The purpose of this chapter is to provide a detailed description of each of the numerous control devices which might or have been used for a neighborhood protection program. The descriptions follow a highly structured format and include physical characteristics, primary traffic effects, typical construction materials and costs, legal status, and examples of current practice. The basic intention is to illustrate the differences in use, impact and cost that can be expected for each of the devices. As in the previous chapter, the devices have been organized into three generic types: positive physical controls, passive controls, and psychological controls. The fundamental difference in these three categories is the way in which the devices exert control over traffic. Physical devices force drivers to take or not take certain actions. Passive controls command or advise that certain actions be taken or not be taken but, save for the possibilities of law enforcement and traffic accidents, nothing prevents motorists from disregarding them. Psychological controls attempt to induce desired behavior patterns and discourage undesired one by playing upon drivers' fundamental perception-reaction traits.

Although physical controls pack the most punch, they also tend to bring with them more and stronger secondary impacts of both desirable and undesirable natures. As a consequence, in many situations the most absolute form of control device will not necessarily be the best choice; a weaker type of device or a mix of device types may be more suitable.

Table 1 provides an index for the individual control device sections and summarizes their
## DIRECT TRAFFIC EFFECTS

<table>
<thead>
<tr>
<th>DEVICES</th>
<th>Volume Reductions</th>
<th>Speed Reductions</th>
<th>Directional Change</th>
<th>Change In Composition</th>
<th>Noise</th>
<th>Safety</th>
<th>Emergency &amp; Service Access</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Physical Controls</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Speed Bumps</td>
<td>Possible</td>
<td>Inconsistent</td>
<td>Unlikely</td>
<td>Unlikely</td>
<td>Increase</td>
<td>Adverse effects</td>
<td>Some problems</td>
</tr>
<tr>
<td>Undulations</td>
<td>Possible</td>
<td>Yes</td>
<td>Unlikely</td>
<td>Unlikely</td>
<td>No change</td>
<td>No problems</td>
<td>Documented</td>
</tr>
<tr>
<td>Rumble Strips</td>
<td>Unlikely</td>
<td>Yes</td>
<td>Unlikely</td>
<td>Unlikely</td>
<td>Increase</td>
<td>Improving</td>
<td>No problems</td>
</tr>
<tr>
<td>Diagonal Diverters</td>
<td>Yes</td>
<td>Likely</td>
<td>Possible</td>
<td>Possible</td>
<td>Decrease</td>
<td>Minor constraints</td>
<td>Some constraints</td>
</tr>
<tr>
<td>Intersection Cul-De-Sac</td>
<td>Yes</td>
<td>Likely</td>
<td>Yes</td>
<td>Possible</td>
<td>Decrease</td>
<td>Improving</td>
<td>Minor constraints</td>
</tr>
<tr>
<td>Midblock Cul-De-Sac</td>
<td>Yes</td>
<td>Likely</td>
<td>Yes</td>
<td>Possible</td>
<td>Decrease</td>
<td>Questionable</td>
<td>Some constraints</td>
</tr>
<tr>
<td>Semi-Diverter</td>
<td>Yes</td>
<td>Likely</td>
<td>Yes</td>
<td>Possible</td>
<td>Decrease</td>
<td>Improved ped. crossings</td>
<td>No problems</td>
</tr>
<tr>
<td>Forced Turn Channelization</td>
<td>Yes</td>
<td>Likely</td>
<td>Yes</td>
<td>Possible</td>
<td>Decrease</td>
<td>Improved</td>
<td>Minor constraints</td>
</tr>
<tr>
<td>Median Barrier</td>
<td>Yes</td>
<td>On curves</td>
<td>Possible</td>
<td>Possible</td>
<td>Decrease</td>
<td>Improved</td>
<td>Minor constraints</td>
</tr>
<tr>
<td>Traffic Circle</td>
<td>Unclear</td>
<td>Minor</td>
<td>Unlikely</td>
<td>Possible</td>
<td>Little change</td>
<td>Questionable</td>
<td>Some constraints</td>
</tr>
<tr>
<td>Chokers and Road Narrowing</td>
<td>Rare</td>
<td>Minor</td>
<td>Unlikely</td>
<td>Unlikely</td>
<td>Little change</td>
<td>Improved ped. crossings</td>
<td>No problems</td>
</tr>
<tr>
<td><strong>Passive Controls</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stop Signs</td>
<td>Occasional</td>
<td>Site red.</td>
<td>Unlikely</td>
<td>Unlikely</td>
<td>Increase</td>
<td>Mixed results</td>
<td>No problems</td>
</tr>
<tr>
<td>Speed Limit Signs</td>
<td>Unlikely</td>
<td>Unlikely</td>
<td>Unlikely</td>
<td>Unlikely</td>
<td>No change</td>
<td>No change</td>
<td>No effect</td>
</tr>
<tr>
<td>Turn Prohibition Signs</td>
<td>Yes</td>
<td>Likely</td>
<td>Yes</td>
<td>Possible</td>
<td>Decrease</td>
<td>Improved</td>
<td>No effect</td>
</tr>
<tr>
<td>One-Way Streets</td>
<td>Yes</td>
<td>Inconsistent</td>
<td>Yes</td>
<td>Possible</td>
<td>Decrease</td>
<td>Possible imp.</td>
<td>No effect</td>
</tr>
<tr>
<td><strong>Psycho-Perception Controls</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transverse Markings</td>
<td>No change</td>
<td>Yes</td>
<td>No effect</td>
<td>No effect</td>
<td>Possible red</td>
<td>No effect</td>
<td>No effect</td>
</tr>
<tr>
<td>Crosswalks</td>
<td>No effect</td>
<td>Unlikely</td>
<td>No effect</td>
<td>No effect</td>
<td>No effect</td>
<td>Ineffective</td>
<td>No effect</td>
</tr>
<tr>
<td>Odd Speed Limit Signs</td>
<td>No effect</td>
<td>No effect</td>
<td>No effect</td>
<td>No effect</td>
<td>No effect</td>
<td>No effect</td>
<td>No effect</td>
</tr>
<tr>
<td>Novelty Signs</td>
<td>No effect</td>
<td>Undocumented</td>
<td>No effect</td>
<td>No effect</td>
<td>Unlikely</td>
<td>No effect</td>
<td>No effect</td>
</tr>
</tbody>
</table>

Specific details of individual applications may result in performance substantially variant from characterizations in this matrix. See text sections on individual devices for more complete performance data, assessments and qualifications.

Table 1. Neighborhood traffic control device characteristics — Summary
<table>
<thead>
<tr>
<th>OTHER CHARACTERISTICS</th>
<th>Construction Effort &amp; Cost</th>
<th>Landscape Opportunity</th>
<th>Site or System Use</th>
<th>Maintenance &amp; Operational Effects Index</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DEVICES</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physical Controls</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Speed Bumps</td>
<td>Low</td>
<td>None</td>
<td>Both</td>
<td>Snowplow problems</td>
</tr>
<tr>
<td>Unduations</td>
<td>Low</td>
<td>None</td>
<td>Both</td>
<td>No problems noted</td>
</tr>
<tr>
<td>Rumble Strips</td>
<td>Low</td>
<td>None</td>
<td>Site</td>
<td>Snowplow problems</td>
</tr>
<tr>
<td>Diagonal Diverters</td>
<td>Moderate to high</td>
<td>Yes</td>
<td>Usually system</td>
<td>Vandalism</td>
</tr>
<tr>
<td>Intersection Cul-De-Sac</td>
<td>Moderate to high</td>
<td>Yes</td>
<td>Both</td>
<td>Vandalism</td>
</tr>
<tr>
<td>Midblock Cul-De-Sac</td>
<td>Moderate to high</td>
<td>Yes</td>
<td>Both</td>
<td>Vandalism</td>
</tr>
<tr>
<td>Semi-Diverter</td>
<td>Moderate to high</td>
<td>Yes</td>
<td>Both</td>
<td>Vandalism</td>
</tr>
<tr>
<td>Forced Turn Channelization</td>
<td>Moderate</td>
<td>Possible</td>
<td>Both</td>
<td>No unusual problems</td>
</tr>
<tr>
<td>Median Barrier</td>
<td>Moderate</td>
<td>Possible</td>
<td>Both</td>
<td>No unusual problems</td>
</tr>
<tr>
<td>Traffic Circle</td>
<td>Moderate to high</td>
<td>Yes</td>
<td>Both</td>
<td>Vandalism</td>
</tr>
<tr>
<td>Chokers and Road Narrowing</td>
<td>Moderate to high</td>
<td>Yes</td>
<td>Both</td>
<td>No unusual problems</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Passive Controls</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stop Sign</td>
<td>Low</td>
<td>No</td>
<td>Both</td>
<td>No unusual problems</td>
</tr>
<tr>
<td>Speed Limit Signs</td>
<td>Low</td>
<td>No</td>
<td>Site</td>
<td>No unusual problems</td>
</tr>
<tr>
<td>Turn Prohibition Signs</td>
<td>Low</td>
<td>No</td>
<td>Both</td>
<td>No unusual problems</td>
</tr>
<tr>
<td>One-Way Streets</td>
<td>Low</td>
<td>No</td>
<td>Usually system</td>
<td>No unusual problems</td>
</tr>
<tr>
<td>Psycho-Perception Controls</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transverse Markings</td>
<td>Low</td>
<td>No</td>
<td>Site</td>
<td>No unusual problems</td>
</tr>
<tr>
<td>Crosswalks</td>
<td>Low</td>
<td>No</td>
<td>Site</td>
<td>No unusual problems</td>
</tr>
<tr>
<td>Odd Speed Limit Sign</td>
<td>Low</td>
<td>No</td>
<td>Site</td>
<td>Vandalism</td>
</tr>
<tr>
<td>Novelty Signs</td>
<td>Low</td>
<td>No</td>
<td>Site</td>
<td>Vandalism</td>
</tr>
</tbody>
</table>
key attributes. Because a structured format has been used to allow for understanding the effects of individual devices, certain information pertaining to all devices such as impact on emergency services, device violations, etc. has been presented in a separate chapter, Chapter 5. The information contained in that chapter is vital to a total understanding of the devices.

An attempt has been made in describing each device to evaluate its impacts both desired and undesired. As a general comment on the State-of-the-Art, more has been planned than has been implemented, and more has been implemented than has been evaluated thoroughly. Thus while the problem of neighborhood traffic management is one with widespread and vital concern, less than might be desired is known about the impacts of most of the devices described herein; thus the reader looking for the definitive nature of each device may be disappointed. It is expected that the future stages of this research project will provide the details missing in these descriptions.

Readers of the report are cautioned against using this chapter alone to quickly pick a device which seems to fit their situation. Once a problem is identified, the analyst must determine whether it is site specific (subject to remedy by a single device at a single location) or endemic to a larger area (requiring a system of remedial devices). Systematic solutions are indicated when an entire neighborhood or district requires action on a number of problems or when the “solution” to one site’s problem will create a new problem somewhere nearby. Techniques for systemic problems are contained in Chapter 4. The essential point here is that analysts should not take too narrow a view of the problem and jump to a solution simply on the basis of characteristics of individual devices as presented herein.

Solutions to systemic problems require strategic approaches and the characteristics of individual control devices affect their suitability for application in particular strategies. For this reason, the conclusion of this chapter outlines some basic area control strategies for responding to various kinds of systemic problems and the types of control devices which can be used in each particular strategy.

Even when problems and the impacts of logical solutions seem confined to a limited site rather than having systemic effects, there are no hard-and-fast guidelines leading to simple choice of the appropriate device. Each situation to a greater or lesser degree involves a unique set of circumstances: street character, mix of resident types, urban activities abutting, street network setting and geometric considerations. So even if a problem is clearly defined and site-limited, it is advisable to carry out at least a simplified version of the planning and evaluation steps outlined in Chapter 4. Doing so guarantees consideration of all reasonable options. Rote application of a uniform solution for all problems of a similar nature is to be avoided.

The merits of permanent versus temporary traffic control devices are discussed at length in Chapter 4 as a strategic planning consideration. It is essential to recognize that permanent versus temporary installation can have significant implications for many of the factors discussed in this control device chapter — materials, cost and operational and safety performance. In many instances the large disparities of experiences reported herein stem from differences between temporary and permanent installations. And because of the performance implications strategic planning decisions on temporary versus permanent installation may be an important factor in choice of control device.

Positive physical controls

Positive physical controls include speed bumps, rumble strips, median barriers, cul-de-sacs, semi-diverters, diagonal diverters, traffic circles, chokers and other less commonly used devices. Their common characteristic is the use of a physical device to enforce or prohibit a specific action, usually the reduction of either speed or volume. Physical controls have the advantages of being largely self-enforcing and of creating a visual impression, real or imagined, that a street is not intended for through traffic. Their disadvantages relative to other devices
are their cost, their negative impact on emergency and service vehicles, and their imposition of inconvenient access on some parts of a neighborhood.

**Bumps, Undulations**

**Speed bumps and undulations**

Speed bumps and undulations are one of three physical devices (the others being rumble strips and traffic circles) which have been used for the primary purpose of reducing speed. They are raised humps in the pavement surface extending transversely across the traveled way. Normally they have a height of less than 5 inches (.1 meter). Length in the direction of travel distinguishes "bumps" from "undulations." Bumps are abrupt humps, normally less than 3 feet (1 meter) in length while undulations are more gradual with lengths of 8 to 12 feet (2-4 meters). Bumps have most often been installed on park roadways and private drives and rarely on public streets. A recent innovation, undulations have been installed on public streets in a few jurisdictions.

![Figure 4. Speed bump](image)

There are several reasons their use on public streets has been limited. The major one is a real and perceived question as to their safety. A study in San Jose, California, has confirmed these safety problems for certain designs. These results are summarized in the sections which follow. The second reason for their lack of use is that they are not included in the Manual of Uniform Traffic Control Devices (MUTCD) and parallel state traffic control and design guides. As a result, many traffic engineers consider them illegal. Tests have also shown that some designs produce less discomfort at higher speeds than at low ones, in direct contradiction to their purpose.
Figure 5. British speed undulation. In Toronto (lower view) undulations have been deployed in pairs.

On a more positive note, a long speed bump, or undulation, has been developed by the Transportation Road Research Laboratory in Great Britain.\textsuperscript{5} While the safety aspects have yet to be evaluated, this design appears to have promise for effectively reducing speed.

**Primary Traffic Effects**

The basic purpose of speed bumps is obviously to reduce speed. However, the actual design of the bumps is critical to their ability to achieve this.

**Effect on Traffic Volume.** Four trial installations of undulations 12 feet (4 meters) long (in the direction of travel) and 4 inches high (.1 meter) in Great Britain have shown that, though installed to reduce speed, the humps can reduce traffic volumes as well.\textsuperscript{79-82} The trial installations consisted of five to nine humps spread over a distance of 1000 to 2700 feet (300 to 810 meters). As shown in Table 1, traffic volumes were reduced by 25 to 40 percent. Another test of this design has taken place in Toronto, Canada. In this test, the undulations were placed in pairs 30 feet (9 meters) apart on two residential streets. No effect on traffic volumes occurred, in part because other protective measures in the neighborhood left these test streets as the only ones with continuity.

<table>
<thead>
<tr>
<th>Location</th>
<th>Time Period</th>
<th>Traffic Before</th>
<th>Traffic After</th>
<th>% Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cuddleston Way, Crowley, Oxford</td>
<td>24 hrs</td>
<td>NA</td>
<td>NA</td>
<td>-41</td>
</tr>
<tr>
<td>Motum Road, Norwich</td>
<td>9 hrs</td>
<td>398</td>
<td>271</td>
<td>-32</td>
</tr>
<tr>
<td>Palace Road, Haringey, London</td>
<td>16 hrs</td>
<td>3212</td>
<td>2413</td>
<td>-25</td>
</tr>
<tr>
<td>Abbotsbury Road, Kensington, London</td>
<td>16 hrs</td>
<td>8154</td>
<td>5833</td>
<td>-28</td>
</tr>
</tbody>
</table>

**Effect on Traffic Speed.** Extensive tests of speed versus discomfort (as perceived by drivers and passengers) have been made in two studies in San Jose, California\textsuperscript{84} and in Great Britain.\textsuperscript{85} The San Jose studies evaluated "short" bumps from 6 inches to 3 feet (.2 to 1 meter) in length and 2 and 3 inches (.1 meter) in height. All of these bumps tested produced either no difference or decreasing discomfort as speed increased. The Great Britain study confirmed this conclusion for short humps. Experiences in the few U.S. cities contacted in the State-of-the-Art search which had tried short bumps support this conclusion. Though none had performed formal evaluations, most withdrew the devices feeling that the higher the speed, the less traffic was impeded by them. Boston, Massachusetts, one of the cities contacted, has retained bumps on public streets though professionals there consider them dangerous and noisy.

The British work has demonstrated that an undulation 12 feet long (4 meters) (in the direction of travel) and 4 inches high (.1 meter) did produce the desired result of speed reduction, with an undesirable comfort index occurring at approximately 20 mph (32 kmph). This design has been tested in four field installations in Great Britain and has reduced the average speed to 15 to 25 mph (24 to 40 kmph), with three
tests in the 15-17 mph (24 to 27 kmph) range.\textsuperscript{79-82}

The installations in Toronto were successful in reducing average speeds from 20-28 mph (32-45 kmph) to 15-18 mph (24-29 kmph); the 85th percentile speeds were reduced from 20-32 mph (32-51 kmph) to 19-21.5 mph (30-34 kmph).\textsuperscript{78}

A third study, computer simulation of vehicle response to two parabolic pavement undulation designs, indicates that in theory, undulations can cause drivers to reduce speeds.\textsuperscript{84} No field testing of these devices has yet been done in the United States.

Effect on Noise. The San Jose and Great Britain studies produce conflicting results with respect to noise. The San Jose experiment measured noise at the bump itself, thus making extrapolation to noise in the neighborhood somewhat difficult. However, the study estimated that nearby residences would experience a 10 to 20 decibel sound level increase when vehicles struck the bump.\textsuperscript{64} The British test cases, which measured noise over an entire day, showed reductions in average noise levels on the building frontage line of 2-5 dBA, primarily due to the reduction in volume.\textsuperscript{79-82} U.S. cities which employed the short speed bumps but did not perform formal evaluations usually did characterize the bumps as noisy.

The Toronto tests found that the undulations tend to increase noise when struck.\textsuperscript{76} Automobiles striking them at 10-15 mph (16-24 kmph) had a noise level equivalent to 25-30 mph (40-48 kmph) on a flat road; trucks passing over the undulations at 5 to 10 mph (8-16 kmph) had noise levels equivalent to flat road travel at 25-30 mph (40-48 kmph). These tests also indicated that the lower speeds caused the increased noise levels to occur over a longer period of time. It might be concluded that if undulations are as successful at reducing speed as the aforesaid speed studies indicate, undulations would probably produce little net change or even a reduction in neighborhood noise levels.

Effect on Air Quality and Energy Conservation. While these effects were not studied, the need to slow slightly for the bumps would tend to have a marginally negative effect on air quality and energy consumption.

Effect on Traffic Safety. The British studies on short and long bumps have not addressed this topic. The San Jose study dealt with it extensively. The study of short bumps showed that they would "present an immediate and specific hazard to some vehicles (bicycles, motorcycles, etc.) and a potential hazard to all vehicles."\textsuperscript{84} In lower speed tests of a fire truck, firefighters were thrown 6 inches to 1 foot (.15 to .3 meters) into the air by the bumps. A trained motorcycle officer was thrown 16 feet (5 meters) in another test. A bicycle suffered a bent rim in yet another. These hazards led the San Jose analysts to conclude that short bumps are an unacceptable hazard on a public roadway. State-of-the-Art search contacts with practitioners in local jurisdictions across the U.S. found a majority convinced that speed bumps were dangerous. Practitioners normally cited the San Jose work and isolated tort cases or observed incidents in support of this viewpoint.

Community Reactions to Speed Bumps. The number of installations of speed bumps and undulations are too few to generalize on community acceptance. However, it can be expected that the noise of the bumps would be a problem for people in their immediate vicinity. Some communities which installed short bumps have removed them due to their noise and observed increase in speed.

Uniform Standards and Warrants

Speed bumps are not included in the MUTCD, nor in any corresponding state traffic control and design manuals. Some states have specifically rejected inclusion of speed bumps in such guides.

Undulations have only been used at a limited number of test sites to date. Specific physical standards for the device are set forth in the referenced TRRL report. It is anticipated that authorization and guidelines for their common use on local residential streets in the U.K. will be forthcoming in the near future.

Miscellaneous

Conventional speed bumps are reported to interfere with winter snow plowing operations. Undulations, however, because of their less abrupt profile, seem unlikely to cause such problems. No interference with snow plowing opera-
Rumble Strips

Tensions has been reported in the case of the Toronto undulations.

Examples of Current Practice

Figure 4 shows a typical short bump used in many private facilities. Figure 5 is the British undulation currently being tested in England and Toronto.

Rumble strips

Rumble strips, patterned sections of rough pavement, were developed in the 1960's as a means for alerting drivers to the presence of a dangerous condition or a specific control device. While used primarily on freeways and arterial streets, they may have potential as a speed reduction device in neighborhoods.

Primary Traffic Effects

Effects on Traffic Volume. None

Effects on Traffic Speed. The studies which have evaluated the effects of rumble strips on speed show their effect to be mainly at the upper end of acceptable speeds in residential areas. A test of 3/4" (.01 meter) chips in Great Britain showed that 1-foot long (.3 meter) strips caused discomfort at about 25 mph (40 km/h). A test of similar material in Contra Costa County reduced speeds 450 feet (135 meters) away from an intersection from 41 to 37 mph (66-59 km/h). Other tests of 3/4" (.01 meter) chips in Minnesota showed speeds 300 feet (90 meters) in advance of intersections to slow from 31 to 25 mph (50-45 km/h). Clearly, these latter tests show small effects at speeds above those desirable in neighborhoods. It is unclear if these strips would cause sufficient discomfort in neighborhoods to affect speeds. A test of 1/2" (.01 meter) high strips, 0 inches (.2 meter) wide and two feet (.6 meter) apart installed in three test locations in Calgary, Alberta showed reductions in average speed of 1-4 mph (1.6-6 km/h) with the resulting speeds being in the 21-28 mph (34-45 km/h) range. Another test in Ottawa, Canada produced a negligible impact on speed. In San Francisco, rumble strips 3/4" (.01 meter) to 1 1/2" (.04 meter) in height reduced speeds from 5 to 15 mph (8-24 km/h) with the post-implementation 95th percentile speed ranging from 16 to 30 mph.
Effect on Traffic Safety. The studies show that the strips have had a noticeable positive effect in reducing accidents when placed in advance of a stop sign. At a T intersection in Contra Costa County, California rumble strips cut the accident rate by 60 percent. Subsequent overlaying of the strips due to repaving brought about a return to the previous pattern, again demonstrating the strips’ effectiveness. Accident experience at nine rural intersections in Illinois decreased by 32-30 percent. Again, these are arterial studies; effects in lower speed residential areas have not been determined. No specific instances of bicyclist safety problems resulting from rumble strips have been reported. However, difficulties caused bicyclists by types of raised pavement markers sometimes used in rumble strips are well documented.

Effect on Traffic Noise. Noise levels have been measured only inside the car in the U.S. studies noted above. The Contra Costa study observed that the ¼” (.01 meter) chippings raised noise levels from 92 to 100 dB, with closed windows. Other studies have suggested more modest increases in the 2-3 dB range. In the Calgary and Ottawa experiments, the strips were removed due to complaints of noise. San Francisco limits application of rumble strips to streets of less than 2500 ADT (due to problems with noise on busier streets).

Effect on Air Quality and Energy Conservation. None demonstrated.

Community Reaction to Rumble Strips. The studies in the two Canadian cities both produced negative citizen reactions to the noise levels generated by the strips.

Typical Construction Materials
- ¼” (.01 meter) chippings sealed in concrete or patterns of Botts dots

Typical Construction Costs
- $200-400 per approach

Uniform Standards

While not treated in the MUTCD, rumble strips are a recognized device in basic traffic engineering reference tests. However, no
specific warrants or design standards are given. Examples of designs currently in use are shown in Figures 6 and 7.

Diagonal diverters

A diagonal diverter is a barrier placed diagonally across an intersection to, in effect, convert the intersection into two unconnected streets, each making a sharp turn. As such, its primary purpose is to make travel through a neighborhood difficult, while not actually preventing it. In actual application, this device is often best used as part of a system of devices which discourage or preclude travel through a neighborhood. Used alone, they will affect only the two specific streets involved.

Primary Traffic Effects

The primary purpose of a diagonal diverter is to reduce traffic volume. It is effective in reducing traffic as a single site application only when the neighborhood it is intended to protect is a limited one. If the neighborhood is larger, with other continuous residential streets parallel to the "problem street," installation of a single diagonal diverter may merely shift through traffic to another local street rather than bounding arterials and collectors. Single site applications of diverters where multi-site approaches are needed has been a common pitfall in the use of diverters to date.

The basic advantages of a diagonal diverter over a cul-de-sac is that, by not totally prohibiting the passage of traffic, it tends to reduce the out-of-direction travel imposed on local residents and maintains continuous routing opportunities for service and delivery vehicles. It also does not "trap" an emergency vehicle and can be designed to permit the passage of some emergency vehicles through the diverter.

Effect on Traffic Volume. Studies to date which have evaluated the traffic effects of diagonal diverters have been primarily system studies; thus the impact of a single installation is difficult to quantify. One of the earliest installations, in Richmond, California in the early 1960's was credited with an overall 16 percent reduction of traffic on neighborhood streets.61 Seattle,
Washington has performed the most comprehensive evaluation of this device and has found that, in a system of devices, traffic on streets with diverters can be reduced from 20 to 70 percent depending on the system of devices in the area, as shown in Table 3. In these studies, traffic on non-diverted streets increased as much as 20 percent. Obviously the amount of traffic reduction in any case is highly dependent on the amount of through traffic at the problem site originally.

Table 3
Traffic changes on streets with diagonal diverters in Seattle, WA

<table>
<thead>
<tr>
<th>Street</th>
<th>Daily Traffic Volume</th>
<th>% Change</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before</td>
<td>After</td>
</tr>
<tr>
<td>Republican Street west of 17th Avenue</td>
<td>1580</td>
<td>1250</td>
</tr>
<tr>
<td>Republican Street east of 17th Avenue</td>
<td>880</td>
<td>380</td>
</tr>
<tr>
<td>East Prospect Street</td>
<td>1000</td>
<td>300</td>
</tr>
<tr>
<td>16th Avenue at East Prospect Street</td>
<td>860</td>
<td>340</td>
</tr>
<tr>
<td>18th Avenue at East Prospect Street</td>
<td>500</td>
<td>270</td>
</tr>
<tr>
<td>East Highland Street at 17th Avenue</td>
<td>840</td>
<td>290</td>
</tr>
</tbody>
</table>

Evaluation of diagonal diverters has not been quantified in other cities where they have been tried, but intuitive and judgmental evaluations suggest that they are effective in reducing but not totally eliminating through traffic. In general, a pattern of devices that turns a neighborhood with a grid-style street pattern into a maze tends to be successful whereas systems which use diverters together with devices such as traffic circles or stop signs are less successful. Diagonal diverters tend to be less successful in areas where heavy pressure on surrounding arterial streets make the diverter-created maze of local streets still preferable to some drivers.

Effect on Traffic Speed and Noise. None of the research documents collected in this study have formally evaluated the effect on traffic speed or noise. General comments from citizens and agency staff suggest that diverters are most effective as speed control devices only in their immediate vicinity, within about 200-300 feet (31-61 meters) of the device. However, they are not primarily installed for this purpose. On the other hand, diverters may eliminate from the street a driver population which had formerly used it as a speedy through route. As a result, the net effect on speeds experienced along the street may be substantial.

Diagonal diverters impose no specific operational effects that would affect noise other than through shifts in volume of traffic and changes in speeds. Changes in noise levels can be estimated from techniques contained in NCHRP Report 174. Occasional tire squeal due to motorists attempting to take the turns too fast may be noted.

Effect on Traffic Safety. Seattle, Washington and Richmond and Berkeley, California have evaluated accident experience before and after the installation of diverters. Each study showed a significant reduction in the number of accidents in the neighborhood; however the actual number in each case was quite small. The Berkeley experience showed that, in parallel to traffic volume shifts, accidents were shifted to arterial streets where a more effective program for dealing with them would be possible. As traffic volume decreased in all cases on the local streets, it is probable that the accident rate is not appreciably affected by diverters.

Community Reactions to Diagonal Diverters

Appleyard's studies in the Clinton Park neighborhood of Oakland, California found residents on diverted streets substantially more satisfied with their neighborhood than residents on other streets. Reaction to diagonal diverters generally revolves around whether specific individ-
uals feel they benefit or lose by the device. Residents generally tolerate the slight inconvenience in access which this device creates; they are less tolerant when the device adds traffic to their street. They are often less tolerant of the device in another neighborhood than they are in their own since they perceive those from a driver's rather than resident's perspective. Voting patterns for two initiative ordinances to remove diverters in Berkeley substantiate this. In areas of the city where few diverters are located, a majority of voters voted for removal. Areas of the city where most of the diverters are located voted overwhelmingly to retain them.

Figure 9. Temporary diagonal diverter — Berkeley, CA.

Desirable Design Features

For a diagonal diverter, the following features should be incorporated for a safe and effective design:

- **Visibility.** The device should have a high target value to be easily visible both during the day and night. Features such as painted curbs and rails, button reflectors, black and yellow directional arrow signs (MUTCD sign W-6), street lighting and elevated landscaping can produce a highly visible diverter.

- **Delineation.** Contourine pavement striping supplemented in those areas where weather permits by pavement buttons are useful in further identifying the proper driving path.

- **Safety.** In addition to the visibility items, materials that do relatively little damage if hit are desirable. These would include shrubs rather than trees for landscaping; breakaway sign poles; and mountable curbs if the device contains additional material besides the curb to prevent violations. Temporary barricades of wood and asphalt berm can also be both safe and effective.

- **Emergency Passage.** Designs which permit emergency vehicles to pass while restricting auto passage are desirable. Since an open emergency vehicle gap is an open invitation for other vehicles to pass through as well, some physical control of the passage may be necessary. Undercarriage barriers, which allow emergency vehicle passage while intercepting lower slung cars have been employed with some success. Designs employing gates or chains are less desirable, since they require emergency vehicles to either stop and open the gate or to "crush" through it. Efforts should be made to insure that parked vehicles do not block the emergency passage.

- **Drainage.** A design which stops short of the existing curbline will usually allow existing drainage patterns to be maintained, thereby reducing overall costs.

- **Violation Prevention.** Clearly the device itself should prevent normal traffic from passing through. Additional wooden or steel posts along the adjacent properties may be needed to prevent drivers from driving on lawns, driveways or sidewalks in deliberate violation of the device.

- **Pedestrians, Bicycles and the Handicapped.** Provision should be made for the continuity of bicycle routes around the diverter. Use of sidewalk ramps for bicyclists can also aid persons in wheelchairs. Extension of sidewalks across the diagonal can provide a safe pedestrian crossing.

Figure 10. Typical undercarriage barrier in diverter's emergency vehicle gap
• **Maintenance.** A design minimizing maintenance would minimize the use of plants requiring irrigation. Non-living material would also reduce costs, so long as the design did not inherently act as a collector of litter.

**Typical Construction Materials**

Temporary Diverters:
- Asphalt Berm
- Concrete Blocks
- Wooden Barricades
- Concrete Bollards with connecting boards or chains
- Steel Posts or U-bars with reflective devices

Permanent Diverters:
- Standard Steel Guardrail
- New Jersey (Concrete) Barrier
- Concrete or asphalt curb — with or without landscaping or continuing sidewalks

**Typical Construction Costs**

- Temporary Diverters $500-2000
- Landscaped Diverters $1000-12000 and upwards
- Additional fire hydrants $1500-2500

**Uniform Standards**

Diagonal diverters are not specifically listed in the MUTCD or parallel state traffic control and design manuals. However, they may be defined as a channeling island and may be constructed of and marked with devices shown in the MUTCD or other design manuals. Diverters are specifically recognized as a form of traffic control channelization in basic traffic engineering texts such as *Fundamentals of Traffic Engineering.*

**Examples of Current Practice**

The physical design of a diagonal diverter can range from extremely simple and inexpensive to costly landscaped permanent fixtures. Figures 8 through 17 show several variations on the theme. Figure 9 is the most simple design. It consists of standard concrete bars placed across the intersection and supported by painted pavement markings and warning signs. The installation is inexpensive, and can be bypassed by fire vehicles if properly designed. It can be violated by a determined motorist. Figure 9 shows the use of concrete bollards as a diagonal diverter, with...
a low concrete block which permits passage of trucks and fire vehicles while prohibiting cars to pass. Bicycles and motorcycles can also easily pass through this design. Figure 10 shows a close-up of the undercarriage barrier.

Figure 11 shows the use of bollards and connecting boards as a diverter. This design suffers from the lack of emergency passage, which could be designed as with Figure 10. The figure shows the use of centerline for added delineation, and space at the curb for drainage and bicycle passage.

Figure 12 shows the Victoria, B.C. technique for creating temporary diagonal diverters. The design is inexpensive and provides a highly visible target for the motorist to avoid. Note also the use of wooden posts in the pedestrian area to prevent violation of the barrier.

Figure 13 shows another low cost, more permanent type of diverter. The chain is reflectorized for target value, and can be removed, with some difficulty and delay, by emergency personnel. Planters surrounded by metal poles and raised traffic bars are used in an attempt to add aesthetics, though it appears everything but the kitchen sink has been thrown into this installation. The overall effect is a needlessly cluttered intersection with little visual impact at a distance; yet it does perform its intended function.

Figure 14 shows the use of standard guardrail as a diverter. While low on aesthetic appeal, the white-painted rail is easily visible to drivers.

Figures 15 through 17 are three examples of more permanent landscaped diverters. Figure 15 shows a technique of maintaining pedestrian continuity through the intersection. Figure 16 is an example of simple landscaping which may be somewhat hazardous, since the large rocks do present an obstacle to vehicles jumping the curb, and no warning signs or markings are present.

Figure 17 shows examples of diverters which perform their intended task and also add a measure of psychological deterrent to through traffic. The landscaping, when viewed by drivers from a distance, gives the impression of a street closed to through traffic, an impression not well presented by a number of the other diverters. Note that Figure 17a's design also retains existing drainage patterns by leaving a
gap between the diverter and the original curb and gutter. Raised centerline markings provide emphasized delineation for motorists, and posts prevent avoidance of the device through use of the sidewalk or private land.

Intersection cul-de-sac

By definition, an intersection cul-de-sac is a complete barrier of a street at an intersection, leaving the block open to local traffic at one end, but physically barring the other. As such, a cul-de-sac represents the most extreme technique for deterring traffic short of barring all traffic from the street in question.

Primary Traffic Effects

Since a cul-de-sac is completely effective at its task of preventing through traffic, the choice of where and whether or not to use it depends largely on other aspects of traffic movement. For example, a cul-de-sac is less desirable in the vicinity of fire stations or police or ambulance bases where emergency vehicle accessibility must be given high priority. It is less desirable than other devices in areas where the potential for multi-alarm fires might exist, since fire departments often wish to maximize the flexibility of vehicular movement in these places. In locations where a heavy traffic generator is near, a full barrier may be the only solution to preventing shortcutting. On the other hand, the design of the cul-de-sac must often allow side or rear access from a local residential street to a high traffic volume generator fronting on an arterial; in this case, a mid-block cul-de-sac, discussed in the following section, may be more appropriate. A cul-de-sac may be desirable adjacent to a park or school where the vacated street can be converted into additional play area. Finally, a cul-de-sac may be considered as a last resort in locations where obstinate drivers violate other less effective devices.

Effect on Traffic Volume. Studies which have evaluated the effect of a cul-de-sac on traffic volume have all shown them to reduce it effectively. Cul-de-sacs at the ends of two streets one-half mile (.8 km) long in Berkeley, California reduced ADT from 9000 to 600 in one case, and from 5700 to 1300 in another. Two block sections in Palo

Cul-de-Sac/Street Closures
Alto, California were reduced to 200 vpd. In Bethesda, Maryland volumes were reduced to 150 vpd. Experiments with three cul-de-sac plans in Dallas, Texas neighborhoods, shown in Figure 18, reduced traffic within the neighborhood from 10,700 to 3500 for Alternative 1, 3800 for Alternative 2 and 4600 for Alternative 3. In these and other cases, the cul-de-sac clearly limited traffic almost exclusively to that generated locally. Exceptions are the occasional vehicle which unknowingly enters a blocked street and then must maneuver to leave it, and those few vehicles which deliberately violate the barrier.

Effect on Speed and Noise. A cul-de-sac is not a speed attenuating device; thus no evaluations have been made of this measurement. However, if the device eliminates a driver population which had previously used the street as a speedy through route, its ultimate effects on traffic speeds experienced on the street may be substantial. Noise has been found to be reduced as a function of the reduction in traffic volume and speed.

Effect on Traffic Safety. Safety evaluations of cul-de-sacs beyond those systemic studies noted in the diagonal diverters section have not been uncovered in the course of this study.

Effect on Emergency and Service Vehicle Access. The cul-de-sac or complete barrier of a street is the neighborhood protective device that is most objectionable to emergency and service personnel. While designs have been developed with emergency vehicle passageways, even these can be rendered ineffective by cars parked in front of the opening. More so than a diagonal diverter, a complete barrier can cause considerable interforonce in the proper placement of vehicles combating a fire. They also limit the number of approaches to and maneuverability at a fire scene.

Police vehicles giving chase to a suspect can occasionally be inhibited by a cul-de-sac with or without an emergency vehicle passage. Where no emergency passage is provided, emergency vehicles can become “trapped” by a full barrier, requiring slow and difficult maneuvering to return to a through street. Cul-de-sacs rarely disturb public transit, since transit routes usually do not pass through local streets, but clear-
ly, a cul-de-sac would interfere with any such routes. School bus and garbage routes can usually be rerouted to bypass these types of barriers with little inconvenience.

**Community Reactions to Cul-de-Sacs.** Communities have generally responded positively to cul-de-sacs particularly where a number of such treatments have been installed in a neighborhood. They have been less well received where they merely shift traffic from one street to another. Some resentment occurs if a long detour for access is caused by a series of barriers. Specific problems have also occurred when a barrier is placed next to a residence with its main entrance on one street and its garage on the other. A mid-block treatment can often solve this problem.

**Desirable Design Features**

A successful cul-de-sac design should incorporate the following features:

- **Location.** Where possible, the barrier forming the cul-de-sac should be placed at an intersecting through street rather than in the interior of a neighborhood. Location in this manner minimizes the inadvertent entrance into the closed street and subsequent maneuvering to exit. Because limited turning space on retrofit cul-de-sacs (see below) may force large vehicles to back out, such cul-de-sacs should not be employed on relatively long blocks. Reference sources vary widely in recommendations for maximum cul-de-sac length in new subdivisions: 250-500 feet, *The Urban Pattern;* 400-600 feet, *Residential Streets;* 1000-1200 feet or 20 single family units, *Community Builders Handbook.* Although this guidance is ambiguous, it is suggested that retrofit intersection cul-de-sacs not be employed on blocks exceeding 500 feet. Figure 19 summarizes considerations in cul-de-sac location.

- **Turning Radius.** A typical minimum turning radius standard for cul-de-sacs in new subdivisions is 35 feet (10.5 m). This permits free 180° turning movements by autos and smaller trucks and maneuvering space for larger vehicles. When an existing residential street, perhaps only 36-40 feet wide is made a cul-de-sac, only an 18-20 foot turning radius can be

![Figure 19. Cul-de-sac location implications](image-url)
provided in the existing traveled way. Most auto drivers will be unable to execute continuous 180° turns in such situations. Bulbing the turning area beyond the existing curblines should be considered where feasible. Parking bans on the approaches to the turning area can also help ease turning movements. If turns are too difficult, motorists will inevitably use private driveways for their maneuvers.

The need for an adequate turning radius is greatest at cul-de-sacs located within a neighborhood where inadvertent entrances to a block are more likely to occur. They are needed less where the barrier is at an arterial, and few strangers are likely to enter the block. In most existing neighborhood street situations it will be impractical to provide turning radius for large single unit and articulated trucks at cul-de-sacs.

- **Visibility.** The most important visibility aspects for cul-de-sacs are at a distance from the device itself. Landscaping or other clearly visible provisions should identify the fact that the street is not a through street. “Not a Through Street,” “Dead End” (W 14-1) or “No Outlet” (W 14-2) signs should be clearly visible at the block entrance to prevent inadvertent entrances.

Visibility requirements for the design itself depend on the nature of the location. Locations with inherently low surrounding volumes need little in the way of visibility. Devices adjacent to arterials should be highlighted with reflectorized paddles or button reflectors. Designs with emergency vehicle passage should include standard “Do Not Enter” (R 5-1) signs.

- **Drainage.** As with diagonal diverters, designs of full barriers can maintain existing curb and gutters, minimizing costs associated with revising drainage flow.

- **Violation Prevention.** In cases where a barrier is placed in the face of even modest community or driver opposition, the lawn, sidewalks, and driveways adjacent to the barrier may require protection by wood or metal posts to prevent

*Parenthetical references are device identification nomenclature from the Manual on Uniform Traffic Control Devices.*
• Pedestrians, Bicycles and Handicapped. Designs with emergency passage provision should also provide for these non-motorized travelers. Without emergency passage, special ramps for bicycles and wheelchairs may be needed if sufficient numbers of them are present. As with diagonal diverters, pedestrian continuity can be aided by extending sidewalks across the end of the barrier.

• Maintenance. Landscaped designs which provide for no irrigation requirements or for plantings similar to adjacent parkways can minimize maintenance requirements.

Typical Construction Materials

All materials listed in the diagonal diverter section can be equally well used for cul-de-sacs.

Typical Construction Costs

• Temporary Barrier $500-2000
• Landscaped Barrier $1000-12,000
• Additional fire hydrant $1500-2500

Uniform Standards

Permanent cul-de-sacs are a standard treatment in the design of new residential developments. Retrofit treatments are not currently recognized in the MUTCD, but can be constructed of materials and techniques present in many design manuals. Basic traffic engineering reference texts do acknowledge the use of retrofit cul-de-sacs for residential traffic management.113

Examples of Current Practice

The physical design of cul-de-sacs, as with all structural protective devices, can vary from inexpensive and simple to expensive and fully landscaped. Figures 20 through 29 present a sampling of typical treatments. Figures 20-22 represent the least costly approach to closing a street. Wooden barricades or asphalt berms, as in Figures 20 and 21, represent a reasonable first step or temporary technique for closing a street. The asphalt berm in Figure 21 includes provision for emergency vehicles with an under-carriage barrier to automobiles.

Figure 22 represents a political as well as a technical solution. In this case, the connection between two ends of a street was never made in the first place. The crude fence thus effectively

Figure 24. Cul-de-sac — Berkeley, CA.

Figure 25. Cul-de-sac — Menlo Park, CA.

Figure 26a. Permanent Cul-de-sac — Palo Alto, CA.

Figure 26b. Permanent Cul-de-sac — Hartford, CT.
accomplishes its purpose.

Figure 23 shows the use of chain link fence as a cul-de-sac tool. The fence was used to extend an existing school play-yard.

Figures 24 and 25 show the use of bollards and planters as part of a barrier. In each case, provision is made for emergency vehicles, although removal of the chain in Figure 25 is somewhat awkward.

Figures 26-28 represent more permanent and elaborate treatments. Figure 26a, a device still under construction, shows intelligent use of planters, provision of emergency passage which is easily mountable by bicycles, undercarriage barrier to discourage violation by autos. Specific connection of ramps across the device for bicycles and wheelchairs, an attractive mounting of the “Do Not Enter” sign, and provision for drainage in accordance with the pre-existing pattern. Figure 26b, similar in concept but with wooden planters rather than the inset concrete planter wells, was observed to experience a high violation rate due to the absence of any physical device discouraging use of the emergency vehicle passage.

Figure 27 shows a similar emergency passage treatment, but no plant materials requiring maintenance. The low fence and bench constructed of redwood make a visually attractive device.

Figure 28 shows a cul-de-sac with the vacated portion of the street converted to a landscaped mini-park.

Finally Figure 29 shows a typical traffic engineering technique which can aid the neighborhood as well as simplifying a complex intersection. At this former six-leg intersection, a minor leg has been blocked to create both of the desired effects. Note that sidewalk ramps, provided for continuity of bike lanes, are visible in the foreground.
Midblock cul-de-sac

A cul-de-sac placed within a block, rather than at one end, performs the same function as an intersectional cul-de-sac with two small differences. A midblock location can be chosen so that the residence at a corner will have easy access to the attached garage without the need to travel several blocks to avoid the barrier. Midblock cul-de-sacs shorten the distance a large vehicle which can't turn around would have to back-up as compared to intersection cul-de-sacs applied to the same streets. It has the disadvantage of being less apparent to the motorist on the through streets, so that occasional vehicles will turn into the blocked street and then have to work their way out. Traffic effects, design features, typical construction materials and costs, and legal status are similar to those listed in the previous section.

A midblock barrier can be especially useful in locations where a high traffic generator borders a residential area. As shown in Figure 30, the barrier can permit access to the generator from an arterial street while protecting the neighborhood from through traffic.

Figures 31-33 show three techniques for constructing midblock cul-de-sacs. Figure 31 shows the use of a fully landscaped median to physically block the street, as well as making clear from a distance that the street is not intended for through traffic. Figure 32 illustrates a special case where an adjacent park was extended into the former right-of-way with the aid of a cul-de-sac treatment. Neither of these designs provide passage for emergency vehicles.

Figure 33 shows a more elaborate treatment providing a buffer between residential and commercial districts, with some widening of the roadway to provide an adequate turning radius. Siting of the cul-de-sac to provide access to driveways is well shown in this figure, as is the provision for emergency vehicles.

Semi-diverter

A semi-diverter is a barrier to traffic in one direction of a street which permits traffic in the opposite direction to pass through. In a sense, it
Semi-Divers

Semi-diverters is a "Do Not Enter" signal to drivers, providing an added level of warning and physical reinforcement to motorists beyond what a simple sign would do. Because they block only half of a street, semi-diverters are easily violated, particularly on low volume streets. At the same time, they provide a minimal impediment to emergency vehicles. Experience has shown that they work best in areas where neighborhood traffic management is generally well-accepted by the public.

Primary Traffic Effects

The primary purpose of a semi-diverter is to reduce traffic volume; it has little value as a speed reduction device. Its best use is when one direction on a street is used as a shortcut. A pair of semi-diverters can be used at opposite ends of a pair of blocks to effectively discourage traffic in two directions.

The semi-diverter's main advantages over full barriers or cul-de-sacs are a reduction of interference with local traffic and a minimization of impact upon emergency and service vehicles. Its major disadvantage is in the ease of violation, particularly at midblock and internal neighborhood locations where the temptation to violate the barrier rather than maneuver and retrace one's path is usually too great.

Effect on Traffic Volume. Evaluation studies to date have shown that semi-diverters can make significant reductions in volume though residents may often focus on the violation level rather than the reduction level. Studies of a neighborhood in San Francisco, where semi-diverters were placed at opposite ends of block pairs, showed an average reduction on four streets of 40 percent to an average of 1000 vpd. Other semi-diverters have shown similar effects, though few have been quantified. A study in Berkeley, California showed a 30 percent violation rate of total movements approaching the barrier from the wrong direction; however, this was only 7 percent of the volume previously using the street.

Effect on Traffic Speed and Noise. Since a semi-diverter is not a speed reduction device, data has not been gathered that would measure its effect. However, if it diverts drivers who formerly used the street as a speedy through route
or shortcut, the actual change in speed experienced after installation may be substantial. Effects on noise levels are directly related to the reduction in traffic volume.

Effect on Air Quality and Energy Consumption. As with most devices considered herein, the air quality changes in the micro-environment are miniscule since most auto-related pollutants which affect neighborhoods are responsive to changes in emissions on a regional basis rather than in a small, localized area. Energy consumption can be assumed to be somewhat increased due to slightly longer distances and added stops on arterial streets.

Effect on Traffic Safety. In San Francisco a study evaluating safety of semi-diverters observed a 50 percent reduction in the number of accidents over a 4-month period. This period is probably too short to be accepted as statistically significant. The apparent reduction in accidents also parallels the almost 50 percent reduction in volume, suggesting that semi-diverters had no real overall effect on the rate of accident occurrence per unit traffic. Experience in Berkeley suggests that rather than a reduction in total accidents, a shift of accident location to major streets may have occurred. Still, even if just a locational shift, this effect should be counted as a benefit because accidents are moved from local streets where they are extremely disturbing to residents to arterials and collector streets where they can be dealt with more effectively using normal traffic safety measures.

Community Reactions to Semi-Diverters

People living on streets with a semi-diverter have been generally favorable to them. The major negative reactions have been due to the observed violations and lack of enforcement to prevent them.

Desirable Design Features

* Location. A semi-diverter is best located at the end of a block to prevent entrance and permit exit. Diverters located in a way such as to prevent exit are easily and frequently violated. Experience suggests that semi-diverters in midblock locations are also more frequently violated than end-of-block placements, though they still have some effectiveness.
Visibility. Since the semi-diverter tends to be a somewhat small device, care should be used to insure visibility, particularly at night. "Do Not Enter" (W 5-1) signs, painted curbs, and reflectorized signs and construction materials are useful for aiding visibility. "Not a Thru Street" signs are needed at the entrance point of a block to prevent inadvertent entrance and subsequent maneuvering to get out.

Violation Prevention. Constriction of the traveled way in the direction in which traffic is permitted to pass the diverter can make violations difficult.

Emergency Passage. This is inherently permitted by the design of the device. As long as sight distance is good, it is quite acceptable for emergency vehicles to travel in either direction on the "open" side of the semi-diverter. However, if traffic is queued on the "open" side, awaiting a gap in cross street traffic, emergency vehicle passage can be delayed.

Bicycles and the Handicapped. Care should be taken to provide a legal bypass for bicycles and wheelchairs; otherwise cyclists in particular will dangerously violate the device by riding "wrong way" on the open side.

Typical Construction Materials

Materials used for diagonal diverters are equally usable for semi-diverters.

Typical Construction Costs

- Temporary Semi-Diverters $300-1200
- Landscaped Semi-Diverters $1000-5000

Uniform Standards

Semi-diverters are not included in the Manual of Uniform Traffic Control Devices. Like other diverters, they define an area which is not in the traveled way and can be comprised of elements included in the MUTCD and other design manuals. Semi-diverters are recognized as residential traffic control treatments in some basic traffic engineering reference texts.43

Examples of Current Practice

Figures 34-38 show some design techniques for semi-diverters. Figure 34 illustrates the placement of a guard rail semi-diverter at an intersection with a major arterial. This is perhaps
the most effective treatment, since the narrowing of the local street makes right turns from the arterial (in violation) most difficult. Figure 35 shows the use of a guard rail semi-diverter at the intersection of two local streets. Pavement bars painted white are used to give added emphasis to the presence of the barrier.

Figures 36 and 37 show another inexpensive treatment; in this case, a standard design for the New Jersey concrete median used for freeways and high-speed facilities is used as the barrier. This is a somewhat unforgiving design when struck by a vehicle, particularly when struck from the side by a vehicle on the arterial street. Figure 37 shows signs and pavement markings on the arterial street to guide arterial traffic safely away from the diverter. In addition, the prominent tracks on the lawn at the right of the figure dramatically show the extent of driver attempts to circumvent the device. Clearly, additional posts or barriers are needed to prevent such violations.

Finally, Figure 38 shows the use of bollards as a semi-diverter in a midblock location. All of these illustrations are temporary or low cost designs. More elaborate landscaped fixtures similar to illustrations shown for diverters and cul-de-sacs are possible.

**Forced turn channelization**

Forced turn channelization usually takes the form of traffic islands specifically designed to prevent through traffic from executing specific movements at an intersection. Its basic function is the same as a diagonal diverter — to make travel on local streets difficult, but not prevent it entirely. Generally this technique is best used at an intersection of a major and a local street, where the major street is basically unaffected by the channelization, or even has its traffic flow qualities enhanced, while through traffic on the local street is prevented. Employed in such locations, it prevents traffic flow from one neighborhood to another across the major street. It can also be used on purely local streets to permit turning movements other than those possible with a diagonal diverter. However, it is more
likely to be violated within a neighborhood, since the threat of enforcement is minimal.

Primary Traffic Effects

As noted above, the primary purpose of forced turn channelization is to make travel through neighborhoods difficult, while not preventing it entirely. As shown in Figures 39-44, forced turn channelization can take numerous forms and must usually be customized to deal with specific traffic movements to be prevented. Because channelization has become a well-accepted and well-used traffic control device, it tends to have a higher level of obedience than the other partial restrictions, particularly when used on an arterial street.

Effect on Traffic Volume. Documented studies of this device generally show that their success depends on whether or not the movement prevented is a significant one. For example, an evaluation of a neighborhood in Seattle using so-called "star" diverter, which permits only right turns on all approaches, had little effect on overall volumes. Channelization on a street in Palo Alto, California reduced volumes to 1000 vpd, while increasing them on surrounding residential streets. The channelization in Figure 43 in Richmond, California is effective in preventing traffic from passing through a neighborhood to access a major shopping center.

Effect on Traffic Speed and Noise. Channelization tends to have a minimal direct effect on speed, other than the required slowing for turning. But if it diverts a driver population which had previously used the street as a high speed through route, the actual change in speeds experienced on the street may be marked. The amount of noise reduction is parallel to the amount of traffic volume and speed reduction.

Effect on Air Quality and Energy Consumption. While this technique does add some slowing and accelerating, as well as added distance on other routes, the effect is considered to be negligible.

Effect on Traffic Safety. Studies have not evaluated the safety effects of these devices, primarily because their effects tend to be masked by other traffic actions. However, numerous traffic engineering studies have shown that
Channelization tends to increase the safety of locations where the design adds clarity and simplicity and is easily understood.

Community Reaction to Channelization. Programs involving channelization have generally been acceptable to communities where proper planning and communication has occurred. Specific problems have come from specific individuals or high volume traffic generators whose access has been impaired. Citizens have also complained where the design did not adequately prevent violations from occurring.

Desirable Design Features

General practices in the area of channelization including design of effective turn radii, merging distances and visual clarity, are applicable to this device. Other desirable features include:

- **Visibility.** Channelization will usually be constructed of some type of raised material, either curb and gutter, concrete bars, or asphalt berm. Painting the devices white will add to the visibility, as will standard signs ("No Right Turn," (R 3-1); "No Left Turn," (R 3-2); etc.) indicating the turns permitted and/or prohibited. Since channelization is generally limited in size and close to the traveled way, the number of signs and other vertical visibility indicators should be limited to minimize physical targets and maintenance while maximizing visual target value.

- **Delineation.** Striping parallel to the device and continued (dashed) through the intersection aids in the clarity of the design.

- **Safety.** Minimizing the "clutter" of excessive signs can minimize the potential for fixed object accidents. However, sufficient signing should be present to avoid inadvertent violation of the intent of the channelization.

- **Violation Prevention** is best done by assuring that the channelization covers a significant part of the intersection, thereby narrowing the area where illegal turning movements can be made.

- **Emergency Passage.** High speed emergency passage is generally difficult to provide for without also providing for easy violation of the
intent of the device. However, emergency vehicles can usually maneuver around such channelization without severe delay. Channelization using raised bars or asphalt berm can be traversed by emergency vehicles with some difficulty and discomfort, particularly to firefighters riding on the outside of an apparatus.

- **Pedestrians, Bicycles and the Handicapped.** Special care should be given to providing routes for bicycles through a channelized area; otherwise, cyclists will tend to make their own way, often in violation of the channelization and sometimes at a hazard to themselves. Islands designed to give adequate refuge for pedestrians should also provide for ramps for wheelchairs.

**Typical Construction Materials**
- Concrete Blocks
- Asphalt Berms
- Curb and Gutter (Islands)
- Pavement Buttons

**Typical Construction Costs**
- Asphalt Berm and concrete blocks $200-1500
- Islands $1000-10,000

**Uniform Standards**

Channelization is a well-accepted MUTCD device, which recognizes the use of all the above materials for use in control of turning movements.

**Examples of Current Practice**

The design of forced turn channelization is a task which must respond to unique conditions of each location. Thus, the approach of customizing each design must be used. Figures 39-46 present only a few of the possible techniques.

Figure 39 is a diagram of the Seattle "star." The design of the island permits only right turns from all approaches.

Figure 40 represents a hybrid of the star and the diagonal diverter, providing for more turning movements than either. Figure 41 shows an actual installation.

Figure 42 shows a diagramatic use of raised islands to prohibit certain movements. The shape of the islands can limit or permit certain desired movements, depending on the specific situation.
Figure 43 shows the use of islands at an entrance to a major shopping center. The islands force traffic leaving the center to turn, thus avoiding the neighborhood in the background. They also force traffic from the neighborhood to use another entrance to the center. The overall effect is to limit the use of the local street as a shortcut. Note that the design makes no special provisions for bicycles, though pedestrians are well served with signal actuation buttons on the median island.

Figure 44 shows the use of bars and buttons to force all traffic to enter or leave a major traffic generator (a city maintenance yard); through traffic is not permitted. While not inherently an absolute barrier to traffic, the design has resulted in effective reduction of traffic. Clearly, this design is dependent on community acceptance and obedience rather than on physical constraint of traffic movements.

Figure 45 shows a simpler forced turn channelization comprised of centerline striping and raised bars.

Figure 46 shows the wrong way to design channelization. The island is so short that it is easily and frequently violated.

Median barrier

The median barrier is a standard traffic engineering device generally used to improve flow on a major arterial street. It has been used to limit the number of places where left turns can be made, thus concentrating turns at places where they can be better controlled, often with turn pockets and signals. Median barriers also limit the number of places where through traffic on local streets can flow from one neighborhood to another.

The median barrier is one of the few devices which can aid arterial flow and neighborhood protection at the same time. By restricting the number of through and turning movements at an intersection, a median barrier can be as effective as a full or partial barrier or diverter in reducing traffic on residential streets. Since the median barrier is an accepted arterial treatment, it is less likely to arouse opposition than other more obvious physical treatments. In terms of planning, the designer or planner need
only consider the needs of the neighborhood as well as the arterial in choosing where to create breaks and turn pockets in the median.

A median barrier is most effective in locations where through traffic is prevented from crossing on a number of local streets; otherwise, the effect would be to merely shift traffic from one local street to another. Often, maintaining median continuity across several local streets is not possible on arterials with commercial developments since this type of land use usually requires numerous breaks in the median. The possibility of designing midblock pockets for U-turn opportunities in such areas could be considered. However, the advisability of this adjustment will depend on the traffic characteristics of the arterial in question. Median barriers do not necessarily require extra pavement width; concrete barriers placed across an intersecting street on the centerline of an arterial can serve the function quite well.

**Primary Traffic Effects**

Neighborhood traffic management related purposes of a median barrier are to prevent left turns onto and from a minor street, to prevent traffic on a minor street from crossing a major arterial, to improve arterial flow, and secondarily, to reduce speed. In conventional applications, median barriers also help prevent head-on collisions of opposed direction traffic. Median barriers have been shown in numerous studies to have a beneficial safety effect as well.

**Effect on Traffic Volume.** The use of the median barrier as a protection device has been best documented in Gothenberg, Sweden. Median barriers were used on a loop road around the central business district, resulting in a traffic reduction of 70 percent on streets inside the loop and an increase of 25 percent on the circumferential street. In the United States, the emphasis in the use of this device has related to their effects on arterial streets, rather than on the neighborhood. However, they have clearly had a beneficial, if unquantified, effect on reducing volumes on some local streets.

**Effect on Traffic Speed and Noise.** Median barriers have been infrequently used to control speeds on small radius curves on arterial and residential streets. By preventing traffic on the outside of the curve from crossing the centerline to “straighten out the curve,” the median barrier emphasizes the degree of curvature and causes traffic to slow. A study in Richmond, California on a 150 feet (45 meters) radius showed that the installation of 1 1/4” (.03 meter) high concrete barriers reduced average speeds from 22 to 16 mph (35-26 kmph). Installations on 170-275 foot (51-83 meter) curves in Concord, California reduced speeds on the outside of the curve by 8-10 mph (13-16 kmph), but had no effect on speeds on the inside of the curve. Curves with radii greater than 300 feet (91 meters), with safe speeds in excess of 30 mph (48 kmph), will generally be unaffected by this treatment.

Median barriers which reduce accessibility to neighborhood streets may exclude a driver population which formerly used the streets as speedy shortcuts. In this sense they might substantially change speeds experienced along residential streets.

**Effect on Air Quality and Energy Conservation.** The use of median barriers has a marginally positive effect on air quality and energy conservation when they improve the quality of flow along an arterial street. Some of these benefits can be lost, however, if turning movements become so concentrated at specific locations that excessive delay and waiting time occurs to turning vehicles. However, as with all of the devices discussed herein, the effect on air quality on local streets is primarily related to over all traffic emissions in the region and little affected by small changes in localized emissions.

**Effect on Traffic Safety.** Studies of median barriers have shown that they improve the safety of the arterial street, and that the improvement is inversely proportional to the number of openings permitted in the median. The effect on safety of local streets has not been quantified, but a reduction in accidents proportional to reductions in traffic can be presumed.
Desirable Design Features

Details of effective design for median barriers are contained in most state design manuals. Warrants and design details are also contained in two NCHRP documents: NCHRP Report 93, "Guidelines for Median and Marginal Access Control on Major Roadways";37 and NCHRP Report 118, "Location, Selection, and Maintenance of Highway Traffic Barriers."38 These publications are concerned primarily with the barriers effect on the arterial streets. Desirable design features in regard to protection of local streets include:

- **Location.** Location of a median barrier should include consideration of prevention of through traffic and shortcutting; however, it must also provide access to high traffic generators bordering a neighborhood. Where these generators exist, some other type of device may be appropriate.

- **Visibility.** Visibility is rarely a problem since arterial streets where medians are placed are usually well lit. Use of reflectorized buttons and "No Left Turn" (R3-2) signs can improve visibility of the median from the local street.

- **Safety.** The two key items for a safe median design involve end point design and pedestrian protection. Design of the end point should minimize damage to a vehicle that strikes the end of the barrier. Techniques such as mountable curb, burying of guard rail ends, and a tapered end for the New Jersey concrete barrier are effective. Signs, light poles and other fixed objects should be located as distant as possible from the end of the barrier. Diverging striping in advance of the barrier is also effective.

Protection for the pedestrian can be accomplished by use of sufficiently wide medians to give the pedestrians "trapped" on the island a relative feeling of safety. Standard minimum design widths of four feet generally do not meet this objective; 6 feet (1.8 meters) is a more desirable goal. Additional protection may be provided through the use of guard rail around the pedestrian area; however, such a design adds another fixed object.
near the travel path, with an inherent potential for fixed object accidents. The probabilities for both fixed object and vehicle-pedestrian accidents on a median should be considered when this added level of protection is provided. Traffic signals designed to be actuated on the median for the separate sides of a roadway also improve pedestrian safety while minimizing delay to the motorist.

- **Emergency Passage.** Emergency passage across a median barrier is provided at regular median openings. In addition, mountable curbs or ramps and paved emergency vehicle passages can be provided.

**Typical Construction Materials**

Common construction materials include raised concrete islands, concrete bars, asphalt berms, "New Jersey Barrier" with or without a raised island, and standard guard rail with or without a raised island.

**Uniform Standards**

Median barriers are a recognized MUTCD device and are provided for in State design manuals.

**Examples of Current Practice**

Figures 47 and 48 show two typical uses of raised median islands to limit turning movements to right turns only. Figure 48 adds visibility emphasis through use of a Right Turn arrow. The latter technique has little value in regions where snow is a problem; a "Right Turn Only" sign could aid visibility in all cases.

Figure 49 illustrates the use of concrete bars in a painted median to prohibit left turns.

Figures 50 and 51 show the use of concrete bars and asphalt berm to reduce speed. As noted, these devices are only partially effective on curve radii of less than 300 feet (91 meters).
Traffic circles

Traffic circles are another arterial treatment which have recently gained increasing usage in residential areas. Originally used mainly in European and eastern U.S. cities at complex intersections, smaller circles are now being tried mainly as speed control devices. They also have some impact on traffic volume. In this latter use, they have little impact unless used as part of a group of circles or other devices that slow or bar a driver's path.

In such situations, volume reductions result from psychological rather than physical impacts on traffic. Their presence when viewed from a distance gives an impression of obstruction to traffic. If drivers have encountered real barriers at other points in the community, they are likely to believe that the circle is yet another one and change routes before they get close enough to see what it actually is.

Actually, traffic circles have little effect either on traffic volume or speed. But they do give the neighborhood a feeling that "something has been done." As with other devices, the perception rather than the reality of an impact may be most useful.

Primary Traffic Effects

**Effect on Traffic Volume.** The studies which have examined traffic volume effects of traffic circles have also included other devices in their proximity; thus the effects of circles on volumes is not presently quantifiable. Professional statements on this effect have been largely subjective, and in some cases biased toward a particular selling point. The case for circles as a volume reducer is thus not clear.

**Effect on Traffic Speed.** The effect on vehicle speed has been shown to be related to the size of the circle, the distance from the circle at which speeds are measured, and the presence or absence of additional obstructions at the intersections.

A study in Sacramento\(^{10}\) tested the effects of varying the size of the circle on traffic speed using temporary circles made from sand-filled barrels, supplemented by "Keep Right" signs. "After" measurements were made one week follow-
ing the change in circle size at distances 50 and 300 feet (15 and 91 meters) from the intersections. Speed differentials 300 feet (91 meters) from the intersections were negligible; however, the larger circles were shown to be effective within 50 feet (15 meters) of the intersection, as shown in Table 4.

Table 4
Vehicle speeds for various traffic circle sizes in Sacramento, CA; 50 feet from intersection

<table>
<thead>
<tr>
<th>Circle Diameter</th>
<th>85th Percentile Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feet</td>
<td>Meter</td>
</tr>
<tr>
<td>No Circle</td>
<td>26 - 38</td>
</tr>
<tr>
<td>14</td>
<td>4</td>
</tr>
<tr>
<td>16</td>
<td>5</td>
</tr>
<tr>
<td>20</td>
<td>6</td>
</tr>
<tr>
<td>24</td>
<td>7</td>
</tr>
</tbody>
</table>

Another study in San Francisco confirmed that within 300 feet (91 meters) of an intersection, the circle has little effect; however, speeds were reduced to 16 mph (26 kmph) at the intersection.

Other studies have shown less effect. A temporary circle in Saratoga, California showed that a circle reduced speeds by 3 mph (5 kmph) from an 85th percentile speed of 32 mph (51 kmph) at a distance of 85 feet (26 meters) from the intersection. An unquantified study in Berkeley, California indicated that the circles of 10-20 feet (3-6 meters) in diameter had little effect on speed.

Effect on Noise, Air Quality, and Energy Consumption. No studies have evaluated these effects. It can be deduced that the effects in the areas are marginal as they relate to small effective changes in speed.

Effect on Traffic Safety. While no formal statistics exist on traffic circle safety, considerable observations have been made of unsafe practices caused by circles. They present an increased hazard to pedestrians by bringing vehicles, some at relatively high speeds, nearer to the curb where the pedestrians are waiting. The deflection they cause to an automobile can also impinge upon a bicyclist's path. Observations have also been made of vehicles striking curbs...
or jumping over them into lawns when diverted by circles. Vehicles are frequently observed passing to the left of a circle when completing a left turn. Each of these are unsafe actions which can be directly attributed to the device itself. The lack of substantiating accident statistics tend to speak more to the short time of usage and usage on low volume streets rather than necessarily indicating inherent safety of the devices.

Community Reaction to Traffic Circles

Community reaction to traffic circles has been mixed. Some people, particularly those in the immediate vicinity of a circle, perceive a reduction in the speed of traffic. Others perceive them to have no effect or to act mainly as a nuisance. The mixed reception makes prediction of the acceptance of this device rather difficult at this time.

Desirable Design Features

- **Location.** Traffic circles should not be located where a clear pedestrian or bicycle demand may create conflicts as noted above.

- **Visibility.** The circle itself should be made of materials with a high target value for both day and nighttime visibility. “Keep Right” (R4-7) signs should be visible on all approaches.

- **Delineation.** Centerlines should be used on each approach to guide traffic around the circle.

- **Safety.** Crosswalks should be located out of the influence zone of a circle. Parking restrictions should be placed adjacent to the intersection to minimize conflicts with parked vehicles.

- **Size.** The circles should be large enough to impact speed, as shown in Table 3, but they must permit trucks and fire engines to make all necessary turning movements.

Typical Construction Materials

Temporary Circles: barrels or concrete bollards

Permanent Circles: bollards or curbed island with or without landscaping
Chokers/Narrowing

Typical Construction Costs

Temporary Circles $500-2000; Landscaped Circles $1000-10,000

Uniform Standards

Traffic circles are not a specific entry in the MUTCD. However, they may be considered to be channelizing islands and are in common use as a traffic control device.

Examples of Current Practice

Figures 52-54 show three examples of temporary traffic circles. Figure 52 illustrates the use of barrels; in this layout, however, the circle is so small and appears so obviously temporary as to have a minimal effect. Figures 53 and 54 illustrate the use of bollards and connecting boards to create circles of larger size. All three make use of the "Keep Right" (R4-7) sign to aid visibility. Figure 55 shows a desirable feature for all neighborhood control devices, a high level of nighttime visibility. Figures 56-58 are examples of landscaped circles on local streets. Figure 56 is in need of added delineation with centerlines and pruning of shrubbery to reveal the "Keep Right" sign. Figure 57 shows the use of a mid-block circle constructed as part of the original street plan. Figure 58 shows a high level of delineation; it also shows posts on each corner as a guard to the sidewalk and lawn.

Chokers

A choker is a narrowing of a street, either at an intersection or midblock, in order to reduce the width of the traveled way. While the term usually is applied to a design which widens a sidewalk, it also includes the use of islands which force traffic toward the curb while reducing the roadway width.

Observations have shown that a choker's greatest value may be in the psychological or perceptual area rather than in its direct effect on traffic. Widened sidewalks increase pedestrian crossing safety and safe areas for people to walk or play, or they may provide added area for landscaping. Often their greatest impact is in improving the appearance of the neighborhood, rather than reducing traffic.
Primary Traffic Effects

Effects on Traffic Volume. Studies to date have shown that chokers are effective only when they either reduce the number of lanes of travel, or where they add friction to a considerable length of street. A study in Fullerton, California showed traffic reductions of 15-30 percent (from 7900 to 6900 on one section and 13,000 to 9500 on another) along a collector street where an island type of choker was used as shown in Figure 65. Locations in San Francisco, California showed reductions in traffic in conjunction with a street plan that narrowed the traveled way and permitted angle parking. Other locations, where intersectional “bulbs” were constructed showed unquantifiably small effects on volume.

Effects on Speed. One study of the effect of chokers on speed in San Francisco showed that they had an insignificant impact. A study of an Ottawa, Ontario street showed that chokers could reduce average speeds by 1-4 mph (1.6-6 kmph) with resulting speeds in the 30 mph (48 kmph) range.

Effects on Noise, Air Quality, and Energy Conservation. No studies have evaluated chokers in these terms. However, the effects can be deduced to be insignificant.

Effects on Traffic Safety. Bulb type chokers can improve the safety of an intersection by providing pedestrian and drivers with an improved view of one another. They also reduce pedestrian crossing distance thereby lowering their exposure time to vehicles.

Typical Construction Materials

Chokers are generally constructed as bulbs by a reconstruction of existing curbs. Island type chokers can be either curb and concrete islands, or concrete bars or buttons.

Uniform Standards

Chokers can be considered to be either normal extensions of the existing curb or channelizing islands as defined in the MUTCD and parallel design manuals.

Examples of Current Practice

Figures 59-65 show examples of current chok-
er usage. Figure 59 illustrates the use of concrete bars to reduce the roadway width as well as the need to consider the turning radius of fire vehicles.

Figure 60 illustrates the concept of constructing bulbs on one side of a street and moving traffic towards the opposite curb. In places, this design can be more economical than choking both curbs. Alternating the side of the street bulbed can also create a serpentine alignment and view-screening effect over a distance, indicating that the street is not intended for through traffic. The design's weakness is in directing vehicles toward an existing curb, creating the potential for accidents for vehicles jumping the curb.

Figure 61 illustrates the use of concrete buttons and bars as a choker to reduce high speed turning of a sharp corner in a residential neighborhood. This design combines choking with the "median on curve" and "forced turns channelization" devices discussed previously.

Figure 62 is an example of using chokers to shield an entire block providing added sidewalk area as well as angle parking. Narrowing of the traveled way to one lane in each direction is the most important feature of the design. Figures 63 and 64 are examples of choker designs which have little effect on traffic but add visual amenities to the street.

Figure 65 is an island choker design used effectively in Fullerton, California.
Other positive physical controls

Among the other positive physical controls which have been tried, or which exist by default, are residential pedestrian and play streets, extreme narrowings, full street closures, gates movable by automobiles, rough pavements and valley gutters. Each of these devices may have some utility to residential street traffic management programs.

In Delft, Holland there has been an active program to convert residential streets into pedestrian-dominated “residential yards” (they are called woonerfs). The program has emphasized pedestrian priorities on these streets, but has stayed with “integrated” solutions, where vehicles and pedestrians are mixed. Sidewalk and curbs are eliminated as shown in Figure 66, but the whole street surface is paved for pedestrians. The street is designed so that the drivers must attend “incessantly to the fact that the car is only one of the users and a guest to other functions having priority.” The streets are broken up in their length with planters, walls, benches, barriers, and mounds. The profile where a car can drive is no more than 6 feet (2 meters) for two-way traffic with a widening for passing every 100 feet (30 meters) and usually shifts every 125 feet (38 meters). Changes of route are overaccentuated by pavement pattern contrasts to appear more abrupt than they really are. One-way streets are not advocated because cars are tempted to drive at higher speeds. At crosswalks where children play, additional narrowing, bumps, and thresholds are used. Parking spaces are designed and limited so that only vehicles of up to 22 feet (7 meters) by 6 (2 meters) can enter these areas. (Greater width, probably 9 feet [3 meters] would be necessary if the concept were to be applied in the U.S. because of the wider vehicles in use here.) Right-angle parking spaces are preferred because they demand more attention from the driver and can be used better by children when they are empty. Parking spaces are limited to clusters of six or seven. The planners have been especially aware of the multi-functional nature of the traffic control devices. This treatment is notable as being com-
On Curves...

and at Intersections.

Officials in The Netherlands are extremely enthusiastic about the effectiveness of their woonerfs. But the radical reconstruction necessary to convert the typical U.S. residential street to a woonerf configuration would be extremely costly. In fact, cost is probably prohibitive except for the possibility of "showcase" applications. By contrast, in The Netherlands woonerven can be created at a cost only incrementally above periodic maintenance costs. This is because most residential streets, curbs and sidewalks there are constructed of paving blocks bedded in sand. Due to settlement, all the blocks are taken up and reset at intervals of six years or so. At such a time there is little extra cost involved in resetting the blocks in patterns characteristic of a woonerf rather than of a normal street — only costs for design, street furniture and plantings are extra.

In Britain, another type of radical street reconstruction scheme has been studied though not yet applied. This involves an extreme narrowing of the traveled way to a single vehicle lane of about 13 feet (4 meters). Used bidirectionally, the street would have occasional turnouts for vehicles in opposed directions to pass one another. Excess street space is converted to sidewalk or landscape areas or used for parking bays where needed. As a protection...
against head-on collisions, the narrowed sections are installed only at locations where sight distance is adequate. Despite this, it appears that the design enhances the possibility of driver error leading to such collisions. The psychological effect of the extreme narrowness, the need to stop for opposed traffic and the inability to pass same-direction traffic, are held likely to discourage use by through traffic and limit speed. As with woonerf, construction cost may preclude generalized use of this treatment in the U.S. But both these type treatments which very positively control streets while leaving them open offer obvious advantages for emergency and service access over the barrier concepts presented previously in this report.

A similar narrowing scheme in which chokers (see prior section) are used to confine the roadway to a single bidirectional lane at discrete points rather than for sections of some length has been used somewhat in Europe. Often these are specifically designed too narrow for large trucks but wide enough for normal autos to pass. No performance data on these has been obtained.

Temporary play streets are common in some East Coast American cities, notably Philadelphia and New York which each had 150 in 1975. These streets are temporarily closed during specified hours in the summer vacation. Many are operated with supervisors and temporary equipment. The surface of the street is marked to facilitate the conduct of various games. They are usually sponsored by block associations or community organizations. Many are on one-way streets, and there must be assurance that the street closing will not adversely affect delivery, parking, or cause problems of diverted traffic. The size of these programs speaks both to the level of need and the capacity of these street systems to function with so many street closures. Most of these streets are in low-income neighborhoods, and the main objectives are to reduce accidents and provide youngsters with play space during the summer.

Total closure of streets is another physical control which has been practiced to a greater extent in Europe than in the United States. Generally, the total elimination of automobiles from a street has been limited to central business dis-

Figure 68. Central Valley Gutter — Del Mar, CA.

Figure 69. Transverse Valley Gutter — Redwood City, CA.

In Sweden, sweeping switchbacks...

and tight kinks are considered for speed control. But vehicles "straightening out the curve" are a concern.
tricts, rather than residential areas. In the United States, such a proposal in residential areas would of necessity be limited to areas where vehicular access to homes and garages was not absolutely necessary. Areas with alleys to provide access might be suitable for such treatment.

Gates are another physical technique which has had little application to public streets in the United States. Mechanical gates have been used to control access to private parking facilities and elaborate architectural gates have been used at the entrances to exclusive residential areas. In Windsor Park, Great Britain there has been some success with movable gravity-closed gates which are opened by the car softly striking the gates themselves. The design is rather crude. The driver must judge how hard to hit the gate so as to open it yet not bounce back to hit his car. The potential for children being hidden by the swinging gates is high. Despite this they have operated to the satisfaction of residents and have been without accidents for 30 years. There would appear to be potential for improving upon this design, assuming that legal implications can be satisfied.

Introducing curvatures on a previously straight alignment has been discussed as a physical speed control device. In San Francisco's ill-fated Richmond district traffic control project, chokers were installed on opposite sides of alternate blocks to create a serpentine alignment. However, due to public controversy the devices were removed before performance measures could be taken. Swedish reference sources suggest the possibility of introducing sweeping curvatures or tighter kinks ("knixars") into the roadway alignment as speed control measures. But they warn of possible associated safety problems. Even farther fetched is the British "Z-track" concept. Still in the paper stage, this concept involves the use of curbs or other barriers to contort the roadway alignment, actually in the approximate shape of the letter N rather than Z, so that a vehicle must actually back down the crossbar in order to continue.

Two existing devices which tend to control traffic as an unintended by-product of their presence are valley gutters and rough pavement. As shown in Figures 68 and 69, valley gutters may run parallel or perpendicular to the direction of travel. In either case, they appear to be somewhat effective in reducing speeds in their immediate vicinity. Likewise, roads with rough surface, possibly in need of repaving, have a speed reducing effect. In neither case can it be suggested that streets should be designed to include valley gutters and rough pavement in order to reduce speed; however, the effect may be reasonable argument for delaying repaving of purely residential streets.

Passive controls

Passive controls involve the use of regulatory signs to inform the driver that a specific action is not permitted, while not physically preventing the action. As such, passive controls are more easily violated than most physical controls. Their advantages include the fact that some can be in force during only portions of the day thus retaining total access for residents during the remainder of the day. They also impose fewer constraints on emergency vehicles, which can ignore them when necessary with little problem or hazard. Experience has shown that even with the violations, some passive controls produce a significant improvement in the level and effect of residential traffic.

Passive controls are most effective in areas where general respect for all types of traffic control is high, where there is a reasonable expectation of enforcement, or where there is little driver resentment of the specific device. Where any of these conditions do not exist, for example, where numerous stop signs are used in opposition to major traffic flows or where a turn prohibition is installed and no reasonable (from the driver's viewpoint) alternative exists, violations of the device can be expected.

Signs which have been used (or may have application) in the protection of neighborhoods include Stop, speed limit, turn prohibition, one-way, "School, Slow," "Do Not Enter," "Not a Through Street," "Dead End," "Local Access Only," and truck restriction signs. Traffic signals also have potential as a passive neighborhood protection device.
Stop signs

The basic purpose of stop signs is to assign right-of-way at intersections with significant volumes or safety problems; warrants for the installation of stop signs for these purposes have existed for many years; yet, stop signs are persistently requested by citizens in order to control speed or reduce volume. A number of studies have tended to show that they have little effectiveness in these areas.

Primary Traffic Effects

Effect on Traffic Volume. Studies show that in order to have a significant effect on volume, a street must be stopped at virtually every intersection. Even so, stop signs are not always effective at diverting volume. A series of stop sign installations in a Saratoga, California neighborhood showed that traffic patterns changed somewhat, but overall traffic entering the neighborhood increased over a one-year period, at least in part due to new homes. An area-wide stop sign program in Palo Alto, California temporarily reduced neighborhood traffic until arterial congestion caused volumes on local streets to return to former levels. Before and after studies on a street in Seattle, Washington showed insignificant diversion. Two successful applications were made in Glendale, California where traffic volumes on a former through street were reduced by 60 percent to 1850 vpd, and Covina, California where installations on two streets one-fourth mile (.4 km) in length, were claimed to be effective in reducing volume. Numerous other examples, mostly unsuccessful or marginally successful have been noted. It can be safely generalized that where local streets offer significant savings in time over arterial and collector routes or allow avoidance of congestion points, STOP signs will do little to effect traffic reductions. But when the local street’s advantage over other routes is marginal they may be enough to shift traffic.

Effect on Traffic Speed. For many years, traffic engineers have received requests from citizens for the installation of stop signs to reduce
speed. The traditional answer is that stop signs are not intended or effective as speed control devices, but are intended and should be used for right-of-way assignment. Statistics on stop sign effectiveness tend to bear out the traditional response. The signs affect speed in the immediate vicinity of the sign, as shown in Figure 70, but between intersections they are either ineffective or produce the contrary effect. For example, a study in Palo Alto showed that in an area with numerous stop signs and a prima facie 25 mph (40 kmph) speed limit, the average speed 300 feet (91 meters) in advance of the signs exceeded the limit at 41 out of 60 sites; the 85th percentile speed exceeded the limit at 57 out of 60 sites. Studies in Walnut Creek, California showed that speeds increased after installation of stop signs; studies in Pleasanton, El Monte and La Mirada, California and Troy, Michigan showed no effective difference in speeds after stop sign installation. A study in Saratoga, California showed an average reduction in speed of less than 3 mph (5 kmph) at six intersections following the installation of stop signs. The general conclusion from these studies must be that stop signs have little overall effect on speed, except within approximately 200 feet (61 meters) of the intersection.

**Effect on Traffic Noise, Air Quality and Energy Consumption.** Stop signs tend to increase noise in the vicinity of an intersection by adding acceleration and braking noise, normally more than cancelling the noise reduction effect of any decreases in traffic speed. None of the studies evaluated quantitatively addressed this specific component of noise. While the deceleration and acceleration which stop signs induce does tend to increase air pollutant emissions and fuel consumption, these changes are inconsequentially small at low volume residential street intersections.

**Effect on Traffic Safety.** The traditional traffic engineering belief is that STOP signs not warranted by traffic volume conflicts or specific site safety conditions (such as inadequate sight distance) would tend to increase traffic accidents. However, evidence to date on the safety effects of STOP signs placed for volume and speed reduction purposes is somewhat mixed. Isolated
studies in Pleasanton and El Monte, California showed increases in the number of accidents in the range of 500-600 percent. A larger study in Palo Alto, California showed little change in the accident rate. However, a study of 57 new four-way stop intersections in Philadelphia showed that accidents were reduced from 273 to 35 in a one-year period. A study of 38 intersections of major streets in St. Paul, Minnesota showed that conversion from 2-way to 4-way control reduced the accident rate by 56 percent; however, these intersections had volumes in excess of what would be expected on a residential street. Another study of 15 intersections in Concord, California showed a 70 percent reduction in accidents after the installation of 4-way stop signs, many with volumes below the warrants of the MUTCD. Without detailed inspections of the individual sites, it is difficult to assess reasons for the mixed results or why the traditional traffic engineering belief is not more convincingly supported in the empirical data. It seems probable that at some of the intersections where safety decrements were measured, placement of the signs in poor visibility positions and lack of supplementary markings account for the accident experience rather than fundamental characteristics related to the warrants. It also seems probable that the cases where safety experience was improved include instances where traditional warrants for stop installation were actually met. Further cases which experienced safety improvements likely include intersections with conditions borderlining traditional warrants.

**Citizen Reactions to Stop Signs.** Stop signs have a very positive image with most citizens, who often see them as a solution to "near miss" as well as actual accident problems. They are also perceived as being beneficial to speeding problems. Negative reactions to stop signs come mainly from residents at the corners who are subjected to additional noise from stopping and accelerating vehicles and from motorists who perceive they are being stopped needlessly.

**Uniform Standards and Warrants.** Stop sign details and warrants for installation are included in the MUTCD. However, the warrants relate to right-of-way assignment and response to site safety conditions and the MUTCD specifically advises that stop signs should not be used for purposes of speed control.

**Obedience to Stop Signs.** Numerous studies have been prepared regarding the degree to which stop signs are obeyed. As a general summary, when not required to stop by cross traffic, only 5-20 percent of all drivers will come to a complete stop, 40-60 percent will come to a "rolling" stop below 5 mph (8 kmph), and 20-40 percent will pass through at higher than 5 mph (8 kmph). The study in Berkeley, California showed that signs placed on arterials and collectors for the purpose of speed reduction were the most flagrantly violated. Thus, stop signs placed in violation of the standard warrants tend to be resent and to some extent ignored by drivers, whereas signs placed for right-of-way purposes tend to be more usually respected.

**Speed limit signs**

Speed limit signs are a regulatory device intended to inform motorists of an absolute or prima facie speed limit imposed by the governing agency. Traditionally, they have been established on the basis of the existing 85th percentile speed on the street or highway in question. In residential neighborhoods, speed limits are usually established on a prima facie basis, and signs are installed only when a problem or neighborhood request occurs. As a basis of comparison, Tables 5 and 6 show a range of neighborhood and school zone speed limits for cities of various sizes.

**Effects on Traffic Volume.** None

**Effect on Traffic Speed.** Studies evaluating the effect of speed limit signs on speed have been largely confined to arterial streets and high speed highways. Performance in the high speed highway cases is considered non-relevant to the residential street situation and not discussed in the assessment below. Findings in United States and European arterial surface street speed limit studies differ. In the United States, studies have generally shown that speed limit signs have very little impact on driver speed on surface arterials. A study dating to 1948 in Champaign and Ur-
bana, Illinois concluded that: 98

- Traffic consistently ignores posted speed limits, and runs at speeds which the drivers consider reasonable, convenient, and safe under existing conditions
- Drivers do not operate by the speedometer but by the conditions they meet
- The general public gives little attention to what speed limits are posted
- The general public has a false conception of speed.

In 1956-58, speed limits were raised on 22 miles (35 km) of streets in St. Paul, Minnesota. Speeds which had previously exceeded the 30 mph (48 kmph) limit were basically unchanged by 35 and 40 mph (56 and 64 kmph) limits. 4 A study in 1960 of 34 speed zones in various U.S. locations in which limits were raised in 30 and lowered in four showed the following: 50

- Where speed limits were raised, the 85th percentile speed decreased by 0.2 mph (.3 kmph). Motorists observing the posted limit increased from 38 to 84 percent.
- Where speed limits were lowered, the limit had little effect on traffic behavior, and voluntary observance of speed limit signs decreased about 10 percent.

A study in Indiana in 1961 of posting speed limits at the border of urban areas found that the 85th percentile speeds were slightly higher after speed limit signs were posted. 25 A study on local streets in La Miranda, California in 1967 showed that 25 mph (40 kmph) signs did little to slow drivers, with 86 percent driving in excess of the limit. 31 Comparisons of similar collector streets in Ottawa, Canada showed that speed limits of 25 mph (40 kmph) and 30 mph (48 kmph) resulted in 85th percentile speeds of 35 mph (56 kmph), regardless of which limit was posted. 39 A test of speed warning signs in Warren, Michigan which advised motorists of the proper speed to travel in order to clear a signal found that these signs too had little effect. 35 By contrast, a test of this system in Germany, where the speed was mandatory rather than advisory, was successful. A study of odd numbered speed limits (19, 21, 22 mph) (30, 34, 35 kmph) in Saratoga, California

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**Special Signs/Speed Limit Signs**

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also had no significant effect. The only positive application of speed limits on urban streets has been in limited cases where speed limit signs were posted on streets previously without limits.\textsuperscript{56}

Little formal documentation on the effectiveness of speed limit signing on local residential streets was found in the State-of-the-Art search. Yet traffic engineers contacted uniformly expressed total lack of confidence in this device as a solution to local residential street problems. One documented study which was found, performed in La Mirada, California, firmly supports the common traffic engineers viewpoint. The data summarized below shows that speed limit signing had virtually no effect on distribution of traffic speed even after reinforcement by means of a police speed enforcement campaign.

In Europe speed limits have generally been effective in reducing speeds on streets, though not always have the reductions been to the limit. Studies in Great Britain, Ireland, Belgium, France, Germany, the Netherlands and Switzerland all showed reductions in the 85th percentile speeds.\textsuperscript{74,43} Like the U.S. work, most of these studies were on roads with collector, arterial or surface highway functions, not local residential streets.

Explanations for the discrepancy in U.S. and European results on arterial/collector streets are speculative. It has been conjectured that Europeans consider conformance to a speed limit to mean traveling at or below the limit while Americans (drivers and enforcement officers) tacitly consider traveling at speeds 5 to 10 mph above the limit as being compliant. If true, this basic difference in the meaning of a limit could obviously be a factor. Or it may simply be the case that American drivers rely more on their own judgment of safe and reasonable speed than the posted limits while Europeans are more strongly influenced by the signs.

Very recent German studies have specifically considered the effect on residential streets of low speed limits — 30 kmp (just under 19 mph). Results reported are sketchy but seem more conformant to American experience than to prior European reports. Studies in Wiesbaden and Hamburg have found that local street drivers do not alter their speed as a result of speed limit

| Table 5 | Speed limits on two lane streets in selected U.S. cities\textsuperscript{100} | Number of Cities Reporting Indicated Limits |
| Speed Limit | Population 100,000 + | Population 50,000 - 100,000 | Population 25,000 - 50,000 | Total |
| MPH (Km/H) | | | | |
| 20 (32) | 1 | 2 | 4 |
| 25 (40) | 23 | 2 | 1 | 36 |
| 30 (48) | 37 | 10 | 6 | 53 |
| 35 (56) | 12 | 9 | 11 | 32 |
| 40 (63) | 5 | 10 | 10 | 25 |
| 45 (71) | 4 | 7 | 5 | 16 |
| 50 (79) | 3 | 5 | 8 | 16 |
| 55 (87) | 1 | 4 | 5 | 10 |
| 60 (95) | 0 | 0 | 10 | 10 |
| 65 (103) | 4 | 5 | 9 | 18 |
| 70 (111) | 2 | 2 | 2 | 6 |
| 80 (128) | 1 | 1 | 4 | 6 |
| 90 (138) | 0 | 0 | 3 | 3 |

Note: Data taken before 55 mph speed limit

| Table 6 | Urban school zone speed limits\textsuperscript{100} | Percent of jurisdictions reporting indicated limit |
| Group | States | Cities over 100M | Cities 50-100M | Cities 25-50M | Other | Total |
| MPH (Km/H) | | | | | | |
| Group | 15(24) | 20(32) | 25(40) | 30(48) | Other | Total |
| States | 42 | 15 | 12 | 0 | 31 | 100 |
| Cities over 100M | 30 | 31 | 27 | 2 | 10 | 100 |
| Cities 50-100M | 20 | 27 | 30 | 1 | 10 | 100 |
| Cities 25-50M | 33 | 33 | 24 | 3 | 7 | 100 |

| Table 7 | SPEED DATA | Location and Date | Range | Percentile Speed | % All Samples | 10 Mile Face |
| | | | | MPH | |
| | Manoa Drive Near A
dale | Morning: | 3-17-66 6:30-9:00 A.M. Th. | 30 | 85 | 97 |
| | | Before 25 MPH speed sign. | 43 | 30 | 37 | 40 | 27-37 | 70% |
| | | After 25 MPH speed sign. & before speed enforcement. | 41 | 31 | 35 | 39 | 25-35 | 77% |
| | | After speed enforcement. | 39 | 30 | 35 | 39 | 25-35 | 75% |
| | | Afternoon: | 3-17-66 3:00-6:00 P.M. Th. | 30 | 34 | 40 | 25-35 | 83% |
| | | Before 25 MPH speed sign. | 43 | 30 | 34 | 40 | 25-35 | 83% |
| | | After 25 MPH speed sign. & before speed enforcement. | 43 | 30 | 35 | 40 | 24-34 | 72% |
| | | After speed enforcement. | 45 | 30 | 36 | 39 | 27-37 | 78% |

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signs. Bremen, Karlsruhe and Nuremberg rejected local street speed limits of this type because of ineffectiveness of the control. Berlin, Hanover, Cologne and Munich have introduced such local street speed limits in individual cases but regard their effectiveness with scepticism. Berlin, Hanover, Cologne and Munich have introduced such local street speed limits in individual cases but regard their effectiveness with scepticism.

Effect on Noise, Air Quality and Energy Consumption. If as suggested above, it is concluded that the limit signs would have little or no effect on traffic speed or volume, the device would not be expected to have any effect on noise, air quality or energy consumption.

Effect on Traffic Safety. Excluding effects of speed limit changes on high speed highways (e.g., the reduction to the 55 mph limit in the U.S.), effects on traffic safety have been reported only in the surveys conducted in Europe. In all of those cases studied, speed zoning produced a reduction in accidents.

Uniform Standards and Warrants. Speed limit signs are a recognized control device in the MUTCD and guidelines for establishing limits are presented in basic traffic engineering references and in the laws of the various states.

Community Reaction to Speed Limits. If speed limit signs posted are significantly lower than prevailing traffic speed, residents normally place some hope in them or in subsequent enforcement. However, if the posted limits are within a few miles per hour of the previously prevailing traffic speed, they really don’t address the resident’s problem and are viewed with derision. And since many residents feels that speeds of 25, 30, or 35 mph (limits which, judging from Table 4, are in force on roughly 80 percent of the residential street situations in the U.S.) are too fast for their street, the basic issue is not whether the signs are effective but the way in which the speed limits themselves are set for local streets in the U.S.

Turn prohibition signs

Turn prohibitions involve the use of standard “No Right Turn” (R 3-10)* or “No Left Turn” (R 3-2) signs, with or without peak hour limitations to prevent undesired turning movements onto residential streets. They are best used at the periphery of a neighborhood rather than within it, a use which will prevent traffic from entering a neighborhood altogether and which will also result in a lower rate of violation.

Turn prohibitions have the significant advantage of being effective only during specified hours of the day, if desired. If shortcutting is occurring only in one or both peak periods, restricting turns only during these periods can allow residents full accessibility during the remainder of the day.

Since turn prohibitions are clearly a passive device, their success will depend on their general acceptance by the affected drivers. In areas where regulations are frequently flaunted or poorly enforced, they will have relatively little effect. Their effectiveness may also be reduced if turns are not permitted or provided for on alternate arterial-collector routes or present a significant perceived delay to drivers. Thus improvement to an arterial condition may be a prerequisite to the successful installation of turn prohibitions.

Primary Traffic Effects

Effect on Traffic Volume. Turn prohibition signs have been shown to have a significant effect in reducing turning volumes, though some violation in the range of 10-15 percent of the original turning volume may be expected. Their effect is thus significant, though less than positive physical barriers. Actual traffic reduction potential depends on the percentage of total traffic on the street which the turning movement to be prohibited comprises. Jurisdictions using turn prohibitions for neighborhood traffic management have reported results in different ways, complicating clear assessment herein. Studies in Montgomery County, Maryland report that peak hour turning prohibitions reduced volumes by as much as 90 percent in one case, and to volumes of 40 vpd in another. Another neighborhood controlled by signs in this county showed only one street with volumes in excess of 2000 vpd. In Hawthorne, California turn prohibitors successfully protected one street from 800-900 vph which were bypassing a signalized

*Parenthetical nomenclature refers to MUTCD designations.
intersection. However, lack of a comprehensive neighborhood signing program resulted in the traffic being diverted onto other local streets rather than onto arterials.33

**Effect on Traffic Speed.** No direct effects on traffic speed are expected. However, to the extent that the device may exclude from the street a driver population which had formerly used it as a speedy through route, significant changes in speeds experienced are possible. No studies of speed effects on the "protected" streets have been reported by jurisdictions using this device.

**Effect on Noise, Air Quality and Energy Consumption.** Noise reductions are proportional to reductions in volume. Effects on air quality and energy consumption can be presumed negligible.

**Effect on Traffic Safety.** The traditional rationale for turn prohibitions has been to improve traffic flow and safety along arterial and collector street corridors. Though none of the jurisdictions using turn prohibitions for neighborhood traffic has reported studies of safety effects, there is no reason to believe the device's site safety performance is any different than when used for conventional traffic control purposes. However, as with conventional applications, there is the possibility that the prohibitions will force motorists to make turns at less safe locations or by means of hazardous maneuvers. Hence, in considering any installation of turn prohibitions, whether for conventional traffic engineering purposes or for neighborhood traffic management, the analyst should determine that safe and reasonable alternatives to the proposed prohibited movement do exist.

Figure 71. Turn prohibition signs, peak hour — Berkeley, CA.
Desirable Design Features. The basic requirement for this or any other sign is visibility. The City of Hawthorne found that 36” by 48” (.9 by 1.2 meter) signs were required, though the more standard 24” x 30” (.6 by .9 meter) are usually acceptable. Signs and pavement markings in advance of the turn can also aid visibility.

Uniform Standards and Warrants. Turn prohibition signs (right and left) are officially recognized MUTCD devices.

One-way streets

One-way streets can be used in two ways to protect a residential area. The traditional technique is to develop a one-way couplet to increase capacity in an area; if effective, the improved operations can draw some traffic formerly using local streets onto the new arterial streets. In a residential area, however, this technique is rarely effective, since at least one of the one-way streets is usually residential in character. As a result the one-way couplet simply transfers the penalty of traffic from one or several lightly impacted residential streets to a single one which becomes severely impacted.

A more successful though less frequently used technique is the use of one-way streets to make travel through a neighborhood difficult, if not impossible. Two basic techniques of accomplishing this aim are shown schematically in Figure 72. At the top of the figure is a typical two-way residential street grid. The central portion shows the technique of turning the local street pattern into a type of maze through the use of short sections of one-way streets. The design allows for local access, somewhat circuitously, but inhibits through movement. The lower portion of the figure shows a technique of providing a limited number of entrances to a neighborhood and making most streets into one-way exits. The maze pattern tends to spread the local traffic onto a number of streets, while making access quite difficult for some blocks. The limited entrance patterns tends to concentrate local entering traffic onto a few streets, but provides easier and more intelligible access patterns. Both techniques can effectively discourage through traffic.
Temporary or reversible one-way streets have been used in applications to provide increased peak direction capacity and improve flows. The possibility of doing exactly the opposite of this — temporary or reversible one-way streets aimed in the direction opposite of peak period dominant flow direction — might also be considered as a possible neighborhood traffic management application.

The use of one-way streets has the great advantage of being a standard control that is well-accepted by the public. It also provides a minimum impedance to emergency vehicles, which can easily and safely violate the signs. When converted to one-way operation, narrow streets where parking had been prohibited can often gain an added parking lane, thus providing an added benefit to residents. As with many non-physical controls, one-way street systems are subject to deliberate violation, but experience shows a rather low violation rate, perhaps due to the fact that any violation will occur over a period of several seconds or minutes — whatever the time is needed to traverse an entire block or blocks — whereas other devices require only a short and fast period of violation. Violation of one-way streets is more likely to be pointed out to the motorist by residents and pedestrians than are violations of other devices.

Primary Traffic Effects

Effect on Traffic Volume. One-way streets used to create discontinuities in a street system have shown a high level of effectiveness. A neighborhood in East Bethesda, Maryland using the technique, reduced maximum hourly volumes to less than 150 vehicles on all streets. In Kansas City, Kansas, a reduction of 20-30 percent was observed after certain blocks in a neighborhood were made one-way. The City Center of Bologna, Italy has been successfully designed to this concept, as have neighborhoods in Toronto and St. Louis, in Barnsbury and Pimlico, London and Nagoya, Japan. On the other hand, a single street in San Jose, California was converted to one-way without maze or other treatment to the rest of the neighborhood. The result was no impact to shortcutting in one of the peak hours and diversion to another local street in the other peak hour. This example illustrates
the need to use one-way streets as an overall neighborhood, rather than a single location, treatment.

**Effect on Traffic Speeds.** The studies evaluating use of the maze technique have not evaluated speed. Speeds have traditionally been higher on through one-way streets. In residential traffic management applications, this tendency can be counteracted by limiting the number of blocks with one-way continuity. And as with other devices which attempt to limit traffic volume and through traffic, use of one-way streets in patterns to achieve that objective may exclude a driver population which formerly used the streets as speedy through routes. Hence, speed reductions may be realized.

**Effect on Noise, Air Quality and Energy Consumption.** While there is again no documentation, the effects on air quality and energy consumption can be deduced to be marginal. Noise reductions can be expected parallel to traffic volume reductions.

**Effect on Traffic Safety.** No documentation is available on the effects on safety of one-way streets as employed for traffic restraint purposes in residential areas. But for rather obvious safety reasons, careful treatment is essential at intersections where opposite direction one-way blocks meet and where a two-way block meets an opposed one-way.

**Uniform Standards and Warrants.** One-way streets are a traditional traffic engineering measure and signs and markings related to one-way operation are included in the MUTCD.

**Desirable Design Features**
- System discontinuity
- Maintenance of reasonable access routes for local residents and visitors
- Minimizing of the length of one-way continuity to reduce speeding
- Use of “No Thru Traffic” signs to prevent inadvertent entry of through traffic
- Limited channelization (paint or paint and bars) at the point where opposing one-way streets meet (See Figure 73)