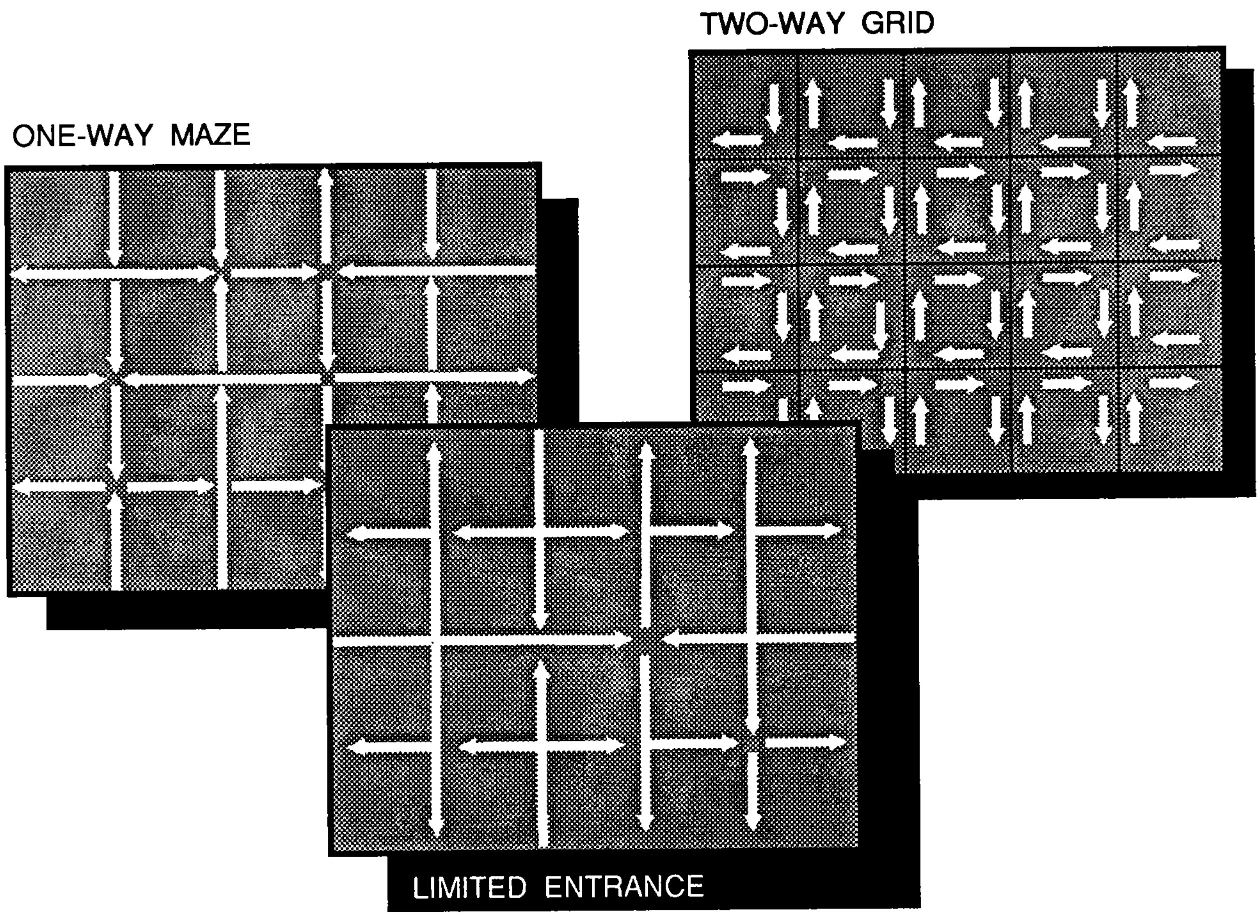
Final Report

AN OPERATING GUIDE FOR THE CONTROL OF RESIDENTIAL CUT-THROUGH TRAFFIC



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Supplementary Notes

Abstract

The objective of this operating guide was to provide direction in conducting studies in accordance with the "Policy and Procedures for Control of Residential Cut-Through Traffic" of the Virginia Department of Transportation. The guide is in eight parts: (1) Policy and Procedures for Control of Residential Cut-Through Traffic, (2) Cut-Through Traffic Studies, (3) Cut-Through Traffic Control, (4) Systems Approach to Developing Alternatives, (5) Development of Alternative Control Plans, (6) Analysis of Alternatives, (7) Preparation of Report, and (8) Selection of Alternative(s).

FINAL REPORT

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(The opinions, findings, and conclusions expressed in this report are those of the authors and not necessarily those of the sponsoring agencies.)

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ABSTRACT

The objective of this operating guide was to provide direction in conducting studies in accordance with the "Policy and Procedures for Control of Residential Cut-Through Traffic" of the Virginia Department of Transportation. The guide is in eight parts: (1) Policy and Procedures for Control of Residential Cut-Through Traffic, (2) Cut-Through Traffic Studies, (3) Cut-Through Traffic Control, (4) Systems Approach to Developing Alternatives, (5) Development of Alternative Control Plans, (6) Analysis of Alternatives, (7) Preparation of Report, and (8) Selection of Alternative(s).

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INTRODUCTION

The objective of the Operating Guide for the Control of Residential Cut-Through Traffic (Appendix A) was to provide direction in conducting studies in accordance with the "Policy and Procedures for Control of Residential Cut-Through Traffic." Upon the adoption of the policy and procedures, the Virginia Department of Transportation (VDOT) became actively involved in residential traffic management. Since VDOT has had limited experience in this area, the guide was developed to aid in the uniform, consistent, and effective implementation of the policy and procedures throughout the Commonwealth of Virginia.

DISCUSSION

The operating guide outlines the basic process of studying the control of residential cut-through traffic.

The operating guide has eight parts:

1. Policy and Procedures for Control of Residential Cut-Through Traffic
2. Cut-Through Traffic Studies
3. Cut-Through Traffic Control
4. Systems Approach to Developing Alternatives
5. Development of Alternative Control Plans
6. Analysis of Alternatives
7. Preparation of Report
8. Selection of Alternative(s)

The first four parts are definitive, and the last four parts are more broadly defined and permit neighborhood-specific factors to be determined by the VDOT staff performing the study. There is much flexibility in each part to accommodate the broad range of problems and neighborhoods likely to be encountered.

RECOMMENDATIONS

The following recommendations are made:

1. This guide should be used by the VDOT district traffic engineering staff to conduct studies for the control of residential cut-through traffic.

2. The VDOT district traffic engineering staff should be encouraged to exchange information on lessons learned from conducting studies for the control of residential cut-through traffic.

ACKNOWLEDGMENTS

A significant portion of this report was prepared by the alternatives subcommittee of VDOT's Cut-Through Traffic Task Force consisting of the author as chairperson; Frank D. Edwards, VDOT, Northern Virginia District; Ronald P. Miner, Fairfax County Police; and W. C. Nelson, Jr., formerly of the Traffic Engineering Division.

The contributions of the following are appreciated: VDOT district traffic engineers, especially Travis A. Bridewell, for reviewing and commenting on the final draft; Tamara A. Otto for preparing the final report; and Linda D. Evans for editing.

APPENDIX A

AN OPERATING GUIDE FOR THE CONTROL OF RESIDENTIAL CUT-THROUGH TRAFFIC

TABLE OF CONTENTS

1. POLICY AND PROCEDURES FOR CONTROL OF RESIDENTIAL CUT-THROUGH TRAFFIC

INTRODUCTION AND DEFINITIONS

Introduction

This policy and attendant procedures identify the specific responsibilities and requirements of the Virginia Department of Transportation (VDOT) and of the affected County/Town in addressing concerns relating to cut-through traffic on local residential streets.

Definitions

Residential cut-through traffic is traffic passing through a specific residential area without stopping or without at least one trip end within the area. It is traffic that would be better served by the street system intended for through traffic, but, for various reasons, uses the residential street system.

Local residential streets are streets within a neighborhood that provide direct access to abutting land uses and serve only to provide mobility within that locality.

POLICY ON RESIDENTIAL CUT-THROUGH TRAFFIC

Policy

It is the policy of VDOT to recognize the problems associated with cut-through traffic and implement appropriate remedial measures wherever possible.

PROCEDURE FOR IMPLEMENTING CONTROLS OF RESIDENTIAL CUT-THROUGH TRAFFIC

Purpose

The purpose of these procedures is to provide clear guidelines for studying the issues of cut-through traffic and implementing the recommended remedial measures.

County/Town Responsibilities

To initiate these procedures, the County/Town must:

- Identify the problem of residential cut-through traffic.

- Request, by resolution of the local governing body, that VDOT review and address possible solutions to the identified problem. This request is submitted to the local Resident Engineer, along with the following support data.

Support Data Requirements

1. Functional classification of the street(s) in question as a local residential street and its relationship to the comprehensive plan.

2. Identification of the problem area, including all streets that are accessed primarily by using the street(s) in question and the associated peripheral roadway networks. Also, include the functional classification and relationship to the comprehensive plan for all streets in the problem area.

3. Verification by the County/Town that cut-through traffic on the local residential street to be studied is 40% or more of the total one hour, single direction volume, and that a minimum of 150 cut-through trips occur in one hour in one direction. Acceptable planning techniques may be used to determine the amount of cut-through traffic. A description of the technique used should be provided to VDOT along with the vehicle volume data.

4. Verification by the County/Town that a petition outlining the perceived problem and signed by at least 75 percent of the total occupied households within the problem area is valid.

5. Identification of alternative routes for through traffic if travel is restricted on the street(s) in question.

It is suggested that the support data requirements be collected in the above order as a means of screening requests.

- It is suggested that the County/Town consider documenting procedures for performing its responsibilities.

<u>VDOT Responsibilities</u>

It is the responsibility of VDOT to complete a study of the roadway network identified in the formal request. This study will be conducted in the following four phases:

1. The Resident Engineer, upon receipt of the adopted resolution, will review and submit it, along with any recommendations, to the District Engineer.

2. As directed by the District Engineer, the District Traffic Engineer will conduct the necessary studies and the evaluation of the County/Town request. The District Traffic Engineer's study may include, but not necessarily be limited to:

- Detailed traffic counts on existing affected streets and potentially affected streets.

- Intersection analyses on the proposed alternative route(s).

- Identification of potential adverse safety impacts.

- Identification of the geometrics of the existing facilities in light of the traffic analysis.

- Speed analyses on affected streets.

- Pedestrian circulation and safety analyses in the study area.

3. Subsequent to completing the necessary traffic studies, the District Traffic Engineer will provide the District Engineer with his findings and recommendations. These recommendations will include alternatives for addressing cut-through traffic, including any sketches or diagrams necessary to implement the alternatives and the impact of each alternative on the existing roadway network.

4. The District Engineer will determine the appropriate alternatives and advise the Resident Engineer, who will convey the findings and recommendations of VDOT to the County/Town.

<u>County/Town/VDOT Joint Responsibilities</u>

1. The County/Town, upon receipt of the VDOT findings and recommendations, shall solicit and receive written comments thereon from appropriate local agencies such as fire, police, rescue, school transportation, etc.

2. A formal public hearing shall be held jointly by VDOT and the County/Town to provide for citizen input on the VDOT findings and recommendations. Advance notice of the public hearing must be provided by VDOT and will consist of:

- VDOT publishing notice in a newspaper published in or having general circulation in the County/Town once a week for two successive weeks.

- County/Town posting notice of the proposed hearing at the front door of the courthouse of the County/Town ten days prior to the meeting.

- VDOT placing signs on the affected streets identifying, by name and telephone number or address, an individual to answer questions concerning the findings and recommendations.

3. The County/Town shall furnish the Resident Engineer a synopsis and transcript of the public hearing and an approved resolution of the actions desired.

<u>NOTE:</u> If the local governing body and the District Engineer fail to agree on the mitigating measure to be implemented, the governing body may appeal to the Commonwealth Transportation Commissioner or his designated representative. The Commonwealth Transportation Commissioner or his designated representative will analyze all the supporting data and render a decision, which will be binding.

Implementation

Implementation of devices to remedy the cut-through situation shall be accomplished through the following sequence:

- The Resident Engineer shall notify the appropriate local governing body and media of the action to be taken and of the estimated date of implementation.
- Signs will be placed on the affected streets identifying, by name and telephone number or address, an individual to answer questions concerning the pending action.
- The Resident Engineer will implement the diversion devices, some of which may be of temporary construction pending evaluation of their effectiveness.

Evaluation

Evaluation of the remedial devices shall be accomplished as follows:

- After the devices have been in place for generally not less than 30 days, but not more than six months, the District Traffic Engineer will re-study the roadway network and convey his findings and any recommendations to the District Engineer.
- The District Engineer will review the District Traffic Engineer's report and will provide this information to the Resident Engineer for transmittal to the local governing body.
- If it is determined that the implemented treatment is not appropriate, the District Engineer may terminate such treatment and may consider alternate treatments, with notification of such action to the local governing body. If the local governing body fails to agree on the mitigating measure, it may appeal to the Commonwealth Transportation Commissioner or his designated representative. The Commonwealth Transportation Commissioner or his designated representative will analyze all the supporting data and render a binding decision.

- If it is determined that the implemented treatment is an appropriate action, the local governing body will identify the source of funding for any permanent construction, as needed.

2. CUT-THROUGH TRAFFIC STUDIES

In "Policy and Procedures for Control of Residential Cut-Through Traffic" (1), item 2 under "VDOT Responsibilities" states that the district traffic engineer will conduct the necessary studies and evaluate the county/town request. In this effort, the district traffic engineering staff may wish to take the following steps:

1. Carefully review the resolution and supporting data submitted by the county/town, and verify the supporting data when possible without a field review. Make revisions as needed, and identify concerns to be addressed.

2. If desired, plan to conduct a field review to verify or obtain the remaining support data. Make revisions as needed, and identify concerns to be addressed.

3. Determine the studies needed, effort required, and possible schedule. Plan the studies.

4. Perform the studies.

5. Analyze the data collected from the studies.

6. Determine if additional studies are needed. If so, plan, conduct, and analyze them.

7. Advise the District Administrator of the findings. This may be done through a memo that (1) describes the situation, the affected neighborhoods, and alternative routes; (2) summarizes activities; (3) presents findings; and (4) states the recommendation to continue or stop the study. Findings should include the magnitude of the cut-through traffic and any other traffic-related problems that are identified. If a cut-through problem is verified, feasible and infeasible alternative routes and alternatives to be considered should be identified.

8. If a cut-through traffic problem is verified, develop and evaluate alternatives as discussed in Section 3.

Step 3 is an important step in the process. In most cases, the conventional traffic engineering study procedures can be applied for the cut-through traffic studies. In every case, it is important to look at the neighborhood as a whole and address possible cut-through paths. Two approaches for obtaining cut-through traffic count data are as follows:

1. Short-cut method using traffic counts and patterns. In this method, traffic count data are collected at points of intersection between the residential street and major road (these are the points of entry/exit in the possible problem direction of the residential area). The magnitude of the cut-through traffic is identified based

on the expected peak hour traffic patterns. For example, if more than 150 vehicles enter the residential area in the a.m. peak hour or leave the area in the p.m. peak hour, it may be assumed that there is a cut-through traffic problem because these traffic movements are contrary to what is expected as the primary movements. This approach is not 100 percent certain and depends on judgment. Moreover, some allowance (e.g., using more than 200 vehicles per hour as a threshold) is suggested to acknowledge commuter patterns other than the typical morning-to-evening pattern. Either manual or machine counts may be used.

2. License plate survey and vehicle occupancy counts. A comprehensive method for collecting data on cut-through traffic volumes is a license plate survey (including time of entry exit) in conjunction with vehicle occupancy counts at the entry/exit points of the residential area. In some cases, it may be possible to position an observer so that both the entry and exit intersections are visible. With this approach, conclusions can be drawn with more confidence than with the short-cut method. Passenger pick-ups and drop-offs and short stops may be identified.

The time period for data collection should be given consideration. Although the threshold for determining a cut-through traffic problem is based on the peak hour, it may be beneficial to have data for a longer time period. This additional time will be particularly helpful in developing alternatives and assessing the impacts of alternatives over a longer time period. For alternatives that will affect traffic all day, 24-hr machine counts will be necessary before and after treatment to assess the impact fully. Machine counts may also be used to identify the time periods for manual traffic counts.

3. CUT-THROUGH TRAFFIC CONTROL

As a result of a traffic analysis, and upon determination of the existence, type, and scope of the difficulties found, there are several possible areas of improvement that may be offered for alleviating cut-through traffic problems. Potential positive and negative impacts should be examined for each cut-through traffic control considered. Of particular concern is the negative impact on the intersections and streets used as alternative routes after the traffic control is implemented.

Improving Arterials

"The most effective and productive method of keeping through traffic off of local and collector streets is to improve driving conditions on the arterials" (2). Before looking to put controls on the local residential streets, the traffic engineer should first attempt to plan for improvements on the proper alternate--the arterial street.

When there is a large volume of through traffic on local residential streets, the adequacy of the arterial street system should first be analyzed. A capacity analyses should be performed to measure the level of service on the arterial street(s) being avoided. Other traffic studies should be conducted as needed. Examples of problems that may be found with arterial streets are

1. lack of an existing or adequate arterial

2. lack of an identifiable arterial

3. traffic problems on the arterials

    - exclusive/permissive left-turn signals

    - insufficient turn lanes

    - nonexistent turn lanes

    - access to major points of destination

    - change of traffic patterns.

Passive Controls

Passive traffic control devices are those that use regulations, warnings, or similar methods to restrict vehicle movement. These devices include signs, traffic signals, and pavement markings. Their effectiveness depends on the cooperation of the motorist and on an effective level of enforcement. The advantages of passive controls are that they are generally inexpensive (except for traffic signals), can be set to operate for limited hours of the day, do not interfere significantly with emergency vehicles, and are generally familiar to motorists. Their disadvantages are that they necessitate voluntary compliance, are easy to ignore, and, if used too extensively, tend to generate resentment and reduced compliance with traffic control devices in general.

Passive controls are most effective in areas where general respect for all 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 a turn prohibition is installed and no reasonable (from the driver's viewpoint) alternative exists, violations of the device can be expected (3).

Passive traffic controls suitable for solving cut-through traffic problems are as follows:

1. "Turn prohibitions involve the use of standard "No Right Turn" or "No Left Turn" signs, with or without peak hour limitations. These prohibit turning movements onto residential streets, thereby reducing volume. They are best used at the periphery of a neighborhood rather than within it. Turn prohibitions have the significant advantage of being effective only during specific 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" (3).

2. One-way streets (Figure 1), when used as an areawide system, are perhaps the most effective form of passive control. Either a "one-way maze" system or a "limited entry" pattern can substantially discourage through traffic. One-way streets have the great advantage of being a standard control that is well accepted by the public. They also provide minimum impedance to emergency vehicles that can easily and safely violate the signs (3).

3. Multiway (four-way) stop signs are perhaps the most controversial form of residential traffic control. Residents are likely to request multiway stop signs more frequently than any other form of control. Stop signs are thought of as a panacea for many traffic problems. Studies of using multiway stop signs as volume control devices show mixed results, with as many instances of success as failure. Similar results were found when stop signs were used for speed control. If warranted by the Manual of Uniform Traffic Control Devices (MUTCD) (4), multiway stop signs may be considered. The larger question arises in areas of liability when multiway stop sign control is used but not warranted. Unwarranted multiway stop sign control not only increases stops, causes delay, increases vehicle operating costs including fuel consumption, and increases air pollutants but also encourages disrespect for stop signs and possibly other traffic control devices. Multiway stop sign control should be used with much caution.

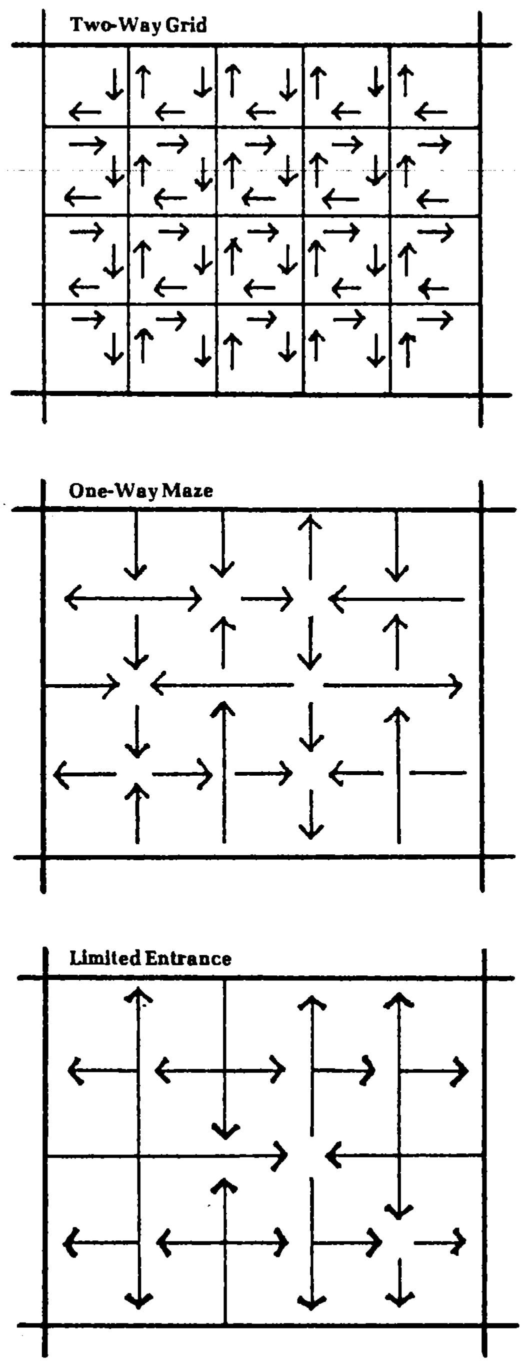


Figure 1. Grid traffic patterns. Source: U.S. Department of Transportation. Federal Highway Administration. 1981. Improving the Residential Street Environment. Report No. FHWA/RD-081/031.

Physical Controls

Physical traffic controls are devices that physically guide or restrict all or selected traffic movements. They have the objective of breaking up the continuity of neighborhood streets to reduce or eliminate their use as through streets. By forcing vehicles to make many turning movements or by requiring excessive travel through an area, they reduce the attractiveness of these streets in terms of travel time, travel distance, and driver comfort in comparison with designated arterial routes. Although not actually preventing the use of these streets, physical controls tend to make travel through the neighborhood more difficult.

Physical traffic controls suitable for solving cut-through traffic problems are as follows:

1. Diagonal diverters (Figure 2) are barriers placed diagonally across a four-legged intersection to, in effect, convert the intersection into two unconnected streets. Although both sections of the street remain through streets to the extent that they are open at both ends, they are effectively removed from the main circulation pattern. By leaving the streets open, access for service and emergency vehicles is still provided. Also, vehicles, particularly trucks, are not trapped and thus required to back out (2).

2. Intersection cul-de-sacs (Figure 3a) are complete barriers of streets retrofitted at the intersection. Use of a cul-de-sac is the most extreme technique for deterring traffic, short of barring all traffic. A cul-de-sac is the neighborhood protective device most objectionable to emergency and service personnel (2).

3. Midblock cul-de-sacs (Figure 3b) are complete barriers within a block rather than at an intersection. They perform the same function as an intersectional cul-de-sac but with two minor differences. The midblock location can be chosen so that the residence at the corner will have easy access to the attached garage without having to travel several blocks to avoid the barrier. Midblock cul-de-sacs shorten the distance that a larger vehicle which cannot turn around would have to back up as compared to an intersection cul-de-sac applied to the same street. Clear and emphatic signing is needed to warn motorists of the cul-de-sac condition (2).

4. Semidiverters (Figure 4) are barriers to traffic traveling in one direction on a street that permit traffic traveling in the opposite direction to pass through. Because they block only half of a street, semidiverters are easily violated. At the same time, they provide minimal impediment to emergency vehicles. Semidiverters are best suited to reduce traffic volume when only one direction of a street is used as a short-cut (2).

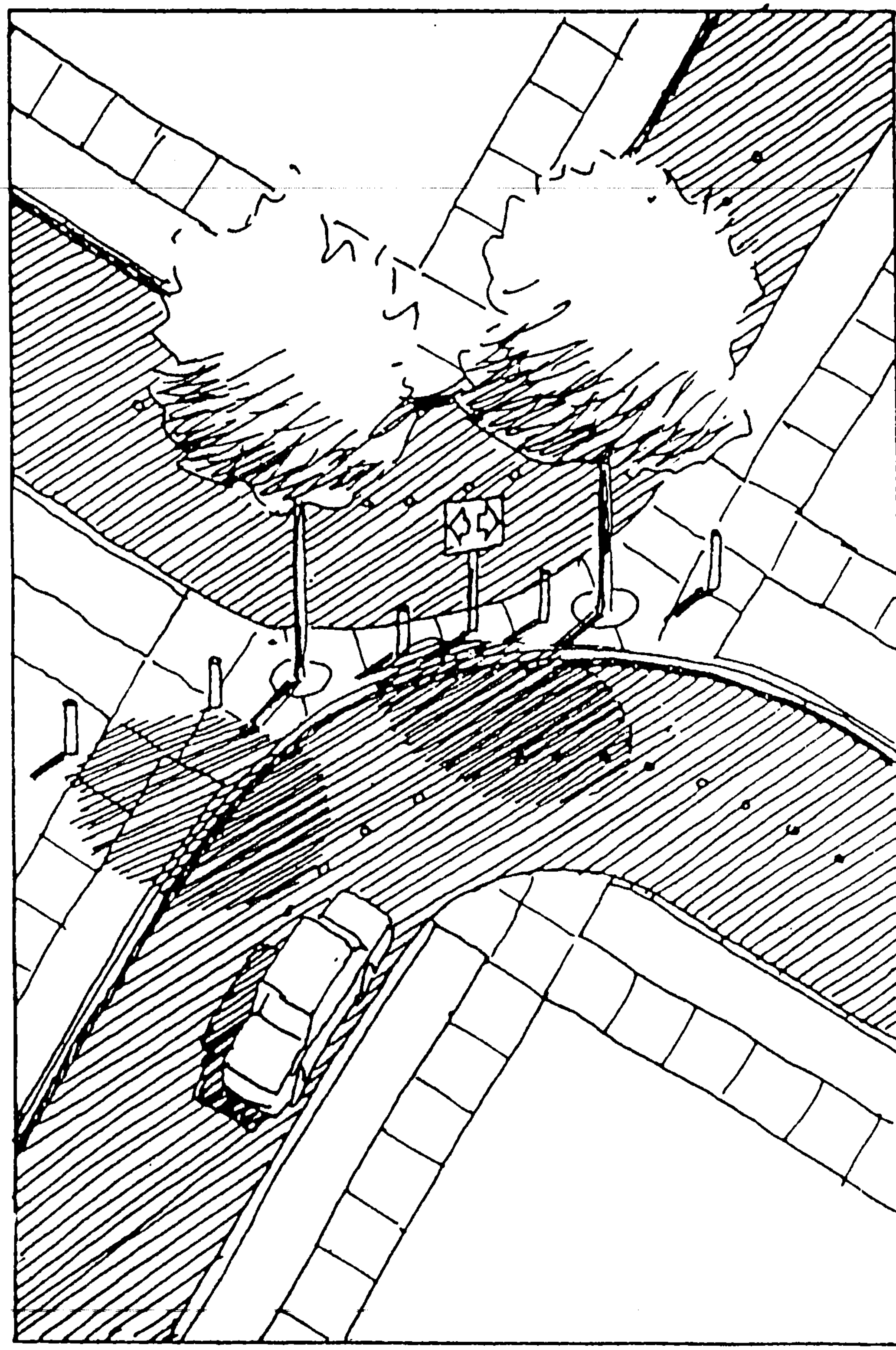
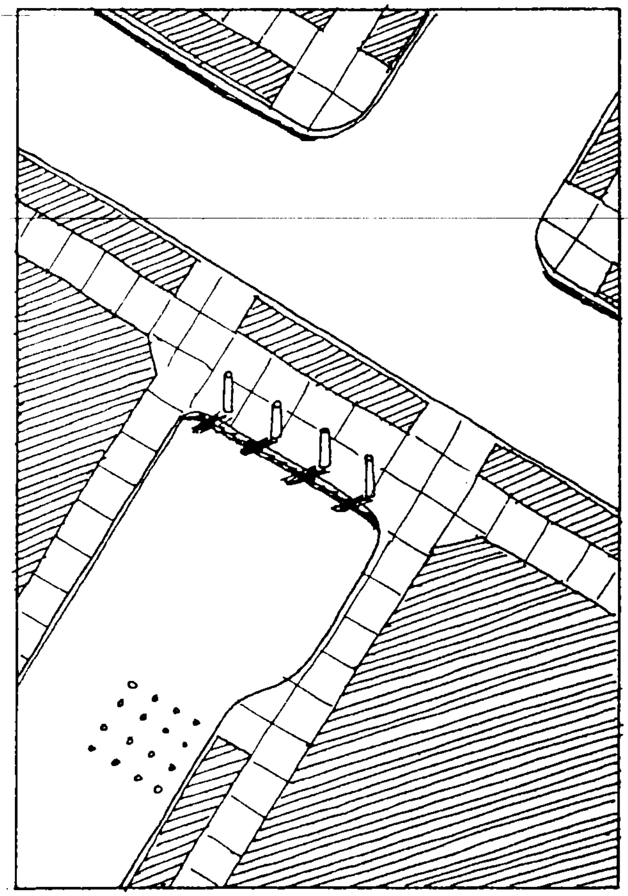


Figure 2. Diagonal diverters. Source: U.S. Department of Transportation. Federal Highway Administration. 1981. Improving the Residential Street Environment. Report No. FHWA/RD-081/031.



Intersection cul-de-sac

Figure 3a

Figure 3b

Midblock cul-de-sac

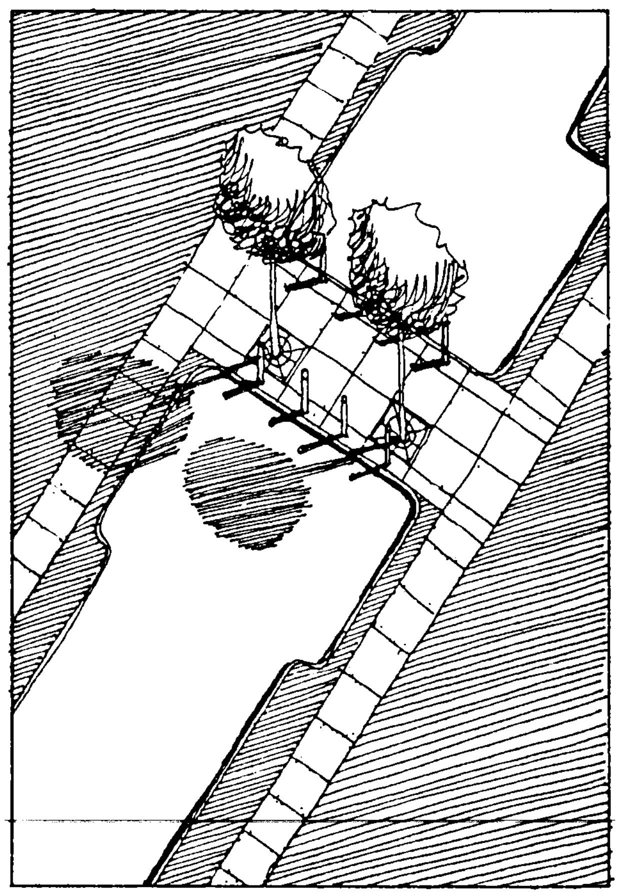


Figure 3. Cul-de-sacs. Source: U.S. Department of Transportation. Federal Highway Administration. 1981. Improving the Residential Street Environment. Report No. FHWA/RD-081/031.

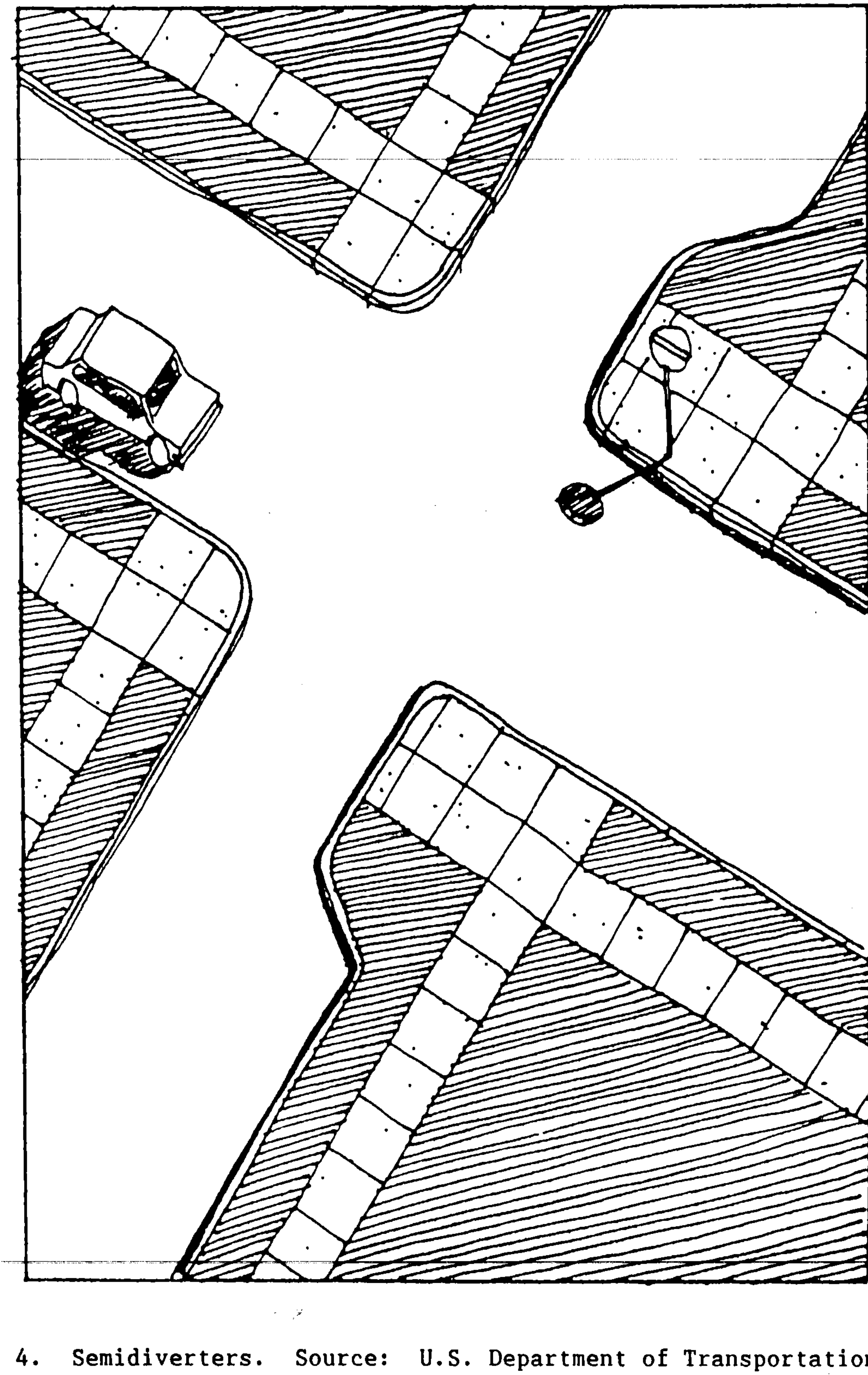


Figure 4. Semidiverters. Source: U.S. Department of Transportation. Federal Highway Administration. 1981. Improving the Residential Street Environment. Report No. FHWA/RD-081/031.

5. Forced turn channelization is comprised of traffic islands specifically designed to prevent traffic from executing specific movements. This is simply an adaptation of techniques used to improve traffic flows along arterial streets except that the movements prevented are specifically selected to discourage through traffic on local streets. Generally, this technique is best used at an intersection of a major and local street where the major street is basically unaffected or perhaps enhanced by the channelization while through traffic on the local street is prevented (2).

6. Median barriers are standard traffic engineering devices employed to prevent left-turn entries to local neighborhood streets from arterials and to prevent through traffic flows from one neighborhood to another across an arterial. A median barrier is most effective in locations where through traffic is prevented from crossing on a number of local streets.

7. Traffic circles (Figure 5) have generally been confined to complex intersections to avoid the need for traffic signals or to accommodate more than four approach roads. On residential streets, small circles have been tried mainly as speed control devices. They do not physically restrict any movement, and their benefit in volume reduction depends on the extent to which they decrease the travel advantages of the road in terms of speed and driver comfort. They have little impact unless they are used as part of a group of circles or other devices that slow or bar a driver's path (2).

8. Speed humps (Figure 6) are raised humps in the pavement surface extending transversely across the traveled way. They are also called undulations and road humps. They normally have a height of less than 4 in and a length of 12 ft. Their length in the direction of travel distinguishes them from speed bumps. Speed bumps, also shown in Figure 6 for contrast, are normally less than 5 in in height, 3 ft in length, and raise more abruptly than humps. Driver discomfort is designed to cause a reduction in speed at the site of the speed hump. The overall effectiveness in reducing the speed and volume for the entire length of the street depends on the frequency, distance, and number of humps. There may be legal and liability ramifications concerning the use of humps, and their use should be carefully examined before installation (3). Guidelines for speed humps that were developed from a literature review are given in the Appendix.

Woonerf Treatment (3)

Although the much publicized Woonerf treatment (Figure 7) developed in The Netherlands might be considered by some to be a physical control, it is considered here as a unique category. First, it is not comprised of a single control device or discrete pattern of devices. It is a composite treatment of a street or group of streets. The changes in traveled way alignment;

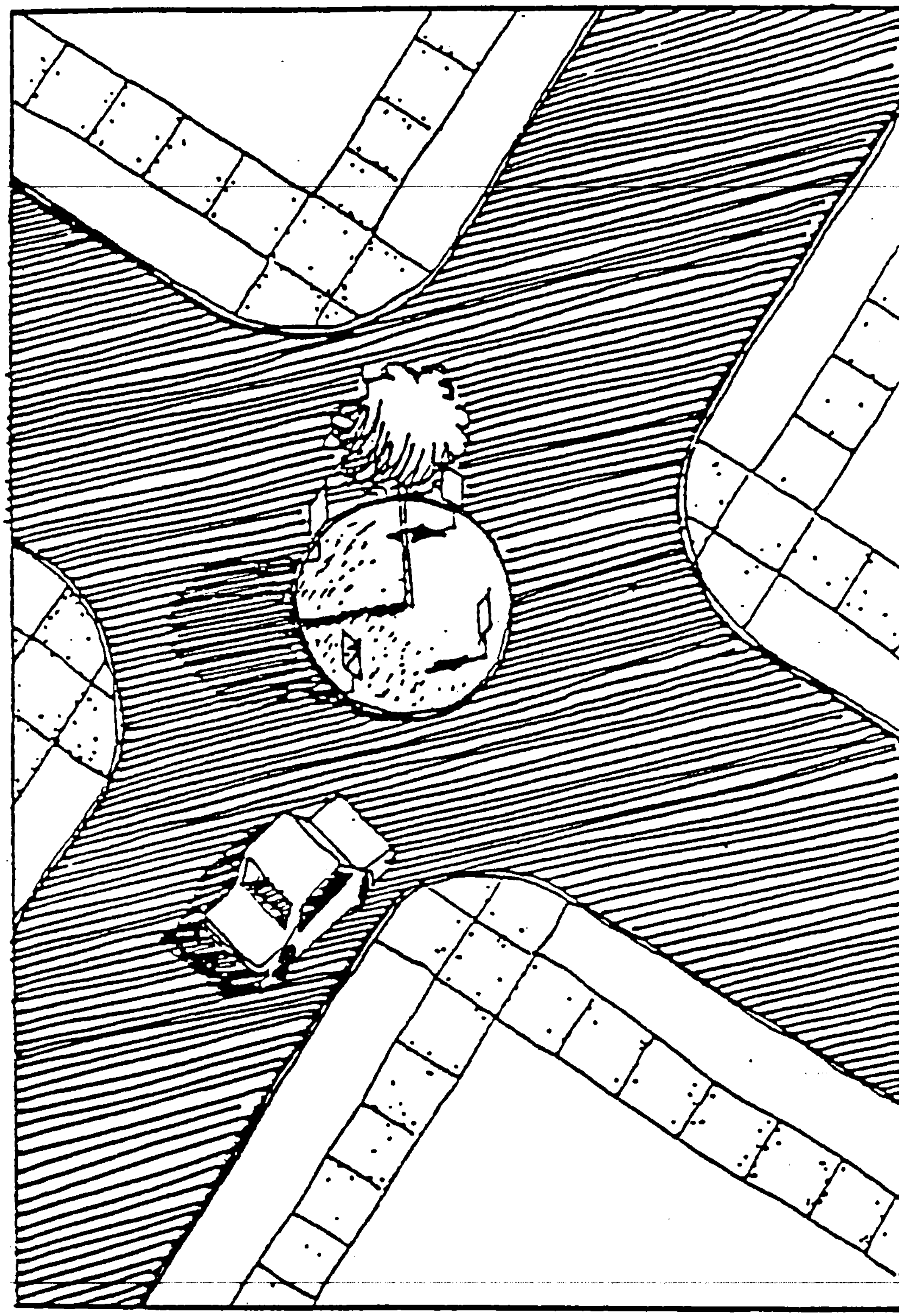
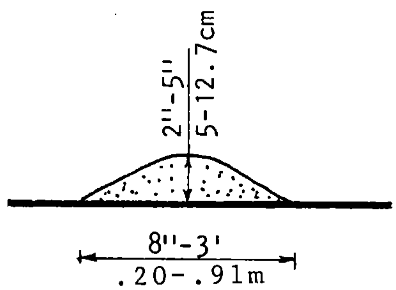


Figure 5. Traffic circles. Source: U.S. Department of Transportation. Federal Highway Administration. 1981. Improving the Residential Street Environment. Report No. FHWA/RD-081/031.

SPEED BUMP



SPEED HUMP

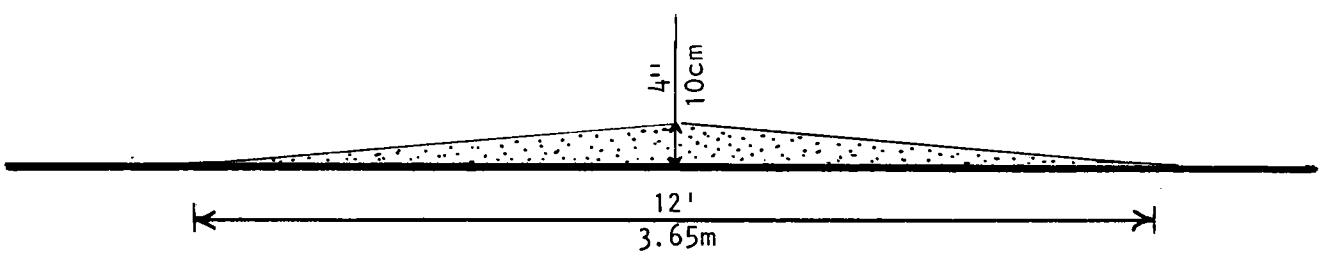


Figure 6. Conventional speed bumps and speed humps. Source: U.S. Department of Transportation. Federal Highway Administration. 1981. Improving the Residential Street Environment. Report No. FHWA/RD-081/031.

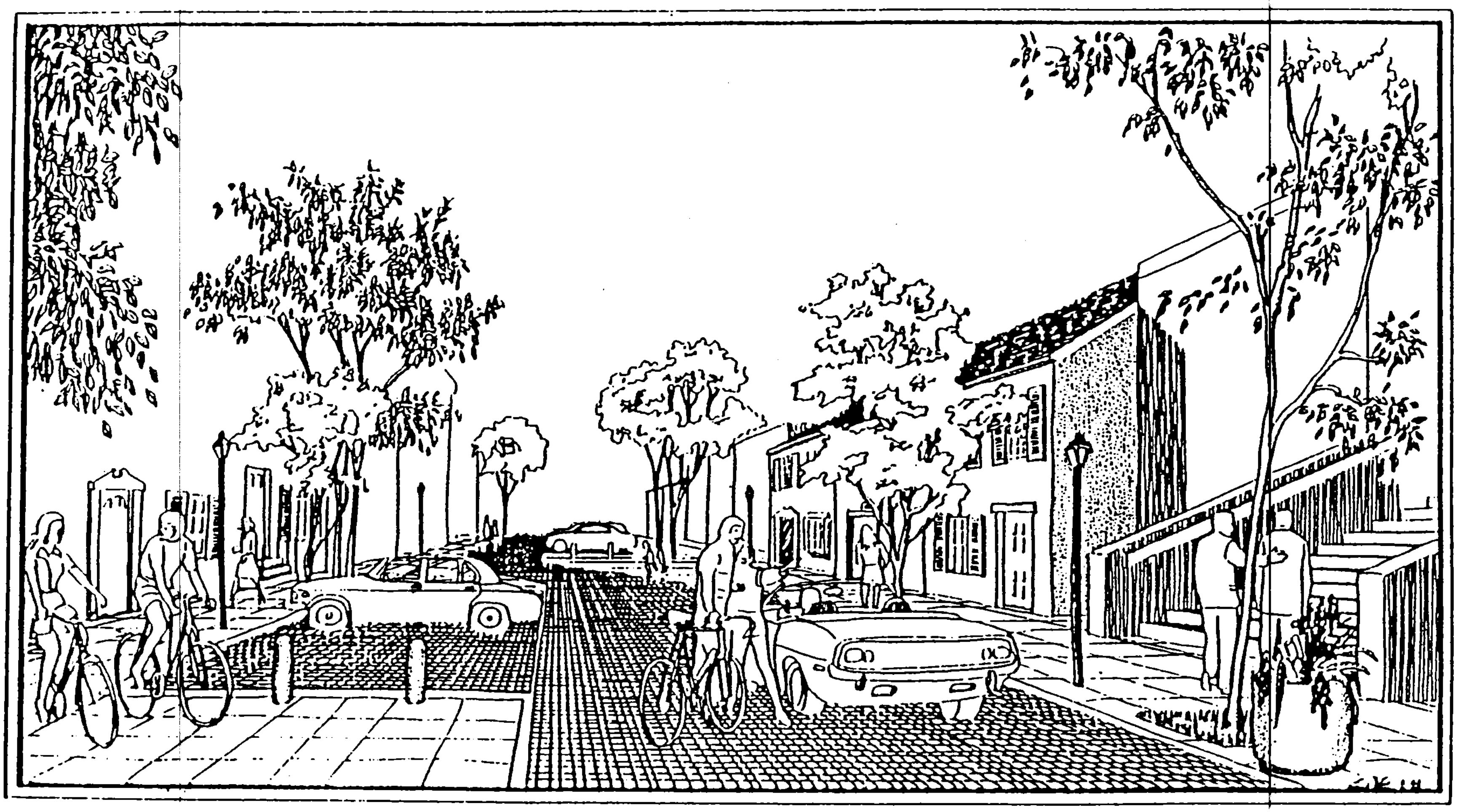


Figure 7. Woonerf treatment. Source: U.S. Department of Transportation. Federal Highway Administration. 1981. Improving the Residential Street Environment. Report No. FHWA/RD-081/031.

narrowings; contrasts in paving materials; and use of planters, walls, benches, ballards, mounds, parking areas, and landscapes have no single set patterns. The treatment is not designed to have individual impacts on traffic but rather for the impact when the street is perceived as a whole by the driver. Second, the Woonerf is not simply a physical control, though physical changes to the roadway are massive. Equally important is the concept of the street as an integrated area--a shared space for multiple uses--as contrasted to the traditional segregation of driving, parking, and pedestrian activities on the ordinary street. This difference in the function of the street space is explicitly recognized in unique rules of the road applicable to driving in a Woonerf. These rules essentially require drivers to operate at a walking pace and give way to pedestrians (while not allowing pedestrians to obstruct drivers unnecessarily).

The Woonerf treatment is perhaps best suited for highly urban areas or newly designed dense residential complexes. Its use in traditional neighborhoods with single-family dwellings may not be feasible because of street width and cost. However, it is a potential alternative and may be considered where applicable.

Unacceptable Controls

There are some physical, passive, and psychological controls that are not satisfactory when applied to cut-through traffic problems.

1. Speed bumps, as differentiated from speed humps, have been consistently rejected for failure to reduce speed other than at their site and because of the potential for vehicle damage and safety factors.

2. Rumble strips are patterned sections of rough pavement normally used to alert drivers to a hazardous condition or on approach to another traffic control device. They have been shown to have no effect in reducing the volume of traffic. Rumble strips, where used, have succeeded in raising complaints from nearby residents concerning the noise levels produced by vehicles traveling them.

3. Psychological/psychoperceptual controls are an attempt to play upon ingrained driver responses to certain stimuli. Transverse lines with increasingly close spacing to give the illusion of increasing speed, odd speed limit signs, and unique message signs are examples of this type of control. Although some success was reported with these devices in areas of transient or occasional motorists, their use in neighborhoods where motorists would become accustomed to them renders their effect minimal, if any, for solving cut-through traffic problems.

Pedestrian Safety

One of the major complaints concerning cut-through traffic has been the adverse effect is has on pedestrian safety. Either high speed or a high volume of traffic, or both, can be potential hazards to adults and children who must cross neighborhood streets. In the interior of neighborhoods where traffic signals are not warranted, there are physical and passive controls that may be used to enhance pedestrian safety.

1. Chokers and road narrowings (Figure 8) at either an intersection or midblock are used to constrain the width of the traveled way. Except where the narrowing is extreme enough to limit use of the choked section to one direction at a time, chokers have not had a significant effect on traffic volume or speed. The primary positive effects have been improved pedestrian safety, landscape opportunity, and definition of neighborhood entity. The widened sidewalks enhance pedestrian safety by reducing the width of the street a pedestrian must cross (3).

2. Pedestrian crosswalks and signing have proven effective when coupled with strategies that channelize paved walkways to designated crosswalks. This concept is seen more in "planned" communities but, with creativity, can be retrofitted into older neighborhoods. Increased use of traditional signage and pavement markings at these main crosswalks can also enhance pedestrian safety.

Enforcement

Physical traffic controls generally create a forced direction of travel for motorists or prevent a specific movement. Some physical controls, such as semidiverters, require moderate enforcement activity. To be effective, passive traffic controls depend on the public's perception of enforcement activity at the specific control location. Whenever passive traffic controls are to be used to control cut-through traffic, the local law enforcement agencies must be consulted. If the local law enforcement agency is not capable of frequent enforcement of passive traffic controls, the public may soon learn to ignore the controls.

Where new traffic patterns are to be established, there should be concentrated enforcement activity in the first weeks of use. The enforcement level can then be gradually lowered, with periodic selective enforcement measures taken to keep the public's perception of "getting caught" heightened.

Two passive traffic controls need special enforcement attention:

Nubs

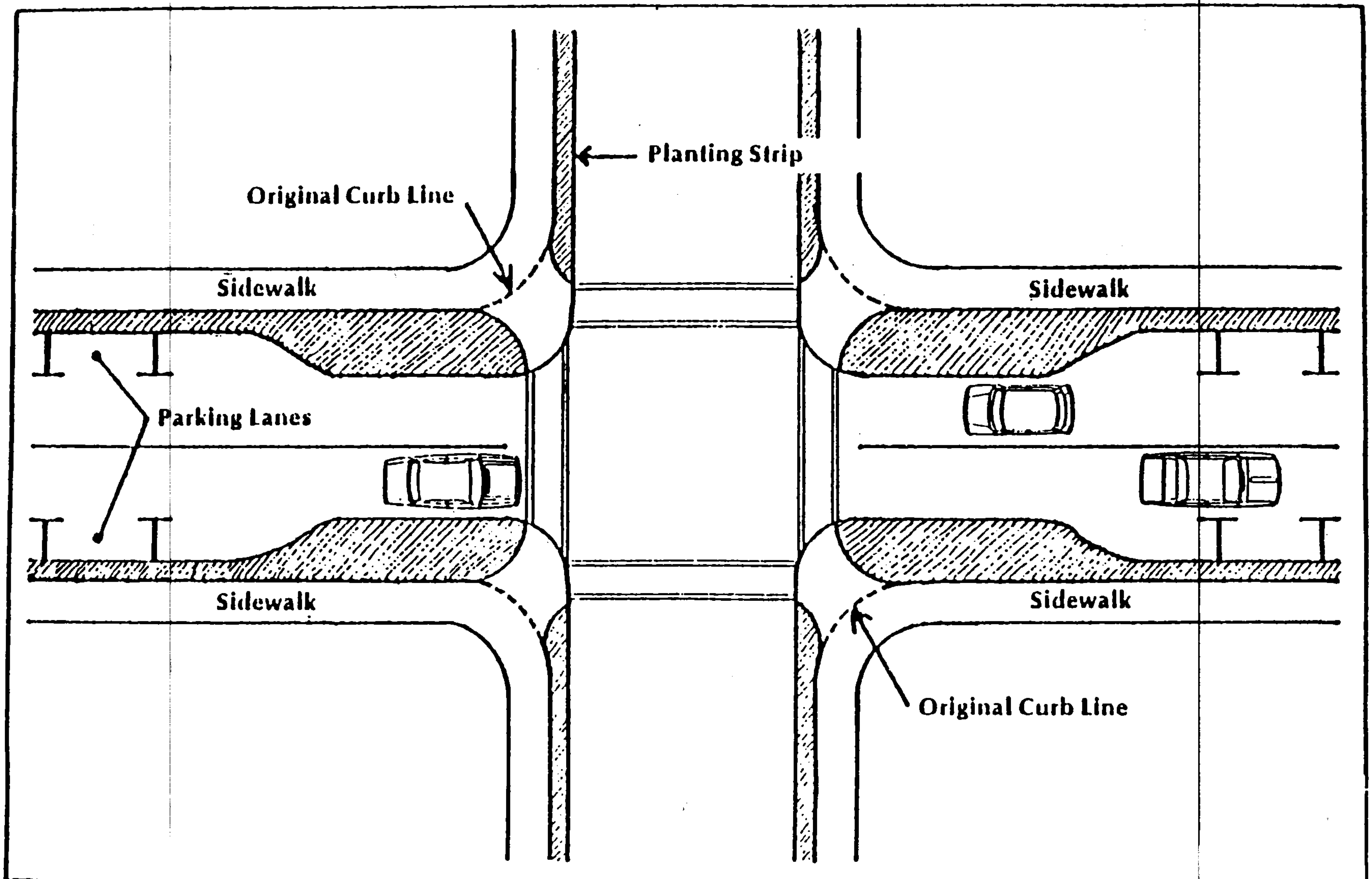


Figure 8. Choker or road narrowings. Source: U.S. Department of Transportation. Federal Highway Administration. 1981. Improving the Residential Street Environment. Report No. FHWA/RD-081/031.

1. Speed limit signs. Where lower speed limit zones are established, the public should be informed by prior notice and conventional signage. Extra speed limit signs should be posted, above the minimums as stated in the MUTCD (4). Posting and enforcement must be "reasonable" in order to gain public acceptance and compliance.

2. Turn prohibitions. Turn prohibitions, especially when limited to peak hours, require sensible, but stringent, enforcement efforts, especially at the onset.

Old habits and patterns of motorists will be slow to change without sufficient warning. Extra, but temporary, markings, such as flags on top of new signs or the presence of uniformed officers to warn motorists of the new traffic pattern, could be used to educate the public. Warning citations should be issued in the first days of the new traffic pattern, with gradual and discretionary escalation to real citations. The acceptance of new traffic patterns by the public is a major part of the success in reducing cut-through traffic problems. Judicious use of extra signs, provision of information to the public, and sensible enforcement can greatly aid the success of any new traffic pattern.

4. SYSTEMS APPROACH TO DEVELOPING ALTERNATIVES

Each of the acceptable neighborhood traffic control devices presented in Section 3 may be considered as one component of a neighborhood traffic management plan. The fundamental concept of the neighborhood as a discrete area treated as a single unit underlies the systems approach of traffic management. Most neighborhood traffic problems are area problems rather than problems for a single site. Moreover, since many of the devices have impacts beyond the immediate site, the affected area should also be considered in the plan. A common cause of failure of neighborhood traffic control in the United States is concentration on individual sites and devices rather than a systematic approach to neighborhood traffic control planning.

There are two planning philosophies that govern the approach for neighborhood traffic control plans. The area-oriented approach works backward from a desired end-state scenario for a neighborhood to a specific plan to achieve that state. The problem-oriented method develops a traffic management plan from an analysis of an array of specific conditions in an area to solve problems. By the very nature of the effort to deal with cut-through traffic, a problem-oriented method is used.

Community involvement and support is an integral part of the systems approach.

There are two basic neighborhood traffic control systems: peripheral and internal barrier systems.

Peripheral Barrier Systems (3)

Peripheral barrier systems prevent traffic from entering a neighborhood by means of controls placed at local street intersections with bounding arterials and collectors. This form of boundary control can be achieved using passive devices, such as turn prohibition signs and one-way streets, or physical devices, such as cul-de-sacs, semidiverters, and median barriers. A primary advantage of the peripheral barrier system is that the potentially intrusive traffic encounters the protective barriers while it is still on the bounding streets and still has a clear option to use these routes to its destination with little out-of-direction travel or delay. By contrast, with internal systems, drivers are first led into the neighborhood before being blocked and perhaps disoriented, trapped, certainly frustrated, and possibly enraged. Another advantage of peripheral systems is that motorists are less likely to violate them along the busier streets where the perceived likelihood of enforcement is greater. A third advantage of the peripheral barrier scheme is that inconvenience to residents while they are driving is relatively limited. Traffic flows internal to the neighborhood are unobstructed, and residents have freedom of egress in any direction and reasonably convenient access in returning to the neighborhood.

Single-Axis Problem (3)

Peripheral barrier systems work best when the problematic through traffic is on a single axis of the street grid as shown in Figure 9. The treatment shown allows streets at right angles to the problem flow to be left open so that vehicles on local trips can enter from the sides; entries are blocked in problem directions.

Two-Axes Problem (3)

If through traffic volumes are problems on two axes of the street grid, with the peripheral barrier scheme, gaps must be left in the protective cordon to provide opportunities to allow neighborhood residents to return home. One solution to the two-axes problem is to supplement peripheral devices with internal devices to prevent the open streets from becoming through routes as shown on Figure 10. Even if this is done, the peripheral barrier scheme tends to be less effective in solving biaxial through traffic problems than in the single-axis situation.

Internal Barrier Systems (3)

Internal barrier systems restrict traffic movement within the neighborhood. Principal devices in internal systems are diverters, semidiverters, cul-de-sacs, median barriers, and one-way streets.

Internal systems are preferred over peripheral ones in cases where (1) problem traffic is biaxial, (2) boundary street-oriented office-commercial uses extend partially into the neighborhood along local streets, (3) traffic conditions preclude a peripheral scheme, or (4) a large traffic generator that requires good access, such as a hospital, is located within the neighborhood. Internal systems can be designed for the single-axis problem if necessary. Internal barrier systems are of three types: return loops, anti-through, and maze.

Return Loops (3)

As shown in Figure 11, return loops force traffic entering from any one of the streets bounding the protected neighborhood to return to the same boundary street from which it entered. Return loops are extremely effective in limiting through traffic. They are also extremely restrictive on resident travel, since each residence has access to only one boundary of the neighborhood. Internal vehicular travel in the neighborhood is virtually impossible, and the system poses considerable barriers to emergency and service travel.

Anti-Through System (3)

Figure 12 shows a typical anti-through system. It prevents traffic from traveling completely across a neighborhood to the opposite side, although the motorist is not necessarily forced to return to the same boundary street from which entry was made. In anti-through systems, most residences have access to two of the neighborhood boundaries. Internal neighborhood travel by automobile is still problematic. Barriers to emergency and service vehicle travel are still formidable, though less so than in the case of a return loop system.

Maze System (3)

Maze systems use physical barriers or other controls in a less intensely restrictive way with the objective to leave no street as a continuous through path across the neighborhood. As shown in Figure 13, through penetration is possible, but only by following a circuitous path. The theory behind the maze is that it will be so confusing to nonlocal travelers that they will not continue to attempt passage. For drivers familiar enough with the system to know how to get through, the out-of-direction travel and turning will make the route through the neighborhood unsatisfying as a short cut.

Of all the internal barrier systems, mazes entail the least inconvenience for residents, as most residents have access to all of the bounding streets. Usually only one or two blocks of out-of-direction travel are required, and a fair degree of internal vehicular circulation within the neighborhood is preserved. However, mazes are less effective against through traffic.

Figure 14 shows a typical example of a hospital and related medical offices (hatched area) located within a neighborhood and a maze system designed to discourage through traffic. The medical complex is directly accessible from all four of the bounding arterials.

Nongrid Patterns (3)

In some suburban situations, problems are analogous to those on a grid, and the peripheral or internal barrier strategies may apply as shown on Figure 15. In other situations, subdivision street patterns produce problems unique to modern suburban development.

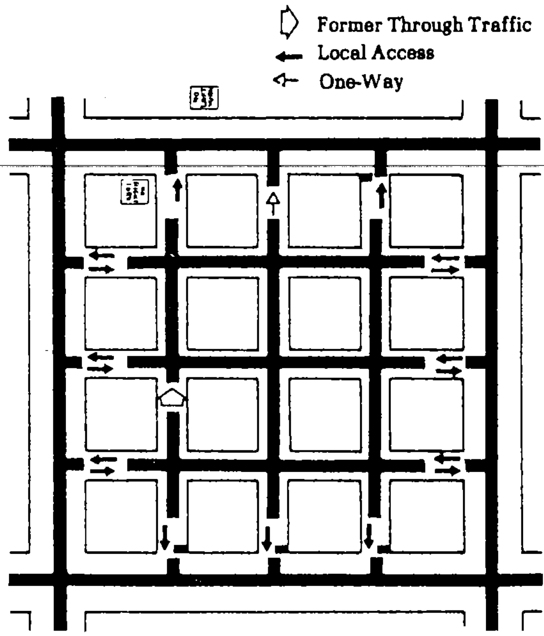


Figure 9. Peripheral barriers, dominant direction.

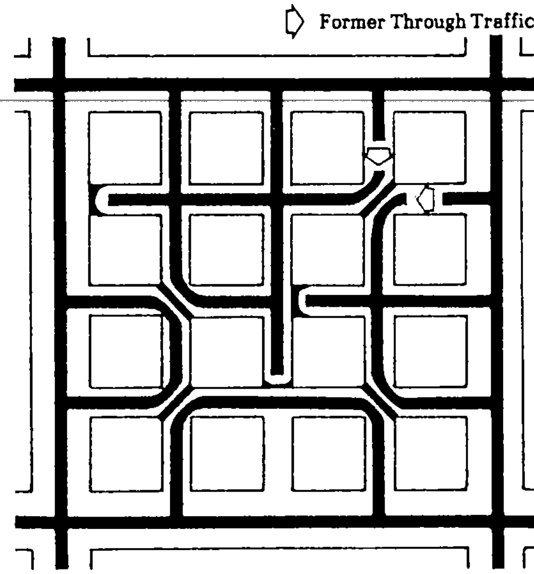


Figure 11. Return loops. Motorists forced to return boundary street of entry.

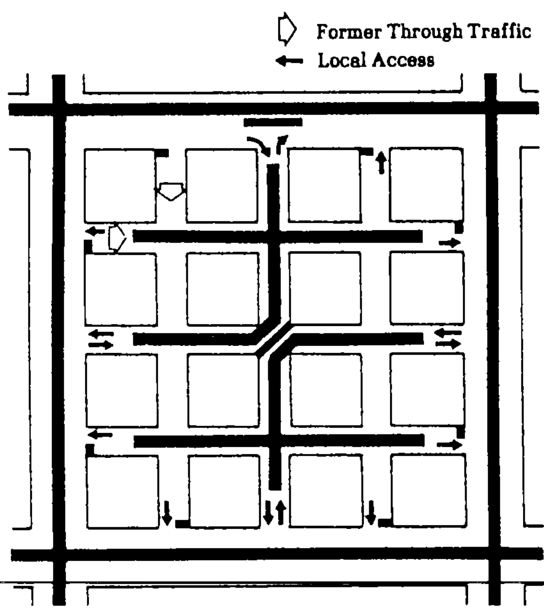


Figure 10. Peripheral barriers, multidirection.

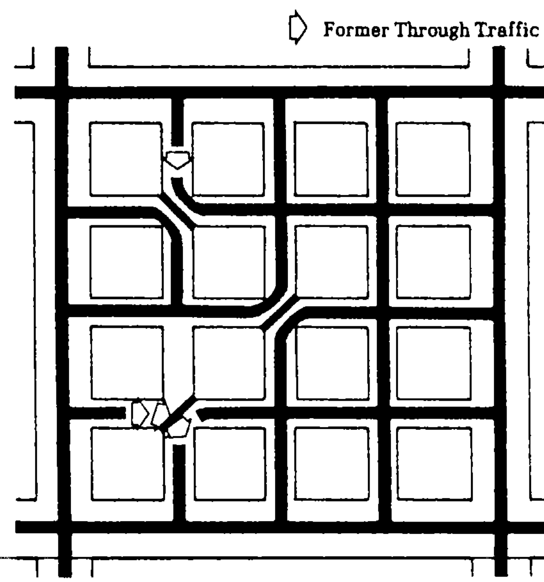


Figure 12. Anti-through system. Travel completely across neighborhood impossible.

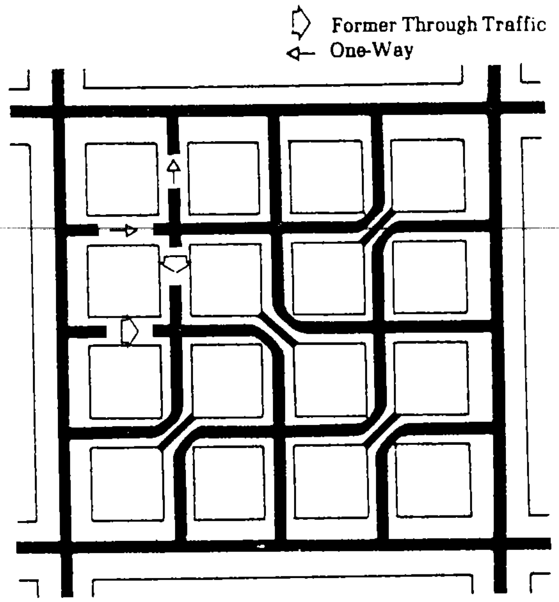


Figure 13. Maze. No direct path across neighborhood, but through travel is possible.

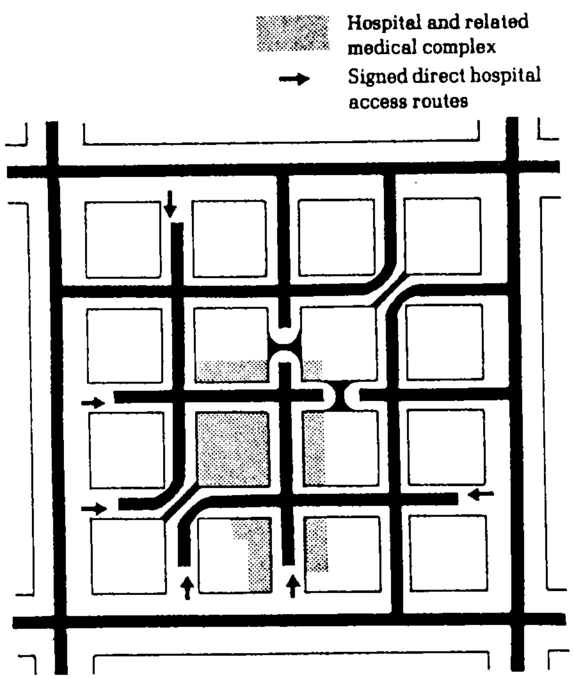
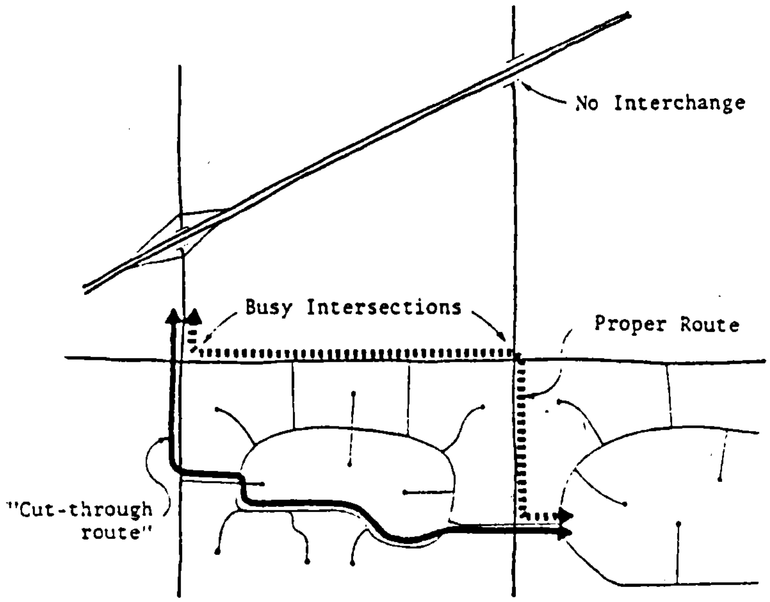
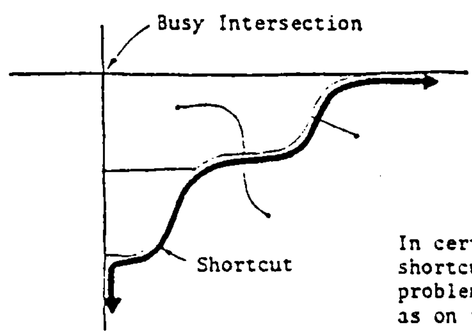


Figure 14. Maze system with internal special generator (hospital).

Source: U.S. Department of Transportation. Federal Highway Administration. 1981. Improving the Residential Street Environment. Report No. FHWA/RD-081/031.



Position of the freeway interchange and congestion at busy arterial intersections leads traffic from one neighborhood to cut through another even on a non-grid system.



In certain circumstances, shortcutting can be as much a problem on non-grid systems as on the grids.

Figure 15. Nongrid system problems. Source: U.S. Department of Transportation. Federal Highway Administration. 1981. Improving the Residential Street Environment. Report No. FHWA/RD-081/031.

5. DEVELOPMENT OF ALTERNATIVE CONTROL PLANS

There are three inputs into the development of alternatives: (1) assessment of the problem and needs, (2) neighbor traffic control devices, and (3) constraints and external factors, including community support. The identification of a problem with cut-through traffic obviously precludes the development of alternatives to solve the problem. The assessment of problems and needs creates the demand for the neighborhood traffic control. The neighborhood traffic control devices and systems represent the supply, the potential solutions, that may be applicable to the problem. Constraints and external factors aid in defining the conditions of the problem neighborhood and the scope of alternatives to pursue.

Guidelines for Development of Alternatives

To be most effective, neighborhood-specific conditions should dictate the development of alternatives. The neighborhood traffic control devices and barrier systems represent elements to be used and system approaches for alternatives, respectively. The following seven statements should serve as an aid in developing alternatives.

1. Improvements to the arterial or boundary routes should be included as an alternative.

2. The alternatives should be tailored to a specific neighborhood.

3. The objectives for each of the alternatives should be defined.

4. The set of alternatives should reflect the full range of technical possibilities and trade-off choices between benefits and undesired impacts.

5. Alternatives should be developed through the exercise of judgment and creativity by the planner/engineer. Where diversion devices are used, temporary construction devices should be considered.

6. The "do-nothing" alternative should be included.

7. The development of alternatives should be an iterative process with feedback from the analysis of alternatives and plan reviewers.

Although not required, it may be preferable to receive input on developing alternatives from representatives of the residents of the neighborhood under study. Potential solutions may be included with the support data required to initiate the study. Otherwise, VDOT may coordinate with the appropriate county/town staff to solicit input from the neighborhood. In this way, alternatives of interest to the neighborhood are more likely to be included in the analysis. Moreover, such input may reduce opposition to the recommended alternatives.

6. ANALYSIS OF ALTERNATIVES

Once a set of alternatives is developed, an analysis of alternatives is performed to estimate the potential effects of the alternatives and tradeoffs between benefits and undesired impacts. Each alternative should be analyzed to estimate the degree to which the identified problems and needs would be resolved and to identify the undesired impacts that would be created.

The purpose of the analysis is to clarify the potential impacts of each alternative. The measures listed in Table 1 are presented as a comprehensive checklist for the analysis. The analyst may select those measures that are important and appropriate for the specific neighborhood under consideration as well as add other measures. In many instances, it may be difficult to assess the projected impacts of the alternatives quantitatively. Innovative uses of capacity and delay analysis techniques may provide opportunities for quantitative assessments. Otherwise, qualitative measures should be used for comparative analysis. Examples of such measures are provided for neighborhood traffic control devices in Table 2 and for peripheral and internal barrier systems in Table 3. Additionally, cost estimates should be provided.

Table 1
ALTERNATIVE ANALYSIS MEASURES

A. Direct Traffic Impacts
   1. Volume reduction
   2. Impact on the routes where the traffic is likely to be diverted
   3. Speed reduction
   4. Directional control
   5. Change in composition (such as truck/car or resident/commuter)
   6. Noise (primarily trucks)
   7. Safety (pedestrian and vehicles)
   8. Emergency and services access (services include school buses, delivery services, trash collection, etc.)
   9. Impact on neighborhood residents (access to arterials and internal access)
   10. Impact on neighborhood nonresidential properties (access to arterials)
   11. Environmental impacts
      a. visual quality of the devices
      b. lost driver trips that use resident driveways
      c. increased travel time/distance/VMT may offset volume reduction
      d. air and noise pollution increases attributable to speed changes

B. Other Characteristics
   1. Construction effort and cost
   2. Maintenance cost (include snowplow impact)
   3. Landscape opportunity

Table 2

QUALITATIVE MEASURES OF NEIGHBORHOOD TRAFFIC CONTROL DEVICES

Devices	Direct Traffic Effects: Volume Reductions	Speed Reductions	Directional Control	Change in Composition	Noise	Safety	Emergency & Service Access
Passive Controls							
Turn prohibition signs	Yes	Likely	Yes	Possible	Decrease	Improved	No effect
One-way streets	Yes	Inconsistent	Yes	Possible	Decrease	Possible improvement	No effect
Physical Controls							
Diagonal diverters	Yes	Likely	Possible	Possible	Decrease	Shifts accidents	Some constraints
Intersection cul-de-sac	Yes	Likely	Yes	Possible	Decrease	Shifts accidents	Some constraints
Midblock cul-de-sac	Yes	Likely	Yes	Possible	Decrease	Shifts accidents	Some constraints
Semidiverter	Yes	Likely	Yes	Possible	Decrease	Shifts accidents	Minor constraints
Forced turn channelization	Yes	Likely	Yes	Possible	Decrease	Improved	Minor constraints
Median barrier	Yes	On curves	Possible	Possible	Decrease	Improved	Minor constraints
Traffic circle	Unclear	Minor	Unlikely	Possible	Little change	Questionable	Some constraints
Undulations	Possible	Yes	Unlikely	Unlikely	No change	No problem noted	No problems noted
Chokers and road narrowing	Rare	Minor	Unlikely	Unlikely	Little change	Improved pedestrian crossings	No problems

continues

Table 2 (cont'd)

Devices	Other Characteristics			
	Construction Effort & Cost	Landscape Opportunity	Site or System Use	Maintenance & Operational Effects Index
Passive Controls				
Turn prohibition signs	Low	No	Both	No unusual problems
One-way streets	Low	No	Usually system	No unusual problems
Physical Controls				
Diagonal diverters	Moderate to high	Yes	Usually system	Vandalism
Intersection cul-de-sac	Moderate to high	Yes	Both	Vandalism
Midblock cul-de-sac	Moderate to high	Yes	Both	Vandalism
Semidiverter	Moderate to high	Yes	Both	Vandalism
Forced turn channelization	Moderate	Possible	Both	No unusual problems
Median barrier	Moderate	Possible	Both	No unusual problems
Traffic circle	Moderate to high	Yes	Both	Vandalism
Undualtions	Low to moderate	None	Both	No problems noted
Chokers and road narrowing	Moderate	Yes	Both	No unusual problems

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

Source: U.S. Department of Transportation. Federal Highway Administration. 1981. Improving the Residential Street Environment. Report No. FHWA/RD-081/031.

Table 3

BARRIER SYSTEM CHARACTERISTICS

Type	Primary Application	Advantages	Disadvantages
Peripheral Barrier Systems	Single-axis problem	o Barriers encountered while on boundary streets, causing little out-of-direction travel or delay o Motorists less likely to violate the system along busier streets o Inconvenience to residents is limited o Passive controls effective for peak periods only	o Less effective in responding to biaxial problems
Internal Systems			
1. Return loops	Biaxial problem	o Extremely effective in limiting through travel	o Extremely restrictive on resident travel (access to one boundary street o Poses considerable barriers for emergency and service travel
2. Anti-through	Biaxial problem	o Effective in limiting through traffic	o Restrictive on resident travel (access to 2 boundary streets) o Barriers to emergency and service travel
3. Maze	Biaxial problem	o Most residents have access to all boundary streets	o Less positively effective in limiting through traffic

After conducting the alternatives analysis, the findings should be fed back to the development of alternatives to develop the next iteration of alternatives. The iterative process is complete when the set of alternatives remains unchanged after feedback from the analysis and other review processes.

7. PREPARATION OF REPORT

At the completion of the analysis of alternatives, the findings or recommendations are prepared for presentation to the District (Engineer) Administrator. The report should include, at a minimum, the following:

- a description of the situation, affected neighborhood, and alternative routes
- a description of the studies conducted and a summary of the findings
- a description of the alternatives
- the findings of the analysis of alternatives
- recommendations to present at the formal public hearing.

8. SELECTION OF AN ALTERNATIVE(S)

The process of placing value on these impacts and weighing tradeoffs is primarily a social and political one (3). The county/town/VDOT joint ~~responsibility portion of Section 1 describes this process.~~

It is important that this process be carefully structured and that the technical information be convincingly presented to enhance the possibility that all the technical issues are given due consideration (3).

It is also possible that alternatives may be modified based on the community involvement and then reanalyzed if necessary.

The decision is made for implementation through an approved resolution of the actions desired from the county/town.

REFERENCES

1. Virginia Department of Transportation. 1989. Policy and procedures for control of residential cut-through traffic. Richmond, Va.

2. Institute of Transportation Engineers. Committee 6422 - Neighborhood Traffic Plans. 1982. Neighborhood traffic plans: Technical report (Draft). Washington, D.C.

3. U.S. Department of Transportation. Federal Highway Administration. 1981. Improving the residential street environment. Report No. FHWA/RD-81/031. Washington, D.C.

4. U.S. Department of Transportation. Federal Highway Administration. 1978. Manual of uniform traffic control devices. Washington, D.C.

SUGGESTION FOR FURTHER READING

Hamburger, W. S.; Deakin, E. A.; Bosselman, P. C.; Smith, D. T., Jr; and Beukers, B. 1989. Residential street design and traffic control. Englewood Cliffs, N.J.: Prentice Hall.

This book includes excellent chapters on tools for neighborhood traffic control and implementing neighborhood traffic control. This book is highly recommended for further reading. It is available from the Institute of Transportation Engineers: (202) 554-8050.

APPENDIX

Guidelines For Use of Speed Humps

GUIDELINES FOR USE OF SPEED HUMPS

INTRODUCTION

A speed hump--also called a road hump, road bump, undulation, or speed control hump--is a gradual hump installed across a roadway on a residential street to induce motorists to reduce speed. The goal is to achieve an 85th percentile speed of between 25 and 30 mph for a street section. The objectives of the guidelines presented here are (1) to identify the roadway and traffic conditions for which speed humps should be considered for use, and (2) to set forth the considerations that go into the design and placement of speed humps. By accomplishing these objectives, the guidelines should provide for the effective use of speed humps.

The guidelines are divided into eight areas:

1. geometric and structural design of roadway
2. characteristics of traffic
3. community support and involvement
4. ranking of eligible streets
5. design and location of humps
6. placement relative to street features
7. method of construction
8. warning signs and markings.

The guidelines are based on a consensus of reports that include recommended guidelines for the installation of speed humps (1-4). Smith and Appleyard established the model for guidelines that have been adopted by several agencies with limited revisions and expansions (1). In the development of these present guidelines, wherever disagreements were found in the literature, the more recent information was given priority, additional information was sought, and finally, engineering judgment was exercised to resolve the differences. The additional information sources are listed under selected references. Items in which disagreements were found are noted by an asterisk.

GEOMETRIC AND STRUCTURAL DESIGN OF ROADWAY

1. The street shall be a local residential street with the primary function of providing access to residents of the abutting residential properties.

2. The street shall have only one travel lane in each direction.

3. The street should not have grades greater than 5 percent.

4. The street should have a horizontal alignment that provides adequate sight distance.

5. The street should have good pavement and drainage.

CHARACTERISTICS OF TRAFFIC

1. The street shall have a posted speed limit of 25 mph.

2. The street shall have a confirmed speed problem or a high incidence of speed-related accidents as determined by a traffic engineering study.

3. The street should not have heavy truck traffic or be on a bus route.

4. The street should not be a commonly used route for emergency vehicles (police, fire, and ambulance services).

5. An average daily traffic of less than 3,000 vehicles per day is suggested. There is no absolute limit. However, because volume is related to the street functions, streets with volumes substantially larger than 3,000 vehicles per day may not be performing the intended function of a residential street.

6. The potential impact of the diversion of traffic to alternate or parallel streets should be considered. The creation of traffic-related problems on alternate streets should be avoided.

COMMUNITY SUPPORT AND INVOLVEMENT

1. The majority of residents on the affected street should support the installation of speed humps. For example, three sets of guidelines included the following: "Speed humps should be installed only when requested by petition of an overwhelming majority of the residents in the affected street."

2. Residents of the affected street, emergency services, school and local bus services, and refuse collection services should be informed during the planning phase through the appropriate citizen participation process.

RANKING OF ELIGIBLE STREETS

Eligible streets are those streets that satisfy the above roadway and traffic conditions and whose residents have requested the installation of the speed humps. Since it is likely that the available funds will not cover the cost of installing speed humps on all of the eligible streets, a method of ranking the eligible streets is needed to ensure that humps are installed where they are most needed.

1. The following point system should be used.

   a. Percentage of vehicles traveling in excess of the 25 mph speed limit. Assign 1 point for each percentage point of traffic determined by a speed study to be exceeding the speed limit.

   b. Average daily traffic volume. Assign 1 point for every 50 vehicles counted in a 24-hour period.

   c. Bonus points for streets in the immediate vicinity of schools. Assign 25 points.

   The maximum point total possible should be 185. Similar criteria are used by at least two municipalities.

2. The eligible streets with the highest rankings and where speed humps can be installed with the available funds are selected.

DESIGN AND LOCATION OF HUMPS

*1. The speed hump shall have a circular cross section 12 ft in length with a maximum height at its midpoint of 3 in, with an allowable tolerance of +1/2 in (Figure A-1). Heights of 3 or 4 in have been effectively used. Although the speed reduction is greater at a 4-in height, several instances of vehicles bottoming out (or scraping the roadway) on the humps have been cited. Hump heights between 3 and 3 1/2 in appear to provide the best results, according to Stephens (5).

2. The last 1-ft length of the hump near the edge of the roadway should be tapered so that it is flush with the lip of the gutter (Figure A-1).

3. The speed humps should be spaced approximately 500 ft apart. The range in hump spacing should be 400 to 550 ft. Recommended spacings in the guidelines vary from 150 to 750 ft. The spacing is determined by the desired 85th percentile speed for the street and the acceptable variation in speed between the humps and on the humps. The location

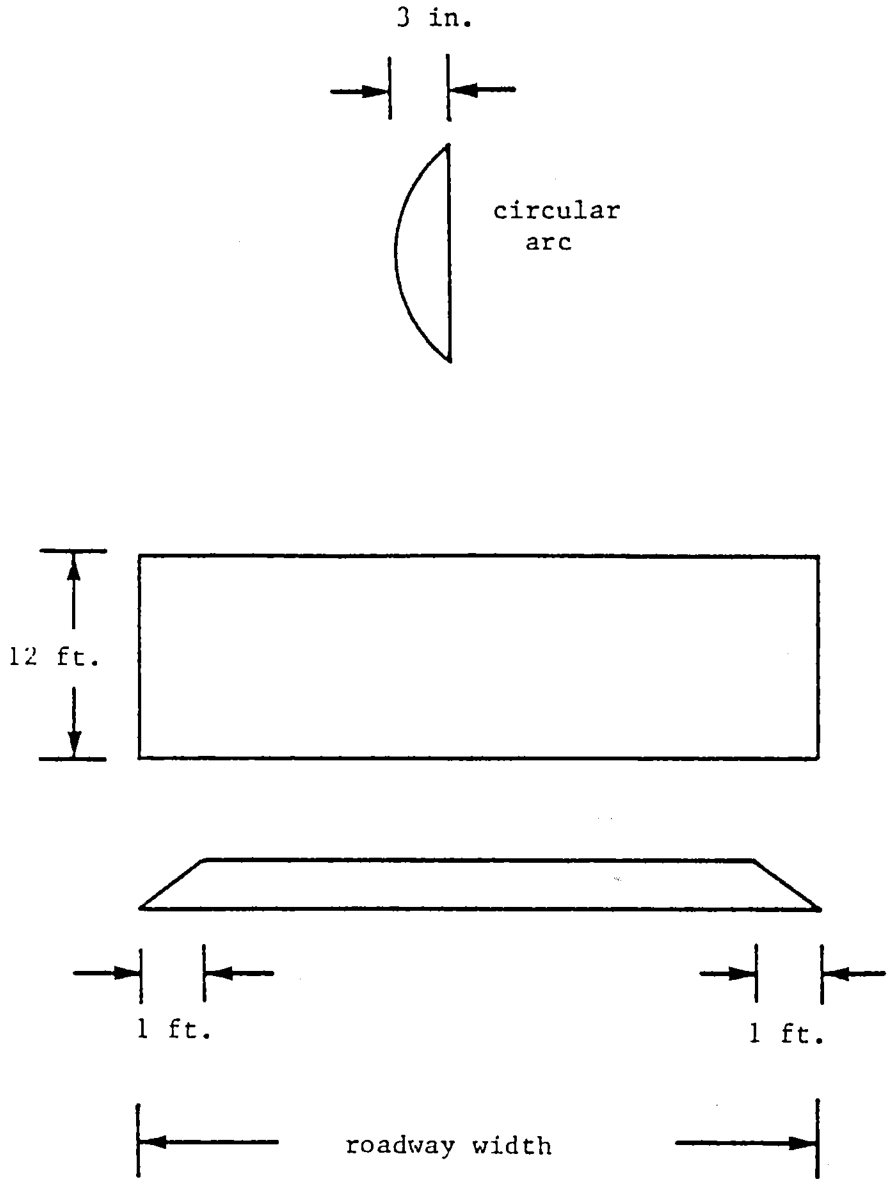


Figure A-1. Design of speed humps.

is also influenced by the hump height and the location of the hump in relation to street features. The suggested spacing is reasonable based on the desired 85th percentile speed and the literature.

4. Each speed hump should be clearly visible for at least 200 ft.

5. Speed humps should be located at least 200 ft from intersections and sharp horizontal curves.

PLACEMENT RELATIVE TO STREET FEATURES

1. Speed humps should be placed on property lines when possible.

2. They should be placed to take advantage of street lighting.

3. They should be placed downstream of drainage inlets.

4. They should not be placed over manholes, gate valves, utility vault accesses, etc.

5. They should not be placed within 5 ft of driveways.

6. They should not be placed at hydrants.

METHOD OF CONSTRUCTION

1. The method of constructing speed humps should ensure

   a. that there is a firm adherence between the hump and the roadway
   b. that the desired shape and tolerance of the hump are achieved
   c. that the hump be compacted to reduce the probability of deformation.

2. Asphalt should be hand-placed and hot-rolled over a tack coat using two templates and should be placed in lifts of 2 in and 3 in. Based on experience with the construction of humps, the use of templates should be required in order to attain precisely the required hump profile. Further, installation in two lifts has been demonstrated to ensure the maximum hump height and shape.

WARNING SIGNS AND MARKINGS

No research has been conducted to determine the most effective warning signs and markings for speed humps. The following recommendations place emphasis on uniformity and consistency with the practices given in the MUTCD (6).

*1. A 30-in standard MUTCD warning sign stating "BUMP" should be installed in advance of the hump in each direction. One set of guidelines recommended that the sign be placed adjacent to the hump to indicate the exact location of the hump to motorists and snowplow operators when the pavement markings and hump shape are obscured by snow.

2. An 18-in standard MUTCD advisory speed plate stating "15 MPH" should supplement the warning sign. The advisory speed plate is used (1) to educate the motoring public, and (2) to recommend a safe speed for all vehicles. The 15 mph value was obtained through tests of a wide range of specialized vehicles including fire trucks; ambulances; transit buses; large trucks such as garbage, dump, and lift (or bucket) trucks; and trucks carrying fragile cargo, such as bottled water.

*3. The pavement marking pattern shown in Figure A-2 should be placed on each hump. Reflective white pavement marking the width of the travel lane should be used to mark the beginning of the hump. Most of the recommended pavement marking patterns resemble crosswalks. In fact, some engineers believe that humps should also serve as crosswalks. It is the author's opinion that crosswalks be reserved for intersections or other locations designated by a traffic engineering study.

At least one municipality uses warning signs and markings guidelines similar to those listed above, as is shown in Figure A-3.

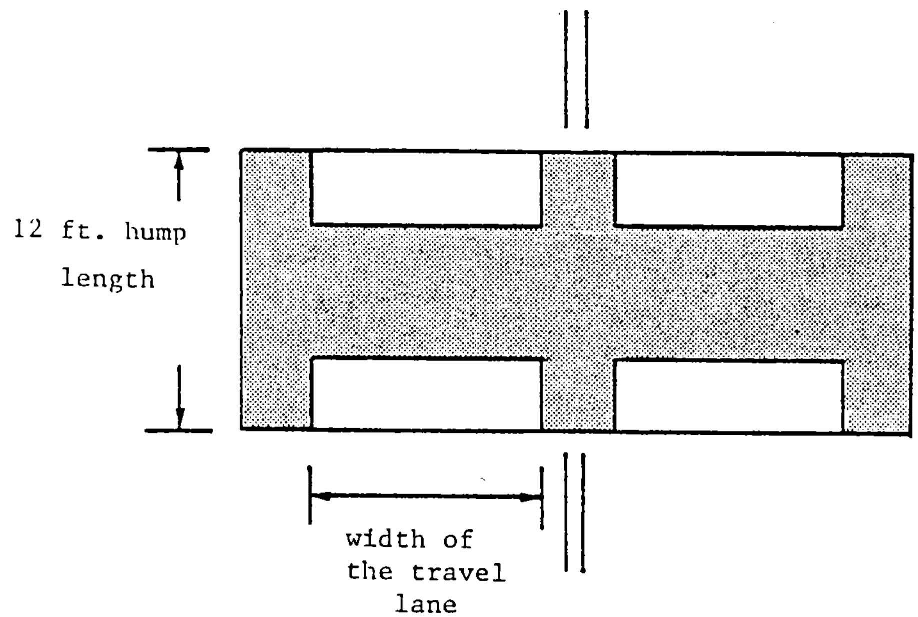


Figure A-2. Pavement marking on speed humps.

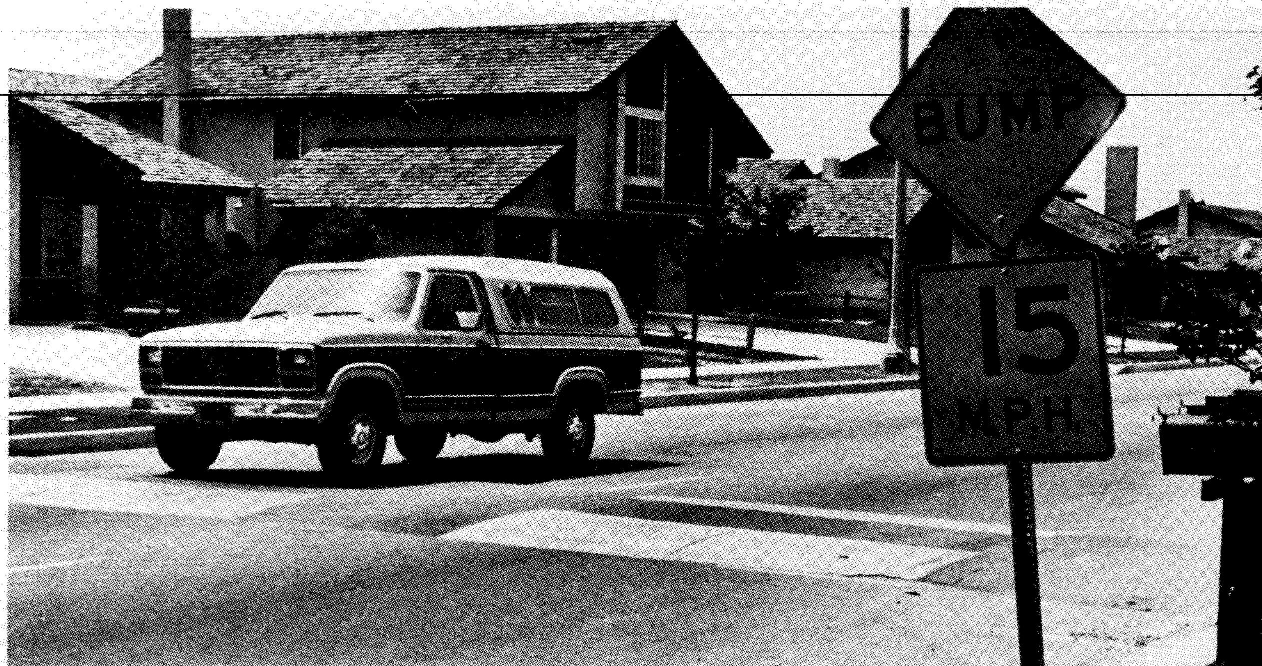


Figure A-3. Example of the use of the warning signs and pavement markings. Source: Transportation Research Board, "Neighborhood Speed Control-A Synthesis of Speed Hump Experience," TR News, Number 11, July-August 1984.

REFERENCES

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2. Clement, J. P. 1982. Speed humps and the Thousand Oaks experience. Department of Public Works, City of Thousand Oaks, Calif.

3. California Traffic Control Devices Committee. 1983. Subcommittee report on pavement undulations (road humps): Final report. Sacramento, Calif.

4. Traffic Engineering Division, City of Sacramento. 1982. Information packet (correspondence on undulations). Sacramento, Calif.

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