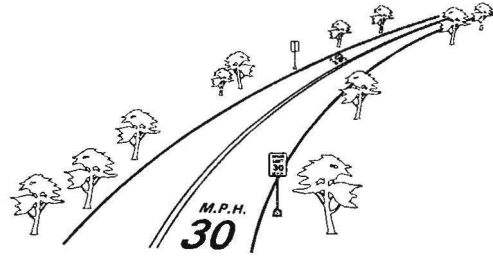


Table 7-4. Summary of Traffic Control Techniques.

TECHNIQUE / Description	Key Advantages	Key Disadvantages
FLASHING BEACONS are used to attract drivers' attention and to inform them of right-of-way conditions or potential roadway hazards.	<ul style="list-style-type: none"> • Are effective in drawing attention to hazards • May be a low-cost solution • Require low maintenance 	<ul style="list-style-type: none"> • Affect may diminish over time if there is a high number of repeat users • May become overused
SCHOOL SPEED ZONES use warning signs, crosswalks, other pavement markings, flashing beacons, and/or traffic signals to alert drivers of the school zone and to inform them of the beginning and ending of the reduced speed area.	<ul style="list-style-type: none"> • Alert drivers of possible pedestrian presence • Use uniform colors and symbols for easy recognition • Reduce speed limits for specified hours only 	<ul style="list-style-type: none"> • Can be costly to implement • Can be costly to enforce • May cause confusion if non-uniform devices or enforcement procedures are used
SPEED LIMIT SIGNS display the speed limit established by law or by regulation. PAVEMENT MARKINGS may be used to reinforce the message.	<ul style="list-style-type: none"> • Signs are well recognized and understood • Pavement markings reinforce speed limit signs • Both are inexpensive to install • Signs can reduce speeds with regular enforcement 	<ul style="list-style-type: none"> • Signs have significant non-compliance rates • Pavement markings are proven not to be effective • Pavement markings may cause concern regarding conspicuity and legibility

Traffic Control Techniques

Table 7-4. Summary of Traffic Control Techniques (continued).

TECHNIQUE / Description	Key Advantages	Key Disadvantages
<p>STOP SIGNS are used to assign the right-of-way at intersections with <i>significant</i> traffic volumes or crash frequencies. Numerous studies have indicated that Stop signs are not effective at reducing speeds or volumes in residential areas.</p>	<ul style="list-style-type: none"> • Are well recognized and understood • Provide positive public perception of reduced speeds and volumes if installed • Are inexpensive to install • Are easy to install • Can improve safety at previously uncontrolled intersections 	<ul style="list-style-type: none"> • Can breed disrespect and non-compliance if used excessively • May cause poor public perception if agency rejects installation request • Have warrants for installation that may be difficult to meet • Are not effective in reducing speed or volume
<p>TRAFFIC SIGNAL COORDINATION allows a platoon of vehicles to progress through a series of intersections at a specified speed.</p>	<ul style="list-style-type: none"> • Can reduce number of stops • Can reduce delay • Can encourage a preferred speed • Can send vehicles through intersections in platoons, reducing time headways • Can stop fewer vehicles • Can conserve fuel and minimize air pollution 	<ul style="list-style-type: none"> • May be difficult to include all intersections within a corridor • May be difficult to optimize both directions
<p>WARNING SIGNS are used to warn drivers of existing or potentially hazardous conditions on or adjacent to a highway or street.</p>	<ul style="list-style-type: none"> • Are easily recognizable • Alert drivers of approaching hazards or unique conditions • Can be supplemented with advisory speeds or flashing beacons to provide drivers with additional guidance 	<ul style="list-style-type: none"> • Can cause disrespect for signs if used unnecessarily
<p>UNIQUE TRAFFIC CONTROL SIGNS include regulatory, informational, warning, and guide signs. Such signs are typically designed for a unique situation believed to warrant special attention.</p>	<ul style="list-style-type: none"> • May be successful in informing drivers of a unique situation 	<ul style="list-style-type: none"> • May not conform to standards in the MUTCD • Are not easily recognized

CHAPTER 7 SUMMARY

Enforcement Techniques

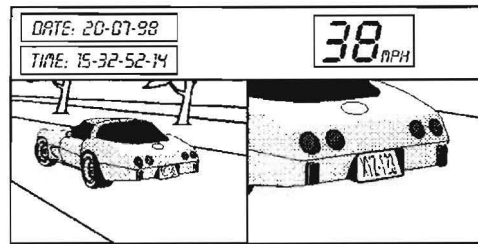


Table 7-5. Summary of Enforcement Techniques.

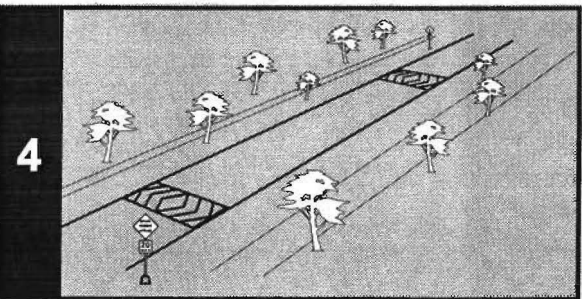
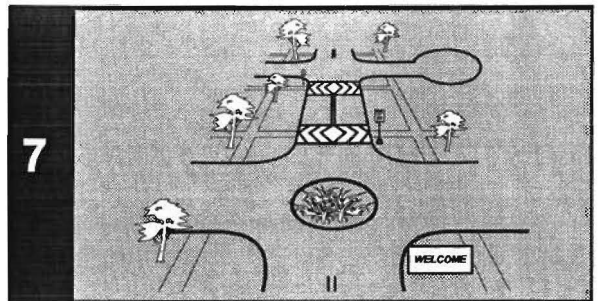
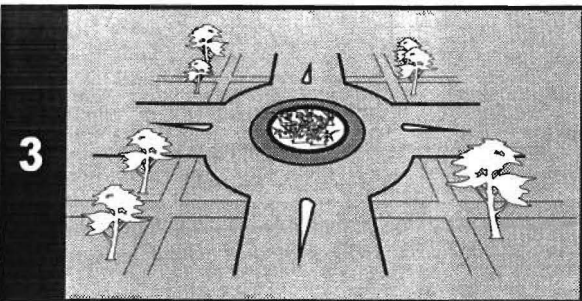
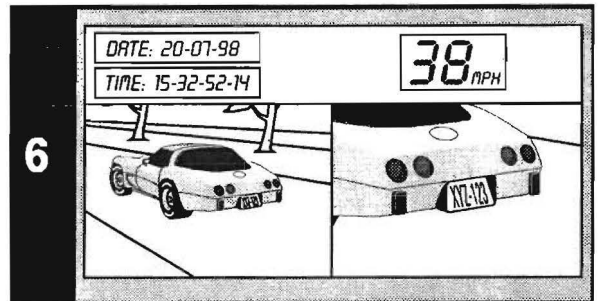
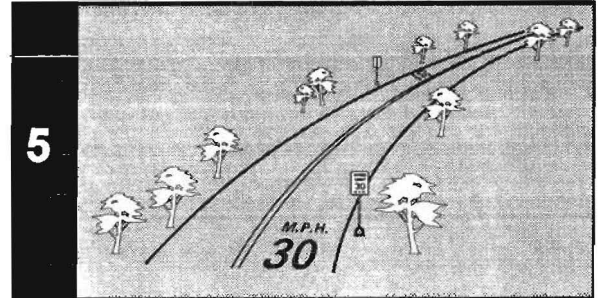
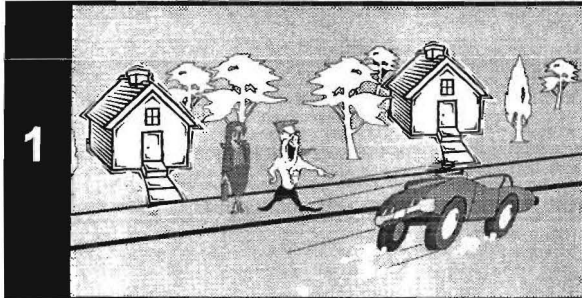
TECHNIQUE / Description	Key Advantages	Key Disadvantages
CITIZEN SPEED WATCH PROGRAMS are public awareness programs involving residents, agency staff, and motorists.	<ul style="list-style-type: none"> • Are an effective public relations and educational tool • Make neighbors feel that they are part of the solution for speeding problems • Long-term effects are possible due to resident interaction 	<ul style="list-style-type: none"> • Are very labor intensive • Are not an enforcement tool
INCREASED ENFORCEMENT (CONVENTIONAL) increases the use of conventional enforcement to reduce speeds in target areas.	<ul style="list-style-type: none"> • Reduces speed during enforcement period • Increases driver awareness of speeding • Makes response quick and effective 	<ul style="list-style-type: none"> • Requires regular long-term enforcement to gain long-term benefits • Is costly for law enforcement agencies
SPEED TRAILERS are mobile roadside devices that use a radar device to detect the speed of approaching vehicles. The devices display the speed limit and the speed of approaching vehicles.	<ul style="list-style-type: none"> • Educate the public of posted and excessive speeds • Are a good educational and public relations tool • Are easily moved from one location to another 	<ul style="list-style-type: none"> • Do not appear effective in reducing speeds after the trailer is removed • Have limited use unless used in combination with enforcement • Have limited use on multi-lane roadways

Enforcement Techniques

Table 7-5. Summary of Enforcement Techniques (continued).

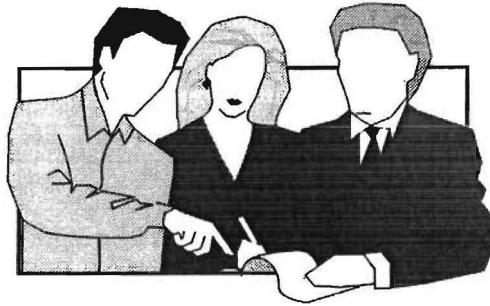
TECHNIQUE / Description	Key Advantages	Key Disadvantages
AUTOMATED ENFORCEMENT uses a radar device, processing unit, and camera to record vehicle speeds and photograph those exceeding the speed limit.	<ul style="list-style-type: none">• Can detect and record information about a large number of speeders• Can provide enforcement in areas where roadway geometry makes it difficult for police officers• Targets speeders objectively	<ul style="list-style-type: none">• Allows impaired or unsafe drivers to remain on the road because no traffic stop is made• May be a less effective learning tool than if the violator were stopped and given a citation immediately• Doesn't allow an officer to give discretion for an emergency situation

APPENDIX RESEARCH STUDY



APPENDIX RESEARCH STUDY

Research Approach



The research approach included the following: reviewing the literature, processing a written mail-out survey, conducting follow-up telephone interviews, performing on-site visits, summarizing experiences, and developing the *Handbook* and related reports. These tasks are summarized below with additional details on the findings contained in the following sections.

Literature Review

A literature review was conducted to identify the current state-of-the-practice for various speed management techniques. The literature review included techniques used on residential streets in addition to those used on collector and arterial facilities. This information was used to define the speed management techniques available, to determine how they are being used, and to focus the study on areas that warranted additional study. For example, the literature search provided very little information on citizen speed watch programs, but the written survey results indicated that citizen speed watch programs have been or are being used successfully by many agencies and citizen groups. The Annotated Bibliography lists the major findings from the literature review.

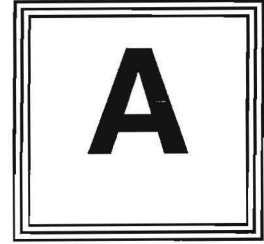
Written Surveys and Telephone Interviews

Surveys were mailed or faxed to 400 agencies to identify locations where speed management techniques have been considered or implemented. Issues addressed by the survey include: public involvement; criteria for approval by residents or businesses; cost sharing procedures; maintenance responsibilities; and locations where speed management techniques have been installed. The survey focused on obtaining information about techniques used on higher speed facilities and indicated limited use of techniques on these facilities. One hundred and fifty-three survey responses were received. Telephone interviews were conducted to obtain more information about particular techniques and specific sites where these techniques have been installed.

Site Visits and On-site Interviews

Locations for on-site visits were selected based upon information obtained through the literature review, through the written survey, through the telephone interviews, and when members of the research team would be in the area for another project. The site visits were used to clarify and expand areas with limited information, to identify useful information about specific techniques and sites, and to identify candidate sites for future research. Photographs taken at the sites are included in the *Handbook*.

RESEARCH STUDY



Research Approach

Both in-state and out-of-state visits were made in order to record a broad spectrum of the types of techniques currently in use. Texas site visits included Austin, San Antonio, College Station, Bryan, Carrollton, Plano, Garland, Arlington, and several towns in the Atlanta District. Out-of-state visits included various sites within the states of California, Oregon, Washington, Georgia, Maryland, Virginia, and Wisconsin in addition to the cities of Toronto, Ontario, and Vancouver, British Columbia, Canada.

Evaluation of Experiences

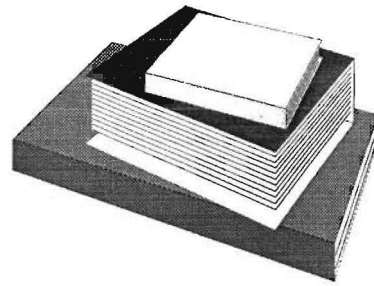
The information obtained through the written surveys, telephone interviews, and on-site visits was summarized by technique. Experiences for each technique include descriptions of the techniques, characteristics of the techniques, notes on their effectiveness or ineffectiveness, maintenance requirements, and advantages and disadvantages. Both successes and problems with various techniques are included in the discussions.

Handbook Development

The *Handbook of Speed Management Techniques* was developed as a user-friendly document to provide practitioners with a general overview of speed management techniques. The *Handbook* includes techniques used on local streets and on collector and arterial streets. The techniques in the *Handbook* are organized into four chapters: Roadway Design Techniques, Road Surface Techniques, Traffic Control Techniques, and Enforcement Techniques. The Roadway Design Techniques chapter included physical techniques designed to alter the driver's path. The Road Surface Techniques chapter discusses changing the roadway surface by adding vertical elements such as speed humps, by narrowing the roadway, or by drawing the driver's attention through the use of pavement markings. The Traffic Control Techniques chapter describes the use of traffic control devices such as signs and flashing beacons to reduce speeds or speed variation. The Enforcement Techniques chapter discusses enforcement techniques such as photo radar and speed trailers to remind drivers of the speed limit and of the speed at which they are traveling. Depending upon the technique, this may result in warning letters or citations being issued to those traveling above the speed limit. Each of these chapters includes descriptions of the techniques, photographs of the techniques, experiences of agencies that have used the technique, and lessons that have been learned.

APPENDIX RESEARCH STUDY

Annotated Bibliography



REFERENCE MATERIALS

Ewing, Reid, Charles Kooshian, and Mark White. *National Traffic Calming Report - State-of-the-Art*. Prepared for the International Institute of Transportation Engineers with funding from the United States Federal Highway Administration. Draft - July 1998. The report is available from the Institute of Transportation Engineers, telephone (202) 554-8050.

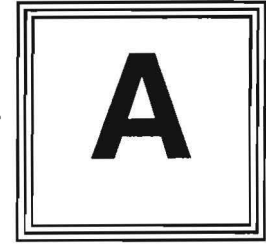
The purpose of the report is to provide information to those who are considering traffic calming as a potential solution and for those who are looking for ways to enhance existing traffic calming programs. Chapters include: (I) Introduction, (II) Selective History of Traffic Calming, (III) Different Measures for Different Purposes, (IV) Engineering and Aesthetics, (V) Impacts on Speeds, Volumes, and Accidents (Plus Other Things), (VI) Legal Status (Overview of Case Law), (VII) Agency Concerns (and How They Can Be Addressed), (VIII) Procedures and Warrants (the "Right" Balance of Flexibility and Standardization), (IX) Beyond Residential Traffic Calming, and an Appendix. The report includes examples of traffic calming techniques, examples where they have been used successfully and unsuccessfully, dimensions and designs of various devices, and cost information. The report is scheduled for publication in December 1998.

Guide to Neighbourhood Traffic Calming. Project 208. The Transportation Association of Canada and the Canadian Institute of Transportation Engineers. Draft - July 1998. The report is available from the Institute of Transportation Engineers, telephone (202) 554-8050.

The Transportation Association of Canada sponsored Project 208 to develop a traffic calming guide with the following objectives: 1) to ensure traffic calming measures consistent nationally, 2) to deter local jurisdictions from developing unique and unsafe devices and conditions, 3) to overcome reluctance of engineers to use traffic calming measures, 4) to address negative concerns and liability implications, and 5) to combine existing efforts into a national entity. The guide is limited to residential streets, including local streets and residential collector roads, where traffic problems such as shortcutting and speeding have the greatest impact and where most reported traffic problems occur. The guide has been divided into four chapters: Introduction, Community Involvement, Applicability and Effectiveness, and Design Guidelines. The guide is scheduled for publication in early 1999.

RESEARCH STUDY

Annotated Bibliography



Slow Down - You're Going Too Fast. The Community Guide to Traffic Calming. Public Technology, Inc. 1998.

This booklet includes 25 humorously written case studies and is designed to meet local governments' and communities' demand for information on traffic calming in trying to provide a better quality of life for their citizens.

Roundabout Design Guidelines. State of Maryland, Department of Transportation, State Highway Administration.

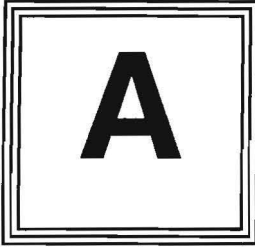
This guide was developed to set a standard approach to the planning, design, and construction of roundabouts in the state of Maryland, given that no federal guidelines exist. The guide uses the Australian Design as a guideline because its design procedure most closely represents current procedures already adopted by the Maryland State Highway Administration.

Florida Roundabout Guide, 2nd Edition. Florida Department of Transportation. May 1998.

This document presents a methodology for identifying appropriate roundabout sites and estimating roundabout capacity and delay. It describes the design principles and standards for roundabouts on state roadways and offers guidelines for operational features such as signing, marking, lighting, and landscaping.

A Guidebook for Residential Traffic Management. WA-RD 368.1. Washington State Department of Transportation. TransAid Service Center. Norwest Technology Transfer Center. Final Report. December 1994.

The *Guidebook* provides an overview of traffic calming devices (table) including definitions, effects on volumes and speed, pollution, and safety, etc. More in-depth descriptions of the techniques are included and separated into toolboxes of accidents, speeding, miscellaneous tools, pedestrians, and excessive volume. Photographs and sketches are included for many techniques. Additional chapters include design issues, legal issues, politics of residential traffic management, and concluding thoughts. The appendix includes a glossary of terms, a pictorial glossary of devices, an annotated bibliography, a residential traffic management flowchart, a section on setting up a self-managed program in small communities, and sample forms for requests.



RESEARCH STUDY

Annotated Bibliography

Neighborhood Traffic Control. North Central Section, Institute of Transportation Engineers. December 1994.

The North Central Section of the Institute of Transportation Engineers has compiled a list of neighborhood traffic control techniques and their effect on traffic volumes, speed, environmental issues, and safety. Information was compiled from experiences in existing neighborhoods. The techniques are presented as a tool box that is organized by ease of implementation. Twenty-five techniques are described, and a summary table describes their effectiveness. Techniques include: truck restrictions, increased enforcement, speed watch, variable speed display, watch for children, pavement markings, street narrowing, turn restrictions, private streets, basket weave stop signs, yield signs, do no enter, speed limit changes, parking restrictions, all way stop, one-way streets, stop sign removal, chokers, partial diverters, street closure, full diverters, traffic circles, median barriers, speed bumps/humps, and curvilinear construction.

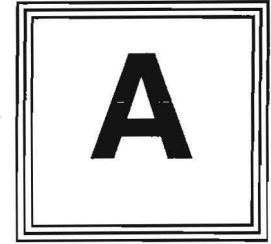
“Traffic Calming and Street Space Management.” In *A Toolbox for Alleviating Traffic Congestion and Enhancing Mobility*, Institute of Transportation Engineers, 1997, pp. 70-73.

This article describes the intent of traffic calming and gives the ITE definition of traffic calming: *Traffic calming is the combination of mainly physical measures that reduce the negative effects of motor vehicle use, alter driver behavior, and improve conditions for non-motorized street users.* In the United States, traffic calming measures focus on lowering vehicle speeds and reducing traffic volumes, most often with physical changes to the streets themselves. The article lists the traffic calming steps that are being considered in Albany, New York, and describes the four major groups of traffic calming in West Palm Beach, Florida. The article briefly discusses benefits-costs and lessons learned for successfully implemented projects.

Guidelines for the Design and Application of Speed Humps. A Recommended Practice of the Institute of Transportation Engineers. Prepared by ITE Traffic Engineering Council Speed Humps Task Force TENC-5TF-01. 1997.

The Recommended Practice provides guidelines for the design and application of speed humps. Speed humps are defined as roadway geometric design features to control vehicular traffic speeds along a roadway; they consist of raised pavement constructed or placed in, on, and across or partly across a roadway. The Recommended Practice provides guidelines for the design and application of speed humps. The report lists the results of speed hump research and testing, factors resulting in the removal of speed humps, a list of jurisdictions known to have used or tested speed humps, guidelines for speed hump use, community

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Annotated Bibliography

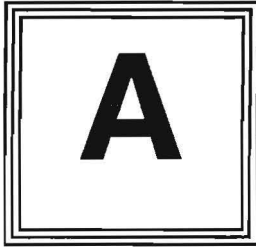
relations and administrative procedures, design and construction considerations, monitoring and evaluation, and other considerations.

Griffin, Lindsay I., and Robert N. Reinhardt. *A Review of Two Innovative Pavement Patterns That Have Been Developed to Reduce Traffic Speeds and Crashes*. Prepared for AAA Foundation for Traffic Safety. February 1996.

This report includes information on two illusion-creating pavement markings that have been developed to reduce traffic speeds and traffic crashes. The converging chevron pattern and the transverse bar pattern have been tested over the past 20 years. The transverse bar pavement marking pattern has been used the most often of several innovative techniques that have been developed. It has been used most often on approaches to roundabouts, particularly on long stretches of highway where it is easy to maintain and habituate to higher speeds. Other applications are on the approaches to horizontal curves, intersections, construction areas, and freeway off-ramps. This report reviews 10 different studies of the effects of transverse bar pavement markings. Results indicated wide variations in outcomes across the studies. The converging chevron pavement marking drew the AAA Foundation for Traffic Safety's interest with reports that this pavement marking was effective in reducing crashes when applied to the Yodogawa Bridge in Osaka, Japan. In the year before painting the bridge, two people died and nine were injured. In the six months after installation of the markings, no accidents were reported. Other reports suggest that crash frequencies may be reduced by 25 to 50 percent by the use of this pavement marking. The costs of applying the pattern are relatively low (\$15,000 to \$90,000), and the service life of four to six years makes this an attractive alternative.

Design and Safety of Pedestrian Facilities. A Recommended Practice of the Institute of Transportation Engineers. Traffic Engineering Council, Committee TENC-5A-5. March 1998.

This publication discusses guidelines for the design and safety of pedestrian facilities to provide safe and efficient opportunities for people to walk near streets and highways. Chapters include: roadway design considerations, pedestrians with disabilities, sidewalks and paths, pedestrian and motorist signing, signalization, crosswalks and stop lines, pedestrian refuge islands, pedestrian barriers, curb parking restrictions, grade-separated crossings, school practices, neighborhood traffic control measures, pedestrian-oriented environments, transit stops, and work zone pedestrian safety.



RESEARCH STUDY

Annotated Bibliography

Australian Standard: Manual on Uniform Traffic Control Devices. Part 13: Local Area Traffic Management. November 15, 1991.

This standard provides descriptions, sketches, pictures, advantages, and disadvantages for various local area traffic management (LATM) devices. The purpose of the *Standard* is to specify appropriate signs, delineation, and pavement markings in order to achieve uniformity. The devices described in the *Standard* include: perimeter treatments, road humps, roundabouts, driveway links, slow points, modified T-intersections, shared zones, and road closures.

PAPERS

Tanda, Wayne K. "All's Quiet on the Home Front (at Last)." In PTI Prism, Summer 1997.

Tanda poses the question of whether legitimate problems drive traffic calming efforts or if traffic calming efforts create legitimate problems. The article discusses the 25-year history of traffic calming in San Jose, California, in addition to programs in Columbus, Ohio; Houston, Texas; Montgomery County, Maryland; Tuscon, Arizona; and Phoenix, Arizona.

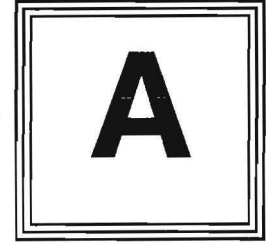
Fischbach, Gillian L., and Robert P. Murphy. "Policies for Residential Traffic Control in Brentwood, Tennessee." Resource Papers for the 1997 ITE International Conference. Tampa, Florida. March 23-26, 1997.

This paper addresses the rationale used for developing the city of Brentwood's multi-way stop policy and speed hump policy, criteria in the policies, and their effectiveness. Measures of effectiveness include impacts on safety, vehicle speeds, and volumes. Political ramifications of the policies are also discussed.

Macbeth, Andrew G. "Calming Arterials in Toronto." Compendium of Papers from the 68th Annual Meeting of the Institute of Transportation Engineers, Toronto, Ontario, Canada. August 1998.

Most traffic calming installations in Toronto are on local or collector streets, and most arterial roads haven't been considered for traffic calming. However, traffic calming has been successfully implemented on several arterial streets carrying up to 20,000 vehicles per day. Toronto's arterial road calming has relied on three main techniques: medians, road narrowings, and bicycle lanes. The common factor in these techniques is the reduction in the number of traffic lanes. Speed reduction is achieved due to the reduced opportunities for overtaking and because the road seems narrower (or the lanes seem narrower). Also, when

RESEARCH STUDY



Annotated Bibliography

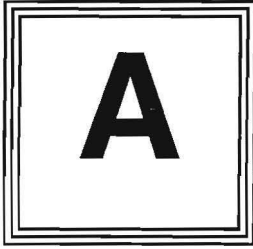
a road has been narrowed to two lanes, speeds are limited by the speed of the leading vehicle in a platoon. Generally, motor vehicle speeds have declined while pedestrian safety and cyclist safety have increased.

Rockwell, Thomas H., Joseph Malecki, and David Shinar. "Improving Driver Performance on Rural Curves Through Perceptual Changes - Phase III." Project EES 428, Final Report. Systems Research Group, Department of Industrial and Systems Engineering, The Ohio State University. March 1975.

Five rural curves in Delaware County, Ohio, were modified to determine driver performance. The curves were modified by adding transverse striping beginning 1100 feet prior to the curve with gradual decreased spacing to the beginning of the curve; accenting the inside perspective angle by widening the inside edge marker at the curve; using Wundt illusion-herringbone lines 500 feet from the curve with decreased spacing into the curve causing an illusion of narrowing roadway prior to the curve; and two curves modified by sign "deceptive curve" to serve as a comparison to pavement markings. It is clear that driver velocity behavior on rural curves can be influenced by the perceptual dimensions of the road scene and that pavement markings can produce speed reduction prior to the curve. Although the effects are relatively short-lived, new or transient drivers would be the primary beneficiaries of such curve modifications (partially because deceptive curves are quickly ascertained by local drivers). Intervehicular speed variations were also reduced, and signing had less impact than pavement marking changes on driver performance.

Fitzpatrick, Kay. *A Review of Automated Enforcement*. Research Report 1232-5. Cooperative Research Program, Texas Transportation Institute, Texas Department of Transportation, in cooperation with the U.S. Department of Transportation, Federal Highway Administration. Report No. FHWA/TX-92/1232-5. November 1991.

This report includes information on automated enforcement devices in the areas of speed enforcement, red-light traffic signal enforcement, and high-occupancy vehicle (HOV) lane enforcement. The report includes summaries and discussions of technology, experiences, legal issues, and public acceptance. Specific information includes: (1) portable billboard speed displays in Richardson, Texas, and Glendale, Arizona; (2) automated speed enforcement devices in Arlington, Galveston County, and LaMarque, Texas; Paradise Valley, Arizona; Pasadena, California; and Peoria, Illinois; (3) automated HOV enforcement in Virginia, California, and Seattle, Washington; (4) red-light enforcement in Pasadena, California, and New York City. Legal issues include photographing the driver, mailing the citation to the vehicle owner, and requiring the owner to identify the driver at the time of the offense.



RESEARCH STUDY

Annotated Bibliography

Hoff, Chris. "Legal Issues Surrounding Photo-Radar Vehicle Speed Enforcement." University of Texas at Arlington. CVEN 5391 - Advanced Study in Transportation Engineering.

This paper summarizes literature on photo radar including background information, history and current use, general legal issues, literature favoring and not favoring the use of photo radar, and future trends in photo radar.

Lockwood, Ian M. "What Is Traffic Calming?" Resource Papers for the 1997 ITE International Conference. Tampa, Florida. March 23 - 26, 1997.

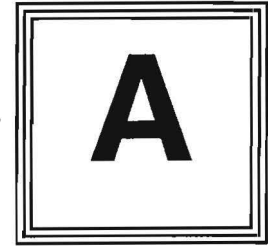
The article discusses the draft definition of traffic calming proposed by the ITE subcommittee, gives an interpretation of the definition including a discussion of traffic calming measures and traffic calming goals, and a discussion of related words and phrases including: traffic calming measures, traffic management, traffic control devices, streetscaping, traffic calming plans, neighborhood traffic calming plans, areawide traffic calming plans, traffic management plans, and neighborhood traffic management plans.

Atkins, Crystal, and Michael Coleman. "The Influence of Traffic Calming on Emergency Response Times." In *ITE Journal*, August 1997, pp. 42-46.

A study conducted in the city of Portland, Oregon, investigated the impacts of speed humps and traffic circles on emergency response times. Four dependent variables were studied: 36 different drivers, type of emergency vehicle (six different types), desirable vehicle speed (four different speeds), and type of traffic calming device (two circles, two 14 foot humps, and two 22 foot humps). The study's primary independent variable was vehicle travel time delay experienced for a combination of dependent variables.

The authors conclude that the three devices resulted in a wide range of travel time delay for the various types of vehicles tested. No effects were reported as a result of driver acceleration and deceleration characteristics. Delays ranged from 0.0 to 10.7 seconds, with two trucks demonstrating higher delay times. The authors recommend further evaluations of delay as a result of different traffic calming measures, and the city of Portland's final product will be a basis for establishing policies for community-wide emergency response routes.

RESEARCH STUDY



Annotated Bibliography

Ben-Joseph, Eran. "Traffic Calming and the Neotraditional Street." Resource Papers for the 1997 ITE International Conference. Tampa, Florida. March 23-26, 1997.

This paper discusses one of the latest trends in subdivision planning: neotraditional design including grids versus cul-de-sacs, safety and accessibility, retrofitting, and shared streets and neotraditional neighborhoods.

Bicknell, D. "Traffic Calming." Proceedings of the Institution of Civil Engineers: Municipal Engineer. March 1993, pp.13-19.

The article discusses the changing attitudes of residents about traffic on their streets and various traffic calming schemes which have been used in Great Britain. Objectives for traffic calming are defined as: (a) reduce speed of vehicles, (b) create conditions which encourage drivers to drive calmly, (c) remove extraneous traffic, (d) enhance the environment, and (e) improve safety.

Brilon, Werner, and Harald Blanke. "Extensive Traffic Calming: Results of the Accident Analyses in 6 Model Towns." Compendium of Technical Papers, Institute of Transportation Engineers Annual Meeting, 1993, pp. 119-123.

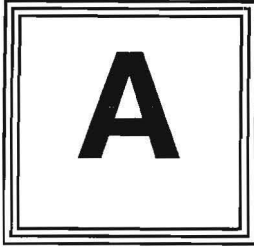
A study conducted in Germany investigated the safety effects after implementing extensive traffic calming measures. Traffic calming areas in six towns were included in a before- and after-construction crash analysis, with comparisons made at "control" sites in each of the towns. Crash data and accident records were obtained from local police authorities over a period of approximately eight to 10 years. The authors conclude that the extensive traffic calming measures have improved safety in the six towns, especially in reducing crashes involving pedestrians and motorcyclists.

Brindle, Ray. "Traffic Calming in Australia-More Than Neighborhood Traffic Management." In *ITE Journal*, July 1997, pp. 26-33.

A group of Australian practitioners met in 1990 to address local area traffic management (LATM) and to address/distinguish between LATM and traffic calming in Australia. The group concluded that LATM (mostly speed control measures) is a tool for traffic calming and identified three levels of traffic calming:

Level I Traffic Calming - lessen speeds and the impacts at the local (residential) level;

Level II Traffic Calming - lessen speeds and the impacts on traffic routes (arterials) where volumes, level of service, and network capacity is more of an issue; and



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Level III Traffic Calming - broad scale traffic calming to lessen city-wide impacts.

The group also developed a “matrix” of various traffic calming techniques for each of the three levels of traffic calming. The measures were divided into “Physical/Environmental” techniques and “Social/Cultural/Attitudinal” techniques. Through this process, Australia has demonstrated that traffic calming goes beyond LATM, as demonstrated by achieving all three levels of traffic calming. With this framework, the practitioners hope to achieve success at all levels, measured by social indicators such as political and social acceptance and economic prosperity for the community.

Burchfield, Robert M. “Traffic Calming Collector Streets - Portland’s Experience.” *Compendium of Technical Papers*, Institute of Transportation Engineers Annual Meeting, 1995, pp. 67-69.

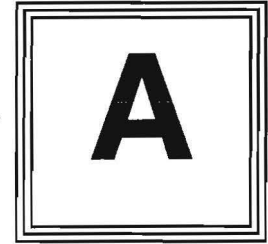
The author summarizes the city of Portland’s experience with traffic calming techniques on three residential collector roadways. Reducing speeds, improving pedestrian safety, and not affecting emergency response times were the primary objectives of traffic calming techniques on these collectors. Many of the devices used include speed humps, traffic circles, median or curb extensions, and entrance features. A consulting firm was hired by the city to assess the effectiveness of the techniques on the collectors. The study determined that reduced vehicle speeds after the installation of the treatments were more compatible with the residential land uses on these collectors, and that traffic calming improved pedestrian and cyclist safety.

Drdul, Richard, and Mike Skene. “Traffic Calming Do’s and Don’ts.” *Compendium of Technical Papers*, Institute of Transportation Engineers Annual Meeting, 1994, pp. 491-495.

The authors of this paper present a summary of the basic principles of traffic calming based on their experience in small and large communities in British Columbia, Canada. The summary is divided into “do’s,” which include guidelines that transportation professionals should follow when implementing traffic calming programs, and “don’ts,” which list common misperceptions about the effectiveness of selected traffic calming treatments and common problems that might be encountered. The authors’ “do” list focuses on educating, informing, and working with the community, its leaders, and all city agencies (fire, police, transit, etc.). The list also provides recommendations on engineering measures to consider, including self-enforcing measures, proper signing, and follow-up studies to determine effectiveness. The “don’t” list provides engineering recommendations of things to avoid, including overuse of stop signs, barriers, and speed *bumps*, and using only one treatment in all locations. The authors also recommend not using traffic calming techniques on collector

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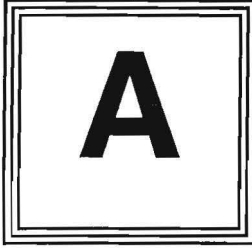
roadways, due to wider roadway widths (more difficult to implement traffic calming measures) and driver expectations.

Elvik, Rune. "The Effects on Accidents of Automatic Speed Enforcement in Norway." Institute of Transport Economics, Oslo, Norway. Preprint for Transportation Research Board, 76th Annual Meeting, January 12-16, 1997.

Automatic speed enforcement using speed cameras was introduced in Norway in 1988. This paper reports the results of a before-and-after study of the effects of automated speed enforcement on accidents. The study controlled for general trends in the number of accidents and regression-to-the-mean. A statistically significant reduction of 20 percent in the number of accidents was found. The number of property-damage-only accidents was reduced by 12 percent, which was statistically significant at the 5 percent level of significance. A decline of 26 percent in injury accidents was found on road sections complying with warrants referring to accident rates and accident density. On road sections not complying with any of the warrants, injury accidents declined by 5 percent. The results of this study confirm the results of previous studies of the effects of automatic speed enforcement on accidents, and the benefit cost ratio was almost 8.0.

Ewing, Reid. "Residential Street Design: Do the British and Australians Know Something Americans Do Not?" In *Transportation Research Record 1455*, Transportation Research Board, Washington, D.C., 1995, pp. 42-49.

In this paper, the author presents some of the fundamental roadway design and traffic calming differences between Great Britain, Australia, and the U.S. The author first introduces the philosophy difference between U.S. practitioners and those abroad. In the U.S., local street design is based on a conservative design approach with wide, tangent streets. This design philosophy, however, encourages higher speeds and volumes. Elsewhere, the approach is more pedestrian-oriented, with sharp horizontal curvature and limited sight distance to reduce vehicle speeds and cut-through traffic. The author then discusses more specific differences between U.S. practices and those abroad. The hierarchy for roadway classification in the U.S. is clearly defined in the AASHTO *Green Book* and includes arterials, collectors, and local roads, each with specific mobility and land access provisions. British and Australian design manuals, however, employ a two-class hierarchy for roadway classification, which includes roads (mobility function) and streets (land access function). Ideally, the two functions do not overlap. The author presents some of the design manuals and guidelines from these three countries to support many of these statements.



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Annotated Bibliography

Ewing, Reid and Charles Kooshian. "U.S. Experiences with Traffic Calming." In *ITE Journal*, August 1997, pp. 28-33.

This paper presents a summary of a survey of local transportation agency usage and experiences with traffic calming measures. The authors conducted mail-out and phone surveys to selected agencies in the U.S., many of which were in Florida. The survey covered the following main issues: 1) types of measures used; 2) justification for using the measures; 3) effectiveness of measures (supporting speed, volume, and/or crash data); and 4) the effects on emergency vehicles and their response times. Other items addressed included geometric design criteria, neighborhood request procedures, and liability issues.

Holland, Maggie. "Making Streets Safer." In *Highways & Transportation*, October 1997.

The article reviews use of various patterns of speed cushions, speed tables, and road humps in the U.K. Specific dimensions and construction techniques are discussed.

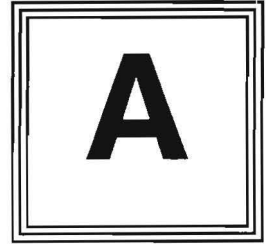
Hodge, A.R. "A Review of the 20 Mile/Hour Speed Zones - 1991." In *Traffic Engineering and Control*, October 1992, Vol. 33, No. 10, pp. 545-547.

The results of the traffic calming measures, most of which included speed tables and entrance features, indicated a reduction in crashes and fatalities after the measures were put into place. The author noted, too, that publicity about the traffic calming measures can further aid in the reduction of crashes.

Kanely, Brian D. "Neighborhood Traffic Calming - Do We Need Warrants?" Resource Papers for the 1997 ITE International Conference. Tampa, Florida. March 23-26, 1997.

This paper presents a summary of data collected in the city of Gainesville, Florida, for the traffic calming programs that have been implemented in that city. Three primary measures have been used in Gainesville, including traffic circles, road closures, and reduced speed limits. The data that were collected for these measures include traffic speeds and volumes, cut-through traffic volumes, and crashes. Other factors considered were street classification and emergency vehicle volumes. Based on the study results, the author concludes that considerable variation in data exists between the site and its implemented measures. Specific traffic calming warrants would be difficult to formulate, and each case should be evaluated independently based on site-specific criteria.

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Kant, Edward J., and Russell D. Muller. "Neighborhood Traffic Management: Development and Implementation - One County's Experience." Resource Papers for the 1997 ITE International Conference. Tampa, Florida. March 23-26, 1997.

This paper discusses the development and implementation of a traffic calming program for Collier County, Florida. The Naples/Collier County MPO formed a Traffic Calming Task Force composed of 25 citizens, traffic professionals, and staff members. The paper discusses the procedural approach, problem identification, development of potential solutions (28 techniques included), implementation of desired alternatives, program scheduling, the Handbook developed, and the program's progress to date.

Kulash, Walter M. "What Is Traffic Calming?" Resource Papers for the 1997 ITE International Conference. Tampa, Florida. March 23-26, 1997.

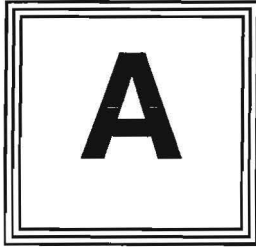
This paper suggests an approach to a nomenclature and classification structure for traffic calming measures based upon the rapidly growing interest in this area. The article defines traffic calming, discusses five basic categories of traffic calming action, includes a flowchart of traffic calming devices, and provides a pictorial menu of traffic calming devices.

Leonard, John D., and W. Jeffrey Davis. "Urban Traffic Calming Treatments: Performance Measures & Design Conformance." In *ITE Journal*, August 1997, pp. 34-40.

The authors of this paper emphasize the need for an established framework for all agencies to follow when selecting and analyzing traffic calming measures (TCMs). The basis for this framework would be the AASHTO *Green Book*, the *Manual on Uniform Traffic Control Devices*, and the *Highway Capacity Manual*. With these resources, and with well-defined goals and objectives, a useful measure of effectiveness for a traffic calming program can be established. The authors present an outline of goals, objectives, and measures of effectiveness that agencies can follow so that appropriate TCMs are chosen and are effective. The authors conclude by recommending changes and additions in AASHTO guidelines to provide information on design criteria for speeds as low as 20 miles per hour, and improved design criteria for roundabouts, diverters, street narrowings, and driveway links.

Letzkus, Albert G., and Thomas Goodman. "Four-Way Stop Intersections - Before and After Accident Study in Maricopa County." In *Western ITE Journal*, August 1997, pp. 5-6.

This paper presents a summary of a traffic study to determine the effectiveness of four-way stop-controlled intersections at reducing crash frequencies. In Maricopa County, Arizona, 10 mostly rural intersections were analyzed for three or four year periods before and after the



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intersection was converted from a two-way to a four-way stop-controlled intersection. The results of the study indicated a major reduction in traffic crashes for all 10 intersections, ranging from 54 percent to 100 percent reduction. The results were significant at the 0.05 level of significance.

Lines, C.J. "Road Humps for the Control of Vehicle Speeds." In *Traffic Engineering and Control*, January 1993, Vol. 34, No. 1, pp. 2-7.

This paper presents the results of early studies on speed humps conducted in Great Britain that eventually led to the development of speed hump guidelines, as well as more recent efforts to improve these guidelines. Numerous speed studies were conducted in the 1970s to develop optimal design and spacing criteria for speed humps. Studies determined the effects of spacing on vehicle travel speeds and determined that 100 meters was ideal for 20 mile per hour speed zones. The research, however, was several years old, and new vehicle designs presented driver discomforts at speeds in which vehicles were expected to cross the speed humps. The speed and spacing relationships indicated that new speeds were higher than the speeds obtained during the 1970s. The authors determined that spacings of less than 85 meters were now necessary for 20 mile per hour speed zones, versus the 100 meter "benchmark" that was established in the 1970s. Various ideal distances are suggested for the different hump designs.

Lockwood, Ian M. "Do We Need Traffic Calming Warrants?" Resource Papers for the 1997 ITE International Conference. Tampa, Florida. March 23-26, 1997.

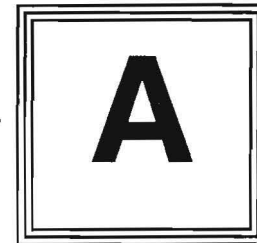
This paper seeks to answer the question of whether a warrant system is needed to justify traffic calming measures and to establish minimum conditions for the various measures. The answer is no; however, in the absence of traffic calming warrants, another approach to initiate traffic calming is suggested. This paper seeks to answer the question of whether a warrant system is needed to justify traffic calming measures and to establish minimum conditions for the various measures. The answer is no; however, in the absence of traffic calming warrants, another approach to initiate traffic calming is suggested. Projects may be prioritized and may also require quantification.

O'Brien, Andrew P. "The Need for Warrants - The Australian Experience." Resource Papers for the 1997 ITE International Conference. Tampa, Florida. March 23-26, 1997.

This paper discusses how warrants were developed for the Canberra Road and street network in Australia and discusses the key features of the warrants of 10 other cities/areas.

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O'Brien, Andrew. "Traffic Calming - Ideas Into Practice." Compendium of Technical Papers, Institute of Transportation Engineers Annual Meeting, 1993, pp. 129-134.

Level I primarily includes roundabouts and traffic circles, speed humps (and bumps), slow points, and street closures. Level II traffic calming is aimed at reducing the impacts on traffic routes (arterials) in Australia. Level III traffic calming, deemed as more difficult to achieve, is reducing traffic impacts at a network level.

Schlabbach, Klaus. "Traffic Calming in Europe." In *ITE Journal*, July 1997, pp. 38-40.

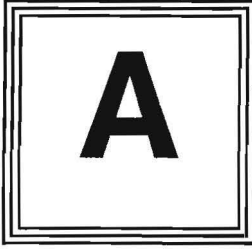
The author of this paper discusses the history of the development of traffic calming techniques and purposes since their introduction in 1970. A Dutch town in 1970 built an "obstacle" or speed hump at the end of an alley to reduce vehicle speeds. The author referred to this application on *woonerfs* as first-generation traffic calming. Second-generation traffic calming schemes broadened significantly from first generation, and the goals were to find low-cost and areawide solutions, to include all roadways, and to consider all modes of transportation.

Skene, Mike, Gene Chartier, Diane Erickson, Gary Mack, and Richard Drdul. "Developing a Canadian Guide to Traffic Calming." In *ITE Journal*, July 1997, pp. 34-36.

This paper describes the efforts by the Transportation Association of Canada (TAC) and Canadian Institute of Trans. Engineers (CITE) to create a bilingual *Guide to Neighbourhood Traffic Calming*. A TAC-sponsored survey of 52 Canadian municipalities in 1993 strongly indicated a need for national guidelines regarding traffic calming. The results indicated that 50 percent of responding municipalities used stop signs as a traffic calming measure; 20 percent have a process for developing traffic calming. For traffic calming implementation, 25 percent of the respondents justify it based on engineering, and 75 percent based on politics. TAC then sponsored Project 208 to develop a traffic calming guide with the following objectives: 1) to ensure traffic calming measures consistent nationally, 2) to deter local jurisdictions from developing unique and unsafe devices and conditions, 3) to overcome reluctance of engineers to use traffic calming measures, 4) to address negative concerns and liability implications, and 5) to combine existing efforts into a national entity.

Speed Management Work Plan. Federal Highway Administration, National Highway Traffic Safety Administration. April 1997.

In 1994, the National Highway Traffic Safety Administration (NHTSA) and the Federal Highway Administration (FHWA) Joint Speed Management Task Force developed a



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comprehensive, multi-faceted plan to examine speed-related issues. This document provides specific activities either in progress or being planned. The fourth category is enforcement—to develop innovative and effective speed enforcement methods, strategies, and programs. Activity 4.3 is Field Test--Laser Speed Enforcement Procedures. It states: Test communities will be selected for using speed measurement technology and various enforcement measures will be developed and tested. Successful strategies will be implemented with accompanying publicity and evaluation.

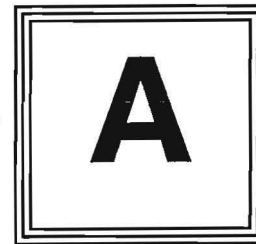
Streff, Fredrick M., and Roger H. Schultz. *Field Test of Automated Speed Enforcement in Michigan: Effects on Speed and Public Opinion*. The University of Michigan Transportation Research Institute. September 1992.

The National Highway Traffic Safety Administration (NHTSA) selected Michigan, New Jersey, and Washington to field test various automated speed enforcement devices (ASEDs) to determine the deterrent impact on speeding and speed-related crashes of the devices. Additionally, the study was used to determine public opinion related to ASEDs that could impact enabling legislation. Speed data analyses indicated that the ASED field test had no effect on travel speeds. However, only warning letters were sent (no citations). Slightly less than one-half of the licensed drivers in the two pilot counties reported knowing about the AED pilot program, and less than one-fifth of the drivers surveyed reported actually having seen an ASED in use. People were reluctant to support a fine-only sanction or a fine-and-points sanction; they were much more willing to support a warning-only sanction. However, as shown in the speed data, a warning-only sanction is unlikely to have an effect on speeding behavior. There was a more favorable response for a more complex sanction where drivers would receive more severe sanctions as they were caught more frequently. The public opinion responses also showed that, on average, people think that rear plate and driver photographs are a slightly greater invasion of privacy than being pulled over by a police officer.

Tan, Hee Wee, and Benjamin J. Ward. *The Effectiveness of 90 Degree Bends in Controlling Speed on Urban Local Roads*. *Research Report ARR 247*, Australian Road Research Board, Ltd., September 1993.

This report documents a study which evaluated the effectiveness of slow points to control speeds on urban local roadways. The design of the slow points in this study were 90-degree bends in the roadway. A total of 11 sites were chosen for a speed evaluation, with the sites varying in degrees of curvature, length of curves, and vertical grades. Speeds were collected at the 90-degree bend (Point A), the midblock location (Point B), and at 20 meters from the next slow point (Point C—stop sign, intersection, etc.). The study concludes that 90-degree

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bends maintain vehicle speeds around 25 kilometers per hour (15 miles per hour), not 20 kilometers per hour (12 miles per hour) as suggested in design codes, and that no particular geometric feature can be used to target a specific operating speed.

Walter, C. Edward. "Suburban Residential Traffic Calming." In *ITE Journal*, September 1995, pp. 44-48.

This paper discusses the concept of traffic calming as reversed traffic engineering—employing traffic calming measures that passively regulate traffic flow. This paper presents some of the results of this effort including vertical alignment modification, horizontal alignment change, and roadway restrictions.

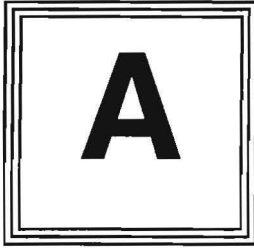
Webster, David C. *Traffic Calming - Four Schemes on Distributor Roads. TRL Report 182*, Transportation Research Laboratory, England, 1995.

This study documents an evaluation of traffic calming techniques on distributor roadways in Great Britain (similar to collector roadways in the U.S.) with higher volumes, speeds, and crash rates. Four cities with a combined 22 sites were chosen to evaluate flat-topped humps (and one chicane) and their impact on reducing vehicle speeds. The hump designs differed in height, length, and ramp gradients. The researchers recorded before and after speeds for a sample of either 200 cars or one week of equipment readings (but not both) at each of the sites. An overall reduction in traffic volumes of 13 to 40 percent was noted for all sites, and an overall reduction in crashes by 32 percent. Public perceptions were also obtained from emergency service personnel and bus operators. Emergency personnel favored the techniques because of reduced speeds and reduced crashes (translating to reduced responses), and bus operators voiced no particular complaints (with the authors concluding that they do not object to driving slower because of the installed techniques).

Webster, David C., and Archie M. Mackie. *Review of Traffic Calming Schemes in 20 MPH Zones. TRL Report 215*, Transportation Research Laboratory, England, 1996.

This report documents traffic calming techniques and their use and effectiveness in 20 mile per hour speed zones in Great Britain. The 20 mile per hour speed zones were/are successful in reducing injury crashes, child injuries, preventing accident migration, and reducing speeds and volumes without affecting adjacent roadways. Based on input from the public, the researchers also found a favorable response from residents in several localities.

Webster, David C. *Traffic Calming - Vehicle Activated Speed Limit Reminder Signs. TRL Report 177*, Transportation Research Laboratory, England, 1995.



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This paper describes a study on the effectiveness of vehicle activated speed limit reminder signs, dynamic signs that inform drivers of their operating speed (similar to speed trailers in the U.S.). The messages on the signs included “SLOW DOWN,” “TOO FAST,” and/or a message that contained their actual speed in miles per hour. The “trigger” speed, the speed that would activate the message, was typically 10 miles per hour over the speed limit. One site’s sign was activated by all vehicles regardless of speed. The results of the speed study indicated that the signs can reduce speeds by a few miles per hour at the sign and maintained at some distance downstream of the sign(s). The overall results indicated a 2 mile per hour reduction in the 85th percentile speed at the sign and 2 miles per hour downstream. The highest speed reductions (up to 7 miles per hour) were noted 100 to 200 meters downstream.

Zein, Sany R., Erica Geddes, Suzanne Hemsing, and Mavis Johnson. “Safety Benefits of Traffic Calming.” Preprint for Transportation Research Board 76th Annual Meeting, January 12-16, 1997.

This research attempted to determine if safety benefits of traffic calming are measurable and significant. Four local projects in the Greater Vancouver area were reviewed. All four projects showed reductions in collision frequency, severity, and annual collision claims costs; average reduction in collision frequency was 40 percent with a 38 percent average reduction in collision claims costs. Eighty-five case studies from Europe, Britain, and North America were also reviewed for safety benefits. International case studies in which more than five pre-calming collisions per year occurred were analyzed separately; in this group of 15 studies, the decrease in collision frequency ranged from 8 to 95 percent. The results of the research provide evidence that safety benefits are both quantifiable and significant.

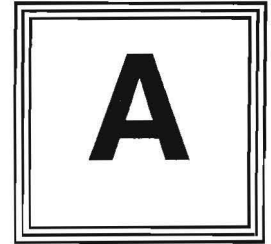
CITY DOCUMENTS

A Traffic Calming Plan for Virginia’s Rural Route 50 Corridor. Fauquier and Loudoun Counties Including Aldie, Middleburg, and Upperville. Route 50 Corridor Coalition. 1996.

The report presents a traffic calming plan for Virginia’s Rural Route 50 Corridor. The 20 mile stretch of Route 50 includes the villages of Upperville, Middleburg, and Aldie. The motivation for developing the plan was to provide an alternative to proposed bypasses around Aldie and Middleburg and for expanding Route 50 from a two-lane road to a multi-lane divided highway. Typical measures inside the villages include raised intersections, raised pedestrian crosswalks, tree-planted medians, small traffic circles, cobblestone strips that signal changes in the speed limit, various paving materials to indicate parking, walking, and driving areas, strategically placed greenery along the streets, and safer pedestrian walkways.

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Neighborhood Traffic Management and Calming Program. City of San Buenaventura, California. Department of Community Services, Engineering Division. June 1997.

This report presents a Neighborhood Traffic Management and Calming Program for the city of San Buenaventura. The report includes background information on traffic calming activities, an overview of neighborhood traffic management and calming options (table), detailed descriptions of neighborhood traffic management and calming options, and a summary of studies on emergency vehicle response times.

“Traffic Calming - League of California Cities.” Annual Conference. October 12, 1997.

The conference proceedings include traffic calming program information from several California cities and one Florida county. The information contains summaries and sketches of various techniques in addition to some photographs and case studies. There is also an Austin, Texas, study of effects of traffic calming on emergency response times and a list of traffic calming videos.

<p>APPENDIX RESEARCH STUDY</p> <hr/> <hr/> <p>Written Survey</p>	<p>SURVEY OF TECHNIQUES TO MANAGE SPEED</p> <p>1. Have you installed or considered speed management techniques on suburban arterials or state highways passing through small towns in your area? <input type="checkbox"/> YES <input type="checkbox"/> NO</p>
------------------------------------------------------------------------------------	----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------

A mail-out survey was performed to identify the types of techniques being used for speed management and to suggest potential sites for on-site visits. Emphasis was placed on techniques used for collector or arterial facilities or state highways passing through small towns. Additional information was requested on local policies and procedures used when considering speed management techniques. The survey is shown in Figures A-1 and A-2.

DISTRIBUTION

Four hundred surveys were distributed to local and state agencies in the United States and Canada. The surveys were distributed to:

- All Department of Transportation districts in 15 states

The 15 states included the eight Federal Highway Safety Information System states, the state of Texas, and others where preliminary research indicated significant speed management activity. These states include: California, Colorado, Florida, Illinois, Kansas, Michigan, Minnesota, Mississippi, Missouri, New York, North Carolina, Pennsylvania, Texas, Utah, and Washington.

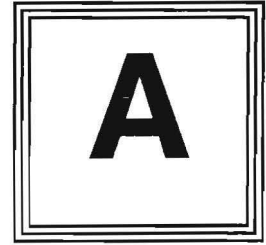
- State agency representatives in the 35 remaining states

The survey was sent to state agency representatives responsible for activities related to the Transportation Research Board.

- 138 ITE traffic calming survey respondents (cities and counties)

In 1995, The Institute of Transportation Engineers conducted a survey of techniques used for traffic calming. The written survey for this study was sent to the respondents of the ITE survey, however, fewer written surveys were sent to California due to the large number of responses in that state.

RESEARCH STUDY



Written Survey

SURVEY OF TECHNIQUES TO MANAGE SPEED For Texas Department of Transportation Project 1770

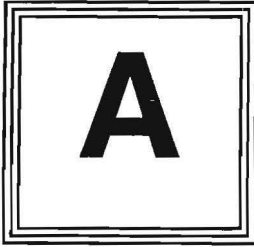
Background. Rural roads are experiencing greater volumes due to bedroom communities, heavy recreational travel, seasonal residencies, and special events. These roadways are now operating as urban or suburban facilities and may include state highways passing through small towns, major collectors within a town, and roadways designed as suburban arterials. **Information on techniques for managing speed is needed for such facilities with posted speeds of 56 to 88 km/h (35 to 55 mph).**

Adapting traffic calming techniques used in residential areas is a possible solution to reducing speeds on these formerly rural roadways and suburban arterials. Some techniques used in residential areas are not appropriate for higher-speed roadways, while others need modifications or a different approach in order to be effective. Little information exists on using speed management techniques on higher-speed facilities. **We need your help in identifying techniques that have been used to manage speed on higher-speed formerly rural roadways and suburban arterials.** These techniques may include, but are not limited to, the following items:

- Bicycle/pedestrian areas
- Changes in direction
- Changes in road surface (brick, etc.)
- Citizen speed watch programs
- Flashing beacons
- Hatched pavement markings
- Increased enforcement (conventional/automated)
- Narrow lanes or streets
- Offset slow points (chokers, chicanes, neckdowns)
- Oversize vehicle restrictions
- Parallel/diagonal parking on street
- Portable speed display/radar trailers
- Presence of non-supervised law enforcement equipment
- Rumble strips
- Speed humps
- Speed limit signs
- Stop/Yield signs
- Traffic circles/roundabouts
- Unique traffic signs
- Upstream signal coordination
- Vegetation, plantings, trees
- Wider pavement markings

Please complete the survey form on the back of this page and return the survey by November 20. If you have questions regarding this survey, you may contact Angelia Parham at (409) 845-9878. The completed survey form can be mailed to the address on the back of this page or faxed to the listed number. **All respondents to this survey will receive a synopsis of the research findings at the conclusion of the project. Thank you for your input.**

Figure A-1. First Page of Survey Form.



RESEARCH STUDY

Written Survey

SURVEY OF TECHNIQUES TO MANAGE SPEED

1. Have you installed or considered speed management techniques on suburban arterials or state highways passing through small towns in your area? YES NO

A. If yes, please complete the table and Questions 2 and 3 below. (See back of page for list of suggested techniques.)

B. If no, please go to Question 4.

SPEED MANAGEMENT TECHNIQUE	I or C?		STREET ADDRESS / CITY	ADT	POSTED SPEED	NEAREST INTERSECTION OR MILEPOST	EFFECTIVE IN REDUCING SPEEDS?		BEFORE AND AFTER STUDY CONDUCTED?		STANDARDS AVAILABLE?	
	I	C					Y	N	Y	N	Y	N
							Y	N	Y	N	Y	N
							Y	N	Y	N	Y	N
							Y	N	Y	N	Y	N
							Y	N	Y	N	Y	N

¹ I= Installed; C= Considered

2. Does your agency have a program/petition designed to handle requests for these techniques? YES NO

3. Is approval required of residents and/or businesses affected by these techniques? YES NO

4. What techniques do you believe would be most effective in reducing/managing speeds on major collectors and arterials in your area? _____

Do you have any additional comments? _____

Thank you for your response!
Please list your contact information:

Please return surveys by
NOVEMBER 20 to:

Name _____

Angelia Parham, P.E.

Agency _____

Texas Transportation Institute

Address _____

Texas A & M University

City _____

College Station, TX 77843-3135

State _____ Zip Code _____

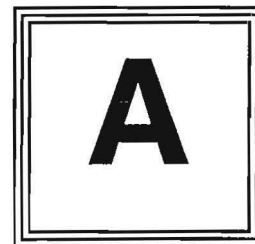
Phone: (409) 845-9878 Fax: (409) 845-6481

Phone _____

E-mail: a-parham5@tamu.edu

Figure A-2. Second Page of Survey Form.

RESEARCH STUDY



Written Survey

- 47 Additional cities in the United States (see Figure A-3)

These cities were selected so that each state had at least one city represented; most had two or more. A larger number of surveys were sent to cities in states where the researchers were aware of very active traffic calming programs (Washington and Florida) and to more cities in Texas in order to obtain more in-state data.

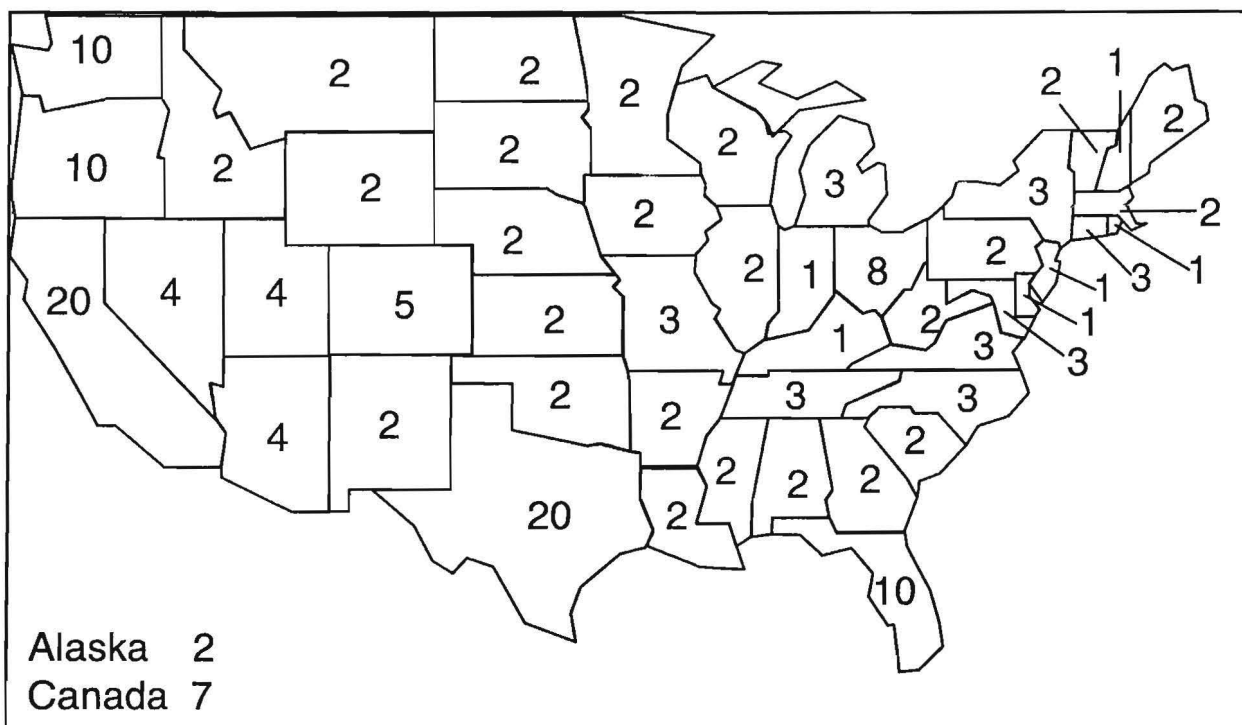
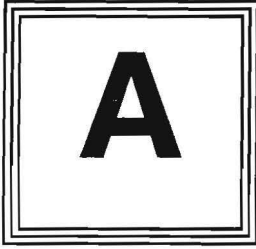


Figure A-3. Number of Cities and Counties Surveyed in Each State.



RESEARCH STUDY

Written Survey

NUMBER OF RESPONSES

A total of 157 written survey responses were received by mail and by fax. The responses were from:

- 41 different states (United States)
- 3 Canadian provinces
- 78 state agencies
- 50 cities
- 4 counties
- 2 others (1 transportation research center and 1 consulting firm)

RESPONSES BY QUESTION

Responses to each survey questions are summarized in the following pages.

1. **Have you installed or considered speed management techniques on suburban arterials or state highways passing through small towns in your area?**

61 YES 80 NO

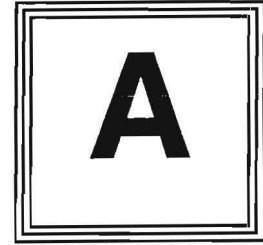
All of the responses are listed in Table 2-1. The top five techniques are:

<u>TECHNIQUE</u>	<u>NUMBER OF RESPONSES</u>
Increased Enforcement	26
Flashing Beacons	23
Speed Limit Signing	22
Radar Trailers	14
Rumble Strips	10

2. **Does your agency have a program/petition designed to handle requests for these techniques?**

31 YES 51 NO

RESEARCH STUDY



Written Survey

3. Is approval required of residents and/or businesses affected by these techniques?

14 YES 60 NO

4. What techniques do you believe would be most effective in reducing/managing speeds on major collectors and arterials in your area?

The top seven answers and number of responses were:

<u>TECHNIQUE</u>	<u>NUMBER OF RESPONSES</u>
Enforcement	39
Speed Limit Signs	17
Signal Coordination with Speed Limit Signage	11
Radar Trailers	9
Photo Radar	8
Narrow Lanes/Chokers	8
Flashing Beacons	6

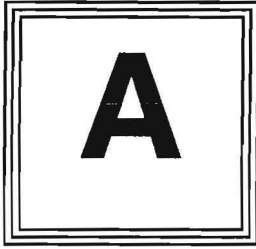
A complete list of the responses is included in Table A-1.

Do you have any additional comments?

A wide variety of comments were received, and a complete listing of the comments is included Table A-2. The comments were related to existing speed management and traffic calming programs, establishing traffic calming programs, usefulness of this research project, local procedure for setting speed limits and the maximum speed limits within cities, and the use of increased enforcement, roundabouts, photo radar, speed trailers, speed limit signs, flashing beacons, speed humps, and rumble strips.

SITES IDENTIFIED

Sites initially identified for phone interviews and/or potential site visits are listed in Table A-3. Additional sites were identified from the 1995 ITE Traffic Calming Survey.



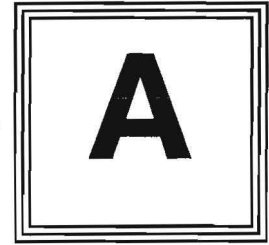
RESEARCH STUDY

Written Survey

Table A-1. Detailed Responses to Question 4: “What techniques do you believe would be most effective in reducing/managing speeds on major collectors and arterials in your area?”

- Additional enforcement and portable speed display/radar trailers
- Adequate speed zone signage and enforcement.
- Aesthetic improvements that encourage alternative transportation uses and gives drivers a perceived reason to reduce speed
- Appropriately posted speed limits based on 85th percentile studies
- Better enforcement, ensuring appropriate speed limits
- Bicycle/pedestrian lanes, increased enforcement, narrow lanes or chokers, parking on streets, signal coordination with signage indicating speed settings
- Bike/ped lanes were not for speed management. Curb bulbouts and offsets in arterial signal systems should provide the best speed management. Photo radar trailers have promise but also legal concerns.
- Can be effective if meets criteria
- Changes in direction and surface, traffic circles
- Changes in road surface or rumble strips, portable speed displays (although not as practical)
- Changes in road surface, increased enforcement including: radar cameras, portable speed display trailers, private “citizen watch” with radar gun
- Changing the character of the streets probably would be the most effective—going from shoulders to curb and gutter. Possibly with on-street parking, signal systems, maybe planted medians. Also aggressive enforcement—automated?
- Compliance with the *MUTCD*
- Conventional enforcement (video enforcement with a ticket by mail program)
- Conventional police enforcement, radar trailers & non-supervised law enforcement devices
- Curb extension, brick walkways, one-way signal-regulated streets, rumble strips, speed humps, considering islands
- Driver education
- Electronic control over vehicles ability to exceed the posted speed limit
- Empower local jurisdictions with populations inactive enforcement of posted speed limits by local law enforcement personnel
- Enforcement coupled with driver education. Interconnected signals would also help.
- Enforcement coupled with signs
- Enforcement, enforcement, enforcement
- Enforcement, narrow lanes, adjacent parking, diversion (voluntary) onto higher speed/higher classification roadways
- Enforcement, short blocks (stop signs)
- Enforcement, signalization
- Establishing a safe and reasonable speed limit is the most effective method
- Establishing reasonable speed limits per established TE guidelines and highlighting any isolated areas of concern with advisory speeds with appropriate warning signs or other treatments as necessary
- Flags attached to speed limit signs, camcorder/law enforcement, bike/pedestrian lanes, wider edge lines
- Flashing beacons (3 respondents gave this answer)
- Have uniform standards statewide
- Higher priority by local courts: more people are impacted by car accidents than guns, drugs, assaults, etc., yet speeding and motor vehicle offenses tend to be considered “minor”
- In order to manage speeds the posted speed must be realistic and then enforced properly. In Michigan we use the 85% method together with review of development, accidents, and type of traffic (commercial, ECT).
- Increased enforcement (conventional and/or automated), portable speed displays/radar trailers. Local police agencies need to be approved to use radar.
- Increased law enforcement, portable speed display/radar trailers.
- Increased speed enforcement, however most local police and DPS do not have enough manpower
- Large speed limit signs, signs could be supplemented with flags or flashers (not intended for widespread use). However, flags and flashers do present maintenance concerns.
- Larger speed limit signs
- Law enforcement, new speed zone study, post speed by 85%, warning signs with advisory speeds and/or flashing beacons.

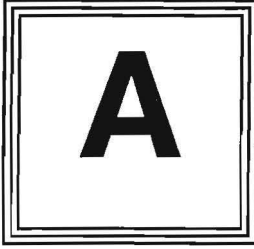
RESEARCH STUDY



Written Survey

Table A-1 (continued). Detailed Responses to Question 4: “What techniques do you believe would be most effective in reducing/managing speeds on major collectors and arterials in your area?”

-
- Law enforcement
 - Look at an operational speed approach to road design versus a design speed approach
 - Lower progression speeds if signal spacing is amenable, lower design speeds (we shouldn't be surprised that people drive 16 km/h (10 mph) over posted speeds when we have design speeds 16 km/h (10 mph) over posted speeds), narrower lanes
 - Major collector arterials should have a higher speed limit than surrounding residential area streets.
 - More presence of police using radar (currently only the Pa. State Police can use radar). Local police can only use VASCAR.
 - Most attempts to change driver behavior have been unsuccessful. The two items listed above are effective only for a short time period during and after implementation. We have not been able to identify an effective, long-term solution to this problem.
 - Most effective method is to conduct a traffic engineering study to determine the most appropriate speed limit and to not set limits that are too low and then try to come up with methods to slow traffic down.
 - Most effective when identified target population or behavior so can devise good campaign. More effective in some areas than others.
 - Narrow lanes, anything that makes the driver uncomfortable at higher speeds
 - Narrow lanes, enforcement
 - Natural tendency of drivers to slow for increased area activity
 - Need should be questioned! Enforcement of legitimate speed zones is essential. On local streets geometric restrictions are best.
 - Never establish a speed zone lower than the pace speed (the 16 km/h (10 mph) increment inside which most of the traffic is driving).
 - None, we just try to base speed limits on 85th percentile speeds.
 - Offset slow points
 - Permanent traffic calming devices such as roundabouts, circles, slow points, and narrow lanes
 - Photo radar, speed sensitive traffic signals
 - Police department is currently used. We have a special motorcycle traffic enforcement unit that helps.
 - Police enforcement of speed limit
 - Police enforcement, making the travel lanes narrower so traffic feels less comfortable
 - Police radar, and when lowering limit place them on a barricade board
 - Portable speed display
 - Posting the 85% speed
 - Presence of non-supervised law enforcement equipment (2 respondents)
 - Presence of state, county, and/or city police, speed bumps normally not allowed on public roads in Illinois
 - Properly posted speed limits and use of photo radar devices
 - Raise speed limits to gain voluntary enforcement instead of having politically correct limits then enforce the reasonable yet prudent speed limits
 - Reduce speed limit by 5 to 10 mph, 2-way stops to 4-way stops where accidents/volume warrant, X-road/side-road warning signs w/ speed plaques
 - Rumble strips made of pavement markings or grooved in the pavement seem to be effective at problem locations.
 - Set speed limit to accommodate the average or 85th percentile speed. Enforce the speed limit posted. Set signal progression at or below the speed limit.
 - Setting the speed limit properly (according to *MUTCD*), followed by adequate enforcement
 - Signal progression
 - Signal progression; narrowed lanes
 - Small rumble strips, upstream signal coordination, vegetation, plantings, trees are OK if sight distance is not a problem
 - Speed enforcement by the police
 - Speed enforcement with photo radar, intersection red-light cameras, more police enforcement with the laser devices, educating the public on speeding
 - Speed limit signs
 - Strict and widespread enforcement, photo radar, roundabouts, a series of 4 roundabouts are planned for Lynch Street in Jackson
 - The best approach is to make the arterial pedestrian friendly with refuge islands, curb extensions, and sidewalks. At key school X-walks we have brakered them with speed bumps, but only on collector arterials.



RESEARCH STUDY

Written Survey

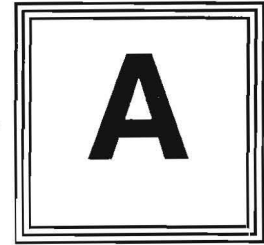
Table A-1 (continued). Detailed Responses to Question 4: “What techniques do you believe would be most effective in reducing/managing speeds on major collectors and arterials in your area?”

-
- They have a speed trap law requiring that any speed zone is set on the 85th percentile.
 - Traffic signal systems work well for coordinating speeds.
 - Traffic signals, driver education, stop signs
 - Upstream signal coordination
 - We are in the same process of looking for alternatives. A committee has been formed to develop a matrix or table of traffic calming techniques available based on the class of the road. That committee has no report printed as yet.
 - We are installing a closed loop signal system that will be set at 56 km/h (35 mph). It is hoped that in addition to better progression, speeds will also be more controlled and more uniform. The presence of police always seems to work.
 - We concentrate all our activities on 48 km/h (30 mph) local streets.
 - We do not install traffic calming/speed reduction techniques on major collectors or arterials in the city of Lakewood, CO. We do install them on minor collectors and local streets.
 - We do not try to manage or reduce speeds on major collectors and arterials. These roads are managed for safe and efficient movement of traffic.
 - We do not use or recommend physical traffic calming measures on major arterials, such as speed humps, physical islands, or sequential stop signs, as used on some city streets. The most effective technique seems to be selective enforcement.
 - We have done diagonal parking in our downtown to slow traffic.
 - We have found that enforcement or enhanced enforcement is very effective in reducing vehicle speeds.
 - We have used portable speed displays in construction.

Table A-2. Responses to the Question: “Do you have any additional comments?”

-
- Item #3 not directly but by going through local government entity.
 - Item #1 at district level-this is handled out of KDOT Bureau of Traffic Engineering.
 - A Department “Traffic Calming Task Force” has recently been established.
 - All arterials in this city are owned and maintained by Multnomah County.
 - Arterials by definition are for movement of traffic. Why try to change them? By reducing traffic movement you change the functional classification to a collector or local road.
 - As per our telephone conversation on November 19, we have not initiated any unique speed management techniques in our area.
 - Auto enforcement is needed in Texas. Users of photo enforcement and tickets by mail, laws need to be enforced by the state.
 - Citizen groups are asking the city to consider traffic calming techniques, but to date we have not installed or seriously considered many.
 - City ordinances restricts highest posted speed limit on city streets to 72 km/h (45 mph) unless board approved. Arterials posted at 64 km/h (40 mph), collectors posted at 48 and 56 km/h (30 and 35 mph).
 - Could we please have a copy of your handbook when it is developed? Thank you.
 - Discourage angle parking, just starting to use radar guns, local agencies use radar trailers.
 - Drivers drive the natural speed for the roads we design. Trying to artificially slow them down through possibly unsafe means must not be done. We need to look at who’s complaining and evaluate the validity of the complaints.
 - Drivers need to obey speed limits that are posted.
 - Flags were intended to be used in speed zone changes from 104 to 88 km/h (65 mph to 55 mph) - before the repeal of the NMSL, drawing attached.
 - For example, the city of Elmira, NY, petitioned us to raise the speed limit on the main urban arterials to 64 km/h (40 mph) to encourage traffic to use it rather than residential side streets.

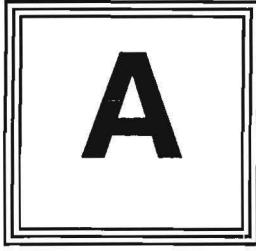
RESEARCH STUDY



Written Survey

**Table A-2 (continued). Responses to the Question:
“Do you have any additional comments?”**

- Gimmicks don't work. Physical modifications often lower speeds, but don't eliminate the hazard of "driving too fast for condition," which is often more of a problem.
- Good topic
- I am not aware of any agency in the Phoenix metro area that is calming arterials or major collectors, only residential collectors and local residential streets. Glendale is pretty urbanized.
- I believe MoDOT's 85% speed "rule of thumb" is too high. An 80% (percentile) would be a safer speed limit to post.
- I believe our efforts in traffic calming on local streets have been largely misguided and hate to see us start trying techniques such as those on collector streets much less arterials.
- I do not know how effective they are, but I would love to try the portable speed display/radar trailers to see if they have any real impact.
- I do not think that traffic calming is appropriate for arterial or collector streets. It should be reserved for strictly local streets only.
- I have concerns over applying traditional traffic calming devices/measures to state arterials. Main reason is the nature of these roads which usually carry large traffic volumes at higher speeds, and their main function of providing for long trip purpose.
- I'm not sure anything will work long term, except enforcement because people learn to ignore the measures. I have heard of reports that changes in pavement texture adversely affects the function of anti-lock brakes.
- If the speed is set by 85% speed warning signs should be all that is needed to reduce speed in high-accident areas or sight restricted areas. Many of the items on your list are not in compliance with the TX Manual of Uniform Traffic Control Devices for Street and Highways.
- If you would like to discuss the programs we have in district 7 jurisdictions (Los Angeles and Ventura Counties), please call to discuss.
- Item #2 was mitigation for constructing a "couple" through a historic district. Speed and traffic volume reduction was desired on city streets at right angles and in between parallel one-way state highways.
- Larger roundabouts properly signed might help.
- Legislation may be a problem and costs at the present time of video enforcement technology are high, has not been tried in Tennessee
- Most speed management programs work to improve/modify the quality of life factors for the surrounding area. The programs are improperly emphasizing their impact on the true level of safety.
- Need to weigh the added risks of any measures to reduce speed. They may cause their own problems which need to be addressed. Speed "humps" are never recommended on higher speeds than 40 km/h (25 mph).
- Nevada's use of the above listed undulations was an isolated case. To my knowledge NDOT has not employed any other speed management techniques other than a reduction in speed limits.
- None
- Not much seems to work except stiff fines when enforcement is continuous. Problem is there are never enough officers.
- Ohio has Home Rule. Once a roadway crosses into a corporation limit, responsibility for traffic control rests with that jurisdiction.
- Our agency is strictly urban.
- Our experience with "speed management" in these streets does not go beyond the standard and ordinary.
- Photo radar
- Please respond with the outcome of your survey
- Police are allowing 16 to 24 km/h (10 mph to 15 mph) over speed limit before enforcing. Local police cannot use radar and must give 16 km/h (10 mph) over with their various timing devices. State police can enforce at 9 km/h (6 mph) over with radar, however, they give 10 to 15.
- Portable speed display, roundabouts. Let us know if we can be of any other help.
- Requests for speed reductions/managements are handled the same as any other request for traffic control changes.
- Speed limits must be reasonable to motorists or they will not be obeyed and cannot be enforced without an inordinate amount of enforcement. The state of Florida utilizes the 85th percentile method for establishing regulatory speed limits.
- Speeds are generally set on 85th percentile so as not to create artificially low speed limits (speed traps).



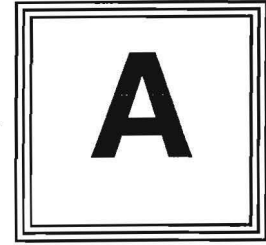
RESEARCH STUDY

Written Survey

**Table A-2 (continued). Responses to the question:
Do you have any additional comments?**

- As development occurs speeds automatically come down. Geometric changes to the roadway (narrowing, center island) and enforcement are the most effective.
- Speeds on arterials and major collectors need to be maintained at high enough levels to effectively move traffic. Reducing the speeds of rural drivers as they come into urban areas is a different issue.
- Techniques that can be incorporated into PaDOT's design standards are greatly needed.
- The accident rates are well above average on the street with diagonal parking.
- The city of Milwaukee currently has a Neighborhood Traffic Management Program that addresses only local and collector streets, but excludes arterials. We are interested in learning about traffic calming techniques for arterials.
- The city of Refugio has a portable speed display/radar trailer. You might want to contact them.
- The KDOT relies on the use of speed limit signs in managing speeds. KDOT is also pursuing the use of roundabouts but has not yet constructed one.
- The subject survey is not applicable to us as we are in an urban region.
- Unique devices work for awhile, but their effectiveness is reduced with time.
- Use of techniques that produce a significant reduction in speed, e.g., offset slow points, roundabouts and speed humps, need to be carefully evaluated because of the potential to move traffic to adjacent parallel streets.
- Vehicle speed is controlled by abutting land use and traffic conditions, not by traffic control devices.
- Very interested in research findings
- We do have "one" mitigation project on a 35 mph, 10,000 ADT "collector" facility. This project involved one raised intrusion and two speed humps.
- We don't have many streets with $SL \geq 56$ km/h (35 mph) in Madison.
- We have also considered marking narrower lanes. We have replaced some unwarranted signals with a 4-way stop. We tried a radar activated "too fast for curve when flashing" (had maintenance problems).
- We have implemented a raised drivable median with plantings on a collector roadway very successfully. AADT approximately 8000, single-family residential street with 34' wide roadway previously.
- We have not had occasion to practice such techniques on the state jurisdiction roads.
- We have profile thermoplastic stripe edge lines on I-35 in Cooke County that works to keep drivers alert. Increased enforcement is best.
- We have tried radar trailers and designed in roadway curvature, very limited success.
- We have used rumble strips in two areas to warn of "stop ahead" locations, but we have not used them for speed reduction only.
- We have utilized speed humps on residential streets and residential collectors for three years. We have found them effective in these areas.
- We only consider speed management techniques for residential low-volume (<4000 ADT) streets (mainly speed humps).
- We prefer to operate as in 4 rather than implement an unreasonable speed limit for a lengthy section of highway, which is usually disrespected, resulting in continued problems at isolated/spot concerns.
- Without active enforcement, I do not believe any passive system will effectively slow motorists that are inclined to obey posted speed limits. Other systems (oversized signs) could and probably would give residents along the roadway a false sense of security.
- You may wish to contact the cities of El Cajun & Santee in the San Diego area. They had a special state exception to requirements for speeds based on traffic and engineering surveys for experimentation on specific arterials.

RESEARCH STUDY



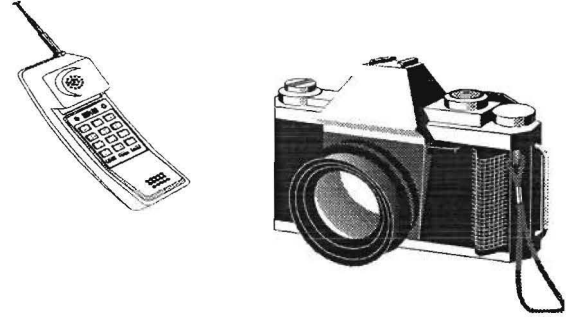
Written Survey

Table A-3. Potential Locations for Follow-up Phone Calls and/or Site Visits.

Texas Sites	Technique	Other States (City/State)	Technique
Brady	Flags on Speed Limit Signs	Ventura, CA	Diagonal Parking
Bryan	Speed Trailers	Santa Barbara, CA	Roundabouts Speed Humps (C) Reduction of Lanes (C)
Conroe	Speed Humps Speed Limit Signs Increased Enforcement	Seattle, WA	Traffic Circles Installation of Medians Change of Legal Speed
Lufkin	Speed Limits on Pavement Law Vehicles Rumble Strips Oversize Signs	Vancouver, WA	Pedestrian Refuge Island Traffic Circle 40 km/h (25 mph) Speed Bump 56km/h (35 mph)
Austin	Rumble Strips Flashing Beacons Speed Humps	Federal Way, WA	Radar Trailer Narrow Lanes Increased Enforcement Lower Progression Speed
Arlington	Street Narrowing Warning Signs and Flashing Beacons	Memphis, TN	Rumble Strips (made of reflective makers)
Carrollton	Fluorescent School Signs Radar Trailer Signal Coordination Speed Limit Signs	Milwaukee, OR	Slow Down Banner Traffic Circle Citizen Speed Watch
Ft. Worth	Offset Slow Points	Hanover, MD	Roundabouts Chokers Brick Crosswalk Landscaping
Richardson	Radar Trailers	Hampton, VA	Speed Table
Atlanta	Rumble Strips/Warning Signs 72 - 112 km/h (45 - 70 mph)	Madison, WI	Enhanced Enforcement Portable Speed Boards Flashing Beacon w/ Speed Limits

APPENDIX RESEARCH STUDY

Phone Interviews and On-Site Visits

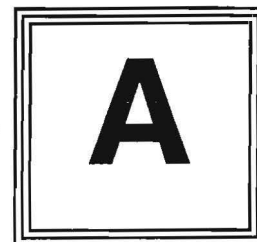


Phone interviews were conducted as a follow-up to the written survey. The interviews provided additional information about specific techniques, programs, or policies identified in the written surveys and to further identify locations for site visits. Additional phone calls were made to agencies responding to the 1995 ITE Traffic Calming Survey in order to find additional sites for specific techniques where information from the written survey was lacking to find additional sites in the proximity of scheduled site visits.

Phone interviews were informal, focusing on the particular experience of the agency being contacted. A questionnaire for phone and on-site interviews was developed as a guideline for pertinent questions, as shown in Figure A-4. Some of the issues addressed in the phone interviews included: public involvement and response; approval process for installation of techniques; the input of emergency response agencies; cost sharing; removal of implemented techniques; landscaping and maintenance responsibilities; any before and after studies that have been conducted. An additional questionnaire to document information for each technique was developed for the phone interviews and on-site visits, as shown in Figure A-5. This form was used to document techniques at specific locations, including such information as roadway classification, speed limit, ADT, public perceptions, the reason for installing the technique, other locations where the technique has been installed, and information specific to the site.

Documentation from the phone interviews and on-site visits is included in appropriate sections of the *Handbook*. Photographs from the on-site visits are used to enhance the descriptions and experiences related to each speed management technique. Phone interviews and on-site visits were made to agency representatives in various states indicated in Table A-4. Many agencies were targeted within the state of Texas, and several of the out-of-state on-site visits were combined with related trips made by the project staff. Additional photographs were provided by contacts of the project staff.

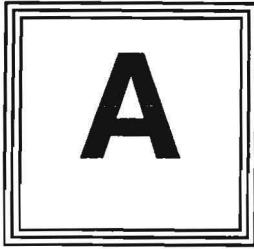
RESEARCH STUDY



Phone Interviews and On-Site Visits

Table A-4. States with Agencies Contacted Through Phone Interviews or On-Site Visits.

State (Province)	Telephone Interview	On-Site Visit
British Columbia		✓
California	✓	✓
Georgia	✓	✓
Maryland	✓	✓
Minnesota	✓	
Mississippi	✓	
Ontario		✓
Oregon	✓	✓
Texas	✓	✓
Virginia	✓	✓
Washington	✓	✓
Wisconsin	✓	✓



RESEARCH STUDY

Phone Interviews and On-Site Visits

INTERVIEW QUESTIONNAIRE - TxDOT Project 1770

----- Phone
----- On-Site

1. Agency _____ State _____ Date of Site Visit _____
Contact Person _____ Title _____
Phone # _____ Office Location _____

2. Does your agency have policies for installation of traffic calming / speed management techniques?
___ Yes ___ No If yes, are copies available? ___ Yes ___ No

3. What approval is required for installation of traffic calming / speed management techniques?
Citizen approval: ___ % ___ Not Required *Legislative / Council Approval Only* ___

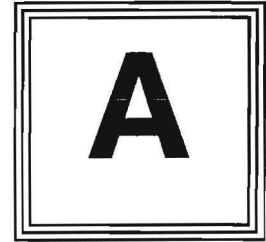
4. Has your agency removed any traffic calming / speed management techniques? ___ Yes ___ No
If yes, what and why? _____

5. Has traffic calming been a significant issue? Have there been any major problems related to traffic calming? Has there been strong citizen reaction? What provided the motivation to install traffic calming techniques? Were there many meetings with citizen groups? Internal meetings? Who is making the decisions? Were any innovation techniques considered (e.g., pavement markings that give the appearance of narrow lanes)? Have there been any major problems related to traffic calming or speed management (i.e., costs, installation difficulties, public meetings, council meetings / approval, etc.)? Has there been strong citizen reaction? _____

Notes: _____

Figure A-4. General Information Form for Telephone or On-Site Interview.

RESEARCH STUDY



Phone Interviews and On-Site Visits

TECHNIQUE QUESTIONNAIRE - TxDOT Project 1770

Agency _____

TECHNIQUE: _____

LOCATION: _____

STREET CLASSIFICATION: *Local* *Minor Collector* *Major Collector* *Major Arterial* *Minor Arterial*

SPEED LIMIT: _____ MPH ADT: _____ veh/day

INSTALLATION DATE: _____ ESTIMATED INSTALLATION COST: \$ _____
\$ _____ / YR to maintain

REASON FOR INSTALLATION: *Political* *Reduce Speed* *Reduce Accidents* *Reduce Volume*
Citizen Request *Other* _____

BEFORE / AFTER STUDY FOR:

<i>Speed</i>	_____ Yes	_____ No
<i>Accidents</i>	_____ Yes	_____ No
<i>Volume</i>	_____ Yes	_____ No
<i>Copies of studies available?</i>	_____ Yes	_____ No

PERCEPTIONS OF THE TECHNIQUE: _____

POSITIVE RESULTS: _____

NEGATIVE RESULTS: _____

TECHNIQUE INSTALLED IN OTHER LOCATIONS IN THIS JURISDICTION? _____ Yes _____ No
If yes, approximately how many? _____

WERE OTHER TECHNIQUES CONSIDERED? *Yes* *No* IF YES, WHAT? _____

SITE INFORMATION: _____

Figure A-5. Technique Questionnaire for Phone and On-Site Interviews.