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TECHNICAL GUIDELINES FOR THE CONTROL OF DIRECT ACCESS TO ARTERIAL HIGHWAYS-VOLUME II DETAILED DESCRIPTION OF ACCESS CONTROL TECHNIQUES

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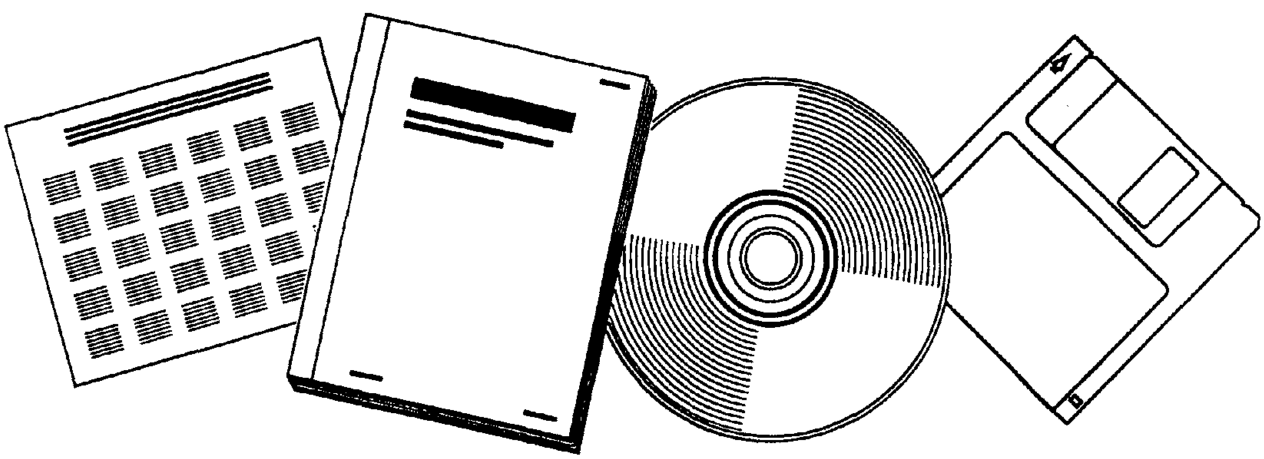

U.S. DEPARTMENT OF COMMERCE
National Technical Information Service

Report No. FHWA-RD-76-87

TECHNICAL GUIDELINES FOR THE CONTROL OF DIRECT ACCESS TO ARTERIAL HIGHWAYS

Vol. II. Detailed Description of Access Control Techniques

August 1975

Final Users' Manual

This document is available to the public
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Prepared for

FEDERAL HIGHWAY ADMINISTRATION

Offices of Research & Development

Washington, D.C. 20590

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TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No.: FHWA-RD-76-87

2. Government Accession No.:

3. Recipient's Catalog No.:

4. Title and Subtitle: TECHNICAL GUIDELINES FOR THE CONTROL OF DIRECT ACCESS TO ARTERIAL HIGHWAYS
Volume II: Detailed Description of Access Control Techniques

5. Report Date: August 1975

6. Performing Organization Code:

7. Author(s): J. C. Glennon, J. J. Valenta, B. A. Thorson, J. A. Azzeh

8. Performing Organization Report No.:

9. Performing Organization Name and Address:
Midwest Research Institute
425 Volker Boulevard
Kansas City, Missouri 64110

10. Work Unit No.:

11. Contract or Grant No.: DOT-FH-11-8121

12. Sponsoring Agency Name and Address:
Office of Research and Development
Federal Highway Administration
U.S. Department of Transportation
Washington, D.C. 20590

13. Type of Report and Period Covered: Final Users' Manual

14. Sponsoring Agency Code: E0222

15. Supplementary Notes:
Michael Freitas, Contract Manager

16. Abstract

This document is intended to give highway agencies general guidelines toward a more comprehensive application of direct access controls to commercial properties on arterial highways. As such it represents the first stage of the implementation for the results contained in the companion research document, "Evaluation of Techniques for the Control of Direct Access to Arterial Highways."

Volume I discusses the basic problem dimension, summarizes the evaluation of the 70 identified techniques, and gives a general decision framework for implementation of access controls. Consideration for implementation include: (1) comprehensive policy development; and (2) the selection of techniques to counteract operational problems on existing highways.

Volume II is a reference document containing detailed descriptions of the design, application, cost, operational effectiveness, and cost-effectiveness of each access control technique.

17. Key Words:
Access control
Traffic operations
Commercial driveways
Highway design
Highway safety

18. Distribution Statement: No restrictions. This report is available to the public through the National Technical Information Service, Springfield, Virginia 22161.

19. Security Classif. (of this report): Unclassified

20. Security Classif. (of this page): Unclassified

21. No. of Pages:

22. Price:

Form DOT F 1700.7 (8-69)

TABLE OF CONTENTS

I. SUMMARY

This volume is a reference document presenting detailed descriptions of 70 techniques for the control of direct access on arterial highways. For convenience to the reader, the 70 techniques are listed in a fold-out classification table on the last page of this volume. The table classifies techniques according to their functional objectives and applicational similarities.

The technique descriptions are presented in the order listed in the table. Again for the readers' convenience the technique number is given at the top of each page describing that technique.

Each technique description discusses what the technique is, how it affects traffic conflicts, how it is applied, where it is applied, what it costs for different site applications, how effective it is in reducing accidents and delay, and what its relative cost-effectiveness is. All of these considerations derive from the research results detailed in the companion research document, "Evaluation of Techniques for the Control of Direct Access to Arterial Highways," and summarized in Volume I of this document. The costs, measures of effectiveness, and benefit/cost ratios given for each technique are state-of-the-art estimates based on typical applications of the technique.

Two appendices supplement the technique descriptions. Appendix A gives details for common design elements. Appendix B gives general accident warrants for implementation.

II. HIGHWAY DESIGN AND OPERATIONS TECHNIQUES

A-1: INSTALL MEDIAN BARRIER WITH NO DIRECT LEFT-TURN ACCESS

The physical median barrier is a route design technique for controlling access on arterial highways. The barrier, which can be a New Jersey type or a simple barrier curb, eliminates direct left-turns at all driveways and U-turns along the highway. Indirect left-turns to driveways are accommodated by right-hand ramps (jug-handle) and cross-overs or by cloverleaf loops at cross streets.

This technique reduces the basic conflict points from 9 to 2 at all driveways. More important, the barrier totally eliminates the more hazardous crossing conflict points at all driveways. The frequency of rear-end conflicts on the through lanes is expected to decrease as a result of the elimination of direct left-turns; on the other hand, the frequency of right-turn conflicts at minor driveways will probably increase proportional to the number of indirect left turns. Some trade off is realized by the creation of additional basic conflict points at indirect left-turn locations. However, this trade-off is minimized if these locations are signalized.

Design and Operational Considerations

The median width is the basic highway element needed for implementation of this technique. The desirable median width for the barrier is 6 ft. This width is sufficient to accommodate a 2-ft wide barrier and a 2-ft clearance on each side. The minimum pavement width is 50 ft on four-lane highways.

Figure A-1.1 shows two possible designs for the barrier. Barrier A is recommended for low-speed arterials because its height is sufficient to redirect low-speed vehicles. Barrier B is strongly recommended for high-speed arterials because its height will shadow headlight glare and will prevent colliding vehicles from vaulting into opposing lanes.

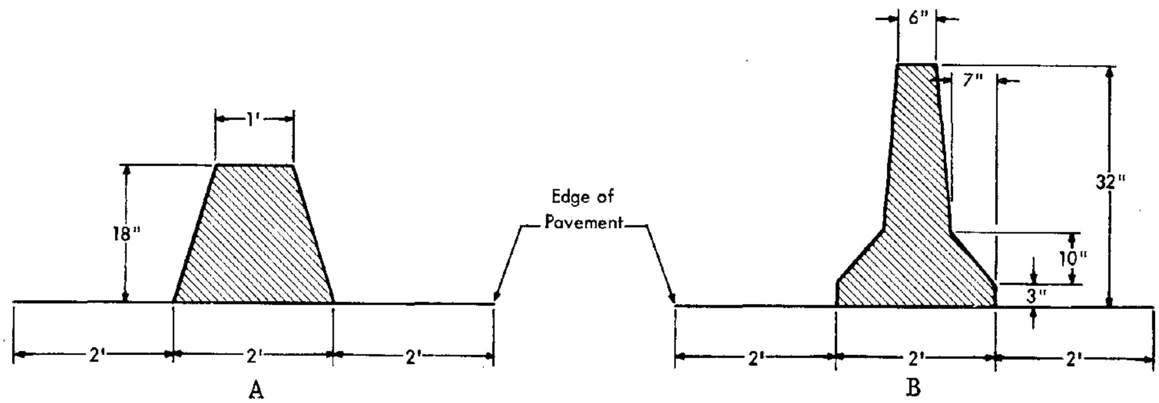


Figure A-1.1 - Median Barrier Cross Sections

Other design elements used in conjunction with this technique are the jug-handle crossover and the cloverleaf loops. A right-of-way width of more than 150 ft is needed at the jug-handle or cloverleaf site, and this requirement in itself may render this design impractical.

The cloverleaf design, Figure A-1.2, is recommended when the distance between major driveways or intersections is less than 1 mile. The jug-handle design, Figure A-1.3, is recommended when major driveways or intersections are spaced at 1 mile or greater. These facilities should be designed to allow a vehicle to exit the through lanes at close to average running speed, decelerate uniformly along the ramp, and stop at the end of the ramp. In all cases, the jug-handle or cloverleaf lane width should equal or exceed 16 ft. The deceleration and storage length requirements are detailed in Appendix A.

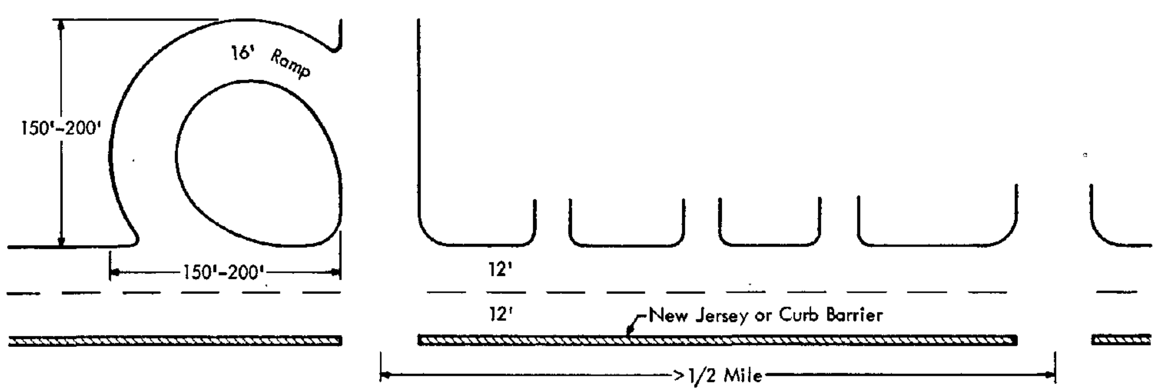


Figure A-1.2 - Median Barrier with Indirect Left-Turn Ramp (Cloverleaf Loop)

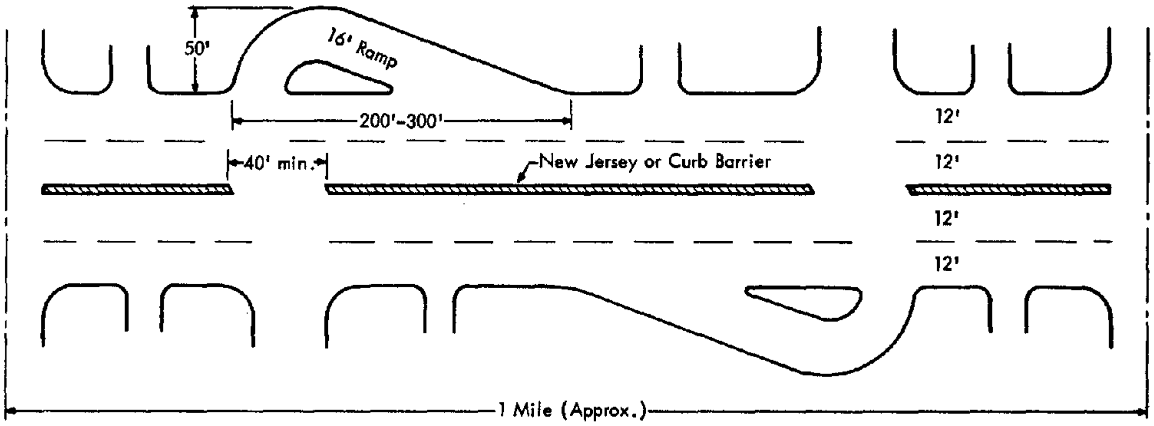


Figure A-1.3 - Median Barrier With Indirect Left-Turn Ramps (Jug-Handle)

An important aspect of the design of the jug-handle is the offset of the median opening from the centerline of the ramp terminus. The offset is necessary to restrict turning vehicles to the correct approach path and to allow for a minimum median opening to discourage direct U-turns. The median opening length can be determined from the tables included in Appendix A. Consideration should be given to signalizing these locations if the appropriate traffic volume warrants are satisfied. Technique A-4 describes signal installation and warrants in detail.

Another important design feature relates to the number of loops used in conjunction with the cloverleaf design. If a single right-hand loop is provided, indirect left- and U-turns are provided by entering the loop on the right, exiting on the minor street, and then making a left-turn from the minor street. If a two-loop design is provided, motorists can use both loops for a complete U-turn. This maneuver is made by entering the right-hand loop on the arterial, exiting on the minor street, going through the intersection, entering the second loop on the minor street and then exiting on the arterial. The main disadvantage of the clover leaf design is that left- or U-turning vehicles have to pass through the intersection either twice or three times. Also, these maneuvers may be confusing to motorists unfamiliar with the design.

Warrants

This technique is generally warranted on multilane arterial highways with speeds greater than 40 mph, ADT's greater than 10,000 vehicles per day, and levels of development between 30-60 driveways per mile. Left-turning movements should equal or exceed 150 vph on a 1-mile section during peak-periods. Also, this technique is warranted along highway sections where mid-block accident experience, involving left-turning vehicles, is excessive (see Appendix B, Table B-II).

Costs

To estimate the basic costs for this technique, three construction options were evaluated. The first option involves the construction of a median barrier on an existing paved median, and construction of a jug-handle or a cloverleaf loop. The major quantities and the costs of constructing 1 mile of improvement are as follows:

Median barrier 5,200 ft x $20	=	$104,000
Pavement (two loops or jug-handles) 900 sq yd x $20	=	18,000
Curb and gutter (on loops or jug-handles) 1,000 ft x $8	=	8,000
Signing and striping	=	1,200
Right-of-way for loops or jug-handles 18,000 sq ft x $3	=	54,000
		$185,200

The second option involves the cost of implementing the technique where additional pavement is required to maintain full through lane widths. The situation arises when less than 6 ft width of median exists and right-of-way is available for widening. The estimated quantities based on a widening of 6 ft are as follows:

Basic construction and right-of-way for indirect left-turn facilities	= $185,200
Pavement widening 3,520 sq yd x $20 (one side)	= 70,400
Curb and gutter 4,000 ft x $8	= 32,000
Relocation of roadside structures, 1 mile x $10,000 (one side)	= 10,000
Patchback, 16 driveways x $400	= 6,400
	$304,000

The third option is considered when right-of-way must be purchased for pavement widening. The major quantities and costs associated with these conditions are:

Basic construction, pavement widening, and right-of-way for indirect left-turn facilities	= $304,000
Right-of-way acquisition for widening 31,600 sq ft x $3	= 94,800
	$398,800

For the second and third site conditions, many useful and desirable improvements could be implemented with little or no additional cost as a by-product of required highway widening and the resultant driveway reconstruction. These improvements include point location techniques, such as improved horizontal and vertical geometrics and relocating of altered driveways.

An important observation when considering implementing this technique is the indirect economic impact caused by the restriction of direct left-turns. The effects on business which results from preventing left-turns at certain driveways should be carefully examined.

Measures of Effectiveness

The basic information taken from available literature indicates 70% of driveway accidents involve left-turning vehicles. For the median barrier, a 60% reduction in driveway accidents was assumed. Also, this reduction was countered by an increase in accidents associated with two signalized indirect left-turn locations. The net result of accident reduction is shown in Table A-1.1.

TABLE A-1.1

ANNUAL ACCIDENT REDUCTION PER MILE BY INSTALLING MEDIAN BARRIER

LEVEL OF DEVELOPMENT (Driveways per Mile)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 30	-2.7	-4.0	-5.0
MEDIUM	30-60	1.8	4.7	8.1
HIGH	> 60	6.3	13.6	21.3

The preceding table shows that the technique will increase accidents for highways with low level of development but is operationally effective in reducing accidents for medium and high levels of development over all volume ranges. The table, however, does not reflect the impact of the barrier itself on accidents. It is difficult to predict whether the barrier will net an increase or decrease in total accidents. The barrier will decrease head-on accidents but will increase the potential of accidents due to vehicles striking the barrier.

Speed, on through lanes, is expected to increase as much as 5 mph when implementing this technique. Consequently, a reduction in travel time will be realized. However, this saving is probably offset by the increase in vehicle travel time for indirect left-turning vehicles and the increased delay to through vehicles if the indirect crossings are signalized.

Evaluation and Comparison

Benefit/cost ratios for the median barrier were determined for the three construction options by using the estimated accident reductions and direct costs. It is evident from Tables A-1.2, A-1.3, and A-1.4 that the barrier technique has low benefit/cost ratios. The main reason is the high initial cost required to implement the technique. It is also observed from the B/C ratio in Tables A-1.3 and A-1.4 that the technique may be impractical when pavement widening and additional right-of-way is needed for construction. The higher costs and limited ranges of application suggests, that other directly alternative median treatment techniques, such as Technique A-2, are more appropriate for most situations.

TABLE A-1.2

BENEFIT/COST RATIOS FOR BASIC CONSTRUCTION OF A MEDIAN BARRIER

LEVEL OF DEVELOPMENT (Driveways per Mile)	HIGHWAY ADT (Vehicles per Day)		
	LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW < 30	-	-	-
MEDIUM 30-60	-	-	1.3
HIGH > 60	1.0	2.2	3.4

TABLE A-1.3

BENEFIT/COST RATIOS FOR BASIC CONSTRUCTION AND PAVEMENT WIDENING FOR A MEDIAN BARRIER

LEVEL OF DEVELOPMENT (Driveways per Mile)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 30	-	-	-
MEDIUM	30-60	-	-	-
HIGH	> 60	-	1.3	2.1

TABLE A-1.4

BENEFIT/COST RATIOS FOR BASIC CONSTRUCTION, PAVEMENT WIDENING AND R/W ACQUISITION FOR A MEDIAN BARRIER

LEVEL OF DEVELOPMENT (Driveways per Mile)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 30	-	-	-
MEDIUM	30-60	-	-	-
HIGH	> 60	-	1.0	1.6

A-2: INSTALL RAISED MEDIAN DIVIDER WITH LEFT-TURN DECELERATION LANES

This median treatment directly controls access on urban multi-lane highways by preventing left-turns and U-turns across the median except at a few designated locations. Access is provided with left-turn lanes at intersections and major driveways. In addition to preventing left-turns at minor driveways, the raised median divider reduces stream friction by separating opposing traffic.

This technique reduces the frequency of total conflicts by reducing the basic conflict points from 9 to 2 at all minor driveways. More important, it completely eliminates the more hazardous crossing conflict points at these driveways. For intersections and major driveways, the frequency and severity of conflicts associated with left-turn vehicles are reduced by allowing deceleration and shadowing of these vehicles in left-turn lanes.

The median divider usually reduces the total number of driveway maneuvers. However, the maximum reduction in the frequency of conflicts is moderated by increases in right-turn volumes at minor driveways where desired left-turns are accomplished through indirect, circuitous paths.

Design and Operational Considerations

Often the median construction will require widening of the existing roadway. Where insufficient right-of-way has been dedicated, additional right-of-way will need to be purchased. The minimum required roadway width is 56 ft. This width accommodates four 11-ft through lanes and a 12-ft median. A more desirable design allows four 12-ft through lanes and a 16-ft median, for a total roadway width of 64 ft (see Figure A-2.1).

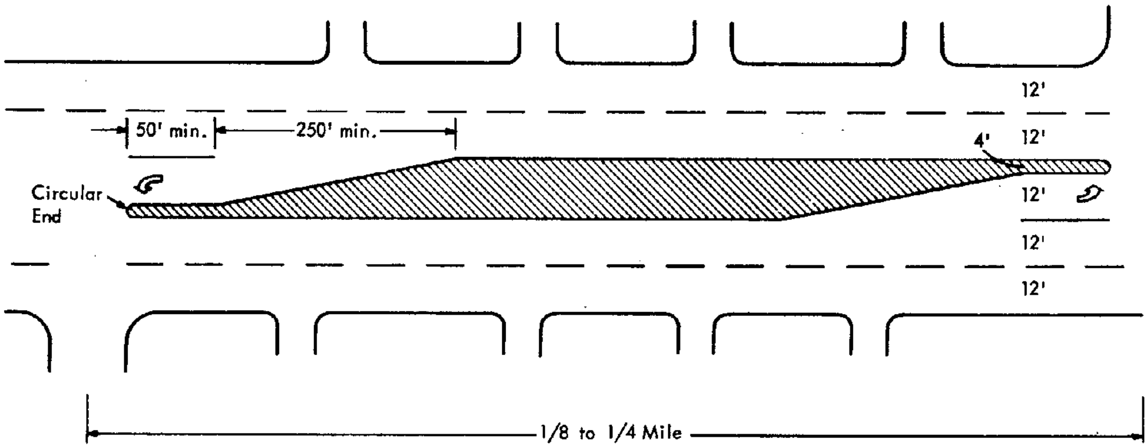


Figure A-2.1 - Raised Median Divider With Left-Turn Deceleration Lanes

The most important element of the recommended design is the median width, which must be adequate to completely shadow left-turning vehicles from through vehicles. A 12-ft median is the narrowest that will accomplish the shadow requirement. The desirable minimum median width is 14 ft. This width will allow a vehicle to be completely protected from through traffic by a 12-ft storage lane. The remaining 2 ft of width is raised to maintain the medial separation. The recommended design has a 16-ft wide median; however, if U-turns are permitted, a 22-ft width is required. The required median widths are listed in Appendix A.

The spacing of median openings is dictated by the recommendations for left-turn lane lengths. These lengths vary from 300 to 1,000 ft for design speeds from 30 to 45 mph (as discussed in Appendix A).

The required deceleration length is that distance needed for a comfortable stop from the average running speed on the highway. The storage length should be sufficient to store the maximum expected vehicle queue. As a minimum, storage length for at least two passenger cars should be provided. The recommended deceleration and storage lengths are listed in Appendix A.

Warrants

This technique is generally warranted on multilane highways with speeds of 30 to 45 mph, ADT's greater than 10,000 vehicles per day, and levels of development greater than 30 driveways per mile. Left-turning movements should exceed 150 vph on a 1-mile section during peak periods. In addition, this technique may be warranted by a high-accident experience associated with mid-block left-turning vehicles (see Appendix B, Table B-II).

Costs

The direct costs of implementing this technique are highly dependent on specific site conditions. To generalize the cost evaluation, three basic site conditions were evaluated.

The first site condition involves constructing the raised median on an existing paved median. The major estimated quantities involved and the costs for constructing 1 mile of improvement are as follows:

Curb and gutter	9,800 ft x $8 =	$78,400
Resurfacing	3,200 sq yd x $6 =	19,200
		$97,600

The second site condition involves the cost of implementing the technique where additional pavement is required within the existing right-of-way. The estimated quantities based on a widening of 7 ft on each side are as follows:

Basic construction	=	$ 97,600
Pavement 8,200 sq yd x $20	=	164,000
Curb and gutter 8,000 ft x $8	=	64,000
Relocation of roadside structures 2 miles x $10,000 (both sides)	=	20,000
Patchback, 60 driveways x $400	=	24,000
		$369,600

The third site condition considers where additional right-of-way is needed to implement the technique. The major estimated quantities and costs associated with this condition are:

Basic construction and pavement	= $369,600
R/W acquisition 73,600 sq ft x $3 =	220,800
	$590,400

For the second and third site conditions, many useful and desirable improvements could be implemented with little or no additional cost as a by-product of required highway widening and the resultant driveway reconstruction. These improvements include point location techniques, such as improved horizontal and vertical geometrics and relocation of altered driveways.

An important observation when considering implementing this technique is the economic impact caused by the restriction of left-turns. The effects on business which results from preventing left-turns at certain driveways should be carefully examined.

Measures of Effectiveness

For a general evaluation of this technique, accident and delay reductions have been estimated for three levels of development and three ranges of highway ADT. For the accident analysis, the basic information taken from available literature indicates a 50% reduction in total accidents can be realized by providing left-turn lanes at intersections (and driveways). At minor driveways, the analysis accounted for a complete reduction in left-turn accidents and an increase in right-turn accidents. The analysis yielded the following table:

TABLE A-2.1

ANNUAL ACCIDENT REDUCTION PER MILE BY INSTALLING RAISED MEDIAN DIVIDER

LEVEL OF DEVELOPMENT (Driveways per Mile)	HIGHWAY ADT (Vehicles per Day)		
	LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW < 30	2.2	4.1	6.3
MEDIUM 30-60	5.8	11.2	17.2
HIGH > 60	10.7	20.7	31.2

This table shows the annual accident reduction per mile ranging from 2.2 for a low level of development and low highway volume, to 31.2 for a high level of development and high highway volume. Absolute percentage changes in accidents are fairly constant for a given level of development, but for a specific highway volume, the percentage change increases as the level of development increases.

In estimating delay reduction for this technique, assumptions were used about the average travel speeds for the various combinations of level of development and highway volume, and for the period that driveway vehicles affect the travel speed on the highway.

Running delays were calculated using the assumed average running speeds listed in Table A-2.2 with a 5-mph increase in running speed after median divider installation for a 1-mile section of highway. This 5-mph increase applies to 35% of through vehicles for a high level of development and 20% of through vehicles for a medium level of development.

These assumptions led to a procedure where changes in travel time could be calculated, thereby evaluating the effects of this technique on delay, as shown in Table A-2.3. Delay reductions were assumed negligible for low-volume highway sections and low levels of development.

TABLE A-2.2

AVERAGE HIGHWAY RUNNING SPEEDS

LEVEL OF DEVELOPMENT (Driveways per Mile)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 30	-	-	-
MEDIUM	30-60	-	30 mph	30 mph
HIGH	> 60	-	30 mph	25 mph

TABLE A-2.3

ANNUAL RUNNING TIME REDUCTION IN VEHICLE-HOURS FOR A 1-MILE SEGMENT OF RAISED MEDIAN DIVIDER

LEVEL OF DEVELOPMENT (Driveways per Mile)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 30	-	-	-
MEDIUM	30-60	-	2,628	6,935
HIGH	> 60	-	6,059	17,046

Evaluation and Comparison

The estimated costs and measures of effectiveness, detailed previously, were used to predict the probable benefit-cost ratio of this technique. Table A-2.4 shows the benefit/cost ratios of the first site condition. As expected, the technique is cost-beneficial for medium and high levels of development and ranges of ADT.

Table A-2.5 shows the benefit/cost ratios for the second site condition, where additional pavement area is required to implement the technique. For this site condition, the technique is also cost-beneficial for medium and high levels of development and ranges of ADT.

Table A-2.6 shows the benefit-cost ratio of the third site condition where right-of-way is needed for the basic implementation of the technique. Under this condition, the technique is limited to fewer cost-beneficial combinations of levels of development and ADT ranges. The obvious reason for this is the large sum of capital required to obtain commercial land for highway construction.

Compared to other median techniques, the raised median divider is one of the better techniques, particularly when the level of development, highway ADT, and peak-hour left-turn volume are high.

TABLE A-2.4

BENEFIT/COST RATIOS FOR BASIC CONSTRUCTION FOR RAISED MEDIAN DIVIDER

LEVEL OF DEVELOPMENT (Driveways per Mile)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 30	-	1.3	1.9
MEDIUM	30-60	1.8	4.7	8.7
HIGH	> 60	3.3	9.3	17.9

TABLE A-2.5

BENEFIT COST RATIOS FOR BASIC CONSTRUCTION PLUS ADDITIONAL PAVEMENT FOR RAISED MEDIAN DIVIDER

LEVEL OF DEVELOPMENT (Driveways per Mile)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 30	-	-	-
MEDIUM	30-60	-	1.2	2.3
HIGH	> 60	-	2.5	4.7

TABLE A-2.6

BENEFIT/COST RATIOS FOR BASIC CONSTRUCTION PLUS ADDITIONAL RIGHT-OF-WAY FOR RAISED MEDIAN DIVIDER

LEVEL OF DEVELOPMENT (Driveways per Mile)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 30	-	-	-
MEDIUM	30-60	-	-	1.4
HIGH	> 60	-	1.5	3.0

A-3: INSTALL ONE-WAY OPERATIONS ON THE HIGHWAY

Converting an urban arterial highway to one-way operations is intended to facilitate better traffic movement by reducing the stream friction between opposing traffic. For a given roadway width, one-way operations can increase capacity by as much as 50%.

Improvements in safety result from one-way operations because the more severe opposing left-turn conflicts are eliminated at all driveways and intersections. Conflict points are reduced from 9 to 2 at driveways where right-turns are permitted. No crossing conflicts are possible for these driveways. On the left side where left-turns occur, the conflict points decrease from 9 to 3, with one crossing conflict point remaining.

When considering this technique for implementation, other system conditions must be reviewed to achieve the best solution for the problem at hand. For instance, turning conflicts are reduced at all intersections. Pedestrian-vehicular conflicts are also reduced because of the decrease in total movements. Also, one-way streets lend themselves to better signal progression. However, some trade-offs may occur by increasing the frequency of conflicts resulting from lane changing encroachments, turns from the wrong lane, and indirect (around-the-block) maneuvers.

Design and Operational Considerations

One-way operations are applicable on undivided urban highways and, depending on the site conditions, can usually be initiated by simply converting all traffic lanes to one direction of travel. Of course, the implementation of one-way streets depends on the availability of a suitable arterial to carry reverse direction traffic. A pair of closely spaced, one-way streets is suggested.

The implementation of one-way operation on arterial sections is encouraged as an alternative to medial design techniques where insufficient right-of-way exists for widening the arterial. Acquiring additional right-of-way for widening reduces the distance from the back of curb to the commercial establishment. And, in some cases, a reduction in commercial activity could result. Internal traffic circulation could also be hindered. These situations should justify one-way operation.

The implementation of one-way operation can usually be accomplished with relatively little effort. Proper signing is the major item required to physically convert a two-way street to one-way operations. Driveway geometrics that might need to be altered are driveway angles and turning radii. Channelization may also require some physical modification. Another technique that could complement the change to one-way operations is the restriction of roadway parking.

It should be evident that the implementation of one-way streets, although inexpensive, must be thoroughly analyzed. The one-way routing must be compatible with the overall traffic plan and be in accordance with community goals.

Warrants

As mentioned earlier, one-way operations can be implemented on two-lane and multilane undivided arterial highways, and a nearby parallel highway is needed to carry the reverse-direction traffic. Commercial driveways should number at least 30 per mile and turning maneuvers into these driveways should comprise 30% or more of the total traffic over a 1-mile section during peak periods. Daily traffic volume should exceed 5,000 vehicles with posted speeds between 30 and 40 mph. Inadequate capacity could also warrant this technique. This technique is also warranted along highways exhibiting high accident rates with insufficient right-of-way available for other remedial techniques (see Appendix B, Table B-I).

Costs

Direct costs associated with this technique should not vary substantially from site to site. However, if additional improvements are also added, such as changes in driveway angles, turning radii, and channelization, a large, relative increase in cost is likely. Costs for this technique are based on providing appropriate signing and striping for 1-mile sections of highway, including the parallel facility. Total cost is estimated at $7,700 with $3,700 attributed to striping (two lane lines on each highway) and $4,000 for signing (80 signs).

Measure of Effectiveness

The literature identifies one-way streets as an important technique for improved traffic operations and safety on urban arterial streets. A 25% reduction in total accidents is representative after converting to one-way operations. Using this reduction, the following table displays estimated annual accident reductions per mile for practical levels of development and highway volume.

TABLE A-3.1

ANNUAL ACCIDENT REDUCTION PER MILE BY INSTALLING ONE-WAY OPERATIONS

LEVEL OF DEVELOPMENT (Driveways per Mile)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	<30	-	-	-
MEDIUM	30-60	-	9.9	14.9
HIGH	>60	-	13.6	20.4

Reductions in travel time of 25% were also identified in the literature. This value was used to calculate travel time reductions for the various levels of development and highway volumes. Travel time reductions depend on the average travel speed over a particular section with a specified level of development and highway volume. The average travel speeds over the entire day are assumed as follows:

TABLE A-3.2

AVERAGE TRAVEL SPEED

LEVEL OF DEVELOPMENT (Driveways per Mile)	HIGHWAY ADT (Vehicles per Day)		
	LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW <30	-	-	-
MEDIUM 30-60	-	30 mph	25 mph
HIGH >60	-	25 mph	20 mph

Using the average travel speeds, and the 25% reduction in travel time over a section of highway after changing to one-way operation, the expected travel time reductions per day are:

TABLE A-3.3

DAILY TRAVEL TIME REDUCTIONS IN VEHICLE-HOURS OVER A 1-MILE SEGMENT AFTER INSTALLING ONE-WAY OPERATIONS

LEVEL OF DEVELOPMENT (Driveways per Mile)	HIGHWAY ADT (Vehicles per Day)		
	LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW <30	-	-	-
MEDIUM 30-60	-	83.3	200.0
HIGH >60	-	100.0	250.0

Evaluation and Comparison

Benefit/cost ratios for converting to one-way operations are contained in the following table.

TABLE A-3.4

BENEFIT/COST RATIOS FOR ONE-WAY STREET IMPLEMENTATION

LEVEL OF DEVELOPMENT (Driveways per Mile)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	<30	-	-	-
MEDIUM	30-60	-	230	530
HIGH	>60	-	290	660

As is evident from the table, changing to one-way street operations is highly beneficial in relation to the costs involved. Even if additional improvements are added, the benefits would surely outweigh the costs.

A-4: INSTALL TRAFFIC SIGNAL AT HIGH-VOLUME DRIVEWAYS

The installation of traffic signals at high-volume driveways can be of significant value when used in a conscientiously applied access control program. Signals at high-volume driveways are intended to reduce inordinate delay to driveway vehicles and to eliminate certain high-frequency conflict points by separating conflicting maneuvers in time. Increasing the number of signal phases decreases the number of conflict points to the level where only basic diverging conflict points remain. A two-phase signalized driveway will have five conflict points, and a three-phase signalized driveway will have only three conflict points. Figure A-4.1 shows a signal installation at a high-volume driveway.

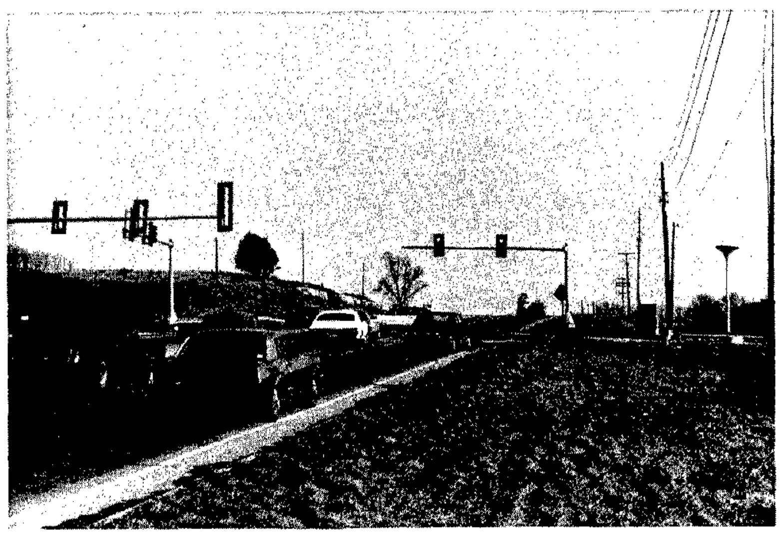


Figure A-4.1 - Driveway Signal Installation

If properly designed, installed, and maintained, traffic signals tend to reduce right-angle collisions, vehicular-pedestrian collisions, and opposing left-turn collisions. Additional benefits can accrue by creating larger gaps in the traffic stream at downstream driveway locations. Some trade-offs may be introduced, however, by increasing rear-end conflicts on the highway and by creating queues that block nearby upstream driveways. Also, indiscriminate application of signals can increase total delay if delay to through vehicles is increased more than delay to driveway vehicles is decreased.

Design and Operational Considerations

The installation of traffic signals at high-volume driveways is similar to that at intersections. Sufficient space is needed for installation and the geometrics of the highway approaches should permit drivers an adequate continuous view of the signal faces. Other geometric controls that should be met are as follows:

1. A minimum of two signal faces should be displayed to through traffic.

2. Unless physically impractical, at least one and preferably both of the signal faces should be located 40 to 120 ft beyond the stop line and within a field of view of approximately 20 degrees right and left, measured from the approach centerline at the stop bar.

3. For suspended signals, the bottom of the signal housing should be 15 to 19 ft above pavement grade at the center of the roadway. For side mounted signals, the bottom of the signal housing should be 8 to 15 ft above the sidewalk or, if none, above the pavement grade at the center of the roadway.

4. The two signal faces should be continuously visible for a distance calculated by the formula:

$$D = 100 + 15\,(V-20)$$

where

D = feet

V = 85 percentile speed in mph

5. Signal supports should be located as far as practical from the edge of the traveled way. As a minimum, they should be 2 ft behind the curb line or, where there is no curb, 2 ft beyond the edge of the usable shoulder.

6. Signals should be spaced at least 1,500 ft apart.

The kind of signal, the cycle duration, and the number of phases depend on traffic volumes and site conditions. However, because commercial driveways usually experience traffic operations for 12 hr or less during the day, and because driveway traffic volumes fluctuate considerably over short periods, fully- or semi-actuated signals should normally be considered. Phasing alternatives are 2- and 3-phase operation for single driveway (3-leg) locations and 2-, 3-, and 4-phase operation for opposing driveway (4-leg) locations.

Warrants

Applicable warrants (MUTCD) for signal installation at commercial driveways include consideration of traffic volumes and accident frequency.

The Minimum Vehicular Volume warrant is intended for application where the volume of intersecting traffic is the principal reason for consideration of signal installation. The warrant is satisfied when, for each of any 8 hr of an average day, the traffic volumes on the highway and on the driveway exceed those given in Table A-4.1.

TABLE A-4.1

MINIMUM VEHICULAR VOLUME WARRANT FOR A TRAFFIC SIGNAL

Number of Lanes for Moving Traffic on Each Approach		Vehicles Per Hour Major Street (Total of Both Approaches)	Vehicles Per Hour on Driveway (one direction only)
Major Street	Driveway		
1	1	500	150
2 or More	1	600	150
2 or More	2 or More	600	200
1	2 or More	500	200

(TECHNIQUE A-4)

The Interruption of Continuous Flow warrant applies when traffic volume on the highway is so heavy that traffic on the driveway suffers excessive delay or hazard. The warrant is satisfied when, for each of any 8 hr of an average day, the traffic volume on the highway and on the driveway exceed those given in Table A-4.2.

TABLE A-4.2

INTERRUPTION OF CONTINUOUS FLOW WARRANT FOR A TRAFFIC SIGNAL

Number of Lanes for Moving Traffic on Each Approach: Major Street	Driveway	Vehicles Per Hour on Major Street (Total of Both Approaches)	Vehicles Per Hour on Higher-Volume Minor-Street Approach (One Direction Only)
1	1	750	75
2 or More	1	900	75
2 or More	2 or More	900	100
1	2 or More	750	100

Frequency of accident occurrence is sometimes a warrant for signal installation. Typical warrants are as follows:

1. An adequate trial of less restrictive remedies has failed to reduce the accident frequency;

2. Five or more reported accidents, of types susceptible of correction by traffic signal control, have occurred within a 12-month period, each accident involving personal injury or property damage to an apparent extent of $100 or more;

3. There exists a volume of vehicular and pedestrian traffic not less than 80% of the requirements specified either in the minimum vehicular volume warrant, the interruption of continuous traffic warrant, or the minimum pedestrian volume warrant; and

4. The signal installation will not seriously disrupt progressive traffic flow.

Costs

The direct cost for installing signals was estimated for two kinds of signal control; a three-phase semi-actuated installation and a two-phase pre-timed installation. These costs are $30,000 for the three-phase installation and $15,000 for the two-phase installation.

Measures of Effectiveness

Because of many conflicting reports, no specific conclusions on the effect of traffic signals on accidents can be offered. Some general comments are possible, however.

For example, high-volume intersections with frequent accidents generally exhibit a noticeable accident decrease when signalized. On the other hand, low traffic volume intersections will usually show an increase in accidents. In general, signals tend to reduce right-angle collisions and increase rear-end collisions. Average accident severity will often decrease with signalization.

A general estimate of accident reduction at higher-volume driveway due to signalization was made based on the assumption that the percentage reduction in accidents is equivalent to the reduction of conflict points. These reduction ratios are 4/9 for two-phase operation; 2/3 for three-phase operation. Tables A-4.3 and A-4.4 show the estimated accident reductions.

TABLE A-4.3

EXPECTED ANNUAL ACCIDENT REDUCTIONS BY SIGNALIZING (TWO-PHASE) COMMERCIAL DRIVEWAYS (THREE-WAY)

DRIVEWAY ADT (Vehicles per Day)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 500	0.12	0.20	0.28
MEDIUM	500-1500	0.28	0.49	0.67
HIGH	> 1500	0.43	0.76	1.02

TABLE A-4.4

EXPECTED ANNUAL ACCIDENT REDUCTIONS BY SIGNALIZING (THREE-PHASE) COMMERCIAL DRIVEWAYS (THREE-WAY)

DRIVEWAY ADT (Vehicles per Day)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 500	0.17	0.30	0.42
MEDIUM	500-1500	0.42	0.74	1.00
HIGH	> 1500	0.65	1.14	1.53

Due to the many factors that can affect delay at signalized intersections, no attempt was made to predict reductions in delay for driveway vehicles. To be effective, however, this delay reduction must exceed the increased delay to through vehicles. Table A-4.5 shows the total expected increase in travel time per day for through traffic.

TABLE A-4.5

INCREASE IN HIGHWAY TRAVEL TIME (HR) PER YEAR BY ADDING SIGNALS

DRIVEWAY ADT (Vehicles per Day)	HIGHWAY ADT (Vehicles per Day)		
	LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW < 500	358	3,975	15,735
MEDIUM 500-1500	358	3,975	15,735
HIGH > 1500	358	3,975	15,735

Evaluation and Comparison

Because no specific evaluation of delay was possible, the benefit/cost ratios for signals were computed based on accident reduction alone. These ratios are shown in Tables A-4.6 and A-4.7.

TABLE A-4.6

BENEFIT/COST RATIOS FOR TWO-PHASE SIGNALS

DRIVEWAY ADT (Vehicles per Day)	HIGHWAY ADT (Vehicles per Day)		
	LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW < 500	–	–	–
MEDIUM 500-1500	–	1.0	1.3
HIGH > 1500	–	1.5	2.1

TABLE A-4.7

BENEFIT/COST RATIOS FOR THREE-PHASE SIGNALS

DRIVEWAY ADT (Vehicles per Day)	HIGHWAY ADT (Vehicles per Day)		
	LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW < 500	-	-	-
MEDIUM 500-1500	-	-	1.2
HIGH > 1500	-	1.3	1.7

In general, traffic signals appear to be of marginal benefit relative to their cost. For this reason all feasible alternatives should be considered before making a decision to install signals.

A-5: CHANNELIZE MEDIAN OPENINGS TO PREVENT LEFT-TURN INGRESS AND/OR EGRESS MANEUVERS

This median technique directly controls access on highways by preventing left-turn ingress and/or egress maneuvers. The left-turn maneuvers are restricted by channelizing the medians on divided highways to physically prevent vehicles from crossing.

The technique reduces the frequency of total conflicts by reducing the basic conflict points from nine to five when eliminating either left-turn ingress or egress maneuvers, and from nine to two when eliminating both left-turn maneuvers at driveways. In particular, this measure eliminates the more severe crossing conflict points caused by left-turn ingress or egress movements. However, the maximum reduction in the frequency of conflicts is moderated by increases in right-turn maneuvers and other indirect left-turns which are accomplished through circuitous paths. Figure A-5.1 shows this technique as it appears in actual field situations.

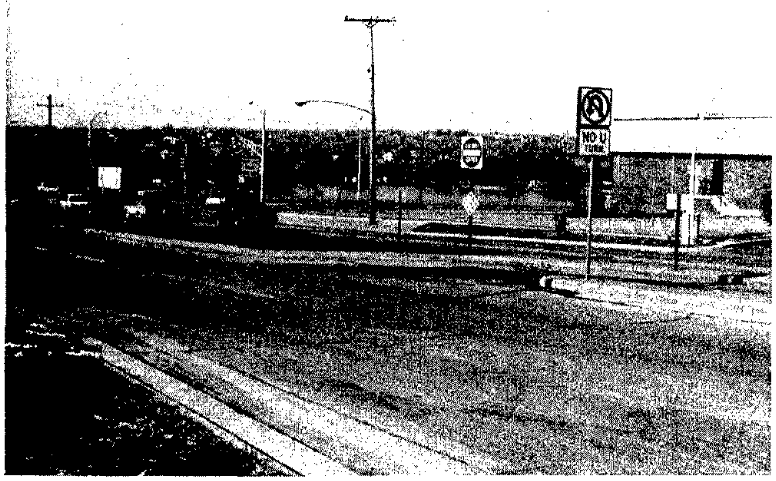


Figure A-5.1 - Channelized Median Opening to Prevent Left-Turn Egress Maneuvers

Design and Operational Considerations

This access control technique is applicable at median openings on divided highways. Generally, the application depends on the site conditions and the need for restriction of left-turn movements. Three cases are considered for the geometric design of this technique.

In the first case, where left-turn egress maneuvers are eliminated, the median will be extended to physically prevent these maneuvers. This condition is common on divided highways with left-turn deceleration lanes at major driveways. The median width must be 14 ft or greater. Figure A-5.2 shows the dimensional requirements for this condition.

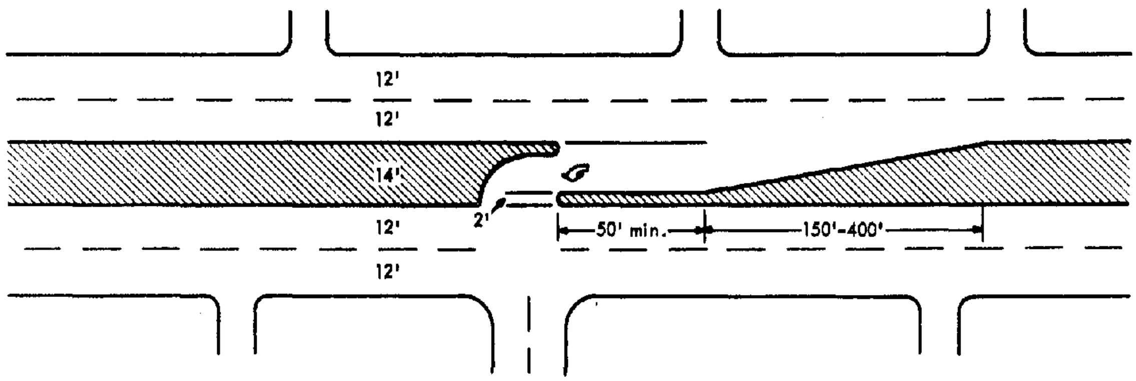


Figure A-5.2 - Highway Medial Channelization to Restrict Left-Turn Egress Vehicles

For the second case, where left-turn ingress maneuvers are restricted, the median will be channelized to prevent ingress vehicles from crossing the median. This condition is generally associated with divided highways having a median opening at the driveway. Usually, deceleration lanes are not provided at these locations and therefore the median width could be as narrow as 4 ft. Figure A-5.3 illustrates this option.

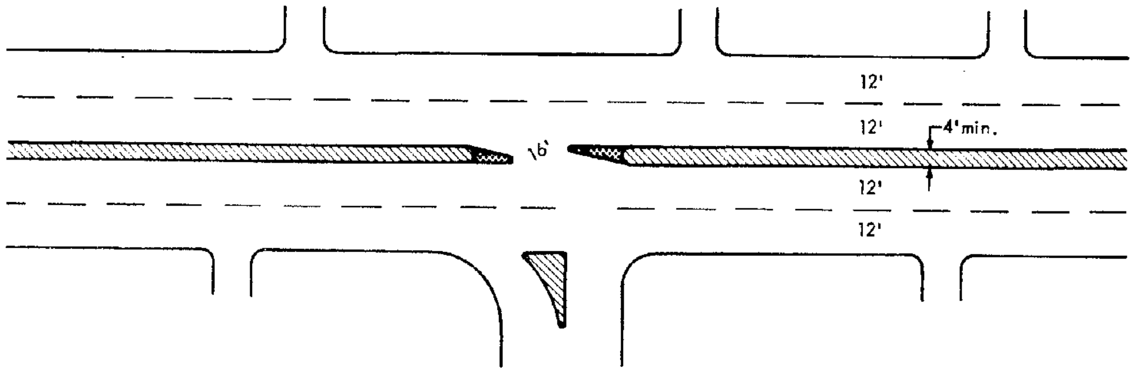


Figure A-5.3 - Highway Medial Channelization to Restrict Left-Turn Ingress Vehicles

For the third case, where both egress and ingress left-turns are prevented, the median opening is closed. Usually, this condition is common to divided highways with narrow medians. Figure A-5.4 shows this application.

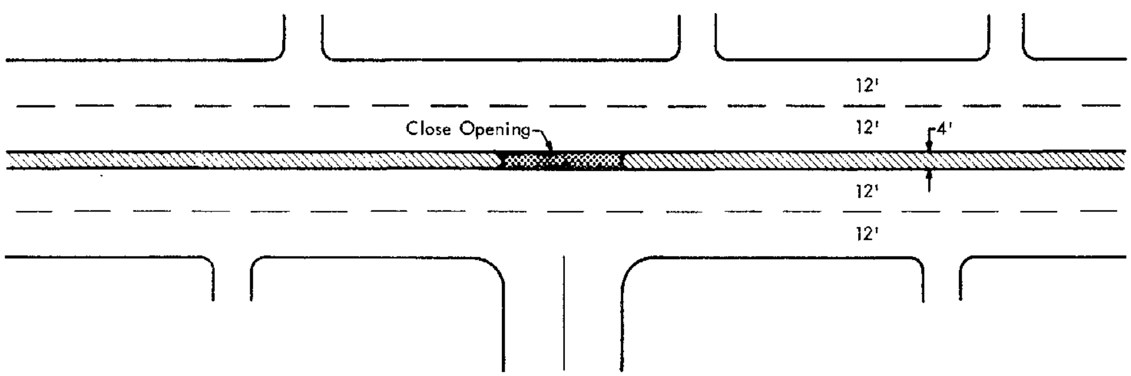


Figure A-5.4 - Median Opening Closure to Restrict Ingress and Egress Vehicles

As shown in Figures A-5.2 and A-5.3, the operational objective of this technique are enhanced by proper driveway channelization. If these islands are properly aligned with the median opening, the intended driveway operations should result.

The restriction of certain turns on highways and/or driveways will cause vehicles to use circuitous routes to obtain the desired maneuver. This operational change must be evaluated within the realm of the total traffic circulation pattern to insure the adequacy of other geometric design elements.

Warrants

This technique is warranted on multilane divided highways with speeds of 30-45 mph, ADTs greater than 5,000 vpd, and levels of development greater than 30 driveways per mile. In particular, it is warranted at driveways where safety problems are caused by a small number of left-turn maneuvers. The prohibited turns should not exceed 100 vpd. Also, this technique may be justified at sites that meet the accident warrants (see Appendix B, Table B-II).

Costs

The direct costs of implementing this technique are associated with specific site conditions and the type of movements restricted. These costs should not vary substantially from site to site when preventing either ingress or egress maneuvers. The cost of closing a median opening, however, is higher because it involves a larger area of improvement. The costs for restricting left-turn egress maneuvers and left-turn ingress maneuvers are estimated at $1,140 and $980, respectively. The closing of a median opening is estimated to cost $1,260. These costs include curbing, surfacing, and signing.

Measures of Effectiveness

The literature indicates that 70% of driveway accidents involve left-turn maneuvers. Of these accidents, 43% are left-turn ingress maneuvers and 27% are left-turn egress maneuvers. This information was used to predict the reduction in accidents at commercial driveways when implementing this technique.

Because the application of this technique is limited to driveways where left-turn maneuvers constitute a small percentage of the ADT, the elimination of left-turn maneuvers is expected to cause less reduction in total accidents than the percentages stated above. Instead, the elimination of both left-turn maneuvers is estimated to effect a 50% reduction in accidents at the driveway. Eliminating left-turn ingress maneuvers is assumed to decrease total accidents by 30% and eliminating left-turn egress maneuvers is expected to result in a 20% reduction in total accidents.

Using the predicted commercial driveway accident values, developed in the operational evaluation, Tables A-5.1, A-5.2 and A-5.3 were developed and list the predicted reductions in annual driveway accidents for each individual design.

TABLE A-5.1

ANNUAL ACCIDENT REDUCTIONS PER DRIVEWAY FOR RESTRICTING LEFT-TURN EGRESS MANEUVERS

DRIVEWAY ADT (Vehicles per Day)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 500	0.05	0.09	0.12
MEDIUM	500-1500	0.13	0.22	0.30
HIGH	> 1500	0.19	0.34	0.46

TABLE A-5.2

ANNUAL ACCIDENT REDUCTIONS PER DRIVEWAY FOR RESTRICTING LEFT-TURN INGRESS MANEUVERS

DRIVEWAY ADT (Vehicles per Day)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 500	0.08	0.14	0.19
MEDIUM	500-1500	0.19	0.33	0.45
HIGH	> 1500	0.29	0.51	0.69

TABLE A-5.3

ANNUAL ACCIDENT REDUCTIONS PER DRIVEWAY FOR RESTRICTING BOTH LEFT-TURN ENTERING AND EXITING MANEUVERS

DRIVEWAY ADT (Vehicles per Day)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 500	0.13	0.23	0.31
MEDIUM	500-1500	0.31	0.55	0.75
HIGH	> 1500	0.49	0.85	1.15

The total delay to vehicles denied the opportunity to turn at these driveways is not significant, because these vehicles represent a small portion of the total ADT. Also, speed on the highway is expected to increase and thereby decrease the delay for through vehicles. Therefore, the net change in total delay is negligible.

Evaluation and Comparison

Benefit/cost ratios for restricting left-turns, are shown for the three construction options in Tables A-5.4, A-5.5 and A-5.6. Evident from these tables is that this access control measure is cost-effective for all volume combinations. This technique compares favorably with other access control techniques dealing with median treatment to restrict left-turn maneuvers.

TABLE A-5.4

BENEFIT/COST RATIOS FOR RESTRICTING LEFT-TURN EGRESS MANEUVERS FROM A DRIVEWAY

DRIVEWAY ADT (Vehicles per Day)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 500	1.2	2.2	3.0
MEDIUM	500-1500	3.2	5.5	7.4
HIGH	> 1500	4.7	8.4	11.0

TABLE A-5.5

BENEFIT/COST RATIOS FOR RESTRICTING LEFT-TURN INGRESS MANEUVERS TO A DRIVEWAY

DRIVEWAY ADT (Vehicles per Day)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 500	2.0	3.5	4.7
MEDIUM	500-1500	4.7	8.2	11.0
HIGH	> 1500	7.3	13.0	17.0

TABLE A-5.6

BENEFIT/COST RATIOS FOR RESTRICTING LEFT-TURN MANEUVERS OF A DRIVEWAY

DRIVEWAY ADT (Vehicles per Day)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 500	2.6	4.7	6.3
MEDIUM	500-1500	6.3	11.0	15.0
HIGH	> 1500	9.9	17.0	23.0

A-6: WIDEN RIGHT THROUGH-LANE TO LIMIT RIGHT-TURN ENCROACHMENTS ONTO THE ADJACENT LANE TO THE LEFT

The physical widening of a right through-lane is intended to reduce the frequency of right-turn encroachment conflicts (sideswipe) on an arterial with narrow lanes and frequent driveways with inadequate approach width. Encroachment conflicts occur when right-turning driveway vehicles swing into the path of another vehicle in the adjacent lane to the left.

Widening a narrow right through-lane necessarily helps to improve the traffic operations. By increasing the lane width, the effects of stream and marginal friction are reduced. This is likely to result in increased travel speeds. The increased lane width should also effect an increase in right-turn enter driveway speeds. Also, the Highway Capacity Manual relates a 19% increase in capacity for a 12-ft lane over a 10-ft lane for uninterrupted flow conditions. Benefits in safety should be realized because of a reduction in encroachment conflicts and rear-end conflicts for right-turn entrance maneuvers.

This technique is desirable for widening the entire length of a section between two successive major driveways or intersections.

Design and Operational Considerations

The application of this technique is appropriate on urban arterial highways. On multilane divided highways with sufficient median width, no additional right-of-way is needed for the pavement widening. Conversely, many undivided highways will require additional right-of-way taking.

Sufficient lane widths for urban arterial highways are 11-13 ft. These lane widths are considered adequate in most cases to insure proper operations. Lane widths in excess of 14 ft for through movements are discouraged because some drivers will interpret the wide lane as two narrow lanes and they will drive accordingly.

Care must be taken in the construction stage to correctly splice the new section to the old pavement. Any reinforcing steel extending from the edge of the old pavement should be straightened and anchored to the widened pavement section. If a poor splice is made, a rugged seam of contrasting pavement will result. In many instances, drivers on the section will either remain on the old pavement or straddle the splice line, slowing down to keep abreast of the splice. Widening could be included in a resurfacing project if right-turn encroachment conflicts are causing problems. The resurfacing would also alleviate the problems associated with the splice.

Warrants

Since encroachment conflicts, due to right-turning driveway vehicles are the problem to be addressed with this technique, a level of development of 20 driveways is the major warranting condition. Traffic volume should exceed 5,000 vpd, and right-turn driveway entrance volume per mile should exceed 100 vehicles during the peak hour. Also, highway speeds should exceed 30 mph. This technique is also warranted where high accident rates indicate that a right-turn encroachment problem exists (see Appendix B, Table B-III).

Multiple driveways with narrow approach widths that only allow minimum turning speeds also warrant consideration of this technique.

Costs

Cost estimates for this technique are based on a 1-mile section of highway with 32 commercial driveways on the side that is widened 3 ft. Two site conditions are considered. The first consists of highway widening only. The construction items and their estimated costs are: pavement ($35,200), curb and gutter ($35,200), driveway patchbacks ($12,800), and relocation of roadside structures ($10,000). These costs result in a total cost for the first site condition of $93,200.

The second site condition consists of acquiring additional right-of-way for the highway widening. The cost estimate for right-of-way acquisition is $47,600. Adding this cost to the basic construction cost of $93,200 results in a total cost for the second site condition of $140,800.

Measures of Effectiveness

No effects on accidents or delay were found in the literature. It is likely, however, that some marginal effectiveness will result. A 2% reduction in total accidents has been estimated after implementation of this technique. The following table lists the estimated annual accident reductions per mile after implementation.

TABLE A-6.1

ANNUAL ACCIDENT REDUCTIONS PER MILE BY WIDENING RIGHT THROUGH-LANE

LEVEL OF DEVELOPMENT (Driveways per Mile)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 30	0.25	0.50	0.76
MEDIUM	30-60	0.40	0.79	1.20
HIGH	> 60	0.55	1.09	1.63

Evaluation and Comparison

Using a 2% reduction in total accidents and the cost estimates for both site conditions, this technique is found not cost-beneficial for any level of development and highway volume. Some reduction in travel time could possibly change some of the benefit/cost ratios to show a marginal benefit.

One option for this technique that is cost-beneficial is restriping an existing multilane highway to allow greater right-lane widths. However, no lane widths should be reduced to less than 11 ft.

A-7: INSTALL CHANNELIZING ISLAND TO PREVENT LEFT-TURN DECELERATION LANE VEHICLES FROM RETURNING TO THROUGH LANES

The installation of a channelizing island between a through and a left-turn lane can be applied on divided urban highways where encroachment problems between through and left-turning vehicles exist. The channelizing island will eliminate sideswipe conflicts between vehicles in the two adjacent lanes. An increase in the number of single-vehicle mishaps, however, may occur due to through vehicles striking the island. Figure A-7.1 illustrates the technique.

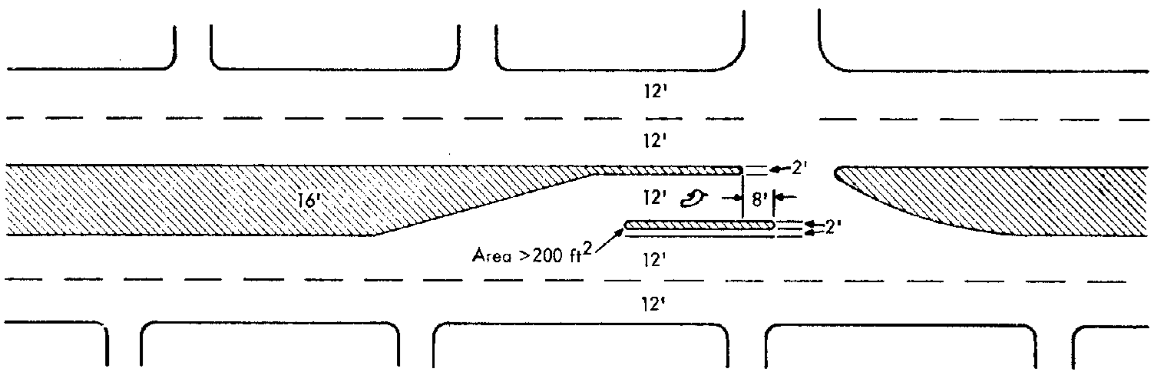


Figure A-7.1 - Channelizing Island to Prevent Left-Turn Deceleration Lane Vehicles from Returning to Through Lanes

Design and Operational Considerations

Medians whose widths are greater than 16 ft are suitable for the application of this technique. Also, lane-widening projects should be considered as candidates for this technique, as the extra width for the island can be designed into the project.

A full lane width of 12 ft should be maintained on all through and turning lanes. In addition, a safety area of 2 ft should be provided between the island edge and the nearest through lane to separate the island from the through driver's line of sight, thus delineating the correct through path. The 2-ft safety area may be discarded if space dictates. However, it is expected that conflicts between through vehicles and the island will occur if this omission is made.

Since no right-angle movements across the island are expected, a 2-ft island width will adequately separate the traffic streams while using a minimal amount of the pavement width, the minimum island area is 200 sq ft. This area is large enough to command driver attention.

The island is placed so its beginning is about 25 ft downstream from the initial point of full left-turn lane width. The island should be terminated so that 6-8 ft of island extends into the intersection. This extension is needed to deter drivers from re-entering the through lanes once they have been committed to the deceleration lane. The extension is long enough to discourage the merge movement, but does not constrain the turning paths of vehicles exiting from the driveway.

Warrants

This technique is warranted on divided highways with greater than 10,000 vpd and at driveways with greater than 50 left-turn ingress vehicles during the peak hour. The site should be characterized by a history of encroachment conflicts due to left-turn vehicles re-entering the through lanes.

Costs

The direct cost of implementing this technique on existing medians is estimated at $1,600. This cost would be somewhat less when the technique is used in conjunction with new median construction.

Measures of Effectiveness

No literature was found on the operational effectiveness of this technique. However, it is felt that some reduction in encroachment conflicts can be realized by implementing the technique. This reduction should be greater than the increase in single-vehicle conflicts with the installed island.

Evaluation and Comparison

On a cost-benefit basis, this technique probably cannot be justified at existing left-turn lanes unless a sideswipe accident history is apparent. But, since it is a low-cost remedy, the island can be justified for high-volume left-turn locations when new median construction is undertaken.

A-8: INSTALL PHYSICAL BARRIER TO PREVENT UNCONTROLLED ACCESS ALONG PROPERTY FRONTAGES

The installation of a physical barrier along a single property or many adjacent frontages is a design technique for controlling access on all kinds of highways. The control of access can be accomplished by erecting fences, barriers, plantings, or curbs adjacent to the roadway or shoulder. Possibilities exist for the construction of rock walls, rail fences, or other structures that are compatible with the aesthetics of the area. Curbing, however, is the most common method.

This design technique reduces the total area of conflict by controlling and defining driveway openings. The frequency of conflicts is reduced because the number of possible conflict points is limited to the defined driveway openings.

Design and Operational Considerations

The candidate locations for this technique are characterized by commercial parking areas, flat graded to the highway, with no physical distinction between the two areas as shown in Figure A-8.1.

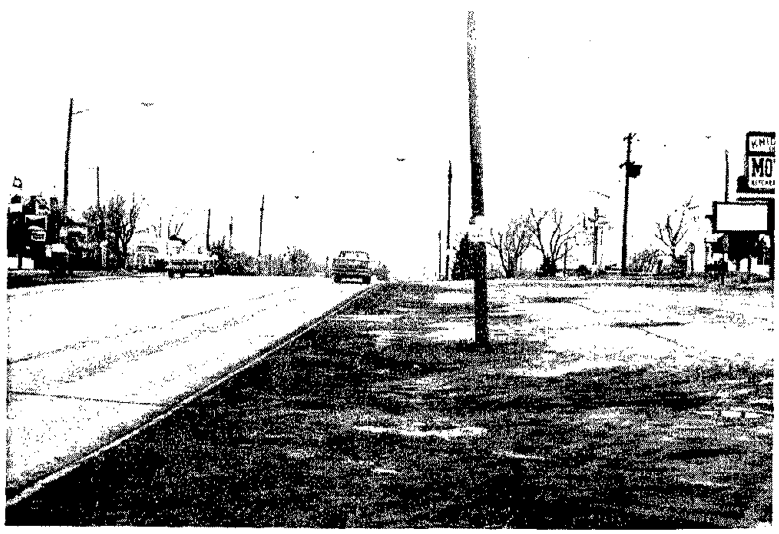


Figure A-8.1

The barrier can be easily constructed adjacent to the pavement leaving all through lanes unaffected. This technique should always be considered when a highway is to be widened. The effectiveness of other techniques can be enhanced by including this inexpensive remedy to open access in the overall construction plan.

Warrants

This technique is warranted on all highways where open access exists and where the highway ADT exceeds 10,000 vpd.

Where open access highways exist, this technique is warranted when the highway ADT exceeds 10,000 vpd and the level of development is greater than 45 driveways per mile. For consideration at single properties only, total driveway ADT should exceed 500 vpd. High accident rates involving the open access situation will also warrant this technique (see Appendix B, Table B-I).

Costs

The direct cost of implementing this technique is not closely tied to specific site conditions. For a 1-mile section, where a barrier curb is installed along both sides of the roadway, the estimated cost is $72,000. No detrimental impact on the area's business activity is expected.

Measures of Effectiveness

For a general evaluation of this technique, accident reductions were estimated for three levels of development and three ranges of highway ADT. Available information indicates that an annual reduction of 0.4 accidents per driveway may be realized when access is controlled by this technique. This accident reduction is most representative for medium- and high-volume driveways located on medium- and high-volume highways, as indicated in Table A-8.1.

TABLE A-8.1

ANNUAL ACCIDENT REDUCTION BY INSTALLING
A PHYSICAL BARRIER AT A COMMERCIAL DRIVEWAY
TO PREVENT UNCONTROLLED ACCESS

LEVEL OF DEVELOPMENT (Driveways per Mile)	HIGHWAY ADT (Vehicles per Day)		
	LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW <30	-	-	-
MEDIUM 30-60	-	0.4	0.4
HIGH >60	-	0.4	0.4

Evaluation and Comparison

The previously detailed direct costs and measures of effectiveness were used to predict the probable benefit-cost ratio of this technique. Table A-8.2 shows the benefit-cost ratios for different levels of development and ranges of ADT. As can be seen, the effectiveness of this technique is expected to be constant for the warranted levels of development and highway volumes.

TABLE A-8.2

BENEFIT-COST RATIOS FOR TECHNIQUE A-8

LEVEL OF DEVELOPMENT (Driveways per Mile)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 30	-	-	-
MEDIUM	30-60	-	1.6	1.6
HIGH	> 60	-	1.6	1.6

A-9: INSTALL MEDIAN CHANNELIZATION TO CONTROL MERGE OF LEFT-TURN EGRESS VEHICLES

The installation of a channelizing island in a median opening will serve to control driveway access by channeling left-turning vehicles into and from the driveway. It will also effectively block vehicles from re-entering the through lanes once they have been committed to a left-turn lane. Figure A-9.1 illustrates the technique.

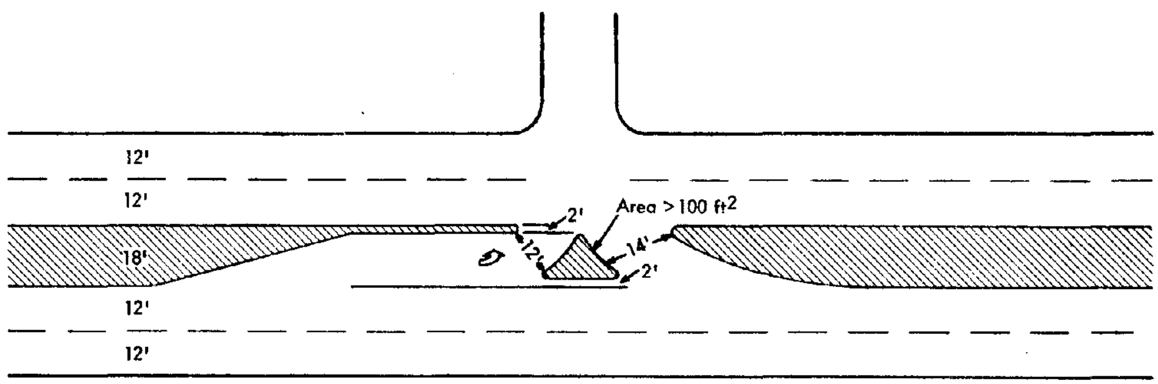


Figure A-9.1 - Channelization to Control Left-Turn Egress

This technique should reduce the frequency of conflicts associated with left-turn egress vehicles because it reduces the total area of the merge conflict. In addition, it forces the left-turn vehicle to merge at a relatively flat angle, thereby minimizing the speed differential with through vehicles.

Design and Operational Considerations

This technique is applicable on all multilane divided highways with median widths greater than 18 ft. The island should be shaped and located to avoid confusing the drivers who use the driveway. Island areas of greater than 100 sq ft should be considered, since the island must command driver attention and action.

The island is offset from the through lane by a 2-ft safety area. The safety area will optically clarify the through vehicles' path. The safety area may be omitted if space dictates. However, single-vehicle conflicts with the island will increase if such an omission is made.

Care must be taken to design and construct the turning channels so that bottle-necks do not occur. A full turning lane width of at least 14 ft must be maintained between the island and the median end. Truck turning movements and dimensions will require greater lane widths. The island should conform to standards recommended by AASHTO.

Since an island is a low profile structure, vehicles will strike it just as they strike medians. Also, extremely large channelizing islands may completely block a line of sight through the median. It is important that the driveway driver has a line of sight through the median. Confusion, wrong turns, delays, and conflicts will occur if the driver cannot see where he should go in order to enter the channelized lane.

Warrants

This technique is warranted on divided highways with greater than 10,000 vpd and at driveways with greater than 50 left-turn egress vehicles during the peak hour. The site should be characterized by a history of merge conflicts associated with left-turn egress vehicles.

Costs

The cost of constructing the island is dependent on the island size. The minimum sized island will cost an estimated $460.

Measures of Effectiveness

No effects on accidents and delays for this technique were found in the literature. It is likely that a small reduction in accidents will result because of the improved shadowing of left-turn egress vehicles. Conflicts between vehicles making simultaneous left-turns in and from the driveway should also decline. On the other hand, single-vehicle encroachments with the island are expected to occur. No numerical values for the anticipated increases and decreases have been formulated.

Evaluation and Comparison

Since no value for benefits was found for this technique, benefit-cost ratios were not calculated. The low cost of construction, however, will yield a relatively high benefit-cost ratio if any accident reduction can be expected. Also, the island can undoubtedly be justified for high-volume left-turn locations where new median construction is undertaken.

A-10: REGULATE HIGHWAY SPEED LIMIT CONSISTENT WITH DRIVEWAY OPERATIONS

The implementation of reduced speed limits aims at limiting the maximum deceleration requirements of highway vehicles. Highway speeds naturally affect traffic operations on the highway and also on the commercial driveways. Of major consideration to the optimum traffic operation on both highways and driveways is the speed differential between turning and through vehicles. Often a large speed differential between through vehicles and turning vehicles is a major cause of accidents.

Design and Operational Considerations

Solomon[1/] had shown a correlation between the incidence of rear-end, two-car accidents and speed differentials on rural highways, which indicates a significant increase in accident potential with speed differentials above 10 mph. However, a speed differential of 10 mph is frequently impractical. Consequently, driveway entrance speeds should be designed as high as practical depending on the specific conditions and location.

For driveway exit maneuvers, an acceptable traffic gap must exist for a vehicle to safely enter a through lane. Naturally, higher roadway speeds demand larger minimum traffic gaps. This gap should include sufficient distance for the approaching vehicle to decelerate to avoid a turning vehicle. Low speed differentials will allow for fewer critical decisions to be made by both drivers.

Warrants

This traffic control measure is only used because of safety considerations. The technique is applicable on all types of highways where, because of restrictive driveway approach widths, existing speed differentials between through and turning vehicles are critical. The level of development should exceed 60 driveways per mile and daily traffic volume should exceed 10,000. Right-turn driveway maneuvers should exceed

1/ Solomon, David, Accidents on Main Rural Highways Related to Speed, Driver and Vehicle. BPR (July 1964).

1,000 per mile during peak periods, and highway speeds should exceed 35 mph.

Costs

Only one cost option has been considered in the implementation of this technique. Three signs per mile on each side of the road were estimated at a total cost of $300.

Measures of Effectiveness

Although regulating highway speed limits should result in reductions in the frequency and severity of accidents, it is difficult to predict whether these reductions will be realized at most locations. Also, because of the speed reduction the negative benefit of increased travel time results. Therefore, total benefits may be nominal.

Evaluation and Comparison

If, for particular warranting conditions, safety were given priority over traffic service, this technique could be considered cost-beneficial. However, the technique should only be used as the last resort. Techniques that increase driveway turning speeds and those that increase driver perception time should be given prior consideration.

A-11: INSTALL TRAFFIC SIGNALS TO SLOW HIGHWAY SPEEDS AND METER TRAFFIC FOR LARGER GAPS

The size of traffic gaps on the arterial is an important factor influencing traffic flow and driver behavior. The installation of additional traffic signals at intersections or major driveways is an operational technique that helps create sufficient traffic gaps and allows driveway vehicles the appropriate use of these gaps. Closely-spaced traffic signals will also tend to slow and regulate highway speeds, which will lessen the speed differential between through vehicles and driveway vehicles. Less time and distance will be necessary for deceleration of through vehicles that conflict with turning vehicles (see Technique A-10 for further detail).

Larger gaps and slower speeds reduce the severity of conflicts between merging and diverging streams of traffic. Also, some reductions in delay to driveway vehicles is expected. The major trade-off associated with this technique is the increased delay to through vehicles.

Design and Operational Considerations

This traffic control measure is used mainly for safety considerations. In applying the technique, signal spacing and timing are the two most important factors. Signal spacing of about 1/4 mile is needed to effect frequent large gaps. Signal timing will depend on site-specific conditions, but requires enough stop time on the mainline to effect sizable gaps. Also, coordination in timing of adjacent signals is necessary to allow simultaneous gaps in both directions for left-turns at intermediate driveways with moderate to high left-turn volume.

Warrants

This technique is applicable on all types of highways where, because of the lack of adequate gaps for driveway vehicles, speed differentials between through and turning vehicles are critical. The level of development should exceed 60 driveways per mile, and the ADT should exceed 10,000 vehicles. Driveway exit maneuvers should exceed 2,000 per mile during peak periods, and highway speeds should exceed 30 mph.

Costs

The direct cost of signalizing a section of highway is a function of the number and type of signals. For individual signal installations the estimated cost is $15,000 for a two-phase pre-timed installation.

Measures of Effectiveness

Measures of effectiveness are difficult to predict because of the wide variety of combinations of site conditions and specific solutions. Also, although some safety and driveway delay benefits should accrue, the increased delay to through vehicle will probably offset these benefits.

Evaluation and Comparison

If, for a particular warranting condition, safety and reduced driveway delay were given priority over highway traffic service, this technique could be considered cost-beneficial. However, all other techniques that decrease speed differentials or increase driver perception time should be given prior consideration.

A-12: RESTRICT PARKING ON THE ROADWAY NEXT TO DRIVEWAYS TO INCREASE DRIVEWAY TURNING SPEEDS

This technique increases the turning speed by removing constraining obstacles, specifically parked vehicles, from areas adjacent to driveways. Parked vehicles may indirectly contribute to driveway accidents by limiting the sight distance or influencing the turning paths of driveway vehicles. This technique is intended as a point measure, although route applications are also feasible. Figure A-12.1 shows a location where parking restrictions may be desirable.

Figure A-12.1 - Candidate Location for Parking Restriction

This technique will reduce the severity and frequency of conflicts by removing, and merging, driveway vehicles at higher speeds. Severity is reduced because the speed differential between turning and through vehicles is reduced. Conflict frequency also benefits from the increase in turning velocity. One possible trade-off that accompanies this technique is a reduction in parking capacity.

Design and Operational Considerations

The banning of parking next to the driveway should allow an additional 8-10 ft in roadway width available for a turning approach. The evacuated parking lane width can be considered as an offset distance, from the curb to the point from which a vehicle will begin a right-turn entry into a driveway. The larger the offset distance is, the faster the vehicle will be able to enter and exit the driveway.

However, the effect of the offset distance on turning speed will be lessened if a vehicle enters the vacated parking lane before starting to turn into the driveway. The turning vehicle should remain in the through lane until the driveway entrance maneuver is started. This can be accomplished by placing a practical maximum on the length of the parking restriction.

There are two advantages to including this length of restricted parking. First, the extra distance will enable more space to visually cue the driveway opening, and second, it will enable more clearance between the turning vehicle and the vehicles allowed to park in the remaining parking lane. A suggested clearance distance is 10 ft.

Figure A-12.2 shows a recommended design for this technique. The distance between no parking zones depends on the driveway width and curb return radii.

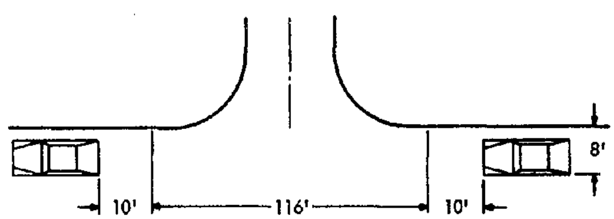


Figure A-12.2 - Recommended Parking Restriction Adjacent to Driveway Openings

Warrants

This technique is warranted at any driveway location where parked vehicles cause excessively slow turning speeds resulting in rear-end conflicts between right-turning and through vehicles. All highway and driveway ADT ranges, and all levels of development will benefit from this technique's application.

Costs

The estimated cost for implementing this technique will be equal for all site conditions. Two no-parking signs per driveway will be required at each site; costing about $100.

Measures of Effectiveness

In evaluating the effect on accidents by restricting parking next to driveways, a 20% reduction in right-turn accidents was assumed. Box[1/] has found that right-turn driveway maneuvers comprise 30% of total driveway accidents. Therefore, a net reduction of 6% in total driveway accidents is expected by implementing this technique. Table A-12.1 lists the expected annual accident reduction after implementing this technique.

Increasing the turning speed of driveway vehicles should affect delay to through vehicles. For this technique, the yearly time savings of increasing the driveway turning speed, from 5 mph to 15 mph, has been calculated. In that delay reduction calculation, the estimated delays for turning speeds of 5 and 15 mph were applied to the driveway and highway ADTs. The results of the delay analysis appear in Table A-12.2.

1/ Box, Paul C., "Driveway Accident Studies, Major Traffic Routes, Skokie, Illinois," unpublished (1968).

TABLE A-12.1

ANNUAL ACCIDENT REDUCTION BY RESTRICTING PARKING NEXT TO DRIVEWAYS

DRIVEWAY ADT (Vehicles per Day)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 500	0.016	0.027	0.037
MEDIUM	500-1500	0.038	0.066	0.090
HIGH	> 1500	0.058	0.102	0.138

TABLE A-12.2

ANNUAL DECREASE IN DELAY (HR) BY INCREASING THE DRIVEWAY ENTRANCE SPEED FROM 5 TO 15 MPH

DRIVEWAY ADT (Vehicles per Day)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 500	-	22.8	30.4
MEDIUM	500-1500	-	91.2	121.6
HIGH	> 1500	-	182.4	243.2

Evaluation and Comparison

The cost-effectiveness of this technique has been calculated using the estimated reductions in accidents and delays, and the estimated implementation cost. Table A-12.3 lists the benefit/cost ratios for all combinations of driveway ADT and highway ADT.

As evidenced by the high benefit/cost ratios, this technique should be implemented wherever possible. This technique will be especially effective if it is applied along with other driveway design techniques.

TABLE A-12.3

BENEFIT/COST RATIOS FOR RESTRICTING PARKING NEXT TO DRIVEWAYS

DRIVEWAY ADT (Vehicles per Day)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 500	5	20	27
MEDIUM	500-1500	12	66	89
HIGH	> 1500	18	123	164

A-13: INSTALL VISUAL CUES OF THE DRIVEWAY

Adequate sight distance and visual realization of the driveway location are very important factors to the safe and efficient operation of driveways and highways. Many existing driveways, however, lack adequate visual cues and are the scene of many vehicular and pedestrian conflicts. Figure A-13.1 shows an isolated driveway with inadequate sight distance.

Figure A-13.1 - Driveway with Restricted Sight Distance

Visual cues of driveways serve to limit maximum deceleration requirements of highway vehicles by increasing driver perception time. Consequently, the severity of conflicts should be lessened. Rear-end conflicts are expected to decrease the greatest.

Design and Operational Considerations

The installation of visual cues for driveways can be accomplished by a variety of schemes. Among these are contrasting pavements, flashing beacons, warning signs, reflectorized curbs, and driveway lighting.

Paving the driveway entrance with a contrasting pavement is an acceptable method to accent a driveway's location. During periods of peak driveway use, which generally occur during the day, the contrast will be most pronounced; however, the contrasting pavement is not visible at night.

Flashing beacons are applicable at an individual driveway or in advance of an individual driveway or a cluster of driveways. Warning signs usually complement the beacon when used as an advance warning system. Flashing beacons are generally more beneficial at locations that otherwise experience nighttime safety problems.

A suspended, red-yellow flashing beacon is a common device used at individual locations. The location is usually an isolated driveway with fairly high daily volumes. A flashing beacon used in conjunction with a warning sign as an advanced warning would most likely be where sight distance is the major problem. All flashing beacons and warning signs should conform to criteria established in the MUTCD.

A reflectorized curb is beneficial for nighttime operations. The curb can be painted bright yellow for daytime operations. Driveway illumination might also be acceptable at locations where safety problems are occuring at night. Illumination at a specific driveway would typically be used at an isolated high-volume location.

The final scheme, a vehicle detection and warning system, would usually be the most expensive to implement. These devices cause driveway vehicles to actuate a detector which illuminates a "caution" sign and/or sounds a buzzer for a preset interval. The system is principally intended as a pedestrian warning method for use at blind driveways.

The optimal solutions for particular locations could be a combination of schemes. For instance, a contrasting pavement entrance with reflectorized curbs might be practical. In this situation, both day and night operations should be enhanced.

Warrants

Since sight distance could be a major problem, any isolated driveways with intersection sight distances less than the minimum, as set up by AASHTO, would warrant this technique. A level of development of less than 30 driveways per mile and daily highway volumes of greater than 2,500 are needed. Highway speeds should exceed 35 mph.

The advance warning sign with flashing beacon would apply to isolated driveways with volumes greater than 500 vehicles per day. The red-yellow flashing beacon and driveway illumination schemes require driveway ADT's greater than 1,000. The advance warning is also warranted when high accident rates indicate localized problems (see Appendix B, Table B-I).

Costs

Three options were considered in the cost analysis. The first involves the suspended, red-yellow flashing beacon at a single location. The cost has been estimated at $3,000 which includes an overhead, three-face signal head and all necessary accessories. The advance warning sign with flashing beacon was estimated to cost $500. The last option, driveway lighting, includes a metal pole, luminaire, wiring, base and other accessories for a total cost of $2,000. These estimates include the present worth of maintenance and replacement costs for a 20-year design life.

Measures of Effectiveness

Several studies were found in the literature regarding the accident benefits of flashing beacons at driveways. These studies have shown remarkable uniformity in reductions of accidents and accident severity. The results indicated greater percentage accident reductions for low highway volumes. Representative reductions of 53% in total accidents for flashing beacons at a single driveway and 24% in total accidents for an advance warning sign and flashing beacon were selected. A factor of 0.4 was applied to the above reductions because consideration is being given to commercial driveways which normally have less nighttime traffic than do intersections.

In addition, street lighting accident studies have shown total accidents to decrease by 42%. A 0.4 adjustment factor was once again applied to the reduction.

Table A-13.1 gives annual accident reductions by using red-yellow flashing beacons at a single location, Table A-13.2 shows annual accident reductions for an advance warning sign with a flashing beacon, and Table A-13.3 furnishes annual accident reductions for illuminating a single driveway location.

TABLE A-13.1

ANNUAL ACCIDENT REDUCTION FOR A RED-YELLOW FLASHING BEACON AT A SINGLE COMMERCIAL DRIVEWAY

DRIVEWAY ADT (Vehicles per Day)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 500	0.05	0.09	0.13
MEDIUM	500-1500	0.13	0.23	0.32
HIGH	> 1500	0.20	0.36	0.48

TABLE A-13.2

ANNUAL ACCIDENT REDUCTION FOR AN ADVANCE WARNING SIGN WITH FLASHING BEACON

DRIVEWAY ADT (Vehicles per Day)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 500	0.02	0.04	0.06
MEDIUM	500-1500	0.06	0.11	0.14
HIGH	> 1500	0.09	0.16	0.22

TABLE A-13.3

ANNUAL ACCIDENT REDUCTION FOR ILLUMINATION OF A SINGLE DRIVEWAY LOCATION

DRIVEWAY ADT (Vehicles per Day)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 500	0.04	0.08	0.10
MEDIUM	500-1500	0.11	0.18	0.25
HIGH	> 1500	0.16	0.29	0.39

Evaluation and Comparison

Benefit/cost ratios were determined for the three options using the measures of effectiveness and cost estimates. As seen in Tables A-13.4 and A-13.6, the benefit-cost ratios of a suspended flashing beacon and driveway illumination are nearly the same. The measures are effective for most driveway volumes and most highway volumes.

Table A-13.5 indicates that the advance warning sign with flashing beacon is the most cost-beneficial of the three options. This measure is applicable to all driveway volumes.

Because of the low cost involved, reflectorized curbs would appear cost-effective for a nominal decrease in accidents. The remaining two schemes, contrasting pavement and a vehicle detection and warning system, would only apply under special conditions.

TABLE A-13.4

BENEFIT/COST RATIOS FOR A SUSPENDED, RED-YELLOW FLASHING BEACON

DRIVEWAY ADT (Vehicles per Day)	HIGHWAY ADT (Vehicles per Day)		
	LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW < 500	-	-	1.3
MEDIUM 500-1500	1.3	2.3	3.2
HIGH > 1500	2.0	3.6	4.8

TABLE A-13.5

BENEFIT/COST RATIOS FOR AN ADVANCE WARNING SIGN WITH FLASHING BEACON

DRIVEWAY ADT (Vehicles per Day)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 500	1.3	2.3	3.6
MEDIUM	500-1500	3.6	6.6	8.3
HIGH	> 1500	5.3	9.6	13.2

TABLE A-13.6

BENEFIT/COST RATIOS FOR ILLUMINATION OF A SINGLE DRIVEWAY LOCATION

DRIVEWAY ADT (Vehicles per Day)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 500	-	1.2	1.5
MEDIUM	500-1500	1.6	2.7	3.7
HIGH	> 1500	2.4	4.3	5.8

A-14: ALTER TERRAIN OR HIGHWAY GEOMETRICS FOR INCREASED SIGHT DISTANCE

Adequate sight distance at driveway entrances is required to allow driveway egress drivers sufficient view of the highway, to choose an acceptable gap, and provide through drivers the necessary perception, reaction, and braking distances to avoid collision with a driveway egress vehicle that has entered the highway.

This technique calls for altering existing site conditions to increase the available sight distance at the driveway. The terrain can be altered by cutting down hillsides, removing walls and fences, or moving signs and billboards. Alterations to the roadway include flattening horizontal and vertical curves. Figure A-14.1 shows a typical sight distance restriction.

Figure A-14.1 - Typical Sight Distance Restriction

Improved sight distance should result in a reduction of the frequency and severity of conflicts by allowing both driveway and through drivers more time to respond to traffic conditions.

Design and Operational Considerations

Sufficient sight distance should be provided, as a matter of standard design procedure, along all arterial highways. Minimum sight distances should be at least equal to the minimum stopping sight distances recommended by AASHTO as listed in Table A-14.1.

TABLE A-14.1

MINIMUM STOPPING SIGHT DISTANCE

Speed (mph)	30	40	50	60
Sight Distance (ft)	200	300	450	650

This technique is highly dependent on individual site characteristics, and no attempt is made here to propose a correct design. The final steps taken should adhere to established engineering principles.

Warrants

This technique is warranted at all existing driveways where adequate sight distance is not available. High accident experience due to inadequate sight distance will also warrant this technique.

Costs

The costs for this technique range from a few hundred dollars for relocating an obstructing sign to several thousand dollars for re-aligning a highway. Since the total cost is highly site-dependent, no cost figures have been estimated.

Measures of Effectiveness

No effects on accidents and delay for this technique were found in the literature. Accident severities and frequency, however, are expected to decrease with increased stopping sight distance.

Evaluation and Comparison

The benefits realized by implementing this technique are generally small in comparison with the cost of implementation. Therefore, benefit/cost ratios may be so small that consideration should be given to examining other cost-beneficial remedies.

A-15: IMPROVE SIGHT DISTANCE BY PREVENTING PARKING ON THE TRAVELED WAY, EITHER TOTALLY OR PARTIALLY

Adequate sight distance at driveway entrances is required to allow driveway egress drivers a sufficient view of the highway for acceptable gaps, and to provide through drivers the necessary perception, reaction, and braking distances to avoid collision with a driveway egress vehicle that has entered the highway.

On many arterials, sight distance is limited by the presence of parked vehicles in the roadway. It has become increasingly difficult for drivers to see a driveway through the windows of modern designed parked cars. Eye contact is frequently impossible because the line of sight between the highway and driveway is blocked by parked vehicles. One way to reduce these disadvantages is to prevent or restrict parking space along a highway.

Because of the sight restrictions, parking on the highway contributes to the frequency and severity of conflicts between driveway vehicles and through vehicles on the highway. Additional frequency of conflicts is caused by the parking and unparking maneuvers themselves.

Design and Operational Considerations

Parking has traditionally been a sensitive public issue. Changes in parking regulations must have the support of the general public, and therefore the simple alteration of parking space might be more acceptable than the wholesale banning of parking. Improved sight distance can also be achieved by inserting a no-parking area between two parking stalls as shown in Figure A-15.1. The advantages of this design are the open space between autos and the width of the parking lane. The major disadvantage is that obstructions still restrict vision, and lane widths may be sacrificed in order to allow a 12-ft lane for parking. At locations where these obstructions enhance accident potential, parking should be banned totally or only for certain periods of the day.

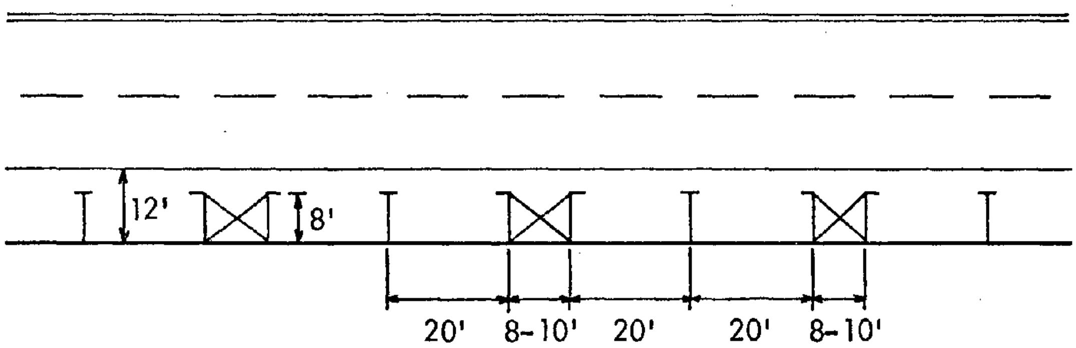


Figure A-15.1 - Recommended Parking Layout

An advantage of completely banning parking is that an additional right lane will be available for vehicle use. This lane may be used as a continuous right-turn lane, or an additional through lane.

Warrants

This technique is warranted on all highway types where sight distance at driveways is affected by the presence of parked vehicles. Highway ADT's and speeds greater than 10,000 vpd and 25 mph, respectively, will also warrant the technique. The level of development should be greater than 30 driveways per mile and more than 20% of the traffic should attempt a turn into a driveway during peak demand periods. For point locations, driveway traffic should be at least 500 vpd.

Costs

The direct cost of implementing this technique is $5,300 per mile. The cost is for appropriate signing of no-parking zones, with an average of one sign every 100 ft on both sides of the highway.

Measures of Effectiveness

The literature has shown that parking accidents account for approximately 15% of the total accidents in urban areas. This percentage has been used in calculating the annual accident reductions anticipated through the implementation of this technique. These reductions appear in Table A-15.1.

TABLE A-15.1

ANNUAL ACCIDENT REDUCTION PER MILE BY PREVENTING PARKING ON THE TRAVELED WAY

LEVEL OF DEVELOPMENT (Driveways per Mile)	HIGHWAY ADT (Vehicles per Day)		
	LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW <30	1.9	3.8	5.7
MEDIUM 30-60	3.0	6.0	9.0
HIGH >60	4.2	8.2	12.3

Evaluation and Comparison

The estimated benefit/cost ratios appear in Table A-15.2. The technique is highly cost-effective for all ranges of ADT and level of development.

TABLE A-15.2

BENEFIT/COST RATIOS FOR PREVENTING PARKING ON THE TRAVELED WAY

LEVEL OF DEVELOPMENT (Driveways per Mile)	HIGHWAY ADT (Vehicles per Day)		
	LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW <30	11	21	32
MEDIUM 30-60	17	34	50
HIGH >60	24	46	69

A-16: IMPROVE SIGHT DISTANCE BY PREVENTING PARKING ON THE RIGHT-OF-WAY

Often, commercial establishments with insufficient setback distances and internal parking problems will use the unpaved highway right-of-way for parking. This situation usually increases the severity and frequency of conflicts between driveway vehicles and through vehicles due to restricted sight distances. Several methods are available to improve this situation. Among them are increased enforcement of the regulation that prohibits such use of the right-of-way and alterations to the area by curbing or fencing.

The use of the right-of-way by commercial establishments should not be encouraged by municipal or state authorities. If encroachment on public land has contributed to accidents on or off the traveled way, steps should be taken to prohibit and prevent the practice. Stepped-up enforcement of regulations may be an effective deterrant. Other remedies should be tried if more critical problems occupy police time.

The unused portion of the right-of-way can be separated from the property by methods suggested for Technique A-8.

Design and Operational Considerations

The simplest method suggested to achieve this technique's purpose is to seek and obtain the active support of property owners to discourage patrons from using the right-of-way for parking. If cooperation with property owners cannot be obtained, a curbed section, or a low profile fence, could be placed just outside of the property line. Also, shrubs can be planted on the property line, but should be low lying varieties so that sight distance is not sacrificed. Another method is to install a shallow drainage ditch next to the property. This remedy should be used only in semi-rural areas.

Warrants

This technique should be implemented at all locations.

Costs

The implementation of this technique ranges from personnel costs for increased police surveillance to extensive plantings. The cost is highly dependent on the method employed as well as individual site conditions.

Measures of Effectiveness

This technique reduces the severity of conflicts by allowing drivers more perception time and a higher probability of conflict perception and avoidance. The literature revealed no accident rate reductions for this technique.

Evaluation and Comparison

This technique is believed to be fairly cost-effective for most ranges of ADT and levels of development. An adequate remedy will be relatively inexpensive to implement, and the benefits will be realized through increased safety.

A-17: INSTALL TWO-WAY LEFT-TURN LANE

A two-way left-turn lane is provided to remove left-turning vehicles from the through lanes and store those vehicles in a median area until an acceptable gap in opposing traffic appears. The two-way left-turn lane completely shadows turning vehicles from both through lane traffic streams. Thus, accident severity and frequency reductions will result. Frequency is reduced by removing stopped or slow left-turning vehicles from the through lanes and severity is reduced by allowing additional perception time to reduce left-turn crossing conflicts. Delay to through vehicles will also be reduced because left-turning vehicles and queues will not block the through lanes.

Design and Operational Considerations

The standard (MUTCD Figure 3-4a) two-way left-turn lane design is shown in Figure A-17.1. The major design requirement for this technique is the median width, which should be at least 14 ft wide.

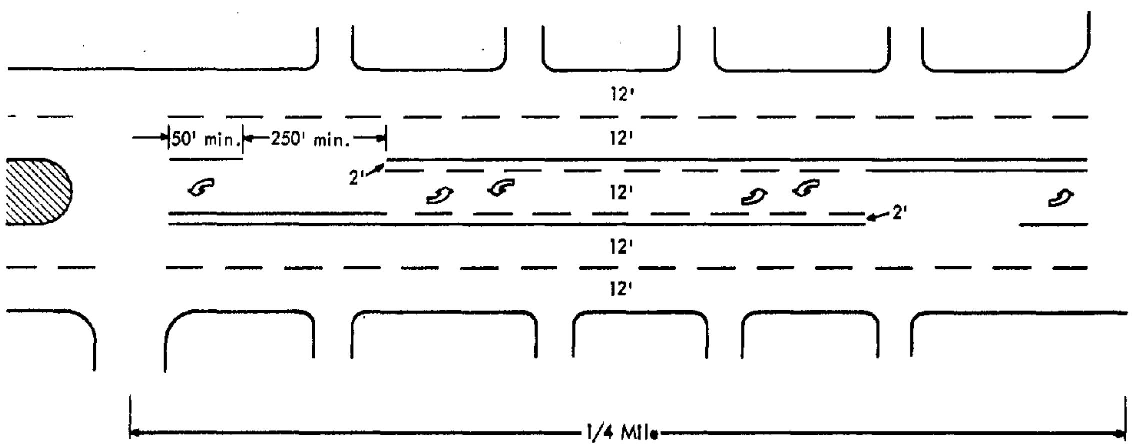


Figure A-17.1 - Two-Way Left-Turn Lane

Warrants

This technique is warranted on multi-lane highways that have closely-spaced driveways with a uniform and medium density of left-turns along the highway. Highway volumes and speeds should exceed 10,000 vpd and 30 mph. The level of development should exceed 60 driveways per mile, with less than 10 high-volume driveways. Left-turn driveway maneuvers per mile should total at teast 20% of through volume during peak periods. High accident rates involving left-turn maneuvers will also warrant this technique (see Appendix B, Table B-II).

Costs

Three construction options were evaluated for this technique. The first option applies at a location that has sufficient paved median width for two-way turn lane construction. The estimated cost for implementing the technique under this basic construction option is:

Median Installation - striping (12,800 ft)	$8,200

The second option applies at locations that have insufficient paved median widths with median widening required. The estimated costs for implementing the technique under this option are:

Basic median installation	$ 82,00
7 ft pavement widening on each side (8,200 yd^2)	164,000
Curb and gutter - 8,000 ft	64,000
Relocation of roadside structures, 2 miles x $10,000 (both sides)	20,000
Patchback - 60 driveways	24,000
	$280,200

The third option applies at locations that require right-of way acquisition for construction. The estimated costs for implementing the technique under this construction option are:

Basic Median Installation	$ 8,200
Highway Widening	272,000
Right-of-Way Acquisition (73,600 sq ft)	220,800
	$501,000

Measures of Effectiveness

The literature on two-way left-turn lanes indicated that accidents could be expected to decline by an estimated 35% after installation. The predicted annual accident reductions per mile are listed in Table A-17.1.

TABLE A-17.1

ANNUAL ACCIDENT REDUCTION PER MILE BY INSTALLING TWO-WAY LEFT-TURN LANE

LEVEL OF DEVELOPMENT (Driveways per Mile)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 30	4.4	8.8	13.3
MEDIUM	30-60	7.1	13.9	20.9
HIGH	> 60	9.7	19.0	28.6

Implementation of this technique might result in additional improvements being made that would contribute to further accident reductions. Such additional improvements might include resurfacing with skid resistant concrete and redesigning nearby intersections. Possible increases in head-on accidents may occur on the median due to two vehicles crossing in opposite directions at the same location. The literature review discounted such occurences from frequently occuring.

In estimating delay reduction for this technique assumptions were made regarding the average travel speeds for the various combinations of level of development and highway volume and for the period that driveway vehicles affect the travel speed on the highway. These assumptions are the same as those detailed in Technique A-2 and, therefore, the estimated delay reductions for the two-way left-turn lane are the same as those given for Technique A-2. These estimates are shown in Table A-17.2.

TABLE A-17.2

ANNUAL RUNNING TIME REDUCTION IN VEHICLE-HOURS FOR A 1-MILE SEGMENT AFTER INSTALLATION OF A TWO-WAY LEFT-TURN LANE

LEVEL OF DEVELOPMENT (Driveways per Mile)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 30	-	-	-
MEDIUM	30-60	-	2,628	6,935
HIGH	> 60	-	6,059	17,046

Evaluation and Comparison

The estimated accident and delay reductions and construction costs were used in calculating benefit-cost ratios for the three construction options. The results appear in tables A-17.3, A-17.4, and A-17.5. Table A-17.3 lists the benefit-cost ratios for the first construction option. The ratios are quite large for all combinations of level of development and highway ADT, indicating that this option is highly cost-effective. The benefit-cost ratios for the remaining two construction options are markedly smaller. The second construction option appears to be cost-effective for medium to high combinations of level of development and highway ADT, while the third construction option is cost-effective only for the higher combinations.

TABLE A-17.3

BENEFIT/COST RATIO FOR BASIC CONSTRUCTION

LEVEL OF DEVELOPMENT (Driveways per Mile)	HIGHWAY ADT (Vehicles per Day)		
	LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW < 30	16	32	48
MEDIUM 30-60	26	66	116
HIGH > 60	35	105	203

TABLE A-17.4

BENEFIT/COST RATIO FOR BASIC CONSTRUCTION PLUS LANE WIDENING

LEVEL OF DEVELOPMENT (Driveways per Mile)	HIGHWAY ADT (Vehicles per Day)		
	LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW < 30	-	-	1.4
MEDIUM 30-60	-	1.9	3.4
HIGH > 60	1.0	3.1	5.9

TABLE A-17.5

BENEFIT/COST RATIO FOR ADDITIONAL RIGHT-OF-WAY

LEVEL OF DEVELOPMENT (Driveways per Mile)	HIGHWAY ADT (Vehicles per Day)		
	LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW < 30	-	-	-
MEDIUM 30-60	-	1.1	1.9
HIGH > 60	-	1.7	3.3

A-18: INSTALL CONTINUOUS LEFT-TURN LANE

This technique is similar to the two-way left-turn lane except it provides individual left-turn lanes for each traffic direction. Each left-turn lane is continuous, except at intersections where a small far-side channelizing island discourages through movements. Left-turn vehicles can be stored in the continuous left-turn lane until an acceptable gap in opposing traffic appears. The continuous left-turn lane will completely shadows turning traffic from both traffic streams. Accident frequency is reduced by removing stopped or slow vehicles from the through lanes, and accident severity is reduced by allowing through vehicles additional perception time to avoid left-turn crossing conflicts. Delay to through vehicles will also be reduced because left-turn vehicles and queues will not block the through lanes.

Design and Operational Considerations

The standard (MUTCD Figure 3-4b) median treatment is recommended for this technique. This design is shown in Figure A-18.1 and is similar to the two-way left-turn lane, except that it has a separate left-turn lane for each traffic direction.

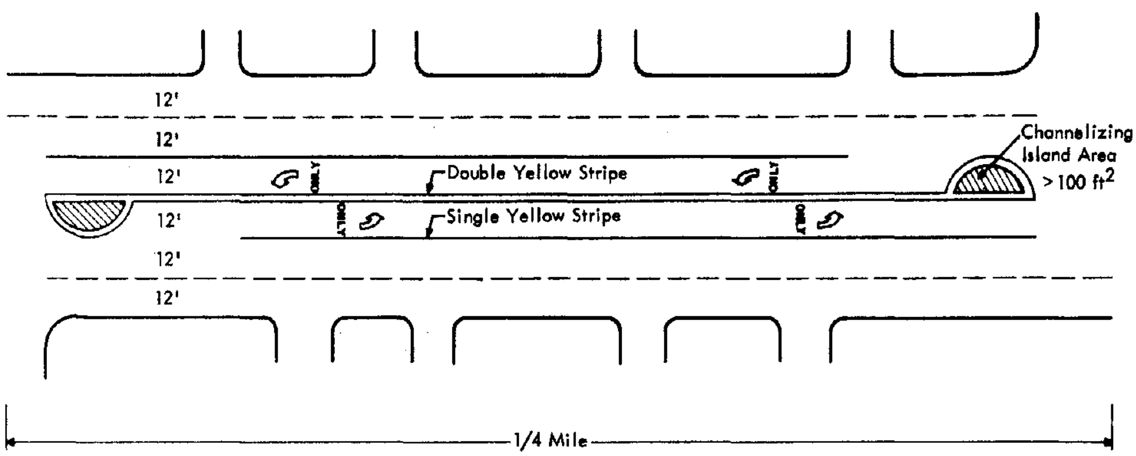


Figure A-18.1 - Continuous Left-Turn Lane

The major design difference between this technique and the two-way left-turn lane is the required median width. A 24-ft wide median is needed for this technique. At locations where 24 ft is not available for median width, it is advisable that a two-way left-turn lane be examined. The recommended median will accommodate two 12-ft turning lanes.

Since the turning lanes are continuous, this technique should be applied over section lengths at least 1/4 mile in length.

Warrants

This technique is warranted on multilane highways that have occasional cross-streets and closely spaced driveways with a uniform and medium density of left turns along the highway. Highway volume and speed should be greater than 10,000 vpd and 30 mph, respectively. At least 60 driveways should be served by 1 mile of highway and high-volume driveways should number less than 10. Left-turn maneuvers should total at least 20% of through vehicles during peak periods along 1 mile of highway. High accident rates involving left-turn movements will also warrant this technique (see Appendix B, Table B-II).

Costs

The costs for implementing this technique were estimated for three construction options. All three options concern a 1-mile long, 24-ft wide median.

The first construction option, which concerns the basic installation of the painted median on an existing paved area, has the following costs:

Median Installation - striping (20,000 ft)	$12,800

The second construction option concerns the basic median installation and pavement widening due to adding two lanes. The estimated costs for the second option are:

Median Installation	$ 12,800
Highway Pavement - 14,120 sq yd	282,400
Relocation of Roadside Structures, 2 mile x $10,000 (both sides)	20,000

Curb and Gutter - 8,000 ft	$ 64,000
Patchback - 60 driveways	24,000
	$403,200

The third construction option concerns the basic median installation, lane widening, and acquisition of additional right-of-way. The estimated costs for the third option are:

Median Installation	$ 12,800
Highway Widening	390,400
Right-of-Way for Widening (126,800 sq ft)	380,400
	$783,600

Measures of Effectiveness

No operational studies relating to this technique were found in the literature. The continuous left-turn lane has two differences when compared to the two-way left-turn lane. First, each direction has its own separate left-turning lane. This should reduce some conflicts that result from opposing vehicles being in the same lane for the two-way left-turn lane. Second, motorists wanting to turn left from a continuous left-turn lane must cross the left-turn lane from the opposite direction, which increases the conflict area. These two differences should tend to cancel each other and, therefore, the expected accident reduction of 35% found for two-way left-turn lanes should also apply to the continuous left-turn lane design.

The estimated annual accident reductions per mile appear in Table A-18.1.

TABLE A-18.1

ANNUAL ACCIDENT REDUCTIONS PER MILE BY INSTALLING CONTINUOUS LEFT-TURN LANE

LEVEL OF DEVELOPMENT (Driveways per Mile)		HIGHWAY ADT (Vehicles per Day) LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 30	4.4	8.8	13.3
MEDIUM	30-60	7.1	13.9	20.9
HIGH	> 60	9.7	19.0	28.6

In estimating delay reduction for this technique assumptions were made regarding the average travel speeds for the various combinations of level of development and highway volume and for the period that driveway vehicles affect the travel speed on the highway. These assumptions are the same as those detailed in Technique A-2, and therefore, the estimated delay reductions for the continuous left-turn lane are the same as those given for Technique A-2. These estimates are shown in Table A-18.2.

TABLE A-18.2

ANNUAL RUNNING TIME REDUCTION IN VEHICLE-HOURS FOR A 1-MILE SEGMENT OF CONTINUOUS LEFT-TURN LANE

LEVEL OF DEVELOPMENT (Driveways per Mile)	HIGHWAY ADT (Vehicles per Day)		
	LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW <30	-	-	-
MEDIUM 30-60	-	2,628	6,935
HIGH >60	-	6,059	17,046

Evaluation and Comparison

The estimated accident and delay reductions and construction costs have been used to calculate benefit/cost ratios for the three construction options. Tables A-18.3, A-18.4, and A-18.5 show these ratios. As might be expected, for all possible options, this technique has lower benefit-cost ratios than does the two-way left-turn lane alternative. Therefore, the two-way left turn should always be considered before this technique.

TABLE A-18.3

BENEFIT/COST RATIOS FOR BASIC CONSTRUCTION OF CONTINUOUS LEFT-TURN LANE

LEVEL OF DEVELOPMENT (Driveways per Mile)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 30	10	21	31
MEDIUM	30-60	17	42	74
HIGH	> 60	23	67	130

TABLE A-18.4

BENEFIT/COST RATIOS FOR BASIC CONSTRUCTION AND PAVEMENT WIDENING FOR CONTINUOUS LEFT-TURN LANE

LEVEL OF DEVELOPMENT (Driveways per Mile)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 30	-	-	1.0
MEDIUM	30-60	-	1.3	2.4
HIGH	> 60	-	2.1	4.1

TABLE A-18.5

BENEFIT/COST RATIOS FOR BASIC CONSTRUCTION, PAVEMENT WIDENING, AND RIGHT-OF-WAY ACQUISITION FOR CONTINUOUS LEFT-TURN LANE

LEVEL OF DEVELOPMENT (Driveways per Mile)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 30	-	-	-
MEDIUM	30-60	-	-	1.2
HIGH	> 60	-	1.1	2.1

A-19: INSTALL ALTERNATING LEFT-TURN LANE

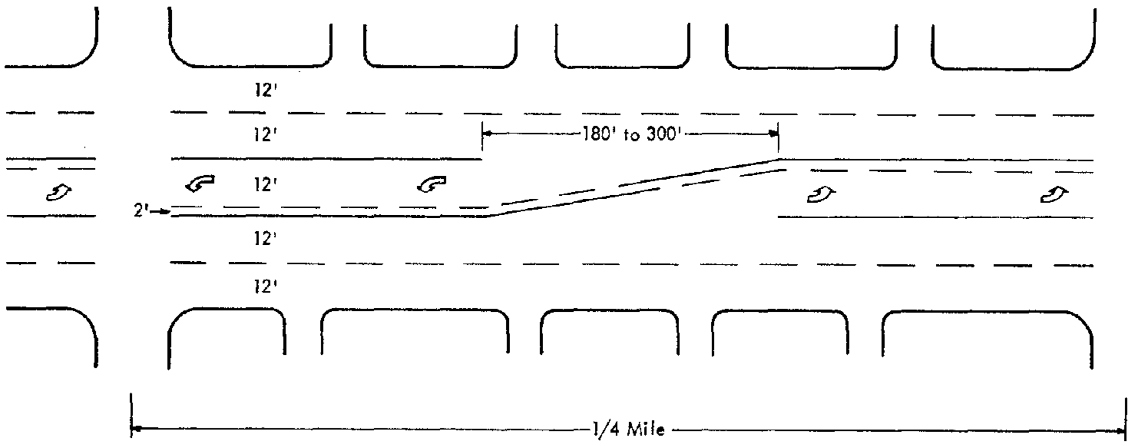
The alternating left-turn lane will allow one traffic direction to have the opportunity to cross the median into driveways, and after a determined distance, the left-turn lane is physically opened to the opposing direction traffic. Thus, both traffic directions have a unique left-turn lane available for continuous left-turn maneuvers over a limited section of highway. Left-turn access to some driveways is prevented because when the left-turn lane is available to one traffic direction, the opposing traffic cannot attempt a left-turn.

Accident frequency and severity reductions will result from the implementation of this technique. Frequency is reduced by removing stopped or slow moving vehicles and queues from the through lanes, and severity is reduced by allowing through vehicles additional perception time to avoid left-turn crossing conflicts. Delay to through vehicles will also be reduced because left-turning vehicles will not block the through lanes.

Design and Operational Considerations

The major advantage of implementing this technique instead of other median treatments lies in the minimum median width required to accomodate the left-turn lane. Since only one lane is used in the median for left-turn movements, the width of the median should be as wide as the turning lane itself. While other techniques require 14- to 24-ft medians for left-turn movements, this technique requires only a 12-ft median. The value of this technique for application on narrow median highways is most evident at locations where pavement widening or right-of-way acquisition would be required for the wider medians.

Figure A-19.1 shows an acceptable design for an alternating left-turn lane. An important design consideration is the configuration of the deceleration taper. In this technique the deceleration taper not only delineates the correct deceleration path, but it also physically serves to separate the left-turn lane for different traffic directions.



A-19.1 - Alternating Left-Turn Lane

The striping scheme shown in Figure A-19.1 is not readily recognized by today's motorist as delineating a left-turn lane. No striping criteria has been universally adopted for use with a technique such as this. The use of turn arrows should help reduce driver confusion.

Warrants

This technique is applicable on all types of highways where sufficient space is available for construction of medial turn lanes. Median widths greater than 11 ft are necessary. Multilane undivided highways with an odd number of lanes will readily accomodate this technique by converting the odd lane to an alternating left-turn lane. Application is particularly appropriate where concentrations of driveways alternate from one side of the highway to the other.

Highway volumes and speeds greater than 10,000 vpd and 35 mph, respectively, will warrant the technique. Left-turn movements should exceed at least 15% of the through traffic over 1-mile of highway during peak-driveway demand periods. The level of development should be greater than 45 driveways per mile with spacings between major driveways or intersections greater than 1,000 ft. High accident rates due to left-turn crossing movements of adjacent driveways will also warrant the technique (see Appendix B, Table B-II).

Costs

The cost for implementing this technique was estimated for three construction options. The first option which concerns only the installations of the painted median on an existing paved area, has the following costs:

Median Installation (striping 16,000 ft)	$10,200

The second option concerns the cost of the basic construction plus highway widening. The estimated cost for this option is:

Median Installation	$ 10,200
Pavement - 8,200 sq yd	164,000
Curb and Gutter - 8,000 ft	64,000
Relocation of roadside structures 2 miles x $10,000 (both sides)	20,000
Patchback - 60 driveways	24,000
	$282,200

The third option concerns the cost of the basic construction, lane widening, and right-of-way acquisition. The estimated cost for this option is:

Median Installation	$ 10,200
Pavement Widening	272,000
Right-of-Way - 73,600 sq ft	220,800
	503,000

Measures of Effectiveness

The literature review indicated that a 28% decrease in accidents could be realized by converting a section of highway to alternating left-turn lane operation. In order to evaluate the effectiveness of this technique, several assumptions regarding the operational characteristics were made. Included in the assumptions are that left-turn access will be provided to all medium and high volume commercial driveways and to only half of the low volume driveways. Turning maneuvers are broken down into 40% left-turns and 60% right turns. After the alternating left-turn lane is installed, 50% of the turning maneuvers that would have been left-turns now can be accomplished only by indirect right-turns. The added number of right-turns is expected to slightly increase right-turn accidents.

The estimated annual accident reductions per mile appear in Table A-19.1

TABLE A-19.1

ANNUAL ACCIDENT REDUCTION PER MILE BY INSTALLING ALTERNATING LEFT-TURN LANE

LEVEL OF DEVELOPMENT (Driveways per Mile)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 30	1.7	3.2	5.1
MEDIUM	30-60	3.5	7.1	11.6
HIGH	> 60	6.4	13.3	21.0

In estimating delay reduction for these technique assumptions were made regarding the average travel speeds for the various combinations of level of development and highway volume and for the period that driveway vehicles affect the travel speed on the highway. These assumptions are the same as those detailed in Technique A-2 and, therefore, the estimated delay reductions for the alternating left-turn lane are the same as those given for Technique A-2. These estimates are shown in Table A-19.2.

TABLE A-19.2

ANNUAL RUNNING TIME REDUCTION IN VEHICLE-HOURS FOR A 1-MILE HIGHWAY SECTION AFTER INSTALLING ALTERNATING LEFT-TURN LANE

LEVEL OF DEVELOPMENT (Driveways per Mile)	HIGHWAY ADT (Vehicles per Day)		
	LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW < 30	-	-	-
MEDIUM 30-60	-	2,628	6,935
HIGH > 60	-	6,059	17,046

Evaluation and Comparison

The estimated accident and delay reductions and construction costs were used to calculate the benefit/cost ratios for the three construction options. Table A-19.3 lists the benefit/cost ratios for the basic median installation, where all combinations of level of development and highway ADT are highly cost-effective.

Table A-19.4 lists the benefit/cost ratios for the basic median installation plus lane widening. This second construction option is cost-effective for medium and high combinations of ADT and level of development.

Table A-19.5 lists the benefit/cost ratios for the third construction option that includes right-of-way acquisition. This option is cost-effective for only high combinations of ADT and level of development.

Since the two-way left-turn lane exhibits higher benefit/cost ratios than does this method, the feasibility of a two-way left-turn lane should be examined before this technique.

TABLE A-19.3

BENEFIT/COST RATIOS FOR MEDIAN INSTALLATION

LEVEL OF DEVELOPMENT (Driveways per Mile)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 30	5.0	9.0	15.0
MEDIUM	30-60	10.0	33	55
HIGH	> 60	19.0	67	141

TABLE A-19.4

BENEFIT/COST RATIOS FOR MEDIAN INSTALLATION PLUS LANE WIDENING

LEVEL OF DEVELOPMENT (Driveways per Mile)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 30	-	-	-
MEDIUM	30-60	-	1.2	2.4
HIGH	> 60	-	2.4	5.1

TABLE A-19.5

BENEFIT/COST RATIOS FOR MEDIAN INSTALLATION, LANE WIDENING, AND RIGHT-OF-WAY ACQUISITION

LEVEL OF DEVELOPMENT (Driveways per Mile)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 30	-	-	-
MEDIUM	30-60	-	-	1.3
HIGH	> 60	-	1.4	2.9

A-20: INSTALL ISOLATED MEDIAN AND DECELERATION LANE TO SHADOW AND STORE LEFT-TURNING VEHICLES

The functional objective of this technique is to remove turning vehicles or queues from the through lanes at a major driveway. Improvements in left-turning operations result from the isolated median and deceleration lane which shadows and stores the left-turning vehicles.

By providing higher diverging speeds and removing the stopped left-turning vehicles from the through lanes, a reduction in the frequency and severity of rear-end conflicts at the driveway should occur. Also, the severity of left-turn crossing conflicts should be reduced because the turning drivers are allowed additional perception time. Some trade-off may occur because of through vehicles colliding with the channelizing islands.

Design and Operational Considerations

The recommended design for this technique is shown in Figure A-20.1. The additional width is usually achieved by flaring the highway width in the vicinity of the isolated driveway location to enable construction of the deceleration lane and channelizing islands.

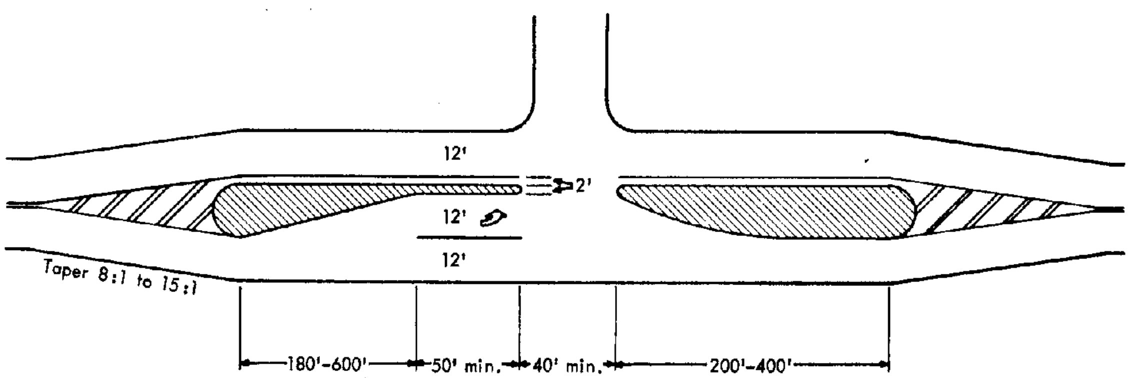


Figure A-20.1 - Isolated Left-Turn Lane

The decision components of this technique are the deceleration lanes (taper and storage), median islands, and the tapering length of the highway. Design parameters for the deceleration taper, storage lengths, and median opening lengths appear in Appendix A. In many cases, right-of-way will be needed to facilitate construction of needed deceleration lanes and median islands.

Warrants

All undivided highways are candidates for this technique. Typical locations would have levels of development of less than 30 driveways per mile, driveway volumes greater than 1,000 vpd, and highway volumes greater than 10,000 vpd. Left-turn volume should exceed 100 vph during the peak period.

Costs

The estimated costs for this technique were separated into two options. The first option consisted of the basic construction which included the median installation (curb and gutter and surfacing, $7,600) and highway widening on each side of 7 ft with 100 ft tapers (pavement, curb and gutter, relocation of roadside structures, and patchbacks, $28,900). The total cost for the basic construction was $36,500. The second option included the acquisition of additional right-of-way ($22,200) plus the basic construction cost of $36,500 for a total cost of $58,700.

When implementing this technique, additional improvements for the driveway should be considered. Altering the driveway geometrics could effect increased benefits to the traffic operations for little additional cost.

Measures of Effectiveness

A basic information used in this evaluation was a 50% expected reduction in total accidents after installation of left-turn bays at unsignalized intersections. Table A-20.1 shows the predicted annual accidents reductions for various highway and driveway volumes.

(TECHNIQUE A-20)

TABLE A-20.1

ANNUAL ACCIDENT REDUCTION BY INSTALLING ISOLATED MEDIAN AND DECELERATION LANE

DRIVEWAY ADT (Vehicles per Day)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 500	0.13	0.23	0.31
MEDIUM	500-1500	0.32	0.55	0.75
HIGH	> 1500	0.49	0.85	1.15

Since no delay data was found in the literature, the delay reductions were estimated using the same approach as Technique A-2, and a multiplying factor of 0.1 to account for the shorter length of highway.

Table A-20.2 gives the predicted annual delay reductions associated with this technique.

TABLE A-20.2

ANNUAL RUNNING TIME REDUCTION (VEHICLE-HOURS) FOR AN ISOLATED MEDIAN AND DECELERATION LANE

DRIVEWAY ADT (Vehicles per Day)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 500	-	-	-
MEDIUM	500-1500	-	263	694
HIGH	> 1500	-	606	1,705

Evident from Tables A-20.1 and A-20.2 is that the operational evaluation was only concerned with medium to high driveway volumes and highway volumes.

Evaluation and Comparison

This technique, which is applied to a specific driveway on undivided highways, does not compete with any other direct alternatives. The calculated cost-benefit ratios shown in Tables A-20.3 and A-20.4 indicate that the technique is cost-effective for higher volume driveways on higher volume highways.

TABLE A-20.3

BENEFIT/COST RATIOS FOR BASIC CONSTRUCTION OF THE ISOLATED MEDIAN AND DECELERATION LANE

DRIVEWAY ADT (Vehicles per Day)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 500	-	-	-
MEDIUM	500-1500	-	-	1.5
HIGH	> 1500	-	1.5	3.2

TABLE A-20.4

BENEFIT/COST RATIOS FOR THE ISOLATED MEDIAN AND DECELERATION LANE WHERE ADDITIONAL RIGHT-OF-WAY IS REQUIRED

DRIVEWAY ADT (Vehicles per Day)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 500	-	-	-
MEDIUM	500-1500	-	-	-
HIGH	> 1500	-	-	2.0

A-21: INSTALL LEFT-TURN DECELERATION LANE IN LIEU OF RIGHT-ANGLE CROSSOVER

This median treatment facilitates left-turn access to a driveway by providing a left-turn deceleration lane in place of a right-angle crossover. The principal objective is to remove turning vehicles or queues from the through lanes, thereby improving the left-turn operations.

The frequency and severity of rear-end conflicts is reduced because turning vehicles can diverge at higher speeds and because stopped vehicles or queues are removed from the through lanes. The severity of left-turn opposing conflicts should decrease because the left-turning drivers will have more perception time in which to make their decisions.

This technique should only be considered where a median opening exists and there is sufficient median width for a deceleration lane.

Design and Operational Considerations

The design parameters for this technique include median width, taper and deceleration length, storage length, and taper configuration. A desirable median width of 16 ft is recommended; 4 ft for a median end and 12 ft for the deceleration lane. The minimum median width is 14 ft; 2 ft for the median end and 12 ft for the deceleration lane. The recommended design elements are specified in Appendix A. A typical design is shown in Figure A-21.1.

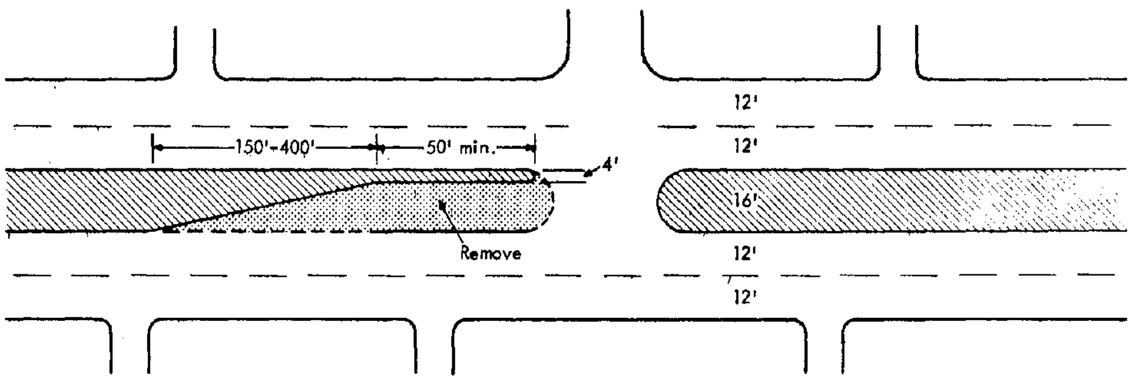


Figure A-21.1 - Left-Turn Deceleration Lane in Lieu of Right-Angle Crossover

Warrants

All multilane divided highways with median widths of 14 ft or greater are potential locations for this application. A median opening must exist in order to provide for turning maneuvers. The development near this location should include fewer than 45 driveways per mile with major driveways or intersections 1/4-1/2 mile apart. Highway speeds should exceed 35 mph and driveway ADT and highway ADT should be less than 1,000 and 10,000, respectively. Left turns should total 10% of the peak period traffic volume.

Costs

The conditions under which the costs were estimated included a 14-ft grass median with no curb. The deceleration lane installation consisted of 200 sq yd of pavement at a total cost of $7,600.

Measures of Effectiveness

A 50% reduction in total accidents was used to predict the annual accident reductions for the highway ADT-driveway ADT combinations. Table A-21.1 reflects the estimated annual accident reductions for this treatment.

TABLE A-21.1

ANNUAL ACCIDENT REDUCTIONS BY INSTALLING A LEFT-TURN DECELERATION LANE IN LIEU OF A RIGHT-ANGLE CROSSOVER

DRIVEWAY ADT (Vehicles per Day)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 500	-	-	1.2
MEDIUM	500-1500	1.3	2.2	3.0
HIGH	> 1500	1.9	3.4	4.5

Major consideration should be given to this technique when left-turning vehicles are causing safety problems (see Appendix B, Table B-II). Some reduction in delay is also expected.

Evaluation and Comparison

The benefit/cost ratios were determined from the operational benefit and cost estimates. These ratios are shown in Table A-21.2.

TABLE A-21.2

BENEFIT/COST RATIOS FOR LEFT-TURN DECELERATION LANE

DRIVEWAY ADT (Vehicles per Day)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 500	-	-	-
MEDIUM	500-1500	-	-	-
HIGH	> 1500	-	-	1.15

A-22: INSTALL MEDIAL STORAGE FOR LEFT-TURN EGRESS VEHICLES

The installation of medial storage for left-turn driveway egress vehicles on multilane divided highways improves left-turn operations by removing those turning vehicles from the through lanes of the highway. This allows left-turn egress drivers additional perception time, which in turn reduces the severity of left-turn egress merge conflicts.

Design and Operational Considerations

This technique is applicable at point locations on multilane divided highways. The design parameters associated with this technique are median width, taper length and configuration, storage length, and island area. The major consideration of this treatment is the amount of storage space needed. Storage should be provided for one passenger vehicle unless the volume of left-turning traffic dictates a need for more storage space. Figure A-22.1 depicts this technique.

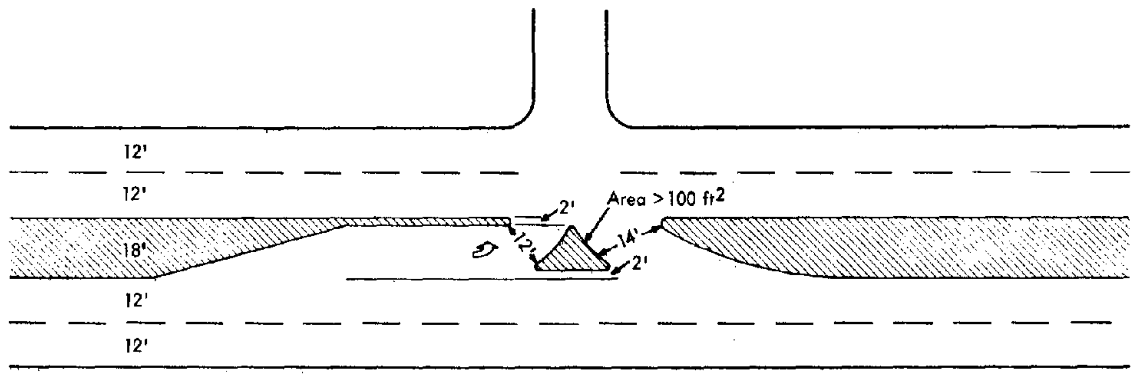


Figure A-22.1 - Medial Storage for Left-Turn Egress Vehicles

A minimum median width of 18 ft is needed for this treatment. Also, a lane width of at least 14 ft must be maintained between the channelizing island and the median end. The island should occupy at least 100 sq ft in order that the path of left-turning vehicles is well-defined. The island should be offset from the through lanes by a 2-ft safety area.

An acceptable design is depicted in Figure A-22.1.

Warrants

All multilane divided highways with median widths of at least 18 ft are applicable locations. A median opening has to exist in order to provide for the turning maneuvers. A development of less than 45 driveways per mile near the location is necessary and highway speeds should range from 30-45 mph. Highway volume should exceed 10,000 vpd and left-turning egress volume should exceed 300 vpd. Frequency of left-turn accidents could also constitute a warrant for this improvement (see Appendix B, Table B-II).

Costs

Cost estimates were based on installing an island and altering the existing median to provide for the storage area. The island installation included 110 ft of curbing ($880) and 35 sq yards of surfacing ($210) for a cost of $1,090. Altering the median consisted of 130 sq yards of paving ($2,600) and 150 ft of curb and gutter ($1,200) for a cost of $3,800. Thus, the total estimated cost of implementing this technique is $4,890.

Measures of Effectiveness

No studies were found regarding the effects of this technique on accidents.

An estimated reduction of 25% in the left-turn egress driveway accidents was used, resulting in a reduction of total driveway accidents of 0.25 (0.27) = 6.75%. Applying this reduction to the estimated number of driveway accidents, Table A-22.1 was developed.

TABLE A-22.1

ANNUAL ACCIDENT REDUCTIONS BY INSTALLING MEDIAL STORAGE FOR LEFT-TURN EGRESS VEHICLES

DRIVEWAY ADT (Vehicles per Day)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 500	0.02	0.03	0.04
MEDIUM	500-1500	0.04	0.07	0.10
HIGH	> 1500	0.07	0.11	0.16

Evaluation and Comparison

Table A-22.2 shows the calculated benefit/cost ratios for this technique, indicating that it is generally not cost-effective. It might be cost-effective, however, if implemented as part of a large median improvement project where some of the construction costs are absorbed by other techniques.

TABLE A-22.2

BENEFIT/COST RATIOS BY INSTALLING MEDIAL STORAGE FOR LEFT-TURN EGRESS VEHICLES

DRIVEWAY ADT (Vehicles per Day)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 500	-	-	-
MEDIUM	500-1500	-	-	-
HIGH	> 1500	-	-	1.0

A-23: INCREASE STORAGE CAPACITY OF EXISTING LEFT-TURN DECELERATION LANE

The deceleration lane shadows and stores left-turning vehicles from the main stream of traffic. When the storage capacity becomes insufficient to handle the turning volume, the safety and capacity of the through lanes is adversely affected. An acceptable solution involves increasing the storage capacity of the deceleration lane to accommodate most peak-period turning vehicles. The effects on operations are reductions in the frequency and severity of rear-end conflicts.

Design and Operational Considerations

The design of this technique involves two alternatives. These alternatives are: (1) increasing the length of an existing deceleration lane where sufficient median length is available; or (2) widening the highway to facilitate left-turning maneuvers from two lanes. The second condition considers the possibility of right-of-way acquisition. Several construction options exist under each of those conditions.

The design for storage capacity should be based on the through traffic volumes for both directions, the percentage of left turns in the one direction, and the highway speed.

Warrants

All multilane divided highways with existing deceleration lanes and insufficient storage lengths are applicable locations. A level of development for the highway section should contain fewer than 45 driveways per mile with major driveways or intersections 1/4-1/2 mile apart. Driveway ADT and highway ADT should exceed 1,000 and 10,000, respectively.

Costs

Costs were estimated for five separate options. These estimates are contained in the following cost summary.

Option 1 - Storage increase for a continuous curbed median (14-ft width, 150-ft length increase).

Pavement - 200 sq yd x $20	=	$ 4,000
Curbing - 300 ft x $8	=	2,400
		$ 6,400

Option 2 - Storage increase for an isolated curbed median (14-ft width, 600-ft section with roadway tapers, 150-ft length increase).

Median construction		
Curb and gutter - 625 ft x $8	=	$ 5,000
Surfacing - 200 sq yd x $6	=	1,200
Widen highway - 12 ft on one side		
Pavement - 200 sq yd x $20	=	4,000
Curb and gutter - 250 ft x $8	=	2,000
Patchback - 2 driveways x $400	=	800
Relocation of roadside structures, 0.1 mile x $10,000 (one side)	=	1,000
		$ 14,000

Option 3 - Storage increase for an isolated curbed median plus additional right-of-way acquisition (conditions same as Option 2).

Median construction and highway widening	=	$ 14,000
Right-of-way - 1,800 sq ft x $3	=	5,400
		$ 19,400

Option 4 - Highway widening for two-lane left-turn bay at an isolated curbed median (conditions same as Option 2).

Median construction		
Curb and gutter - 325 ft x $8	=	$ 2,600
Surfacing - 400 sq yd x $6	=	2,400

Widen highway - 12 ft on one side

Pavement - 1,100 sq yd x $20	= $22,000
Curb and gutter - 750 ft x$8	= 6,000
Patchback - 3 driveways x $400	= 1,200
Relocation of roadside structures, 0.1 mile x $10,000 (one side)	= 1,000
	$35,200

Option 5 - Highway widening plus additional right-of-way acquisition for two-lane left-turn bay at an isolated curbed median (conditions same as Option 2).

Median construction and highway widening	= $35,200
Right-of-way - 9,900 sq ft x $3	= 29,700
	$64,900

Measures of Effectiveness

The basis for evaluation relied on information from the literature, which predicts that annual accidents will decline 50% after the installation of left-turn lanes at unsignalized intersections. This reduction is also applicable to commercial driveway intersections.

An additional assumption was used in the evaluation. If the storage capacity is insufficient, the left through lane would be blocked by the left-turning vehicles during the two peak hours. The two peak hours would affect 20% of the total daily traffic volume, and during this time accident rates would be unaffected by the left-turn lane. Therefore, the technique should affect a 10% (0.5 x 0.2) reduction in total accidents. The predicted annual accident reductions are given in Table A-22.1.

TABLE A-23.1

ANNUAL ACCIDENT REDUCTION BY INCREASING STORAGE CAPACITY OF LEFT-TURN DECELERATION LANE

DRIVEWAY ADT (Vehicles per Day)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 500	0.026	0.045	0.062
MEDIUM	500-1500	0.063	0.11	0.15
HIGH	> 1500	0.097	0.17	0.23

Using the expected 50% reduction in accidents, Table A-23.1 displays these values for commercial driveways by providing adequate storage spaces.

Estimates of delay reduction are similar to those used in Technique A-2. Since A-2 is a route measure and A-23 is a point measure, an initial factor of 1/10 was applied to the delay estimated in Technique A-2. Also, since the through lanes are assumed to be affected for 2 hr in Technique A-23, the 5-mph increase in running speed will occur 20% of the time for all driveway volumes. Table A-23.2 lists the expected delay reductions due to increasing the storage capacity of an existing left-turn deceleration lane.

TABLE A-23.2

ANNUAL RUNNING TIME REDUCTION (VEHICLE HOURS) DUE TO INCREASED STORAGE CAPACITY OF A LEFT-TURN DECELERATION LANE

DRIVEWAY ADT (Vehicles per Day)	HIGHWAY ADT (Vehicles per Day)		
	LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW < 500	-	-	-
MEDIUM 500-1500	-	263	694
HIGH > 1500	-	345	973

Delay reductions were estimated using the same approach as Technique A-2, and a multiplying factor of 0.1 to account for the shorter length of highway.

Evaluation and Comparison

Cost/benefit ratios were calculated for each of the five cost options. Tables A-23.3 through A-23.6 list the benefit/cost ratios for four of the options. The option that consists of widening to a two-lane left-turn slot (including additional right-of-way) was not cost-beneficial at any level. For the four options listed, these tables indicate that the technique is generally cost-effective for the higher driveway volume and highway volume categories.

TABLE A-23.3

BENEFIT/COST RATIOS FOR A 150-FT LENGTH INCREASE ON A CONTINUOUS CURBED MEDIAN

DRIVEWAY ADT (Vehicles per Day)	HIGHWAY ADT (Vehicles per Day)		
	LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW < 500	-	-	-
MEDIUM 500-1500	-	2.5	5.9
HIGH > 1500	-	3.4	8.3

TABLE A-23.4

BENEFIT/COST RATIOS FOR A 150-FT LENGTH INCREASE ON AN ISOLATED CURBED MEDIAN

DRIVEWAY ADT (Vehicles per Day)	HIGHWAY ADT (Vehicles per Day)		
	LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW < 500	-	-	-
MEDIUM 500-1500	-	1.1	2.7
HIGH > 1500	-	1.6	3.8

(TECHNIQUE A-23)

TABLE A-23.5

BENEFIT/COST RATIOS FOR A 150-FT LENGTH INCREASE ON AN ISOLATED CURBED MEDIAN (INCLUDES ADDITIONAL RIGHT-OF-WAY

DRIVEWAY ADT (Vehicles per Day)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 500	-	-	-
MEDIUM	500-1500	-	-	1.9
HIGH	> 1500	-	1.1	2.8

TABLE A-23.6

BENEFIT/COST RATIOS FOR WIDENING TO A TWO-LANE LEFT-TURN SLOT

DRIVEWAY ADT (Vehicles per Day)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 500	-	-	-
MEDIUM	500-1500	-	-	1.1
HIGH	> 1500	-	-	1.5

A-24: INCREASE THE TURNING SPEED OF RIGHT-ANGLE MEDIAN CROSSOVERS BY INCREASING THE EFFECTIVE APPROACH WIDTH

This technique is aimed at improving the left-turning maneuvers of vehicles at median openings. The objective is achieved by increasing the approach width and thereby increasing the turning speed of crossover vehicles. The improved design of median crossover reduces the severity of rear-end conflicts by reducing the maximum deceleration requirements of through vehicles following turning vehicles.

Design and Operational Considerations

This technique is applicable on multilane divided arterial with right-angle crossover openings. The key element needed for the improved geometric design of the median opening is the width of the median itself. That width should be 4 ft or greater.

There are several ways to increase the approach width of a median opening. Listed below are four options aimed at improving the geometric design of median openings:

1. Increase the width of the left lane in the vicinity of the median opening. A sufficient lane width for arterial highways is from 11-13 ft. These lane widths are considered adequate for comfortable maneuvers by turning vehicles. A minimum of 2 ft widening is recommended for this design. Also, a 10:1 taper is desirable for proper operation. Figure A-24.1 is a typical layout of the proposed design.

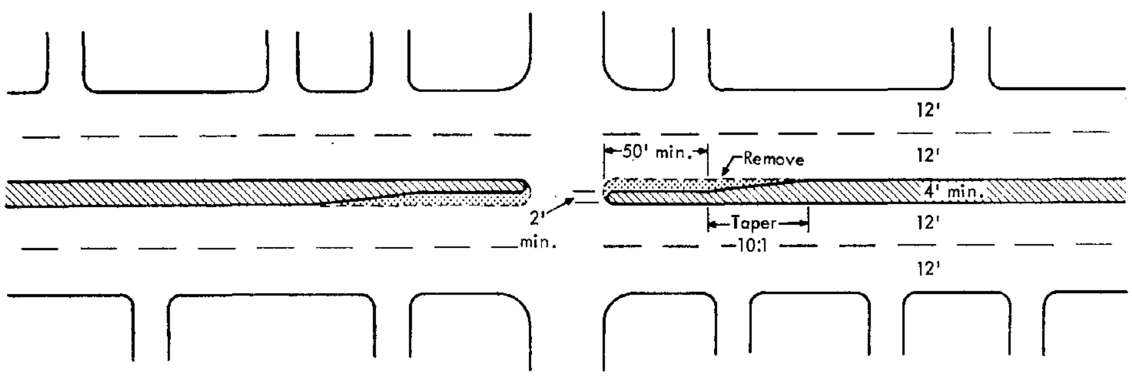


Figure A-24.1 - Widening of Left Lane

2. Increase the left-lane width by flaring. The minimum flare offset should be 2 ft at a rate of 15:1 taper. Figure A-24.2 is a typical design.

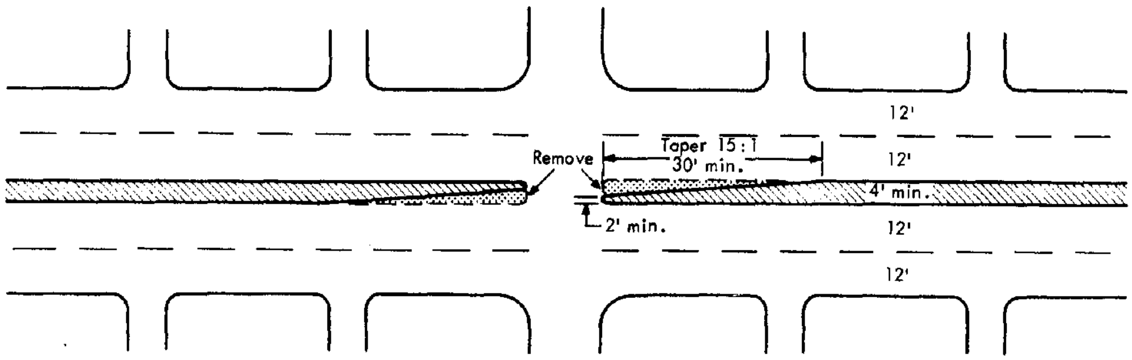


Figure A-24.2 - Widening of Left Lane

3. Increase the approach width by increasing the return radius of the side of the median nearest to the turning vehicle. This geometric improvement is suggested for median having a width of 15 ft or more. Figure A-24.3 illustrates the technical design elements of the proposed improvement.

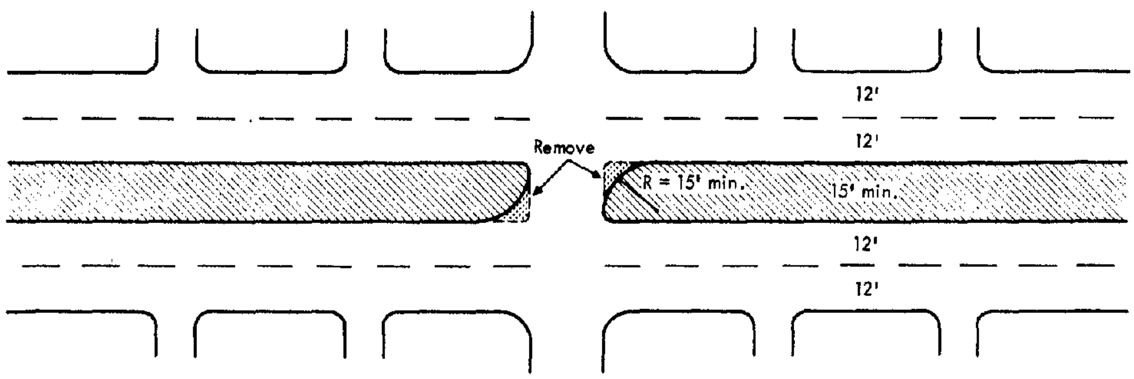


Figure A-24.3 - Increasing the Approach Width

4. Increase the total width of the median opening. The additional width helps turning vehicles to perform the maneuver with larger radii. The total width of the opening, however, should not exceed 50 ft. Figure A-24.4 is a typical design of this case.

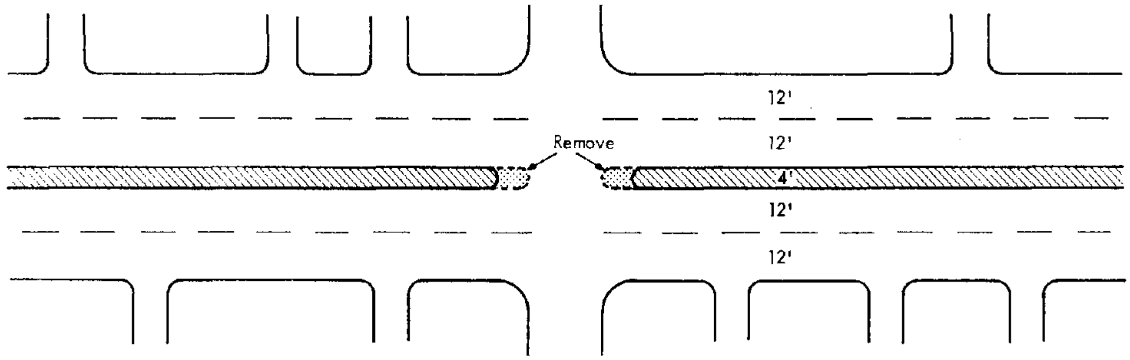


Figure A-24.4 - Widening the Median Opening

Warrants

The application of this technique is possible on multilane divided highways with median widths exceeding 4 ft. Level of development should exceed 15 driveways per mile and traffic volume should exceed 5,000 vpd on the highway.

Costs

Cost estimates for this technique were based on four technical options for implementation. The first consisted of a 2 ft uniform widening of crossover lane. The costs for this option are as follows:

Pavement 14 sq yd x $20 =	$280
Curb and Gutter 75 ft x $8 =	600
	$880

The second option consists of flaring the crossover lane. The expected costs are as follows:

Pavement 4 sq yd x $20 =	$ 80
Curb and Gutter 30 ft x $8 =	240
	$320

The third option consists of increasing the return radius of the median opening. The estimated costs are:

Pavement 6 sq yd x $20 =	$120
Curb and Gutter 25 ft x $8 =	200
	$320

The last option consisted of increasing the median opening width by 10 ft (5 ft on each side). The median is assumed to be 6 ft wide. The expected costs and quantities are:

Pavement (both sides) 7 sq yd x $20 =	$140
Curb and Gutter 25 ft x $8 =	200
	$340

Measures of Effectiveness

No effects on accidents or delay for this technique were found in the literature. However, it is likely that some operational effectiveness results. A 4% reduction in total driveway accidents was estimated for this technique. The annual accident reductions are listed in Table A-24.1.

TABLE A-24.1

ANNUAL ACCIDENT REDUCTIONS BY INCREASING THE EFFECTIVE APPROACH WIDTH OF RIGHT-ANGLE MEDIAN CROSSOVER

DRIVEWAY ADT (Vehicles per Day)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 500	0.01	0.02	0.03
MEDIUM	500-1500	0.03	0.04	0.06
HIGH	> 1500	0.04	0.07	0.09

Evaluation and Comparisons

Benefit/cost ratios for this technique were determined for the four construction options by using the estimated accident reductions and direct costs. Evident from Tables A-24.2, A-24.3, and A-24.4 is the cost-effectiveness of the technique for high volume driveways associated with high ADT on the arterials.

TABLE A-24.2

BENEFIT/COST RATIOS FOR INCREASING UNIFORMLY THE CROSSOVER TURNING LANE

DRIVEWAY ADT (Vehicles per Day)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 500	-	-	1.0
MEDIUM	500-1500	1.0	1.3	2.0
HIGH	> 1500	1.3	2.4	3.0

TABLE A-24.3

BENEFIT/COST RATIO FOR INCREASING THE APPROACH WIDTH BY FLARING THE CROSSOVER LANE OR INCREASING THE RETURN RADIUS

DRIVEWAY ADT (Vehicles per Day)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 500	-	1.9	2.8
MEDIUM	500-1500	2.8	3.7	5.6
HIGH	> 1500	3.7	6.5	8.4

TABLE A-24.4

BENEFIT/COST RATIOS FOR INCREASING THE APPROACH WIDTH BY INCREASING THE WIDTH OF THE MEDIAN OPENING

DRIVEWAY ADT (Vehicles per Day)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 500	-	1.8	2.6
MEDIUM	500-1500	2.6	3.5	5.1
HIGH	> 1500	3.5	6.1	7.9

A-25: INSTALL CONTINUOUS RIGHT-TURN LANE

A continuous right-turn lane is essentially a combination of right-turn acceleration and deceleration lane that is extended to accomodate several nearby driveways. It is used along a section of highway where driveways connot otherwise accomodate right-turning queues and/or high enough right-turn speeds. This technique reduces the frequency and severity of rear-end conflicts by removing turning vehicles at higher speeds and by shadowing right-turn queues.

Design and Operational Considerations

To operate as intended, continuous right-turn lanes should not exceed about 1/4 mile in length. Often the lane can be located between two adjacent intersections as shown in Figure A-25.1.

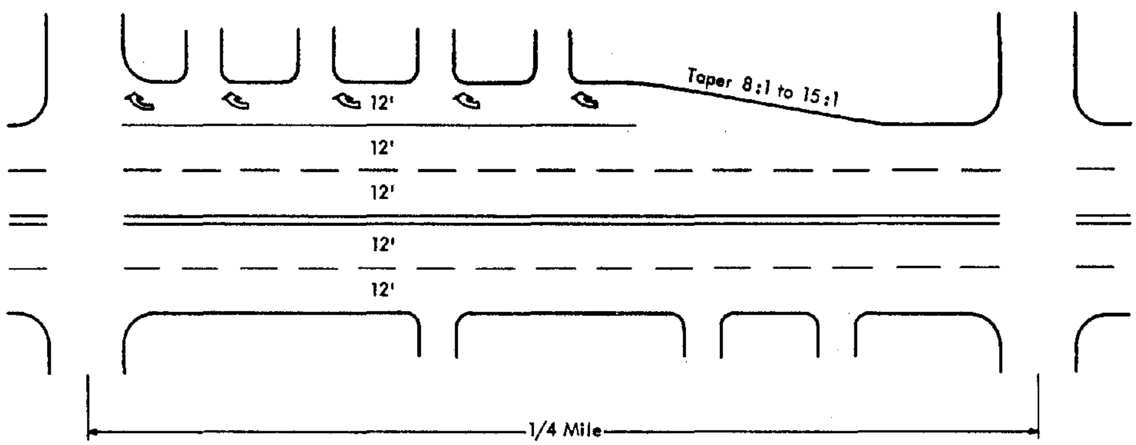


Figure A-25.1 - Typical Design for Continuous Right-Turn Lane

Continuous right-turn lanes should be 11 - 13 ft wide. Where curb and gutter sections are utilized, the gutter pan width may be included as a part of the minimum width of the turning lane, but desirably the lane width should be in addition to that of the gutter pan. Appropriate taper design standards are shown in Appendix A, as a function of highway speed. The lane should be striped for right-turn only using pavement arrows.

Warrants

This technique is warranted on all types of highway with volumes exceeding 15,000 vpd, levels of development greater than 60 driveway per mile, and speeds above 30 mph. Right-turning vehicles per mile should exceed 20% of the directional highway ADT.

Costs

The direct cost for implementing this technique for one quarter mile section was estimated for two construction options. The first option costs are as follows:

Paving (12 ft lane) 1,760 sq yd x $20	=	$35,200
Curb and gutter 1,100 ft x $8	=	8,800
Relocation of roadside structures 0.25 mile x $10,000 (one side)	=	2,500
Patch Driveways	=	3,200
		$49,700

The second construction option considers the cost of the basic construction plus acquiring right-of-way. The estimated costs for implementing this option are:

Basic construction	=	$49,700
Right-of-way 15,800 sq ft x $3	=	47,400
		$97,100

Measures of Effectiveness

For this evaluation, a quarter-mile highway section on one side was used as the basic unit. High levels of development were assumed to have nine commercial driveways of which three are medium volume and six are low volume. Medium levels of development were assumed to have six commercial driveways of which two are medium volume and four are low volume. Low levels of development with an average of two driveway per quarter mile on one side were not evaluated. Also, as seen from the above assumptions, high volume driveways were not considered to be candidates as part of this technique.

For the accident analysis, it was assumed that each driveway would experience a 50% reduction in right-turn accidents, or a 15% reduction in total driveway accidents. The results of this analysis are shown in Table A-25.1.

TABLE A-25.1

ANNUAL ACCIDENT REDUCTION PER QUARTER MILE BY INSTALLING CONTINUOUS RIGHT-TURN LANE

LEVEL OF DEVELOPMENT (Driveways per Mile)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 30	-	-	-
MEDIUM	30-60	0.35	0.60	0.82
HIGH	> 60	0.52	0.90	1.23

Delay reduction estimates, shown in Table A-25.2, were derived by assuming 30% right turns and delay reductions per right-turn vehicle of 3 sec on medium-volume highways and 4 sec on high-volume highways.

TABLE A-25.2

ANNUAL DELAY REDUCTION (HOURS) BY INSTALLING CONTINUOUS RIGHT-TURN LANE

LEVEL OF DEVELOPMENT (Driveways per Mile)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 30	-	-	-
MEDIUM	30-60	-	274	365
HIGH	> 60	-	410	547

Evaluation and Comparison

Based on the operational effectiveness and cost estimates, Table A-25.3 shows the benefit-cost ratios for the cost option excluding right-of-way costs. If right-of-way purchase is required, the technique is not cost-effective. Without right of way acquisition, the technique is only cost-effective for the combination of high highway volume and high level of development.

TABLE A-25.3

BENEFIT/COST RATIOS FOR CONTINUOUS RIGHT-TURN LANE (EXCLUDING RIGHT-OF-WAY PURCHASE)

LEVEL OF DEVELOPMENT (Driveways per Mile)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 30	-	-	-
MEDIUM	30-60	-	-	-
HIGH	> 60	-	-	1.3

A-26: CONSTRUCT A LOCAL SERVICE ROAD

Frontage roads are access control measures that have numerous functions, depending on the kind of arterial highway they serve and the character of the surrounding commercial area. They segregate local traffic from the higher-speed through traffic, and intercept driveways of abutting commercial establishments. Cross connections between the through traffic lanes and frontage roads, usually provided in conjunction with crossroads or intersections, furnish the means of access between through roads and adjacent property. Thus, the through character of the highway is preserved and is unaffected by subsequent development of the roadside.

The frontage-road system can add tremendous flexibility to the operation of a highway when utilized as an auxiliary facility. A continuous frontage-road system provides maximum land service to properties abutting the highway facility. Also, during periods of saturated flow on urban highways, frontage roads provide the operational flexibility often required to alleviate congestion on the system.

The frontage road, as an access control measure, reduces the frequency and severity of conflicts along the highway by preventing direct left turns and removing slower turning vehicles from the through lanes. This technique decreases delay on the highway for through vehicles as a result of the elimination of marginal stream friction. Some trade-offs are realized by increasing the frequency of conflicts and delay by indirect routing for some maneuvers.

Design and Operational Considerations

Frontage roads are generally parallel to the arterial highway. They may or may not be continuous and may be on one or both sides of the arterial. The frontage roads may be at variable distances from the through traffic lanes depending on the site geometrics and the traffic operations. Figure A-26.1 shows a typical frontage road design.

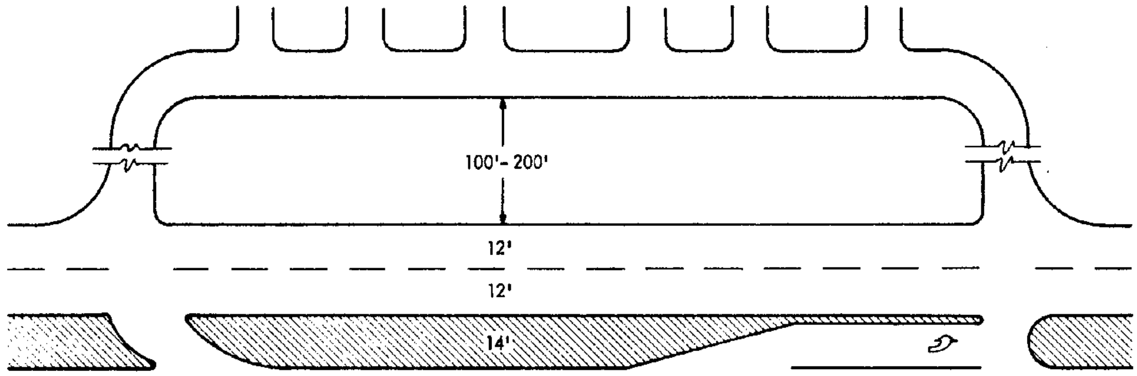


Figure A-26.1 - Typical Frontage Road Design

The design of frontage roads is affected by the type of service it is intended to provide to abutting commercial developments. Where a frontage road is continuous and passes through highly developed areas, its primary function is that of general service, and it assumes the character of an important local street. At the other extreme, where the frontage roads are only a few blocks long, follow an irregular pattern, border the rear and sides of buildings, or serve only scattered development, traffic will be light and operation will be limited in character.

One-way frontage roads are much prefered to two-way because they reduce the degree of interference between vehicular traffic. In addition, one-way frontage roads require less pavement and right-of-way. Two-way frontage roads at busy at-grade intersections complicate crossing and turning movements and impair the efficiency and safety of the entire intersection. Where a major highway joins a two-way frontage road, the potential for wrong-way entry is greatly increased. This problem is greatest where the highway joins the frontage road at an acute angle.

Two-way frontage roads may be considered for partially developed urban areas where the adjoining street system is so irregular or so disconnected that one-way operation would introduce considerable added travel distance and cause undue inconvenience. Also, two-way frontage roads may be necessary for suburban areas where points of access to the through facility are infrequent, where only one frontage road is provided, where streets connecting with the frontage street are widely spaced, or where there is no parallel street within a reasonable distance of the frontage road.

Connections between the arterial and the frontage road are an important element of design. On urban arterials with slow-moving traffic, slip ramps or simple openings in a narrow outer separation may work reasonably well. However, on rural arterials with higher speeds, the ramps and their terminals should be liberally designed to provide for speed change and storage lanes.

The dimensional requirements for the connections between arterials and frontage roads depend largely upon the geometric characteristics and the operational requirements of both facilities. For instance, in lightly developed commercial areas, an intersection designed to fit minimum turning paths of passenger vehicles may operate satisfactorily. In highly developed areas, however, an intersection designed to meet minimum geometric requirements will seldom operate satisfactorily unless certain of the traffic movements are prohibited. Separate signal indications can be utilized to relieve some of the conflicts between the various movements but this can be done only at the expense of excessive delay to most of the traffic.

The preferred alternative to restricting turns is to design the intersection with adequate dimensions, particularly the width of outer separation. This permits the intersections between the cross street and the frontage roads to be well removed from the cross-street intersection with the main lanes. For satisfactory operation with moderate-to-heavy traffic volumes on the frontage roads, the outer separation should preferably be 150 ft or more in width at the intersection. The 150-ft dimension is derived on the basis of the following considerations:

(1) It is the miniumum acceptable length needed for placing signs and other traffic control devices to give proper direction to traffic on the cross street.

(2) It usually affords acceptable storage space on the cross street in advance of the main intersection to avoid blocking the frontage road.

(3) It enables turning movements to be made from the main lanes onto the frontage roads without seriously disrupting the orderly movements on traffic.

(4) It facilitates U-turns between the main lanes and the two-way frontage road. (Such a maneuver is geometrically possible with a somewhat narrower separation but is extremely difficult with commercial vehicles.)

(5) It alleviates the problem of wrong-way entry onto the through lanes of the arterial.

Accordingly, outer separations at intersections should be 150 ft or more in width wherever practicable and feasible. Narrower separations are acceptable where frontage road traffic is very light, where frontage roads operate one-way only, or where some movements can be prohibited. Turning movements that are affected most by the width of outer separation are: (1) left turns from the frontage road onto the highway; (2) U-turns from the through lanes of the arterial onto a two-way frontage road; (3) right turns from the through lanes of the arterial onto the outer roadway. With narrow separations there is the ever-present risk of wrong-way entry onto the through lanes, however.

Except for the width of outer separation, the design elements for intersections involving frontage roads are much the same as for conventional intersections.

Warrants

Frontage roads are warranted in the planning stage for primary divided arterials with speeds of 40-55 mph and an anticipated high level of development (greater than 60 driveways/a mile). Usually traffic volumes exceeding 20,000 vpd are associated with this type of development.

Costs

The direct cost of constructing frontage road systems is site specific and highly variable. An estimate of 0.5-1.5 million dollars per mile is appropriate for general evaluation. The main element contributing to high cost is the right-of-way requirement.

Measures of Effectiveness

Frontage roads, next to grade separation, provide the ultimate access control of arterial highways. Properly designed frontage roads effectively control access to through lanes on the arterial, provide access to adjoining property separate local from through traffic and permit circulation of traffic on each side of the main arterial.

Although the literature lacks sufficient data and investigation of the operational effects of these types of facilities, accident reductions are expected due to elimination of direct conflicts. A total account of frontage road consequences is dependent on site conditions and the operational parameters associated with the developments.

Evaluation and Comparison

It is inconceivable to deny the traffic operational benefits gained by the complete separation of conflicts between local turning traffic and through traffic using the main arterial. Generally, these benefits are characteristic of outer roadway systems and have been long associated with freeway and expressway systems. The function of frontage roads for these highly traveled roadway systems is certainly justifiable when compared to other alternatives to fulfill the high degree of access control needed. However, the nature and magnitude of direct access control for surface arterials is significantly different from that of freeways. The benefit/cost ratios for various systems of frontage roadways are predicted to be low, (less than unity for many applications) because of the prohibitive construction and right-of-way costs.

A-27: CONSTRUCT A BYPASS ROAD

The continued growth of commercial strips along major arterials has magnified the problem of access control. Many highway agencies have been unable to alleviate congestion occurring in the vacinity of such commercial developments. Attempts to relieve the congestion have ultimately led to building a bypass route--a technique currently utilized by most state highway agencies.

Bypasses provide motorists with the opportunity to avoid heavily developed or congested areas without conflicting with local traffic. As a result, this technique reduces the frequency and severity of conflicts on both facilities by separating longer distance and faster moving through traffic (including trucks) from slower local traffic.

Design and Operational Consideration

There are four kinds of bypass highways; each designed and located so that traffic may travel at much higher speed than can be achieved on the customary direct route through congested locations.

The standards for bypass design are similar to that of any major highway. Thus, the design and physical requirements are highly dependent on site conditions and the extent of development. The main operational objective of a bypass highway is to divert through traffic from the highly commercialized route with its associated traffic conflicts potential to a less developed lower traffic volume route.

As a commercial strip increases in population and activity, the percentage of traffic that has a destination somewhere within that area also increases. The natural thought of highway officials and of the road users is to route the through traffic around the business area or even around the entire urban area via a bypass route. Often this proposal meets with strong opposition from the business interests, especially from those merchants who cater to the highway traveler. A second objection usually comes from the owners of the land proposed for the bypass and often from owners of nearby land.

The completely new right-of-way for implementing this technique makes it easy to control access to the bypass. Access control is mandatory for the bypass route itself, to prevent the roadside from being filled with business establishments and attracting traffic that would return congestion levels to their previous conditions.

Warrants

Bypasses are warranted when the arterial it substitutes for, has a traffic volume greater than 20,000 vpd, a level of development greater than 60 driveways per mile, and when no other access control technique can solve the problem. Excessive accident rates may also warrant a bypass (see Appendix B, Table B-I).

Costs

The direct cost for constructing a bypass highway is highly variable and depends on the physical requirement for the new facilities. An estimate of one million dollars per mile is thought to be adequate for general evaluation.

Measures of Effectiveness

Through traffic speed may increase from an average urban speed of 10 to 20 mph to a bypass speed of 40 to 50 mph, depending upon the local conditions. This higher speed results in two specific benefits. First, the vehicle running cost per mile is usually decreased materially by eliminating the costly slowdowns and stops. Certain bypass routes may add some overall distance as compared to the existing arterial. If so, any added distance would add to the running cost distance, but it is not likely that such added cost would exceed the gain resulting from eliminating the speed changes. Second, higher average speed on the bypass route results in an appreciable reduction in travel time. By increasing the average speed from 15 mph to 45 mph, the time reduction per mile of travel would be 2.67 min/vehicle. Through traffic, therefore, usually makes significant gains in both vehicle running cost and travel time by the use of the new bypass highway.

Local traffic often receives the same two benefits. When the through traffic moves to the bypass, the main arterial is free from much of its congestion. The remaining vehicles move faster and endure less delay.

A third road-user benefit is found in the fact that the bypass serves as a traffic distributor for local internal traffic and for external traffic with one trip end within the urban area. This distributor action brings relief to the arterial street system.

Accident costs are probably also reduced by the bypass. The urban property damage-only accident rate would be reduced on a vehicle-mile basis, however, the injury accident rate may be increased because of higher speeds on the bypass.

Evaluation and Comparison

The community as a whole usually experiences a net beneficial consequence from the bypass. It gains a quieter city, less air contamination, less vibration of buildings from heavy trucks, and does not have to suffer the inconvenience and disruption from widening and reconstruction of a local street to gain the added traffic capacity. And, the motor-vehicle users will be benefited by less congestion and better accessibility.

The effects of bypasses on traffic could be observed and measured. But the economic and social consequences of bypasses on commercial communities are difficult to observe and still more difficult to measure. Overall, it is difficult to justify the cost-effectiveness based on operational improvements except when the bypass is the only feasible alternative for solving the operational problems on a high-volume route with a high level of commercial development.

A-28: REROUTE THROUGH TRAFFIC

In this technique the separation of through traffic from local traffic is achieved by using other adjacent facilities to reroute through traffic. The technique helps to reduce congestion and the frequency and severity of conflicts by separating and rerouting higher-speed through vehicles to where they have less potential of conflict with slower-speed local traffic.

Design and Operational Considerations

The rerouting of through traffic should only be undertaken when other alternatives have been rejected on technical, economical, or legal grounds. The existence or availability of a suitable alternate route is necessary. Minor adjustments may be needed on the new route to account for the new traffic surge. For instance, signals may be introduced or improved for this purpose. Other design requirements and/or operational improvements depend on local site conditions.

Rerouting through traffic has traditionally been a sensitive issue with the public, especially when residential areas are affected. Commercial establishments have developed along the fixed route, and quiet residential areas have developed away from major arterials. A rerouting of a large volume of traffic may upset local business and alter this development scheme. Communities' goals and growth can be affected by such a rerouting scheme.

Rerouting can prove sometimes to be an inexpensive means to reduce congestion on many arterials. The new route must fit into a transportation plan aimed at achieving a community's goals.

Warrants

Rerouting through traffic is warranted when the number of access points on arterials exceeds 80 driveways per mile and ADT is over 20,000 vpd. Also, this technique is warranted when other on-site techniques are infeasible. Frequent accidents associated with driveway maneuvers could also constitute a warrant for application of this technique (see Appendix B, Table B-I).

Costs

The direct costs of rerouting through traffic range from practically nothing to a large sum of capital. This cost depends largely on the characteristics of the parallel facility where the through traffic is being accommodated.

Measures of Effectiveness

Although the literature does not contain direct evaluation for this technique, the operational benefits from accident delay reduction could be considerable for certain specific conditions.

Evaluation and Comparison

This technique can be cost-effective where (1) high levels of development and high traffic volume require major access control improvements; (2) a suitable facility is available for rerouting through traffic; and (3) the implementation cost associated with rerouting is small.

III. DRIVEWAY LOCATION TECHNIQUES

B-1: OFFSET OPPOSING DRIVEWAYS

This technique involves the longitudinal separation of driveways on opposite sides of the highway, and it can be implemented either at existing locations or as an optimization practice when authorizing driveway permits.

Offsetting driveways should be considered if opposing driveways are causing crossing conflict problems. The separation distance will better facilitate driveway-to-driveway maneuvers and will eliminate the concentrated conflict area that is present with opposing driveways.

The functional objective of offsetting driveways is to limit the number of conflict points. Conflict points are reduced from 32 for directly opposing driveways (4-leg intersections) to 18 for the two offsetting driveways (two 3-leg intersections). The more severe crossing conflict points decrease from 16 to 6.

Implementing this technique will cause an increase in the frequency of left-turn ingress and right-turn egress maneuvers. Also an increase in weaving maneuvers results.

Design and Operational Considerations

The major element of the recommended design is the separation distance between the two offsetting driveways. This distance should be large enough so that the motorist can make a definite turn onto the arterial, weave safely to the inner lane and then turn into the other driveway. The separation distance should prevent diagonal crossing movements.

The minimum spacing between driveway intersections is determined by the distance required to negotiate the weaving maneuver safely. If the driveways are too closely spaced, problems might be created by the blocking of some movements by left-turn queues at the approach to the other driveway. The above conditions require a minimum driveway separation of 300 ft.

Driveway-to-driveway weaving maneuvers consist of different turning patterns, depending on the driveway offset configuration. Figure B-1.1 illustrates the different weaving patterns involved.

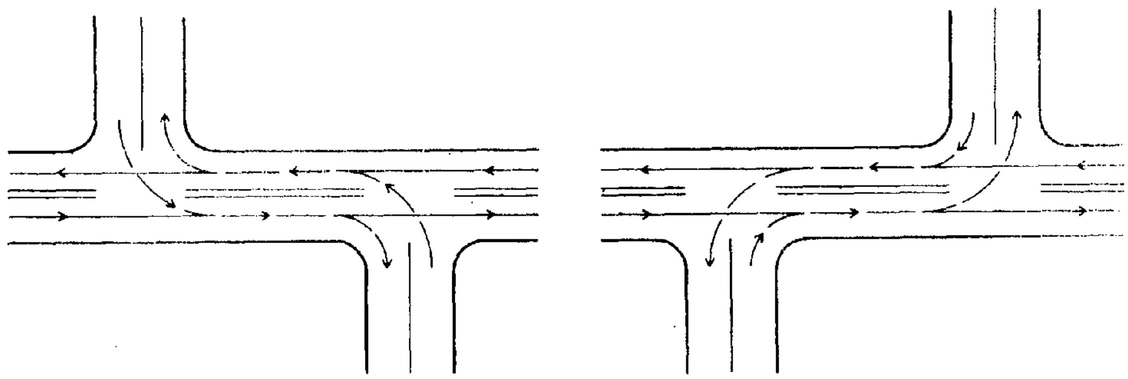


Figure B-1.1 - Difference in Weaving Maneuvers Resulting From Driveway Offset Configuration

Greater interference to through traffic is likely when the driveways are offset as shown by the drawing on the right. The right-turn egress to left-turn ingress maneuver poses a greater threat to traffic safety than does the left-turn egress to right-turn ingress maneuver.

Warrants

This technique can be implemented on all undivided highways where the traffic volumes do not warrant 4-way traffic signals at driveway locations. Property frontage must also be sufficient to accomodate the 300-ft driveway separation. Development near the driveway location should contain fewer than 45 driveways per mile with highway speeds ranging between 30 and 45 mph. Driveway volume should exceed 1,000 vpd and highway ADT should be less than 10,000. Driveway-to-driveway maneuvers should total at least 150 per day or 30 during the peak hour. Accident experience could also warrant the application of this technique (see Appendix B, Table B-I).

Costs

The conditions for which the costs were estimated for this technique involve the closing and relocating of one driveway. Closing one driveway (100 sq yd) was estimated at $1,200 and constructing the new driveway (130 sq yd) was valued at $3,100 for a total implementation cost of $4,300. If application of this driveway location technique occurs in the permit authorization stage, no incremental cost is involved.

Since construction of a new driveway is included in the implementation of this technique, it would be beneficial to apply other low-cost driveway design techniques. One example of an inexpensive technique that should yield additional benefits would be C-8, "Increase the Effective Approach Width of the Driveway."

Measures of Effectiveness

The operational evaluation was concerned with the estimated difference in annual accidents between the opposing driveways and the offsetting driveways. These differences resulted by comparing the accidents at an unsignalized, four-way intersection (opposing driveways) against those of two, three-way commercial driveway intersections (offsetting driveways). The estimated annual accident reductions for offsetting opposing driveways are shown in Table B-1.1.

Evaluation and Comparison

Table B-1.2 lists the benefit/cost ratios for this technique, which were derived from the estimated costs and the accident reduction benefits.

It is clearly evident from Table B-1.2 that offsetting opposing driveways is cost-beneficial for all the volume combinations which warrant this technique. The effectiveness will be greatly enhanced when this driveway location technique is implemented through the driveway permit authorization process.

The offsetting of opposing driveways is very favorable when comparing the cost-effectiveness of other point location techniques. It should be recalled that this technique has only limited application. Consideration should be given only at locations where serious crossing conflict problems occur and where signals are not warranted.

(TECHNIQUE B-1)

TABLE B-1.1

ANNUAL ACCIDENT REDUCTIONS BY OFFSETTING OPPOSING DRIVEWAYS

DRIVEWAY ADT (Vehicles per Day)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 500	0.4	0.7	1.0
MEDIUM	500-1500	0.9	1.7	2.3
HIGH	> 1500	1.6	2.6	3.6

TABLE B-1.2

BENEFIT/COST RATIOS FOR OFFSETTING OPPOSING DRIVEWAYS

DRIVEWAY ADT (Vehicles per Day)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 500	3.0	4.9	7.0
MEDIUM	500-1500	6.3	12.0	16.0
HIGH	> 1500	11.0	18.0	25.0

B-2: LOCATE DRIVEWAY OPPOSITE A THREE-LEG INTERSECTION OR DRIVEWAY AND INSTALL TRAFFIC SIGNALS WHERE WARRANTED

Where traffic signal warrants can be satisfied (see Technique A-4) this measure involves locating a driveway opposite a three-leg intersection either during the driveway permit authorization process or by relocating an existing driveway. Traffic operations along an arterial are directly affected by the number and location of driveways or intersections. Interference to traffic operations should be minimized by constructing an additional driveway opposite an existing three-leg intersection rather than at a neighboring location. As the number of access points along an arterial decreases, the quality of traffic flow will usually improve unless congestion results at the access locations due to the turning vehicles. Because of the greater separation between driveways, a more efficient progression speed for through vehicles should be realized. The installation of traffic signals helps to regulate vehicle speeds and also controls the turning maneuvers. Figure B-2.1 shows the application of this technique.

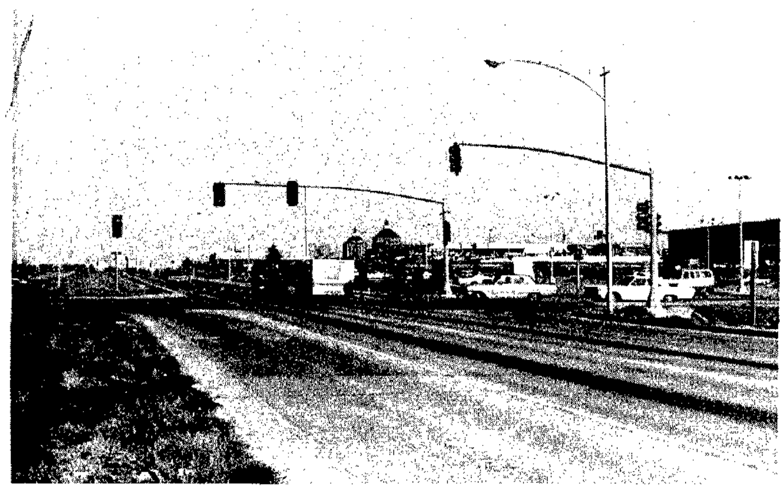


Figure B-2.1 - Driveway Located at Signalized Intersection

Reducing the number of conflict points is the functional objective of this technique. Conflict points are reduced from 18 for the two separate three-leg intersections to 10 for three-phase signalization of a 4-leg intersection. The more severe crossing conflict points are reduced from 6 to 3.

Design and Operational Considerations

The major elements associated with this technique are the driveway construction and traffic signal installation. Driveway design depends upon the specific function of the driveway and also the location and conditions under which the driveway will be operating. All design elements such as width, angle, radii, channelization, and vertical geometrics should provide for optimum driveway operations. These driveway design elements are specified in the Driveway Design and Operations Techniques.

The second major design element related to this technique is the installation of traffic signals. All design elements such as signal sight distance, signal head height, signal support location, and number of phases are included in Technique A-4, "Install Traffic Signals at High-Volume Driveways." All traffic signal installations need to meet at least one of the warrants in the MUTCD.

The number of signal phases at a driveway location directly affects both the highway and driveway traffic operations. Maximum safety is achieved when each conflicting traffic stream is provided with its own separate signal phase so there is no conflict with other movements during that interval.

Warrants

This technique is warranted on all types of highways where sufficient frontage is available to locate a driveway opposite a three-leg intersection or driveway. If an existing driveway is being relocated, the separation distance before relocation should be less than 300 ft. Driveway-to-driveway maneuvers should number either 30 during the peak hour or 150 per day for a signalized location. Cross-street volume should exceed 1,000 vpd and highway ADT should be greater than 10,000.

Costs

Two options were considered in the economic evaluation. The first consisted of installing a traffic signal at the permit authorization stage. A two-phase signal was considered and estimated at $15,000. The second option included the closing and relocating of an existing driveway plus a traffic signal installation. The driveway closing and relocating was estimated at $4,300 which resulted in a total cost for the second option of $19,300.

Measures of Effectiveness

The accident evaluation for this access control measure is based on comparing the estimated annual accidents at two commercial driveways with the estimated annual accidents at a four-legged, signalized intersection. The estimated annual accident reductions that result from this technique are shown in Table B-2.1.

TABLE B-2.1

ANNUAL ACCIDENT REDUCTIONS BY LOCATING A DRIVEWAY OPPOSITE A THREE-LEG INTERSECTION OR DRIVEWAY AND INSTALLING TRAFFIC SIGNALS

DRIVEWAY ADT (Vehicles per Day)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 500	- 0.58	- 1.0	- 1.4
MEDIUM	500 - 1500	- 0.6	- 1.0	- 1.4
HIGH	> 1500	- 0.6	- 0.8	- 1.2

Installing signalization at a location will undoubtedly increase delay to through vehicles. However, delay to driveway vehicles could either increase or decrease depending on the traffic volumes and composition. For this reason, no measure of effectiveness on delay was estimated.

Evaluation and Comparison

This measure for controlling access is not cost-effective because the accident evaluation has indicated that accidents will increase after this technique is implemented. However, the estimated accident prediction tables might not be representative for a specific site location. Where a significant number of driveway-to-driveway maneuvers exist and driveway separation is insufficient, the accident problem could be more severe than the accident table predicts. This would tend to reverse the negative benefits and possibly produce a cost-effective access control measure at signalized driveway intersections.

Considering delay would also affect the cost-effectiveness of this technique. It seems likely that an increase in through vehicle delay would more than counter any decrease in delay to driveway vehicles. The result would be a negative impact on the cost-effectiveness.

A total evaluation indicates that this technique is a non-beneficial access control measure. Consideration should not be given to this technique until other driveway location or design treatments have been examined.

B-3: INSTALL TWO ONE-WAY DRIVEWAYS IN LIEU OF ONE TWO-WAY DRIVEWAY

This access control technique involves the opening of two one-way driveways to replace a single two-way driveway. Although it appears that this technique may decrease the overall safety of the location, by increasing access points, it actually should increase safety through the resulting reduction in total conflict points.

The two one-way driveways, by limiting the turning maneuvers that can be made at each driveway, will have eight conflict points, two of which are crossing conflict points. The two-way driveway has nine conflict points, of which three are crossing conflict points. The overall benefit of implementing this technique is that one crossing conflict point is eliminated. Also, by separating the opposing driveway flows, head-on encorachment conflicts on the driveway are eliminated.

Design and Operational Considerations

Since this is a driveway location technique, the driveway details concerning return radius, alignment angle, and offset distance are not discussed. These design parameters are discussed in connection with Technique C-8, "Increase the Effective Approach Width of the Driveway."

One parameter that is important in this technique is the distance between the two one-way driveways. Generally, the greater the distance between two adjacent driveways, the safer traffic operations will be. Crossing, diverging, and merging movements all occur in the vicinity of driveway openings. Only straight line movements are assumed to occur on the highway between two driveways with a large separation distance. Of course, a practical limit must be placed on the separation depending on specific site conditions. Driveway separation distances are discussed in detail under Technique B-5, "Regulate the Minimum Spacing of Driveways."

Another important element is the orientation of one-way driveways. The one-way driveways should be oriented so that the driveway vehicle, if it must exit and re-enter the driveway in its search pattern, does not cross through two directions of highway traffic. The direction of the one-way driveways is discussed in connection with Technique C-16, "Reverse One-Way Driveway Operation from In-Out to Out-In."

Two strategies exist for implementing this technique. The original two-way driveway can be changed to one-way operation and one additional one-way driveway can be added, or the original driveway can be vacated and two one-way driveways can be constructed. Both strategies may involve the redesigning or realignment of the internal parking areas.

Warrants

This technique is warranted at point locations on all types of highways. The level of development should be less than 60 driveways per mile. Highway ADT should be greater than 10,000 vpd, and highway speeds should be less than 35 mph. At the commercial site, at least 40 vph should turn left across through traffic to enter the driveway during peak periods. Frontage widths should be at least 150 ft where practical to insure that minimum driveway separation distances can be attained.

Costs

The costs for this technique were estimated for two construction options. The cost of the first option, which involves converting the original two-way driveway to one-way operation and constructing an additional one-way driveway, is estimated at $3,200.

The second option involves vacating the original driveway and opening two one-way driveways in its place. The estimated cost for the option is $7,500. Of this cost, $1,200 is allotted to closing the original driveway, $6,200 is needed to construct the new driveways, and $100 is for signing.

It should be pointed out that driveway and highway safety can be optimized with no additional cost by implementing other driveway design and operations techniques in conjunction with this technique.

Measures of Effectiveness

The major benefit realized by this technique is that conflict points are reduced by a factor of one-ninth. The resulting accident reductions are listed in Table B-3.1.

TABLE B-3.1

ANNUAL ACCIDENT REDUCTIONS BY INSTALLING TWO ONE-WAY DRIVEWAYS IN LIEU OF ONE TWO-WAY DRIVEWAY

DRIVEWAY ADT (Vehicles per Day)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 500	0.02	0.05	0.06
MEDIUM	500-1500	0.07	0.12	0.16
HIGH	> 1500	0.11	0.18	0.26

No specific delay effects for this technique were found in the literature review. It is not felt that any substantial benefits will be gained in delay to through or driveway vehicles.

Evaluation and Comparison

Benefit/cost ratios have been calculated for the two construction options using the estimated accident reductions and costs. The benefit/cost ratios for the first construction option appear in Table B-3.2. Table B-3.3 contains the benefit/cost ratios for the second construction option.

These benefit/cost ratios are not too encouraging. The ratios, however, are expected to increase if this technique accompanies others aimed at reducing accidents on the highway. These techniques would include adding or altering driveway geometrics.

It is not recommended that this technique be implemented until other access control measures have first been examined.

TABLE B-3.2

BENEFIT/COST RATIOS FOR CONSTRUCTION OPTION 1

DRIVEWAY ADT (Vehicles per Day)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 500	-	-	-
MEDIUM	500-1500	-	1.1	1.5
HIGH	> 1500	1.0	1.7	2.4

(TECHNIQUE B-3)

TABLE B-3.3

BENEFIT/COST RATIOS FOR CONSTRUCTION OPTION 2

DRIVEWAY ADT (Vehicles per Day)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 500	-	-	-
MEDIUM	500-1500	-	-	-
HIGH	> 1500	-	-	1.0

B-4: INSTALL TWO TWO-WAY DRIVEWAYS WITH LIMITED TURNS IN LIEU OF ONE STANDARD TWO-WAY DRIVEWAY

This access control technique is aimed at reducing conflicts at a single driveway location by replacing the single driveway with two limited-turn driveways. The immediate effect of this technique is that conflict points are reduced. The two driveways will have a total of six conflict points, two of which are crossing conflict points. The one two-way driveway has nine conflict points, three of which are crossing conflict points. Turning velocities can be increased by angling the driveways to receive turning vehicles.

Design and Operational Considerations

It is recommended that the two limited-turn driveways be aligned at a 60 degree angle with the through lanes, as shown in Figure B-4.1. This angle will enable turns to be made at higher speeds, and the required driveway deceleration distance can be easily fitted into the angled driveway length. The horizontal driveway design elements selected should conform to the recommendations discussed in Technique C-8, "Increase the Effective Approach Width of the Driveway."

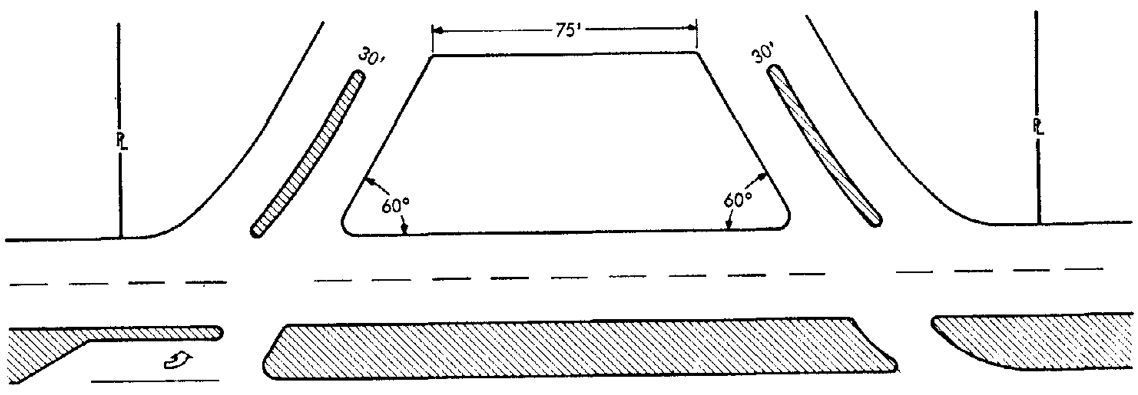


Figure B-4.1 - Two Two-Way Driveways with Limited Turns

The minimum recommended driveway spacing is 75 ft at the right-of-way line. This distance is determined by the extent of vehicle congestions that may occur where the two angled driveways converge. The restrictions imposed by driveway separation distances require that frontage widths be at least 200 ft. This requirement eliminates highly developed areas from consideration for the technique. The driveway separation distances should conform with the distances listed in Technique B-5.

This technique requires medial channelization. If sufficient median area exists to construct the required medial channelization, it is suggested that this technique be implemented as an addition to the median project. It would not be feasible to construct the median to accommodate only this driveway configuration.

Warrants

This technique is warranted at point locations on divided highways with sufficient median width. The level of development should be less than 60 driveways per mile. Highway ADT should be greater than 10,000 vpd, and highway speeds should be greater than 35 mph. At the commercial site, at least 40 vph should turn left across through traffic to enter the driveway during peak periods. Frontage widths should be at least 200 ft when practical to insure that minimum separation distances can be attained.

Costs

The costs for implementing this technique were estimated for two construction options. The first construction option involves the cost of implementation in the permit authorization stage. In this option, one additional driveway is constructed and adequate channelization is provided, for an estimated $3,940.

The second construction option involves closing one driveway and constructing two new ones. The estimated construction cost is $8,240.

In addition to the driveway construction costs, the cost of closing an existing median opening and constructing two replacement median openings has been evaluated. The estimated cost of closing an existing median opening is $5,480. The cost of opening two medial bays is $20,000. It can be seen that the added cost of the median work is very high when compared to the cost of the driveway construction. It is recommended that this technique be undertaken only as a low-cost addition to a median construction project.

Measures of Effectiveness

The implementation of this technique is expected to affect accident severity and frequency. Severities should be reduced because the speed differential between through lane and turning vehicles is reduced. Accident frequencies should also decrease because the number of conflict points is reduced from 9 to 6. Severe crossing conflict points are reduced from 3 to 2.

Since total conflict points are reduced by one-third, this factor was applied to the accidents expected to occur at the original driveway. The results of this accident reduction analysis appear in Table B-4.1.

TABLE B-4.1

ANNUAL ACCIDENT REDUCTIONS BY INSTALLING TWO TWO-WAY DRIVEWAYS WITH LIMITED TURNS IN LIEU OF ONE TWO-WAY DRIVEWAY

DRIVEWAY ADT (Vehicles per Day)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	<500	0.09	0.15	0.21
MEDIUM	500-1500	0.21	0.37	0.50
HIGH	>1500	0.32	0.57	0.77

No significant effects on delays to highway vehicles are expected to occur after implementing this technique.

Evaluation and Comparison

The estimated costs and accident reductions discussed previously were used to calculate the benefit/cost ratios for all possible combinations of driveway and highway ADT. Table B-4.2 and B-4.3 list the benefit/cost ratios for the two construction options.

As can be seen from these tables, this technique is cost-beneficial for medium and high combinations of driveway ADT and highway ADT.

The benefit/cost ratios listed in these tables will be drastically reduced if any construction within the median accompanies this technique. If, however, this technique accompanies a median construction technique, as an additional low-cost option, the cost-effectiveness of the median construction technique will be increased.

TABLE B-4.2

BENEFIT/COST RATIOS FOR INSTALLING TWO TWO-WAY DRIVEWAYS WITH LIMITED TURNS AT THE AUTHORIZATION STAGE

DRIVEWAY ADT (Vehicles per Day)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 500	-	1.1	1.6
MEDIUM	500-1500	1.6	2.8	3.8
HIGH	> 1500	2.4	4.3	5.8

TABLE B-4.3

BENEFIT/COST RATIOS FOR INSTALLING TWO TWO-WAY DRIVEWAYS WITH LIMITED TURNS (CLOSE ONE DRIVEWAY AND CONSTRUCT TWO)

DRIVEWAY ADT (Vehicles per Day)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 500	-	-	-
MEDIUM	500-1500	-	1.3	1.8
HIGH	> 1500	1.2	2.1	2.8

B-5: REGULATE MINIMUM SPACING OF DRIVEWAYS

The minimum spacing of driveways is a regulatory method used by many agencies to regulate the frequency of access points along highways. This technique can be implemented at existing locations or during the driveway permit authorization stage. Strategies for achieving this objective at existing driveways include closing of driveways or closing and relocating driveways.

This technique indirectly reduces frequency of conflicts by separating adjacent, basic conflict areas and limiting the number of basic conflict points per length of highway. The technique is expected to reduce the severity of rear-end conflicts as it allows more deceleration distance and perception time for motorists. Some trade-offs may be realized by increasing average delay and rear-end conflicts at driveways as a result of increasing the average volume per access point.

Design and Operational Considerations

The critical element in implementing this technique is the designation of a minimum distance between adjacent driveways. The distance between driveways must allow driveway vehicles to safely accelerate, decelerate, and cross traffic streams without excessive interference with through traffic or traffic using adjacent driveways. Thus, the minimum spacing is related to the operational characteristics of the highway and interactions between adjacent driveways. Such interactions include conflicts between vehicles entering the traffic stream simultaneously from adjacent driveways and blocking of adjacent driveways by left-turn queues.

Table B-5.1 shows the recommended minimum spacing based on normal acceleration and deceleration rates for various highway speeds.

TABLE B-5.1

MINIMUM SEPARATION OF ADJACENT DRIVEWAYS

Highway Speed	Rate of Deceleration	Rate of Acceleration	Minimum Spacing
20 mph	8.5 fps^2	3.0 fps^2	85
25 mph	8.5 fps^2	2.5 fps^2	105
30 mph	8.5 fps^2	2.1 fps^2	125
35 mph	8.5 fps^2	1.7 fps^2	150
40 mph	8.5 fps^2	1.7 fps^2	185
45 mph	8.5 fps^2	1.7 fps^2	230
50 mph	8.5 fps^2	1.7 fps^2	275

Closely spaced driveways on undivided arterials cause a multitude of conflicting areas as a result of overlapping maneuvers. The separation of conflicting areas becomes the critical element in driveway spacing. A minimum separation of 85 ft is recommended at these locations. This separation is sufficient to insure that minimum vehicle turning-paths from adjacent driveways do not overlap.

The excessive turning maneuvers of major driveways have a pronounced effect on adjacent driveways. Queueing vehicles desiring to enter driveways may block the entrances to minor driveways. Usually this situation is associated with major signalized driveways. At these locations, the minimum spacing is a function of the traffic volume using each driveway and the constraints imposed on each driveway by the nature of the highway operation and design of each access point.

Warrants

This access control technique is generally warranted for all types of arterials where conflict areas overlap and delays are excessive. Highways with volumes greater than 5,000 vpd and speed greater than 25 mph are candidates for consideration. Also, the technique is warranted on arterials which have a level of development ranging from 30-60 driveways per a mile and frontage widths greater than 100 ft. Minimum driveway volumes greater than 200 vph at peak periods is necessary for warranting this technique.

Costs

The direct cost of implementing this technique was estimated for three construction options. The first option requires closing a number of driveways with a cost of $1,200 for each closing. The second option calls for closing and relocating a number of driveways with an estimated cost for each driveway of $4,300. The third construction option calls for implementing the minimum spacing at the permit authorization stage at no incremental cost to the highway agency. Where major construction is expected, many additional improvements can be implemented with little or no additional cost. These improvements include point-location techniques such as upgrading of horizontal and vertical geometrics of newly constructed driveways detailed in the Driveway Design and Operations Techniques.

Measures of Effectiveness

Although several highway agencies and researchers have dealt with the effect of driveway density per mile, no documentation was found on the relationship between driveway spacing and accidents or delays. In many cases, the number of potential conflict points have induced an increase in accident occurrence. It is felt that a considerable decrease in accidents will occur after implementing this technique because of the probable reduction in conflicts. Accident severity and delay area also expected to decrease because of expected increase of separation between adjacent conflict areas.

Evaluation and Comparison

Although no numerical values were given to the anticipated accident reductions and delays, the B/C ratios are expected to have high numerical value because of the low cost. The three construction options, therefore, are expected to be cost-beneficial. Of particular importance, is the third option which implements the technique at the permit stage without any cost to the highway agency. The reason is that no direct cost to the public is associated with reasonable regulatory policies.

B-6: REGULATE MINIMUM CORNER CLEARANCE

This access control standard regulates the distance between a crossroad intersection and the nearest driveway location. In this text, corner clearance is defined as the distance, measured along the back of the arterial curb, from the nearest edge of a driveway to the nearest edge of the intersection.

This technique moves the basic driveway conflict area away from the vicinity of an intersection by regulating the distance from the driveway to the intersection. The major effect is that the minimum spacing of access points is increased, resulting in larger stopping sight distances and driver perception times. An additional effect is that driveway vehicles will be delayed less by standing queues at signal-controlled intersections. A possible trade-off is that access to some corner commercial properties may be partially or totally denied.

Design and Operational Considerations

The major design and operational consideration that accompanies this technique is the effect of a signalized intersection on corner driveways. The corner lot driveway, which is upstream from the intersection, can be blocked when a standing queue backs upstream from a traffic signal. For this condition, the recommended minimum corner clearance is equal to the average signal queue length. Driveways located just downstream from a signalized intersection will also be influenced by queue length. Here the queue will appear across the highway, and left-turn egress traffic will be delayed until the queue length dissipates.

At unsignalized intersections, corner clearance distances need only be sufficient to insure adequate and unrestricted turning movements by driveway traffic. The minimum recommended corner clearance for this condition is 50 ft.

Warrants

This technique may be applied on all types of highways where corner lot driveways create conflict and delay problems to through and driveway traffic. Highway ADT and speed should exceed 5,000 vpd and 25 mph, respectively. Severe limitations on corner frontage widths may render this technique impractical at locations with frontage width widths less than 100 ft.

Costs

The costs for implementing this technique have been estimated for three construction options. The first option involves closing the corner driveway at an estimated cost of $1,200. The second option closes the corner driveway and opens an alternative driveway at the correct corner clearance distance, at a cost of $4,300. The third option requires corner clearance to be regulated in the permit authorization stage at no incremental cost to the highway agency.

The effects of this technique can be optimized, for little additional cost, if the driveway design parameters detailed in the Driveway Design and Operation Techniques are included in the driveway reconstruction plans.

Measures of Effectiveness

Although no effects on accidents or delays were documented in the literature, reductions could occur in both areas after implementing this technique. Accident severity and frequency will decrease because the driveway conflict area has been removed from the immediate intersection vicinity, thus increasing through vehicle perception and braking distances. Delays to driveway traffic decrease because the turning vehicle will not be delayed by signal queues.

Evaluation and Comparison

Since no value was assigned to the expected reduction in accidents, no numerical values could be estimated for benefit/cost ratios. It would appear that the construction options involving capital expenditures will have small benefit/cost ratios when compared to the third construction option, which regulates corner clearance distance during the permit authorization stage. The third option will have an extremely high benefit/cost ratio. This is because there is little cost to the highway agency associated with a regulatory policy.

It is recommended that this technique be implemented in the permit authorization stage.

B-7: REGULATE MINIMUM PROPERTY CLEARANCE

The regulation of minimum property clearance distances is an access control standard that helps increase the minimum spacing of access points. Property clearance is the distance, measured along the arterial curb, from the extended property line to the nearest edge of the driveway.

The technique is expected to reduce deceleration requirements on the highway. Conflicts will be reduced because drivers are allowed more perception time between successive conflict areas.

Design and Operational Considerations

One reason for regulating the minimum property clearance distance is that driveway vehicles can exit one driveway and safely enter the adjacent driveway. For this maneuver a minimum property clearance distance of 15 ft is necessary.

The minimum property clearance distance of 15 ft will allow a vehicle to perform the maneuver from one driveway to another with a minimal turning path. If higher turning velocities are desired, larger property clearances should be considered.

Of more importance in highway-driveway interactions is the minimum separation of driveways. It would make little sense to follow the minimum property clearance guidelines if the recommended driveway spacing could be implemented just as easily. The recommended property clearances should serve as a guideline if minimum driveway separation distances cannot be implemented directly. In this case, the recommended separation distance can be equally split between the neighboring properties with the property clearance recommendation shown in Table B-7.1.

(TECHNIQUE B-7)

TABLE B-7.1

RECOMMENDED PROPERTY CLEARANCE

Highway Speed (mph)	Property Clearance* (ft)
20	40
25	50
30	60
35	75
40	90
45	115

* These values are half those shown in Table B-5.1.

Warrants

This technique may be applied on all highway types where insufficient property clearance contributes to conflicts and delays to the through and driveway traffic. Highway ADT and speed should exceed 5,000 vpd and 25 mph.

Costs

The costs for implementing this technique have been estimated for three construction options. The first option involves vacating an incorrectly located driveway. The estimated cost for this option is $1,200.

The second option involves closing an incorrectly located driveway and opening a replacement driveway in an acceptable location. The estimated cost for this option is $4,300.

The third option requires property clearances to be regulated in the permit authorization stage at no incremental cost to the highway agency. The effects of this technique can be optimized, for little additional cost, if the driveway design parameters detailed in Technique C-8 are included in the driveway reconstruction plans.

Measures of Effectiveness

Small reductions in accidents and delays should result from implementing this technique. Although no literature was found that documents this prediction, the reductions should be similar to those suggested for other driveway spacing techniques.

Evaluation and Comparison

It would appear that the construction options that involve large capital expenditures will not be cost beneficial. The third construction option, however, which regulates property clearance distance during the permit authorization stage, should have a high benefit/cost ratio, because of no direct cost to the highway agency.

B-8: OPTIMIZE DRIVEWAY SPACING IN THE PERMIT AUTHORIZING STAGE

This is a general operating practice that maximizes the spacing of adjacent driveways during the permit authorization stage. The technique is intended to supplement the operational benefits expected from Technique B-5, "Regulate Minimum Driveway Spacing."

This technique indirectly reduces the frequency of conflicts by separating adjacent conflict areas and limiting the number of basic conflict points per length of highway. The implementation of the technique is expected to reduce the severity of conflicts as it allows more deceleration distance and perception time between driveways.

Design and Operational Considerations

The best way to illustrate the utilization of this technique is by the following example. Consider three adjacent properties having frontage widths of 400 ft, 600 ft, and 300 ft. Each property is permitted two driveways with a minimum separation distance of 200 ft. One possible arrangement, satisfying these requirements, is shown in Figure B-8.1. Although this arrangement is technically acceptable, it lacks the proper utilization of the spatial entities affecting adjacent driveways and highway operation. A better arrangement, using the optimization technique, is shown in Figure B-8.2.

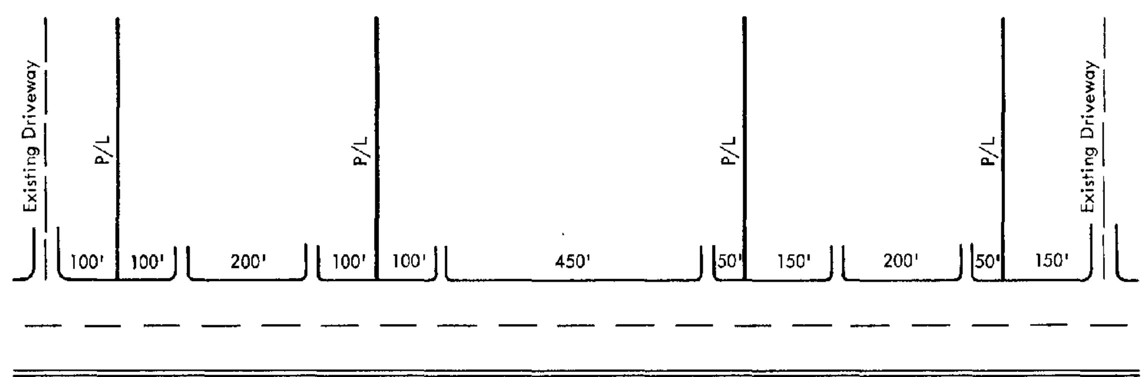


Figure B-8.1 - Driveway Locations that Satisfy Minimum Spacing Requirements

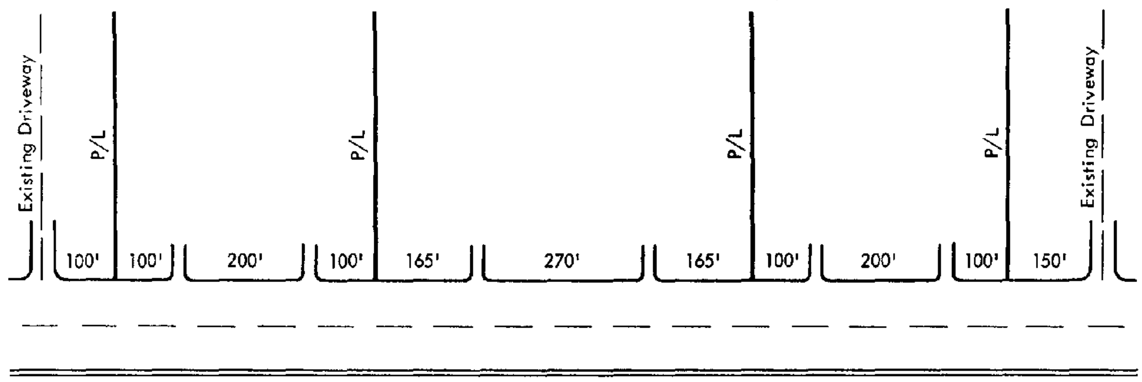


Figure B-8.2 - Optimization of Driveway Locations

Warrants

This technique is warranted for all types of highways. Its application is limited to the permit authorization stage. Highways with volumes and speeds greater than 5,000 vpd and 25 mph, respectively, are prime candidates. Also, the technique is warranted on arterials, which have an anticipated level of development range from 30-60 driveways per mile. Minimum anticipated driveway volumes of 1,000 vpd are required.

Costs

There are no incremental costs associated with the implementation of this technique at the permit authorization stage.

Measures of Effectiveness

The real opportunity for highway agencies to implement this technique occurs at the permit authorization stage. Although the effects on accidents and delays are immeasurable at this stage, the technique is expected to have some benefits. The optimization of operationally effective access control techniques, dealing with a reduction in the frequency of access points on highways, is expected to reduce accidents and delay on the highway. The amount of reduction is site specific and depends on several variables such as traffic volumes, turning maneuvers, and the extent of development of the commercial area.

(TECHNIQUE B-8)

Evaluation and Comparison

The benefits of this technique are similar to those of the techniques that reduce the number of access points. And, because no incremental costs are incurred by the highway agency in the permit authorization stage, the cost-effectiveness is expected to be relatively high.

B-9: REGULATE MAXIMUM NUMBER OF DRIVEWAYS PER PROPERTY FRONTAGE

This general access control standard limits the number of driveways per property relative to the length of available frontage. It is a route alternative that minimizes the number of driveways per length of highway.

Generally, regulating the maximum number of driveways per property frontage limits the number of conflict areas and provides turning drivers more time and distance to execute their maneuvers.

Basic conflict points will be reduced proportionately to the reduction in driveways. This results in a reduction in the frequency of conflicts. The severity of conflicts should also decrease because deceleration requirements are lessened.

If, because of the application of this technique, traffic volume increases significantly at existing driveway locations, an increase in the frequency of conflicts at these locations is likely. Also, regulating the number of driveways permitted for a specific frontage length could have a significant impact on the business activity at that location. These problems should be considered before denial for an additional driveway is given or before an existing driveway is closed.

Design and Operational Considerations

The major consideration for this technique involves the spacing of driveways for a particular frontage. In general, no peoperty frontage should be denied access to an arterial and minimum spacings between driveways should be provided, as outlined in Technique B-5. General guidelines for the number of driveways are as follows:

1. One driveway should be provided to each frontage.

2. Not more than two driveways need to be provided to any single property unless the frontage width exceeds 600 ft.

3. Access to small adjacent frontages should be consolidated where possible.

The location of driveways within a particular frontage also depends on the minimum property clearance and possibly a minimum corner clearance. These distances were outlined in Techniques B-6 and B-7.

In the process of limiting the number of driveways per property frontage (indirectly limiting the number of driveways per mile), driveway vehicles are afforded more maneuvering distance and time with less interference. Through traffic will be expedited because of fewer conflicting locations and the functional integrity of the highway will be enhanced.

Warrants

The application of this access control measure is warranted on all existing arterial highways or as a standard for all new facilities. For implementation on existing highways, highway volumes and speeds should exceed 5,000 vpd and 30 mph. Total access volumes to a property should exceed 500 vpd.

Costs

The first cost option consists of closing one driveway on an existing facility. The estimated total cost was $1,200. The second option involves regulating the number of driveways at the permit authorization stage which has no incremental cost to the highway agency.

Measures of Effectiveness

Eliminating one driveway on a specific frontage was used as a basis for the accident evaluation. The accident reductions were calculated by reducing the number of commercial driveways by one per mile. These reductions and their corresponding highway ADT ranges are as follows:

Highway ADT Range	Annual Accident Reduction per Driveway Eliminated
< 5,000	0.25
5,000 - 15,000	0.49
> 15,000	0.73

Total delay is likely to decrease with this technique because conflict points are reduced and the spacing between access points is increased.

Evaluation and Comparison

Table B-9.1 reflects the benefit/cost ratios expected after implementing this technique.

It is evident that limiting the number of driveways per property frontage is a very cost-effective measure. The greatest value of this technique seems to lie in its power as a standard for new facilities.

TABLE B-9.1

BENEFIT/COST RATIOS RESULTING FROM CLOSING ONE DRIVEWAY ON A PROPERTY FRONTAGE

HIGHWAY ADT (Vehicles per Day)		
LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
6.4	12	19

B-10: CONSOLIDATE ACCESS FOR ADJACENT PROPERTIES

This general operating practice encourages adjacent property owners to construct joint-use driveways in lieu of separate driveways. Strategies for implementing this technique include closing existing driveways or authorizing joint-use driveways.

A prime example for this technique is the neighborhood shopping center, where access to several properties is provided by a few access points. The feasibility of this technique is viewed primarily at the permit-authorization stage. The joint driveway will cause a reduction in the concentration of driveways along an arterial. The reduction in driveway concentrations is expected to be accompanied by a reduction in the frequency and severity of conflicts.

Design and Operational Considerations

The physical means by which access can be consolidated between two adjacent properties involves construction of a joint use driveway between the two properties. It is recommended that the joint-use driveway be owned by both property owners. That is, the driveway should be located precisely straddling the property line dividing the two establishments. This practice will not enable either owner the opportunity to deny or restrict access to his neighbor's property.

The resulting joint-use parking area should be accompanied by an efficient internal circulation plan. Internal circulation is discussed in detail in connection with Technique C-21, Require Adequate Internal Design and Circulation Plan. Consideration should also be given the driveway design parameters of return radii, offset distances, alignment angles and lane widths, which are discussed under Technique C-8.

Warrants

This technique is warranted on all types of highways. Highway ADT should exceed 10,000 vpd and highway speeds should be greater than 35 mph. Driveway pairs with more than 50 vehicles using each driveway per hour will be good candidates for this technique.

Costs

The cost of implementing this technique was estimated for three construction options. The first option involves closing both single-use driveways and constructing the joint-use driveway on the property line. The estimated cost for this option is $5,500. The second construction option involves the situation where one property is developed, and plans are submitted by the second property owner to open a driveway. The existing driveway is closed and a joint-use driveway is constructed on the property line for approximately $4,300. The second option is implemented during the permit-authorization stage. Also implemented during the permit stage is the third construction option. In this option, joint-use driveways are required on newly developed sites as no incremental cost to the highway agency.

Measures of Effectiveness

The technique indirectly reduces the severity and frequency of conflicts by eliminating one driveway and increasing the spacing of access points. Severity is reduced because some of the accidents that were predicted to occur on the highway will be moved to the parking lot between the two properties where speeds are lower. Accident frequency will also be reduced because the minimum deceleration requirements are relaxed. The accidents associated with the two individual driveway volumes are exponentially related to the driveway and highway volumes.

Accident reductions were calculated for various levels of highway ADT and driveway ADT combinations. High volume driveways have been excluded because their combination will cause more congestion and conflicts. The results of the accident reduction evaluation appears in Table B-10.1

TABLE B-10.1

ANNUAL ACCIDENT REDUCTION FOR CONSOLIDATING DRIVEWAYS

DRIVEWAY ADT (Vehicles per Day)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 500	0.10	0.17	0.20
MEDIUM	500-1500	0.33	0.50	0.70
HIGH	> 1500	-	-	-

No specific effects on delay times were found in the literature. It is expected however, that a slight decrease in delay to through vehicles will occur due to the elimination of one driveway along the highway. The delay to driveway vehicles is expected to increase, because the joint-use driveway will have an increased volume. The effects on total delay will be small.

Evaluation and Comparison

The estimated accident reductions and costs were used to calculate a benefit/cost ratio for combinations of highway and driveway ADT's for each construction option. Table B-10.2 lists the calculated benefit/cost ratios for the first construction option. Table B-10.3 lists the benefit/cost ratios for the second option. It can be seen, by comparing the values in the two tables, that the benefit/cost ratio increases as the construction cost decreases. Since the third option has no cost associated with it, the corresponding benefit/cost ratios are very large.

(TECHNIQUE B-10)

TABLE B-10.2

BENEFIT/COST RATIOS FOR CONSTRUCTION OF JOINT USE DRIVEWAY AND CLOSING THE TWO EXISTING DRIVEWAYS

DRIVEWAY ADT (Vehicles per Day)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 500	-	-	1.1
MEDIUM	500-1500	1.8	2.7	3.8
HIGH	> 1500	-	-	-

TABLE B-10.3

BENEFIT/COST RATIOS FOR CONSTRUCTION OF JOINT USE DRIVEWAY BY CLOSING A SINGLE DRIVEWAY

DRIVEWAY ADT (Vehicles per Day)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 500	-	1.2	1.4
MEDIUM	500-1500	2.3	3.5	4.9
HIGH	> 1500	-	-	-

B-11: REQUIRE HIGHWAY DAMAGES FOR EXTRA DRIVEWAYS

This general access control policy requires the abutting property owner or developer to pay for highway damages if he desires an additional driveway beyond the number considered suitable and sufficient for access. The additional driveways are permitted only if they conform to other established driveway regulations. The compensation should reflect the increased operating and accident costs assumed by the motoring public. Payment for damages can be required either on existing facilities or for sites being developed.

The policy of requiring highway damages must be established by statute, code, ordinance or other means in order to be enforceable. Such a policy should help to discourage the construction of additional driveways. The average spacing of access points would be increased and driveway maneuvers will create less interference with through vehicle movement, thereby achieving better compatibility between accessibility and traffic operations.

Conflict points are indirectly reduced if the technique is a successful deterrent to additional driveways. A reduction in the frequency of conflicts would follow. The increased separation distance between basic conflict areas would increase perception time and lessen deceleration requirements, thus decreasing the severity of conflicts.

Design and Operational Considerations

The guidelines for implementation of this technique will derive from the basic driveway spacing policy of the highway agency. Techniques B-5 and B-9 discuss possible spacing criteria.

Warrants

Requiring highway damages for extra driveways must be applied in the planning stage. This technique is applicable to higher volume highways using specified standards for the number of driveways permitted for specific frontage widths.

Costs

Two distinct situations involve costs associated with this technique. The first situation is where requiring highway damages for extra driveways is effective in limiting the number of access points. There is no cost to concerned highway agencies under these circumstances. The cost related to the second situation involves a damage payment by a property owner or developer where an additional driveway is constructed beyond the number determined as suitable and sufficient for access. This penalty cost should reflect the additional operating costs and possible accident costs incurred by the motoring public as a result of the additional driveway. Operating costs will rise if it is estimated that interference between highway and driveway vehicles causes total delay to increase. Total accidents might increase depending on the location and design of adjacent driveways and also the operating characteristics of the highway-driveway system.

Measures of Effectiveness

The effectiveness of this technique as an access control measure, is dependent upon the degree to which the requiring of highway damages suppresses additional driveway construction. The accident and delay benefits would be estimated from the specific site and operating characteristics.

Evaluation and Comparison

This access control measure can only be effective where the damages being assessed are large enough to discourage the use of additional driveways. The requiring of damages needs to be established by law in order to make the measure enforceable. Such statutes or codes are difficult to enact and they also cause some degree of inflexibility in the area of access control. It is felt that the legal and administrative problems would make this technique impractical and undesirable.

B-12: BUY ABUTTING PROPERTIES

This access control measure is aimed at reducing the frequency of access points by purchasing small parcels that remain after a highway improvement. This elimination of potential access points can aid substantially in protecting the functional integrity of the highway by minimizing the frequency and severity of conflict points.

Design and Operational Considerations

Highway improvement projects frequently require the acquisition of right-of-way. The amount of right-of-way acquired may take a substantial percentage of individual abutting properties. At locations where insufficient property area remains on which to conduct business, the total property should be acquired by the highway agency. Generally, if more than one-half of the property is acquired for additional right-of-way, and insufficient property area remains to house commercial buildings with adequate parking areas, then the total property should be purchased.

Warrants

This technique can be implemented on all types of highways where right-of-way acquisition leaves small parcels of commercial land.

Costs

The costs for implementing this technique are highly site specific. The cost of land and the additional area to be acquired will determine part of the implementation cost. The remainder of the implementation cost may include items such as moving or demolishing buildings, payments for sales lost during moving, and litigation expenses.

Measures of Effectiveness

The public acquisition of commercial land, and the consequential closing of the driveways on that land, will eliminate a number of potential conflict points. The possibility of accidents occurring at those locations will be completely eliminated. Reduced accident severities and frequencies will accompany the reduction in total conflict points. Delay to through vehicles will be reduced because the elimination of the driveways will enable traffic to move at higher speeds. The minimum deceleration requirements will be increased because the purchased land will be free of access points, giving the highway an open space appearance. The actual values for these reductions cannot be estimated because the technique is very sensitive to site-specific conditions.

Evaluation and Comparison

Since the costs and operational reductions are highly site specific, no representative cost-effectiveness can be established. This technique should only be considered when right-of-way acquisition leaves scattered land parcels.

B-13: DENY ACCESS TO SMALL FRONTAGE

The denial of access to small frontages is a regulatory policy that prohibits direct access to the arterial highway. Legal problems are usually encountered and are concerned with the availability of suitable and sufficient access. Compensation is required if suitable and sufficient access cannot be provided.

This technique, as in other regulatory driveway location techniques, separates basic conflict areas by limiting the number of access points. The frequency and severity of conflicts will be reduced because conflict areas are further separated, and driver perception times and distances are increased. The number of frontages which are denied access affects the degree to which the frequency and severity of conflicts is changed.

Design and Operational Considerations

The critical feature relating to this regulatory policy is the frontage width. It is recommended that access be denied to all frontages that are less than 50 ft in width if minimum driveway separation distances and minimum property clearance distances cannot be met. These minimum distances are recommended in Techniques B-5 and B-7.

Since the feasibility of implementing this technique is questionable, other alternatives should be considered for the small frontage situation. Two other Techniques, B-10 and C-19, may be particularly appropriate to this situation.

Warrants

This access control policy is applicable in the permit authorization stage for all arterial highways when frontage widths are less than 50 ft. The denial of access is warranted because minimum driveway separation and property clearance distances cannot be met.

Costs

Three options arise in the permit authorization stage. The first option considers the situation where access is totally denied and access rights have to be purchased. The cost of purchasing access rights, in this case, amounts to buying out the property owner. The cost of buying the property will depend on the location, land use served and many other factors. The last two cost options involve the application of other techniques necessary to the implementation of this technique. Mutual cooperation and agreement between adjacent property owners is necessary in both cases. Technique C-19, "Encourage Connections Between Adjacent Properties," is a possible supplementary technique. The estimated cost would include the cost for constructing the connection ($980) and the possible cost of acquiring access rights. The need for acquiring access rights would depend upon local jurisdictional regulations. If access rights are needed, the cost should reflect any estimated delcine in business by not providing direct highway access. The second technique which could supplement this access control policy is Technique B-10, "Consolidate Access for Adjacent Properties." The estimated cost ($4,300) includes the closing of one existing driveway and constructing a joint-use driveway on the property line (see Technique B-10).

Measures of Effectiveness

The accident analysis for the first option was based on the elimination of one, low-volume commercial driveway. It is assumed that no medium or high volume driveways are likely on small frontages. Table B-13.1 lists the accident reductions that result.

TABLE B-13.1

ANNUAL ACCIDENT REDUCTIONS BY ELIMINATING THE DRIVEWAY ON A SMALL FRONTAGE

DRIVEWAY ADT (Vehicles per Day)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	<500	0.26	0.45	0.62

The accident reductions for the third option is based on the accident evaluations for the supplementary Technique B-10. Only three combinations of driveway volume are applicable to this technique since small frontages are assumed to accommodate only low-volume driveways. The three combinations useful to this technique are 250 + 250, 250 + 1,000, and 250 + 2,000.

Evaluation and Comparison

The first option could only be marginally cost-effective because of the excessive cost of buying out the property owner. The second option (see Technique C-19) could be cost-beneficial where connections between adjacent properties are constructed and no access rights need to be purchased. The third option (see Technique B-10), which deals with the consolidation of access, is less cost-effective than if connections between adjacent properties are used, because of the increased cost of closing one driveway and constructing the new consolidated access driveway.

The application of this technique is not recommended where access rights have to be acquired. The technique is recommended when used in combination with Techniques B-10 or C-19.

B-14: CONSOLIDATE EXISTING ACCESS WHENEVER SEPARATE PARCELS ARE ASSEMBLED UNDER ONE PURPOSE, PLAN, ENTITY, OR USAGE

This is a general operating practice that requires specific changes on commercial sites when they are assembled for development or redevelopment. The consolidation is accomplished by voiding existing driveway permits upon alteration of the property functions. The new permit authorization depends on the developer's plans to use some existing driveways and close or relocate other driveways.

The objective of this technique is to increase average spacing of access points along the highway. The consolidation of driveways reduces the number of access points and thereby increases the spacing of driveways. The increase in driveway spacing provides motorists of turning vehicles more time and distance to properly execute their maneuvers. The severity of conflicts should decrease because deceleration requirements are lessened.

Design and Operational Considerations

The design elements which require consideration for this technique are the number and spacing of driveways to the newly assembled parcel. These elements depend on the new frontage width and the anticipated driveway volumes. In many cases, the newly assembled parcel requires fewer access points to the arterial than the original parcels before consolidation.

The number of driveways depends largely on the frontage width of the newly assembled parcel. Technique B-9 suggests some guidelines for the number of driveways permitted.

The spacing of driveways is also a crucial element in implementing this technique. Techniques B-5 and B-8 suggest some guidlines for minimum spacing and subsequent optimization of this policy.

Another element pertaining to the design considerations of this technique is the use of existing driveways. These driveways should be considered for utilization when adjacent parcels are assembled, if they meet the design criteria and locational policy on newly built driveways. Although this condition is site specific, special consideration must be given to the possible alteration of the parking design and the property internal circulation plan.

Warrants

The application of this access control technique is warranted on all highways where existing parcels are assembled under one purpose.

Costs

The cost of implementing this technique will be borne by the property owner. This cost depends on the permitted number of driveways and their geometrics. For the economic evaluation that follows, an implementation cost of $1,200 has been assumed.

Measures of Effectiveness

The implementation of this technique is likely to reduce the number of access points for newly assembled parcels. Eliminating one driveway on a new parcel is used as a basis for the accident evaluation. The accident reduction values were calculated on the basis of reducing one commercial driveway per mile. These reductions and their corresponding highway ADT ranges are as follows:

Highway ADT Range	Annual Accident Reduction Per Driveway Eliminated
< 5,000	0.25
5,000 - 15,000	0.49
> 15,000	0.73

By reducing the number of conflict points with this technique, total delay is likely to decrease. However, no estimates have been made since delay is so site specific.

Evaluation and Comparison

Table B-14.1 shows the benefit/cost ratios expected after impelementing this technique. It is evident from the table that consolidating access to existing parcels is a cost-effective measure for all levels of development and highway ADT's.

TABLE B-14.1

BENEFIT/COST RATIOS RESULTING FROM CLOSING ONE DRIVEWAY ON A PROPERTY FRONTAGE (PER MILE)

HIGHWAY ADT (Vehicles per Day)		
LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
6.4	12	19

B-15: DESIGNATE THE NUMBER OF DRIVEWAYS TO EACH EXISTING PROPERTY AND DENY ADDITIONAL DRIVEWAYS REGARDLESS OF FUTURE SUBDIVISION OF THAT PROPERTY

This is a general regulatory policy, which designates the maximum number of driveways permitted to each existing property before development. The implementation of this technique requires an advance planning policy with a formal planning document made readily available to abutters. Such policy denies additional driveways regardless of future subdivision of that property.

The objective of this technique is to maintain average spacing of access points along the highway. This objective is achieved by regulating the maximum number of driveways per property frontage. The increase in average driveway spacing provides motorists turning into driveways with more time and distance to properly execute their maneuvers.

This access control measure increases the minimum spacing of access points. This results in a reduction in the frequency of conflicts. The severity of conflicts should also decrease because deceleration requirements are lessened.

Design and Operational Considerations

The design elements requiring major considerations for this technique are the number and spacing of driveways. These elements depend on frontage width and driveway volumes. Technique B-9 suggests guidelines for the number of driveways permitted. However, this number should be reduced if the functions of the property do not require that many access points. Techniques B-5 and B-8 suggest guidelines for minimum spacing at driveways and subsequent optimization of this policy.

Legal implications of this technique might render it impractical. For instance, properties beyond the right-of-way line cannot be controlled by the authority granted to the state highway department. Although, local authority have control over zoning and subdivision, careful coordination by the state highway department will be required to implement this technique.

(TECHNIQUE B-15)

Warrants

The application of this access control technique is warranted on all newly planned highways where commercial activities are anticipated.

Costs

There are no incremental costs associated with the implementation of this technique at the planning stage.

Measures of Effectiveness

The opportunity for highway agencies to implement this technique is at the planning stage. Although the effects on accidents and delays are immeasurable at this stage, reduction in frequency of access points on highways is expected to reduce accidents and delay on the facility. The amount of reduction is site specific and depends on several variables such as the traffic volumes, turning maneuvers, and the extent of development of the commercial area.

Evaluation and Comparison

The cost-effectiveness of this technique is much the same as the benefits of other techniques which reduce the number of access points and increase the average spacing.

B-16: REQUIRE ACCESS ON COLLECTOR STREET (WHEN AVAILABLE) IN LIEU OF ADDITIONAL DRIVEWAY ON HIGHWAY

This access control technique is aimed at maintaining the average spacing of driveways by locating additional driveways on collector streets instead of on the arterial highway when the existing driveways on a property are utilized to their capacity. This technique will reduce conflict frequency and severity diverting some driveway vehicles to the collector street location where traffic volumes and speeds are lower.

Design and Operational Considerations

Additional access should be provided on the collector street instead of on the highway when the existing driveways are shown to be excessively congested or if exceptionally long delays occur to driveway and highway vehicles. The placing of the additional driveway on the collector will reduce the congestion and delay occurring at the highway locations because some of those driveway vehicles will choose to use the less congested collector street. The resulting change in highway operations will include a higher turning volume at the highway-collector intersection, and smaller turning volumes at driveways on the highway.

The location of the collector street driveway should be far enough from the intersection to insure that interruption to the highway-collector intersection is minimized. The corner clearance distance is detailed in Technique B-6.

Warrants

This technique can be implemented on all types of highways at properties where highway and driveway queues are intolerable. Highway volumes should exceed 10,000 vpd, and speeds should be less than 45 mph. Levels of development greater than 45 driveways per mile will especially warrant consideration. The availability of a suitable collector street is essential for implementing this technique.

Costs

The implementation costs have been estimated for two construction options. The first option occurs when the highway agency determines that the existing access points no longer adequately facilitate the efficient movement of traffic into and from driveways. In this situation an additional driveway can be constructed on a collector street at a cost of $3,100. The cost should be borne by the highway agency because the extra driveway was required by that authority.

The second option occurs when the property owner requests an additional driveway on the collector. If the highway agency determines that the request is warranted, the cost will be borne by the property owner. Although the highway agency still determines the driveway location, the property owner will have to pay for the improvement, and the highway agency assumes no incremental cost.

Measures of Effectiveness

This technique reduces the frequency and severity of conflicts by diverting some driveway vehicles to the collector street. The collector street in question will generally have a lower volume than the highway. Accidents are expected to be reduced as shown in Table B-16.1. These reductions represent the difference between locating the additional driveway on the collector as opposed to on the arterial highway.

TABLE B-16.1

ANNUAL ACCIDENT REDUCTION DUE TO REQUIRING DRIVEWAY ACCESS ON LOW-VOLUME COLLECTOR INSTEAD OF ON MEDIUM- OR HIGH-VOLUME HIGHWAY

DRIVEWAY ADT (Vehicles per Day)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 500	-	0.19	0.36
MEDIUM	500-1500	-	0.47	0.87
HIGH	> 1500	-	0.73	1.33

No delay reductions were estimated because the amount of delay at each site is too dependent on site-specific variables such as traffic speeds, available gaps, and traffic volumes.

Evaluation and Comparison

Table B-16.2 shows the benefit/cost ratios for the first option where the highway agency assumes the cost of the additional driveway. This option is cost-effective for all warranted conditions. The second option, in which no incremental cost is borne by the public, will have even higher values.

TABLE B-16.2

BENEFIT/COST RATIOS FOR CONSTRUCTING DRIVEWAY ON LOW-VOLUME COLLECTOR INSTEAD OF ON MEDIUM- OR HIGH-VOLUME ARTERIAL HIGHWAY

DRIVEWAY ADT (Vehicles per Day)	HIGHWAY ADT (Vehicles per Day)		
	LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW < 500	-	1.8	3.5
MEDIUM 500-1500	-	4.6	8.4
HIGH > 1500	-	7.0	13.0

It is not implied that a highway agency should wait for the property owner to first request an additional driveway, and then approve the request at the owner's expense. The highway agency should initiate the additional driveway request, and thus assume an active role in access control of highway operation. At locations where the property owner requests an additional driveway, but where the warrants are not satisfied, the driveway may still be approved as detailed in Technique B-20.

B-17: REGULATE MINIMUM SIGHT DISTANCE

This regulatory policy is designed to control driveway location by imposing minimum sight distance standards for driveways. The policy takes effect by closing and relocating existing driveways or by regulating new driveways in the permit authorization stage. Regulation of sight distance is generally more applicable to suburban-rural locations.

The technique enables the driver of a vehicle, which is on the driveway, to see a sufficient distance in both directions along the highway and to enter the highway without creating a hazardous situation. The increased sight distance also decreases the speed differential between highway and driveway vehicles by allowing the through driver more perception time, which helps to reduce maximum deceleration requirements. These conditions should lead to a reduction in the severity of conflicts.

Design and Operational Considerations

Minimum sight distance requirements are dependent on highway operating conditions and the physical characteristics of the roadway. Minimum sight distances are recommended by AASHTO ("A Policy on Geometric Design of Rural Highways," pages 393-401). The conditions under which the distances were calculated include the distance required for perception and reaction by the driver of a through vehicle and also the braking distance needed. The sight distance for stop-controlled intersections should be measured from an eye height of 3.75 ft to an object height of 4.5 ft. Table B-17.1 lists the minimum sight distances recommended for this technique.

TABLE B-17.1

MINIMUM SIGHT DISTANCE

Design Speed (mph)	Sight Distance (ft)
30	200
35	225
40	275
45	325
50	350

The location of direct access driveways must also allow for the location or setback of buildings and other fixtures, as well as any potential obstructions near the roadway, such as shrubbery, signs, or parked vehicles. These physical features all have a significant effect on the available sight distance.

Warrants

The application of this technique should always be considered in the permit authorization stage. Application to existing highways is appropriate where high-accident rates are associated with sight distance restrictions (see Appendix B, Table B-I).

Costs

Costs were estimated for two options which are possible when implementing this technique. The first option involves closing and relocating one driveway for a total cost of $4,300. The second option is implemented during the permit authorization stage at no incremental cost to the highway agency.

Measures of Effectiveness

No accident or delay studies concerning sight distance were found in the literature. The major impact of this technique is centered about the effects of sight distance on the safety of a particular location. Regulating sight distance on existing facilities or in the permit authorization stage should effect increased safety benefits, but these benefits are largely site specific. Greater benefits are likely at locations where sight distance is the major problem and where speeds and traffic volumes are high.

Evaluation and Comparison

The first option of closing and relocating a driveway will be cost-effective when regulating sight distance at a location will eliminate one accident every 7 years or less. The technique will certainly be cost-effective when implemented during the permit authorization stage. When a driveway is being closed and relocated under any of the other driveway location techniques, consideration should always be given to the regulation of minimum sight distance.

B-18: OPTIMIZE SIGHT DISTANCE IN THE PERMIT AUTHORIZATION STAGE

This is an operating policy which considers driveway location to optimize sight distance. Optimizing sight distance occurs in the permit authorization stage after a thorough review of the driveway location plans. The review enables the driveway to be located where maximum sight distance is available, consistent with other locational controls.

The technique enables the driver of a vehicle, which is stopped on the driveway outside the edge of the traveled way, to see a sufficient distance in both directions along the highway and to enter the highway without creating a hzardous situation. Optimizing the sight distance also decreases the required speed differentials between highway and driveway vehicles. Drivers are afforded more perception time which helps to reduce maximum deceleration requirements. These conditions lead to a reduction in the severity of conflicts.

Design and Operational Considerations

Although frontage widths pose some limitations on the actual location, driveways should be located at the point of optimum sight distance along the frontage. This technique attempts to achieve sight distances greater than required minimums as given under Technique B-17.

The sight distance optimization for driveway location must allow for the location or setback of buildings and other fixtures, as well as any potential obstructions near the roadway, such as shrubbery, signs, or parked vehicles. These physical features all have a significant effect on the available sight distance. The adherence to other driveway location regulations such as driveway spacing (Technique B-5) and property clearance (Technique B-7) is also required.

Warrants

Requests for driveway permits in the authorization stage warrant this access control treatment. All highway types are candidates with particular attention to high-speed highways.

Costs

Since the implementation of this technique is enacted during the permit authorization stage, no incremental costs are borne by the highway agency.

Measures of Effectiveness

The major impact of this technique is centered about the effects of sight distance on the safety of a particular location. Optimizing sight distance in the permit authorization stage should effect increased safety benefits. These benefits are largely site specific. Benefits will likely be greater where speeds and traffic volumes are high.

Evaluation and Comparison

The optimization of sight distance will certainly be cost-effective. When driveways are being located in the permit authorization stage, the application of other driveway location techniques should also increase the overall effectiveness.

B-19: <u>INSTALL SUPPLEMENTARY ONE-WAY RIGHT-TURN DRIVEWAYS TO DIVIDED HIGHWAY</u>

This driveway location technique is aimed at removing turning vehicles and queues from sections of the through lanes. Strategies for achieving this objective involve installing supplementary one-way right-turn driveways to an existing T-driveway on divided highways. The supplementary driveways can be installed to serve both egress or ingress vehicles.

This technique is intended at high-volume driveways to eliminate conflicts on the driveway and secondary rear-end conflicts on the highway associated with right-turn maneuvers. Where the T-driveway has only one lane, each for ingress and egress, this technique will add substantially to the total driveway capacity.

Design and Operational Considerations

Figure B-19.1 shows a typical design for this technique. It is particularly appropriate at large regional or neighborhood shopping centers where adequate frontage width is available. Where possible, the supplementary driveways should be angled for increased turning speed. Also, this pattern will require some attention to the redesign of internal circulation patterns.

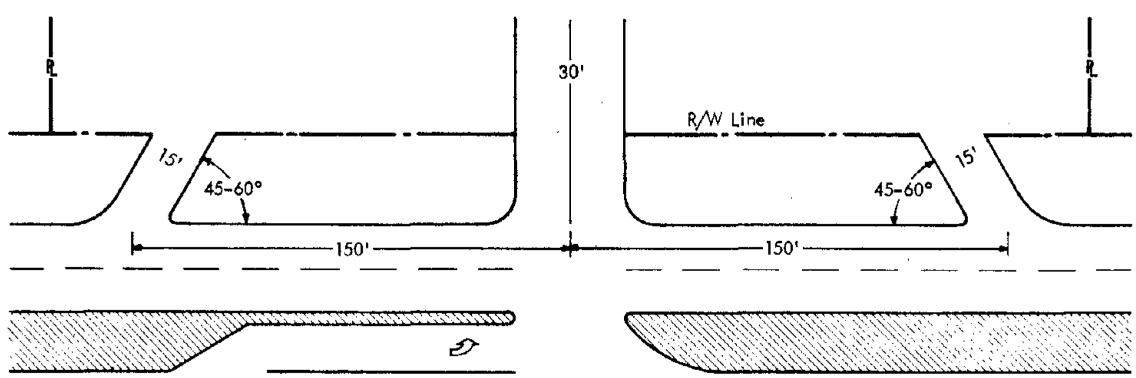


Figure B-19.1 - Supplementary One-Way Right-Turn Driveways

(TECHNIQUE B-19)

Warrants

This technique is warranted at high-volume driveways on multi-lane highways that have volumes and speeds greater than 10,000 vpd and 30 mph. A minimum 300-ft frontage width is desirable.

Costs

The estimated costs for implementing this technique were based on constructing one supplementary driveway. This cost is $3,100.

Measures of Effectiveness

Although no specific accident or delay reduction measures were found in the literature, this technique should be effective in reducing both accidents and delay for the warranted conditions.

Evaluation and Comparison

Although no benefit/cost ratios were calculated, this technique is believed to be cost-effective for the warranted conditions.

B-20: INSTALL SUPPLEMENTARY ACCESS ON COLLECTOR STREET WHEN AVAILABLE

This driveway location technique is aimed at removing turning vehicles or queues from sections of the through lanes. The strategy for achieving this objective is to provide supplementary access to a single property at a collector street location. The technique provides an additional access point for vehicles to use when entering or exiting a property.

The average volume of all driveways to a property will decrease after the supplementary driveway absorbs some of the total volume. Conflicts frequency will be reduced on the highway, and total conflict severity should be reduced by moving some of the conflicts to the lower speed collector. Delay to arterial and driveway vehicles will be reduced because the individual driveway volumes are smaller.

Design and Operational Considerations

This technique is similar to Technique B-16, except that here the driveway capacity warrant and the highway ADT criteria are not applicable. In this technique, a supplementary driveway is requested for a property whose driveway capacity is not heavily taxed.

Warrants

This technique is warranted on all types of unlimited access highways. Levels of development greater than 45 driveways per mile will especially warrant consideration. The availability of a suitable collector street is essential to this technique. The individual existing driveways need not be utilized to a high percentage of their capacities.

Costs

There is no incremental cost to the highway agency associated with the implementation of this technique. The cost of opening the supplementary driveway is $3,100 and will usually be borne by the property owner.

Measures of Effectiveness

Accidents will be reduced on the highway because the anticipated driveway volumes will be smaller. The reduction on the highway may not be large enough to offset the additional accidents that will occur on the collector street. However, the overall accident severity is expected to decrease because the speed on the collector street is generally lower than on the arterial.

Annual accident reductions have been estimated by considering that variations in accident rates accompany varying driveway volumes. A comparison of several single volume accident rates will yield the accident reductions expected. Table B-20.1 lists sample driveway combinations for before-and-after volume situations, and the accident reductions corresponding in each combination. The collector driveway is represented by the lowest volume in the "After" column and the accident rate was computed for a low-volume collector. A negative number in the accident reduction column indicates a net increase in accidents.

TABLE B-20.1

ANNUAL ACCIDENT REDUCTIONS BY INSTALLING SUPPLEMENTARY ACCESS ON COLLECTOR STREET

Driveway Combinations		Highway	Accident
Before	After	ADT	Reduction
750; 750	500; 500; 500	10,000	0.01
1,000; 1,000	750; 750; 500	10,000	-0.15
1,500; 1,500	1,250; 1,250; 500	10,000	-0.03
2,000; 2,000	1,500; 1,500; 1,000	10,000	-0.03
750; 750	500; 500; 500	20,000	0.17
1,000; 1,000	750; 750; 500	20,000	-0.03
1,500; 1,500	1,250; 1,250; 500	20,000	-0.03
2,000; 2,000	1,500; 1,500; 1,000	20,000	-0.03

As the demand for access to the property increases, the accident reduction figures will become positive and larger. No specific values are available to estimate driveway delay changes. The advantage in implementing this technique lies partially in the delay eliminated by locating the supplementary driveway on the collector street instead of on the arterial highway.

Evaluation and Comparison

Because of the negative estimates for accident delay this technique does not seem to be cost-effective. However, this result may be due to certain insensitivities in the evaluation method.

B-21: INSTALL ADDITIONAL DRIVEWAY WHEN TOTAL DRIVEWAY DEMAND EXCEEDS CAPACITY

This is a technique aimed at removing turning queues or vehicles from sections of the through lanes. The technique provides supplementary access to single properties when the demand for access exceeds existing driveway capacity.

The additional driveway will reduce the delay occurring to through and driveway vehicles by allowing an additional access point for vehicular use. Speeds on the highway may be increased because the length of queues waiting to enter a driveway will be reduced. The technique will also allow driveway turning maneuvers to be made with less delay.

Although additional conflict points are introduced by the driveway additions, the frequency of rear-end conflicts may decrease, under certain conditions of driveway use, because the length of turning highway queues is reduced.

Design and Operational Considerations

The additional driveway should conform to the design recommendations as outlined in the Driveway Design and Operations Techniques. The location of the driveway also should be determined by methods detailed in several Driveway Location Techniques. Particular attention should be given to driveway separation, corner clearance, property clearance, and the maximum number of driveways per property.

Under no circumstances should additional access be granted if the property already has the maximum number of driveways permitted for its frontage. Additional access should be provided on collector streets where available. Another alternative is to redesign the driveway entrances to facilitate more efficient operations.

Warrants

This technique is applicable on all highway types. The demand for an access must be such that delays and conflicts are frequent. Driveways with volumes greater than 5,000 vpd located on highways with traffic volumes and speeds greater than 10,000 vpd and 35 mph, respectively, are prime candidates.

Costs

The cost for implementing this technique will most often be borne by the highway agency. The cost for adding one driveway is estimated at $3,100. The highway agency should initiate the driveway request. In this way, an active role in access control can be assumed by the agency, and a periodic review of access control situations will be made. In instances where the property owner requests an additional driveway, and this technique is warranted, the owner will bear the cost.

Measures of Effectiveness

The adding of a driveway to a property could slightly increase the accidents occurring at that location. The benefit of this technique will lie in the delay reduction realized. If the average peak period delay to total traffic can be reduced by 2 sec per vehicle, and there are 1,800 vehicles on the highway during each peak hour, then a total reduction in delay of approximately 2 hr per day can be realized. This corresponds to an annual benefit of $2,400. For the same conditions, accidents are expected to increase by around 0.3 accidents per year, due to the additional driveway. The net annual benefit in this example is $1,560.

Evaluation and Comparison

No cost-effectiveness evaluation can be made because the benefits are highly site specific. This technique, which has limited application, can be highly cost-effective where warranted. However, specific attention should be paid to other alternatives that provide for efficient driveway operations through the redesign of existing driveways.

IV. DRIVEWAY DESIGN AND OPERATIONS TECHNIQUES

C-1: INSTALL TWO ONE-WAY DRIVEWAYS IN LIEU OF TWO TWO-WAY DRIVEWAYS

This driveway operations technique is aimed at limiting the number of basic conflict points at a single property. Specifically, it reduces the number of crossing conflict points by changing driveway operations from two two-way driveways to two one-way driveways. This technique is applied during the permit-authorization stage or at existing sites with appropriate reconstruction. The directional control accompanying one-way operations will result in improved driveway and highway operations by allowing a smaller variety of maneuvers to be made at each driveway. As a result, highway speeds will increase, and delay times will be reduced.

Accident frequencies are expected to decrease, because the total number of conflict points will be reduced from 18 to 10. Four crossing three merge, and three diverge conflict points are eliminated at the two driveways. Accident severities are not expected to substantially decrease.

Possible detrimental effects may occur because turns made into, or from, the wrong driveway may initiate a severe conflict. Also, if a vehicle misses the intended entrance driveway, no other opportunity will exist to enter the other driveway.

Design and Operational Considerations

The individual direction of travel on the driveways is an important consideration with this technique. The driveways should be operationally arranged so that the one-way directions are egress and then ingress proceeding downstream. This operational strategy is detailed in technique C-16; "Reverse One-Way Driveway Operations from In-Out (Proceeding Downstream) to Out-In."

The recommended driveway separation distance to be used with this technique were determined for use with the out-in driveway configuration. They were determined by considering the highway speed and through lane exposure time experienced by an exiting driveway vehicle. Table C-1.1 lists the recommended driveway separation distances.

(TECHNIQUE C-1)

TABLE C-1.1

RECOMMENDED DRIVEWAY SPACING DISTANCES

Highway Speed (mph)	Driveway Spacing (ft)
20	85
25	105
30	125
35	150
40	185
45	230
50	275

Warrants

This technique is warranted on all types of highways where highway speeds are less than 50 mph and traffic volumes greater than 10,000 vpd. At point locations, individual driveway volumes should be greater than 300 vpd. Frontage width requirements are determined by the driveway separation and highway speed. The minimum acceptable frontage width is 120 ft, for a highway speed of 20 mph. High accident rates involving driveway maneuvers will also warrant this technique (see Appendix B, Table I).

Costs

The cost for implementing this technique is estimated at $100. The cost covers the amount necessary to erect two driveway directional one-way signs at existing driveways. The same cost is assumed during the permit-authorization stage. Additional costs may arise if driveway channelization is desired.

Measures of Effectiveness

The immediate results of this technique is that four crossings, three merge, and three diverge conflict points are eliminated. Since the alternative two two-way driveways have a total of 18 conflict points, a reduction ratio of 5/9 was applied to the predicted annual accidents for the two two-way driveways to arrive at the expected accident reduction for this technique. The results of the operational effectiveness evaluation appear in Table C-1.2. No benefits were estimated for delay reductions, but, any delay increase to driveway traffic is expected to be balanced by a decrease in through traffic delay.

TABLE C-1.2

ANNUAL ACCIDENT REDUCTIONS BY INSTALLING TWO ONE-WAY DRIVEWAYS IN LIEU OF TWO TWO-WAY DRIVEWAYS

DRIVEWAY ADT (Vehicles per Day)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 500	0.28	0.50	0.68
MEDIUM	500-1500	0.70	1.22	1.66
HIGH	> 1500	1.08	1.88	2.56

Evaluation and Comparison

Table C-1.3 lists the benefit/cost ratios of this technique for each combination of highway and driveway ADT. The high values listed in the table are indicative of the value of this technique. The low implementation cost coupled with reasonable accident reductions make this technique a powerful access control tool.

TABLE C-1.3

BENEFIT/COST RATIOS FOR INSTALLING TWO ONE-WAY DRIVEWAYS IN LIEU OF TWO TWO-WAY DRIVEWAYS

DRIVEWAY ADT (Vehicles per Day)	HIGHWAY ADT (Vehicles per Day)		
	LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW < 500	84	148	204
MEDIUM 500-1500	208	364	496
HIGH > 1500	320	560	764

This technique would probably be cost-beneficial even if very small reductions in accidents were to occur. The small implementation cost will enable the technique to be applied at many locations where more expensive techniques would be non cost-beneficial. This technique compares very favorably with other access control techniques that alter driveway operations. The benefits realized with this technique can be optimized if additional driveway design methods are simultaneously implemented.

C-2: INSTALL TWO TWO-WAY DRIVEWAYS WITH LIMITED TURNS IN LIEU OF TWO STANDARD TWO-WAY DRIVEWAYS

This technique is aimed at reducing conflicts at properties by replacing two two-way driveways with two limited-turn driveways. This can be done during the permit authorization stage or at an existing location with appropriate reconstruction.

This technique reduces the frequency of conflicts at a single property by eliminating four crossing, four merge, and four diverge conflict points. Accident severities and vehicular delays are not expected to change substantially. Turning velocities can be increased by angling the driveway to receive turning vehicles.

Design and Operational Considerations

It is recommended that the two limited-turn driveways be aligned at a 60-degree angle with the through lanes where practical. This angle will enable turns to be made at higher speeds, and the required driveway deceleration distance can easily fit into the angled driveway length.

The minimum recommended two-way driveway width is 30 ft. This width is sufficient to accommodate two vehicles. A wider driveway width will allow greater separation between egress and ingress vehicles. The driveway width selected should conform to the recommendations discussed in Technique C-7, "Regulate the Maximum Width of Driveways."

When this technique is applied at existing sites, two design options are possible. The first design simply restricts the turning movements that are possible at the existing driveways as shown in Figure C-2.1. The second design involves closing the existing driveways and constructing two angled, channelized driveways as shown in Figure C-2.2.

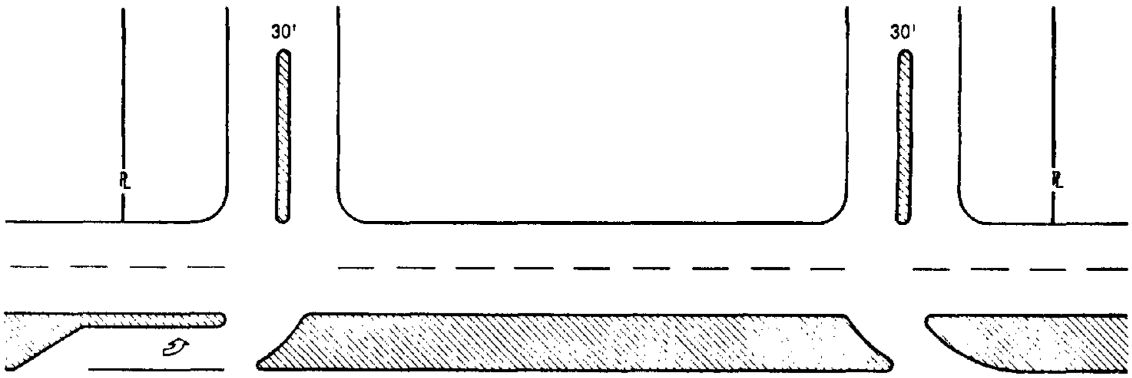


Figure C-2.1 - Two-Way Driveways with Limited Turns

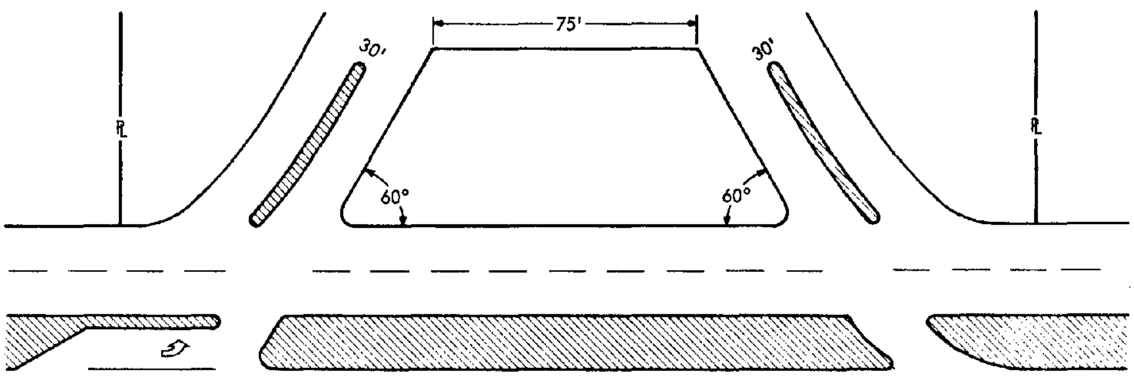


Figure C-2.2 - Angles Two-Way Driveways with Limited Turns

The minimum recommended driveway spacing at the right-of-way line is 75 ft for the angled design. This distance is determined by the extent of vehicle congestion that may occur where the two angled driveways converge. The restrictions imposed by driveway separation distances require that frontage widths be at least 200 ft. This requirement eliminates highly developed areas from consideration for the technique. The driveway separation distances should conform with the distances listed in Technique B-5, "Regulate Minimum Spacing of Driveways."

This technique requires highway medial channelization to facilitate ingress and egress movements. The restricting of turning movements at existing sites will not need extensive medial modifications.

Warrants

This technique is warranted at point locations on all types of highways. The level of development should be less than 60 driveways per mile. Highway ADT should be greater than 10,000 vpd, and highway speeds should be greater than 35 mph. At the commercial site, at least 40 vph should turn left across through traffic to enter the driveway during peak periods. Frontage widths should be at least 200 ft where practical to insure that minimum separation distances can be attained. The technique will also be warranted at locations where accident experience indicates a change in driveway operations.

Costs

The costs for implementing this technique were estimated for three construction options. The first construction option concerns the permit authorization stage. This option will occur when a median construction project is planned and this technique accompanies that project. The cost will be for the installation of a driveway curb and surfacing for two driveways. The estimated cost for this option is $840.

The second construction option occurs when an existing site is altered to conform to this technique. The option concerns closing two standard driveways and installing two angled, limited-turn driveways for $9,440. In addition, the required medial turn bays are constructed. The estimated total cost for the second construction option is $16,940.

The third option involves installing driveway channelization to the two existing T-driveways. The estimated cost for the third option is also $840. It is believed that additional driveway design techniques can be implemented with this method for little additional cost.

Measures of Effectiveness

This technique will reduce accident frequencies because the number of conflict points is reduced from 18 to 6.

Since total conflict points are reduced by a factor of 2/3, a reduction factor of 2/3 was applied to the accident frequency expected to occur at the original two driveways. Table C-2.1 lists the expected annual accident reductions.

TABLE C-2.1

ANNUAL ACCIDENT REDUCTIONS BY INSTALLING TWO TWO-WAY DRIVEWAYS WITH LIMITED TURNS IN LIEU OF TWO STANDARD TWO-WAY DRIVEWAYS

DRIVEWAY ADT (Vehicles per Day)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 500	0.34	0.60	0.82
MEDIUM	500-1500	0.84	1.46	2.00
HIGH	> 1500	1.30	2.26	3.06

No significant effects on delays to highway vehicles are expected to occur after implementing this technique.

Evaluation and Comparison

Benefit/cost ratios were calculated for each of the construction options. Table C-2.2 lists the benfit/cost ratios for implementing the technique in the permit authorization stage or at existing locations where only driveway channelization is required. Table C-2.3 lists the benefit/cost ratios for the construction option that involves relocating existing driveways and providing for medial construction.

The first and third options are highly cost beneficial for all combinations of highway and driveway ADT, because those options involve small implementation costs. The second option is cost beneficial only for some higher volume combinations. From this evaluation, it is evident that this technique should be implemented as an addition to a median construction project where possible. This technique, especially when implemented in the permit authorization stage, compares favorably with other driveway operational techniques, and it can be an effective tool in an access control program.

TABLE C-2.2

BENEFIT/COST RATIOS FOR OPTION 1 (DRIVEWAY CHANNELIZING CURBS) AND OPTION 3 (EXISTING DRIVEWAY CHANNELIZING CURBS)

DRIVEWAY ADT (Vehicles per Day)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 500	12	21	29
MEDIUM	500-1500	29	51	70
HIGH	> 1500	46	79	107

TABLE C-2.3

BENEFIT/COST RATIOS FOR OPTION 2
(TWO ANGLED DRIVEWAYS PLUS MEDIAL CONSTRUCTION)

DRIVEWAY ADT (Vehicles per Day)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 500	-	1.1	1.4
MEDIUM	500-1500	1.5	2.6	3.5
HIGH	> 1500	2.3	4.0	5.3

C-3: INSTALL CHANNELIZING ISLAND TO PREVENT LEFT-TURN MANEUVERS

This driveway design technique directly controls access by preventing left-turn ingress and egress maneuvers. The left-turn maneuvers are restricted by a channelizing island in the driveway throat. The main objective of this technique is to reduce the number of conflict points by limiting the basic crossing conflicts.

The technique reduces the frequency and severity of conflicts by reducing the basic conflict points from nine to two at a driveway. This measure completely eliminates the crossing conflicts that accompany left-turn ingress and egress maneuvers. However, the reduction in conflicts is moderated by a possible increase in right-turn and indirect left-turn maneuvers. Travel time may increase to vehicles denied the opportunity to make left turns.

Design and Operational Considerations

This technique is applicable on all undivided highways where left-turn ingress and egress maneuvers cause safety problems. The important design elements for this technique are the triangular island and its location. The island should be large enough to command the driver's attention and it should be offset at least 4 ft from the through traffic lanes. Three cases are considered for the geometric design of this technique.

The first case eliminates left-turn ingress maneuvers. Widening of the driveway will be required to accommodate the large turning radius for right-turn ingress maneuvers. At least a 50-ft curb return radius is recommended for the optimum operation of this design, as shown in Figure C-3.1.

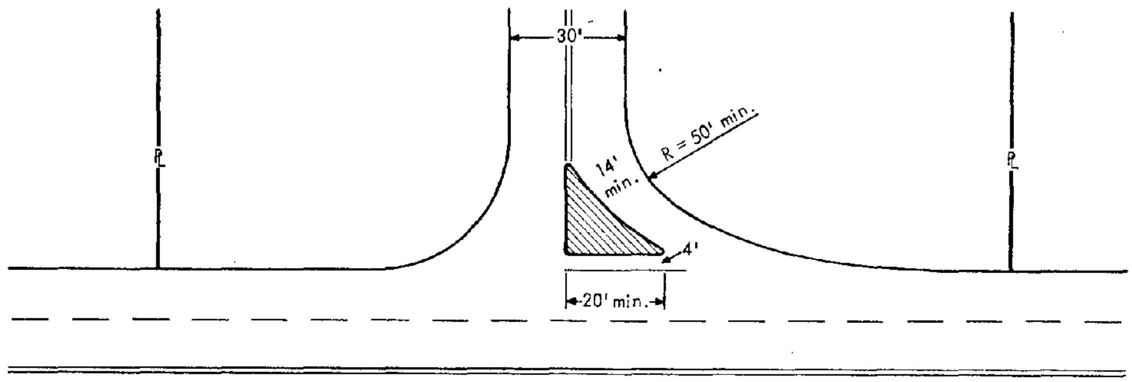


Figure C-3.1 - Driveway Channelizing Island to Prevent Left-Turn Ingress Maneuvers

The second case eliminates left-turn egress maneuvers. Again a driveway channelizing island is located in the driveway throat to prevent left-turn egress maneuvers. Widening of the driveway is required to accommodate the island. A 50-ft curb return radius is recommended for the optimum operation of this design as shown in Figure C-3.2.

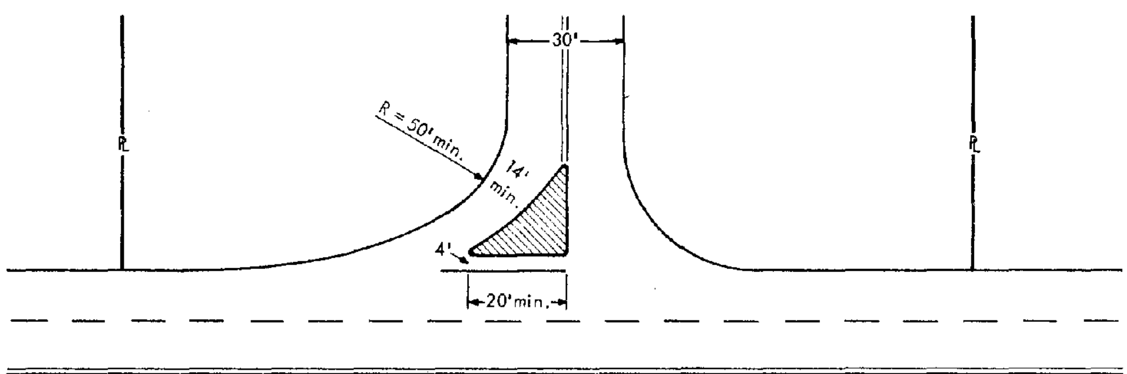


Figure C-3.2 - Driveway Channelizing Island to Prevent Left-Turn Egress Maneuvers

The third case eliminates both left-turn egress and ingress maneuvers. A triangular shaped island is located in the driveway throat to prevent both maneuvers. Widening of the driveway on both sides is required to accommodate the turning radii for right-turn egress and ingress vehicles. A minimum of a 50-ft curb return radius is recommended for the efficient operation of this design as shown in Figure C-3.3.

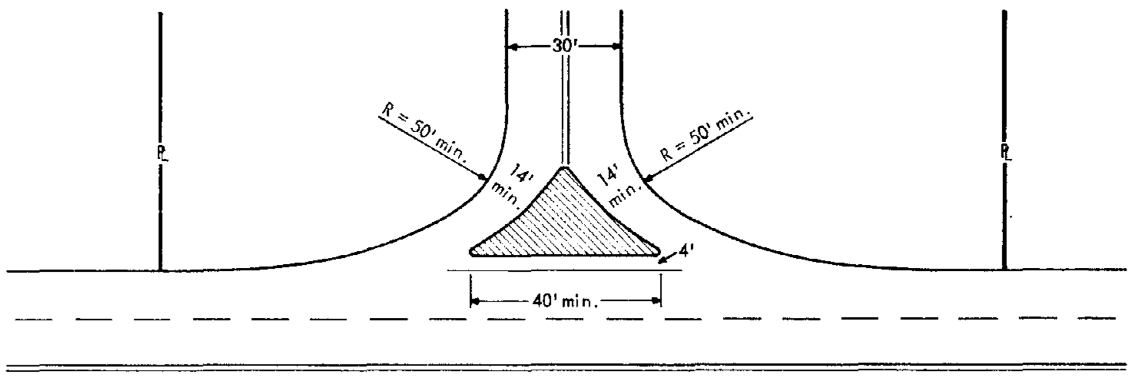


Figure C-3.3 - Driveway Channelizing Island to Prevent Left-Turn Egress and Ingress Maneuvers

The restriction of certain turns on highways and/or driveways will cause vehicles to use circuitious routes to accomplish the desired maneuvers. This operational change must be evaluated within the realm of the total traffic circulation pattern to insure the adequacy of other geometric and operational elements.

<u>Warrants</u>

This technique is warranted on undivided highways with speeds of 30-45 mph, ADT's greater than 5,000 vpd, and driveway volumes of at least 1,000 vpd. The prohibited turns should number less than 100 vpd. High left-turn accident rates will also warrant this technique (see Appendix B, Table B-II).

Costs

The direct costs of implementing this technique have been estimated for three construction options. The first and second construction options call for installing a 200 sq ft channelizing island on the driveway to prevent either left-turn egress or ingress maneuvers. The direct cost of each option is $1,850. This cost includes curbing, widening, signing, and surfacing.

The third construction option calls for installing of a 400 sq ft triangular island on the driveway to prevent both egress and ingress left-turn maneuvers. Widening of the driveway is also required to facilitate adequate right-turn maneuvers. The estimated cost is $3,660. This cost includes curbing, widening, signing, and surfacing.

Measures of Effectiveness

The literature indicates that 70% of driveway accidents involve left-turn maneuvers. Of these accidents, 43% are left-turn ingress maneuvers and 27% are left-turn egress maneuvers. This information was used to predict the reduction in accidents at commercial driveways when implementing this technique.

Because the application of this technique is limited to driveways where left-turn maneuvers constitute a small percentage of the ADT, the elimination of left-turn maneuvers is expected to cause less reduction in total accidents than the percentages stated above. Instead, the elimination of both left-turn maneuvers is estimated to result in a 50% reduction in total accidents at the driveway. Eliminating left-turn egress maneuvers is assumed to decrease total accidents by 20% and eliminating left-turn ingress maneuvers is expected to result in a 30% reduction in total accidents.

Using the predicted commercial driveway accident values developed in the operational evaluation, Tables C-3.1, C-3.2, and C-3.3 were developed and show the predicted reductions in annual driveway accidents when implementing this technique for each driveway design.

TABLE C-3.1

ANNUAL ACCIDENT REDUCTIONS PER DRIVEWAY FOR RESTRICTING LEFT-TURN EGRESS MANEUVERS

DRIVEWAY ADT (Vehicles per Day)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 500	0.05	0.09	0.12
MEDIUM	500-1500	0.13	0.22	0.30
HIGH	> 1500	0.19	0.34	0.46

TABLE C-3.2

ANNUAL ACCIDENT REDUCTIONS PER DRIVEWAY FOR RESTRICTING LEFT-TURN INGRESS MANEUVERS

DRIVEWAY ADT (Vehicles per Day)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 500	0.08	0.14	0.19
MEDIUM	500-1500	0.19	0.33	0.45
HIGH	> 1500	0.29	0.51	0.69

TABLE C-3.3

ANNUAL ACCIDENTS REDUCTIONS PER DRIVEWAY FOR RESTRICTING BOTH LEFT-TURN EGRESS AND INGRESS MANEUVERS

DRIVEWAY ADT (Vehicles per Day)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 500	0.13	0.23	0.31
MEDIUM	500-1500	0.31	0.55	0.75
HIGH	> 1500	0.49	0.85	1.15

The total delay to vehicles denied the opportunity to turn at these driveways is not significant, because these vehicles represent a small portion of the total ADT. Speed on the highway is expected to increase and thereby decrease the delay for through vehicles. Therefore, the net change in total delay is negligible.

Evaluation and Comparison

Benefit/cost ratios for restricting left-turns, are shown for the three construction options in Tables C-3.4, C-3.5, and C-3.6. It is evident from these tables that this access control measure is cost-effective for all volume combinations. This technique compares favorably with other access control techniques dealing with driveway channelization to restrict left-turn maneuvers.

TABLE C-3.4

BENEFIT/COST RATIOS FOR RESTRICTING LEFT-TURN EGRESS MANEUVERS FROM A DRIVEWAY

DRIVEWAY ADT (Vehicles per Day)	HIGHWAY ADT (Vehicles per Day)		
	LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW < 500	-	1.5	2.0
MEDIUM 500-1500	2.1	3.6	4.9
HIGH > 1500	3.1	5.5	7.5

TABLE C-3.5

BENEFIT/COST RATIOS FOR RESTRICTING LEFT-TURN INGRESS MANEUVERS TO A DRIVEWAY

DRIVEWAY ADT (Vehicles per Day)	HIGHWAY ADT (Vehicles per Day)		
	LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW < 500	1.3	2.3	3.1
MEDIUM 500-1500	3.1	5.4	7.3
HIGH > 1500	4.7	8.3	11.0

TABLE C-3.6

BENEFIT/COST RATIOS FOR RESTRICTING LEFT-TURN MANEUVERS OF A DRIVEWAY

DRIVEWAY ADT (Vehicles per Day)	HIGHWAY ADT (Vehicles per Day)		
	LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW < 500	1.1	1.9	2.5
MEDIUM 500-1500	2.5	4.5	6.1
HIGH > 1500	4.0	6.9	9.4

C-4: INSTALL DRIVEWAY CHANNELIZING ISLAND TO PREVENT DRIVEWAY ENCROACHMENT CONFLICTS

This access control measure involves the construction of a driveway median island to control ingress and egress vehicle maneuvers. The technique can be applied either to existing driveways or in the permit authorization stage.

The technique will reduce head-on encroachment conflicts between driveway ingress and egress vehicles. Ingress and egress traffic will be directed to separate sides of the driveway median island. Some increases in single-vehicle accidents can be expected due to driveway vehicles striking the island.

Design and Operational Considerations

The driveway medial channelizing island should be raised and have a minimum width of 4 ft and a minimum length of 25 ft. The length of island will vary depending on driveway operations, available driveway length, and internal parking configurations. The use of a driveway medial channelizing island to completely separate ingress and egress vehicles is shown in Figure C-4.1.

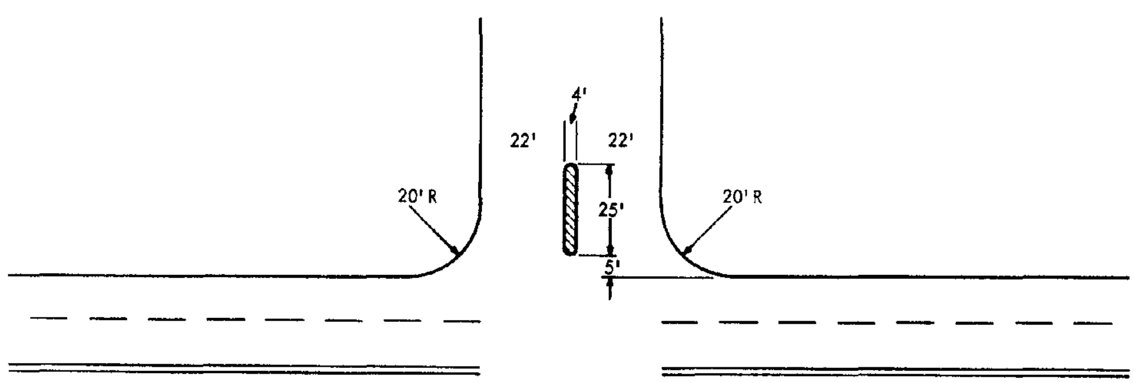


Figure C-4.1 - Driveway Median Channelizing Island

The medial island should not be constructed on the driveway if the resulting driveway width is insufficient for safe and efficient driveway operations. Driveway widening may be necessary in that case. The recommended minimum total driveway width is 48 ft. A greater total driveway width is usually required in order to achieve a desired vehicle turning radius because turning vehicles cannot encroach on opposing driveway lanes.

The offset of the end of the island from through traffic lanes should be at least 5 ft. This distance allows a sufficient separation from the through traffic lanes.

A second application of this technique is shown in Figure C-4.2. The simple installation of barrier curbing will prevent egress vehicles (proceeding from the right in the picture) from encroaching on the ingress path close to the driveway opening.

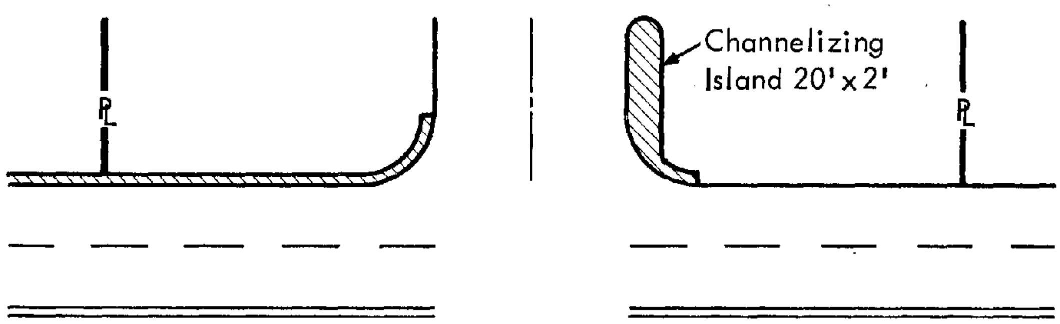


Figure C-4.2 - Driveway Barrier Curbing

Warrants

This technique is applicable on all types of highways and for driveways with two-way operations. A history of driveway head-on accidents between opposing vehicles or between entering and parking vehicles would warrant this treatment. Highway traffic volume should exceed 5,000 vpd with speeds ranging from 25-45 mph. At least 500 vpd or 100 vehicles during the peak hour should utilize the driveway before constructing medial channelization.

Costs

Three construction options were considered for implementation of this technique. The first option included widening the driveway by 4 ft and installing a 25 ft x 4 ft medial island. The estimated total cost was $1,060.

The second option included a 20 ft x 2 ft curb section located on one side of the driveway. The curbing was estimated at $320. The last option was a combination of the previous two options with both a medial island and curbing on one side of the driveway being constructed. The total estimated cost for the combination option is $1,380.

Measures of Effectiveness

Although no data relating this technique to accidents or delay reductions were found, accident reduction estimates for the three options were made. A 4% reduction in total accidents was used for the medial island installation and driveway widening. The corresponding accident reductions are shown in Table C-4.1. A 3% reduction in total accidents was used for the driveway curbing. Table C-4.2 lists the accident reductions for this option. The combination option was estimated to reduce total driveway accidents by 5%. The accident reductions are contained in Table C-4.3.

TABLE C-4.1

ANNUAL ACCIDENT REDUCTIONS BY WIDENING THE DRIVEWAY AND INSTALLING MEDIAL CHANNELIZATION

DRIVEWAY ADT (Vehicles per Day)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 500	0.010	0.018	0.025
MEDIUM	500-1500	0.025	0.044	0.060
HIGH	> 1500	0.039	0.068	0.092

TABLE C-4.2

ANNUAL ACCIDENT REDUCTIONS BY INSTALLING DRIVEWAY CURBING (ONE SIDE)

DRIVEWAY ADT (Vehicles per Day)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 500	0.008	0.014	0.019
MEDIUM	500-1500	0.019	0.033	0.045
HIGH	> 1500	0.029	0.051	0.069

TABLE C-4.3

ANNUAL ACCIDENT REDUCTIONS BY WIDENING THE DRIVEWAY AND INSTALLING MEDIAL CHANNELIZATION AND DRIVEWAY CURBING (ONE SIDE)

DRIVEWAY ADT (Vehicles per Day)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 500	0.013	0.023	0.031
MEDIUM	500-1500	0.032	0.055	0.075
HIGH	> 1500	0.049	0.085	0.115

Delay to driveway or highway vehicles is expected to change very little and therefore no delay reductions have been estimated.

Evaluation and Comparison

Benefit/cost ratios for the three construction options are contained in Tables C-4.4, C-4.5, and C-4.6.

Tables C-4.4 and C-4.6 indicate that these options are cost-effective for medium and high driveway volumes. The driveway curbing option (Table C-4.5) also appears cost-beneficial for some low-volume driveways.

Implementing any of these options is recommended in the site planning stage since the highway agency does not assume incremental costs. When considering this technique for existing facilities, prime consideration must be given to the site layout and intended operations.

A history of encroachment accidents will also be helpful in estimating possible benefits. Supplementing this technique with other low-cost measures, such as increasing the effective approach width (Technique C-8), may increase the total cost-effectiveness.

TABLE C-4.4

BENEFIT/COST RATIOS FOR WIDENING THE DRIVEWAY AND INSTALLING MEDIAL CHANNELIZATION

DRIVEWAY ADT (Vehicles per Day)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 500	-	-	-
MEDIUM	500-1500	-	1.2	1.7
HIGH	> 1500	1.1	1.9	2.6

TABLE C-4.5

BENEFIT/COST RATIOS FOR INSTALLING DRIVEWAY CURBING (ONE SIDE)

DRIVEWAY ADT (Vehicles per Day)	HIGHWAY ADT (Vehicles per Day)		
	LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW < 500	-	1.3	1.8
MEDIUM 500-1500	1.8	3.1	4.2
HIGH > 1500	2.7	4.8	6.4

TABLE C-4.6

BENEFIT/COST RATIOS FOR WIDENING THE DRIVEWAY AND INSTALLING MEDIAL CHANNELIZATION AND DRIVEWAY CURBING (ONE SIDE)

DRIVEWAY ADT (Vehicles per Day)	HIGHWAY ADT (Vehicles per Day)		
	LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW < 500	-	-	-
MEDIUM 500-1500	-	1.2	1.6
HIGH > 1500	1.1	1.8	2.5

C-5: INSTALL CHANNELIZING ISLAND TO PREVENT RIGHT-TURN DECELERATION LANE VEHICLES FROM RETURNING TO THROUGH LANES

The application of this technique involves installing a channelizing island to separate through-lane and right-turn deceleration lane vehicles. The channelizing island prevents turning vehicles from encroaching on the through lanes and also guides the decelerating driver into the driveway by defining the desired vehicle path.

The functional objective of this treatment is to eliminate the encroachment conflict point for right-turn ingress vehicles. A reduction in encroachment (basically sideswipe) conflicts will occur. However, an increase in the number of single-vehicle mishaps may occur due to vehicles striking the island.

Design and Operational Considerations

The prominent design and operational aspects of this technique are the island geometrics and location. A 2-ft island width will adequately separate the traffic streams while using a minimal amount of the pavement width. A minimum island area of 200 sq ft is needed to command driver attention. Additional right-of-way may be required if widening is needed to retain adequate lane width.

The island should be placed so it begins about 25 ft downstream from the initial point of full right-turn lane width. The end of the island should extend 6-8 ft into the driveway intersection. This extension is essential to deter drivers from re-entering the through lanes once they have been committed to the deceleration lane. The extension is long enough to discourage deceleration lane vehicles from returning to the through lanes, but does not constrain the turning paths of vehicles exiting from the driveway. Figure C-5.1 illustrates the technique.

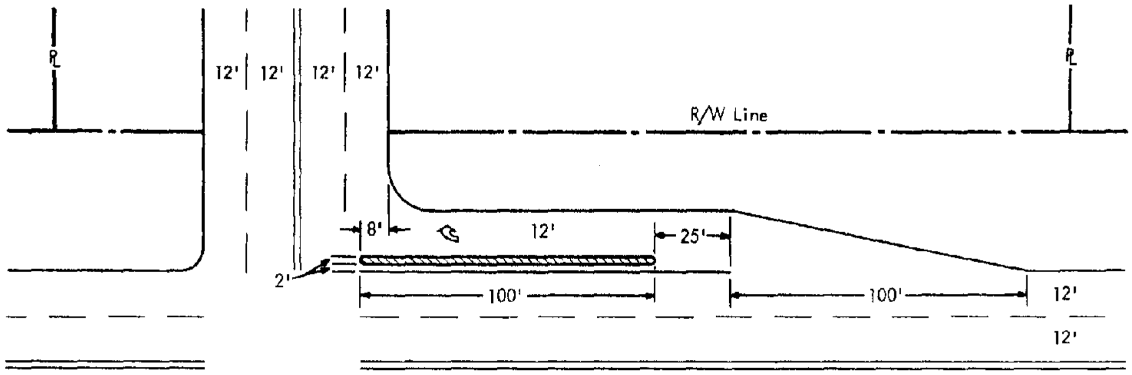


Figure C-5.1 - Channelizing Island to Prevent Right-Turn Deceleration Lane Vehicles from Returning to Through Lanes

A full lane width of 12 ft should be maintained on all through and turning lanes. In addition, a 2-ft safety area should be provided between the island edge and the nearest through lane to separate the island from the through driver's line of sight. The 2-ft safety area may be eliminated if space restrictions dictate. However, conflicts between through vehicles and the island may occur if this omission is made.

Signing is necessary to inform motorists that right-turn ingress maneuvers are to be made by entering the deceleration lane. The sign should direct turning maneuvers to the deceleration lane and might include the message, "Right-Turn Only." Signing should precede the island to enable adequate driver response. Island delineation should also be considered to facilitate nighttime operations. Recommended schemes include island reflectorization (paint or buttons) or driveway illumination.

Warrants

This technique is applicable to all highways with greater than 10,000 vpd. At least 50 right-turn ingress vehicles should enter the driveway during the peak hour. The site should be characterized by a history of encroachment conflicts due to right-turn ingress vehicles re-entering the through lanes.

Costs

Three cost options were considered for implementing this technique. Where no pavement widening is required, installing a 100 ft x 2 ft island was estimated at $1,600. The second option involved widening the deceleration lane by 4 ft within existing right-of-way. The cost breakdown for this option includes $900 for payment, $960 for curb and gutter, $300 for relocation of roadside structures and $1,600 for island installation. The total cost for the second option is $3,760. The final option required 400 sq ft of right-of-way acquisition at $1,200 plus the costs associated with Option 2 which brings its total estimated cost to $4,960.

Measures of Effectiveness

No data were found on the operational effectiveness of this technique. However, some reduction in encroachment conflicts should be realized by implementing the technique, and the reduction should more than offset the expected increase in single-vehicle conflicts with the island. Also, the severity of vehicle-island conflicts should be less than the severity of vehicle-vehicle encroachment conflicts.

Evaluation and Comparison

Probably none of the construction options for this technique can be economically justified unless a particular location has experienced a history of encroachment conflicts. However, the technique may be justified as a subordinate to Technique C-17, "Install Right-Turn Deceleration Lane."

C-6: INSTALL CHANNELIZING ISLAND TO CONTROL THE MERGE AREA OF RIGHT-TURN EGRESS VEHICLES

This driveway design technique reduces the frequency of conflicts by reducing conflict areas. The channelizing island will designate the correct right-turn egress path, and more clearly define the merge area.

The technique will reduce accident frequency and severity between right-turn egress vehicles and through traffic. These reductions will result from moving the basic conflict area longitudinally from the immediate driveway intersection. Delay is not expected to change. Possible tradeoffs might occur because of vehicles striking the channelizing island.

Design and Operational Considerations

The two critical design elements associated with this technique are the island's area and location. The island must be large enough to command attention and it should be located at least 4 ft from the through lanes. A desirable turning lane width of 16 ft is recommended and the island must be at least 100 sq ft in area. Figure C-6.1 shows a typical design for this technique.

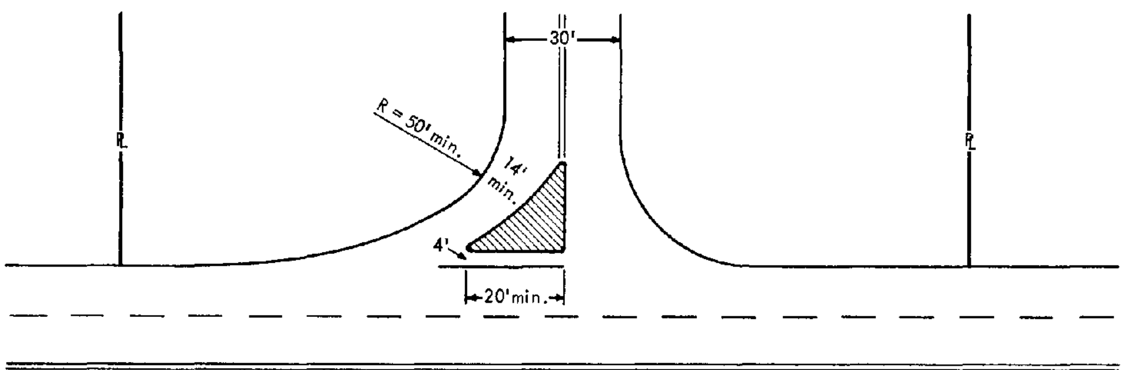


Figure C-6.1 - Right-Turn Egress Channelizing Island

The island may be located outside of the available right-of-way. This would require either right-of-way acquisition or a widening of the highway shoulder to accommodate the new construction.

Warrants

This technique is warranted on all types of highways. Highway volumes should exceed 10,000 vpd, and highway speeds should be from 25 to 45 mph. Right-turn egress maneuvers should exceed 30 per hour. Total driveway volume should be less than 100 vph. This technique can also be applied at locations where accident histories indicate that an egress merge problem exists (see Appendix B, Table B-III).

Costs

The cost of implementing this technique is estimated at $1,770. This estimate includes the cost of island construction and additional driveway pavement area. If right-of-way is also needed, the implementation costs would increase.

Measures of Effectiveness

The major effect of implementing this technique is that the right-turn egress vehicle will be oriented toward the merge area by the channelizing island. The merge maneuver will be more easily made, and interference with the through lanes will be minimized. Also, the egress vehicle will be directed to only one through lane. This will eliminate conflicts arising when a driveway vehicle merges and directly weaves through two adjacent through lanes.

Although the literature did not reveal any specific accident reductions for this technique, it did reveal that right-turn egress maneuvers are involved in 15% of total driveway accidents. For this technique, it was conservatively assumed that 20% of these accidents will be reduced. Therefore, a 3% annual reduction will occur through implementing this technique. This percentage reduction was used in calculating the annual accident reductions that are listed in Table C-6.1. No delay reductions were found in the literature review.

Evaluation and Comparison

The benefit/cost ratios for this technique have been calculated and appear in Table C-6.2. The accident reduction benefits render this cost-beneficial only for the high driveway and high highway volume combination.

TABLE C-6.1

ANNUAL ACCIDENT REDUCTION BY INSTALLING CHANNELIZING ISLAND TO CONTROL THE MERGE AREA OF RIGHT-TURN EGRESS VEHICLES

DRIVEWAY ADT (Vehicles per Day)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 500	0.008	0.014	0.019
MEDIUM	500-1500	0.019	0.033	0.045
HIGH	> 1500	0.029	0.051	0.069

TABLE C-6.2

BENEFIT/COST RATIOS FOR INSTALLING RIGHT-TURN EGRESS CHANNELIZING ISLAND

DRIVEWAY ADT (Vehicles per Day)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 500	--	--	--
MEDIUM	500-1500	--	--	--
HIGH	> 1500	--	--	1.2

This technique could be beneficial when used as a part of an overall driveway channelization project. Total driveway channelization would include other driveway design techniques, including channelizing islands to control the merge of right-turn ingress vehicles, and driveway medial channelization. These, and other driveway design techniques, will optimize the benefits realized through driveway channelization.

A direct alternative to this technique is C-12, "Install Right-Turn Acceleration Lane," which is warranted when the maximum driveway turning volumes suggested above are exceeded.

C-7: REGULATE THE MAXIMUM WIDTH OF DRIVEWAYS

This is a regulatory technique aimed at reducing conflict areas by defining the maximum width of driveway openings on the highway. The maximum width is a function of the types of vehicles using a facility as well as their entering or exiting speeds. This technique is applicable at a point location or as a standard for all driveways. Curbing is usually used to define the extent of a driveway opening. Figure C-7.1 shows a potential candidate for application of this technique.

Figure C-7.1 - Uncontrolled Driveway Width

The reduction in potential conflict area is expected to be accompanied by a reduction in accident frequencies and severities. No trade-offs are anticipated by regulating maximum driveway widths.

Design and Operational Considerations

The width of a driveway opening can be a critical element in driveway design and operation. A driveway opening is measured at the curbline, and it defines the area available for occupancy by driveway vehicles. Excessively large driveway openings are more likely to promote hazardous operational maneuvers unless driveway channelization is provided. This is because a wide driveway opening could be occupied by several egress and ingress vehicles making simultaneous maneuvers.

The maximum driveway width is a function of parameters including required turning radii, highway and driveway operating conditions, curb offset distances, curb return radii, and driveway alignment angles. The recommended maximum driveway width will thus vary as these parameters change. For optimal operational and site conditions, the required widths should comply with those recommended in Technique C-8. It is further recommended that, for a total driveway width exceeding 60 ft, driveway channelization be included with the implementation of this technique.

Warrants

This technique is warranted on all highway types where excessively large driveway widths exist. Highway volumes should exceed 5,000 vpd and highway speeds should be less than 45 mph. Driveway volumes should exceed 250 vpd. The technique is also warranted for general application along highways that experience high accident rates associated with undefined driveways (see Appendix B, Table B-I).

Costs

The cost for implementing this technique is estimated at $480. This cost involves reducing one driveway width from 120 ft to 60 ft by the installation of curbing. The technique can be implemented at no cost to the highway agency when it is authorized during the permit stage or when driveway reconstruction is mandatory.

Measures of Effectiveness

The technique indirectly reduces the frequency and severity of conflicts by improving driver expectancy of where conflict points are located. Conflict severities are reduced by allowing highway drivers more time to perceive and avoid a potential conflict.

Information on the effects of driveway widths indicate that a reduction of 0.4 annual accidents can be expected when a driveway with uncontrolled width is modified to include width control. The reduction is most representative for medium and high volumes on the driveway and highway.

Evaluation and Comparison

The estimated cost and accident reductions were used to calculate the benefit/cost ratio for this technique. This ratio is 25 for medium and high levels of highway and driveway ADT.

The effects of implementation can be optimized if other recommended driveway design techniques accompany this one. Specific design recommendations are detailed in connection with Technique C-8, "Increase the Effective Approach Width of the Driveway."

C-8: INCREASE THE EFFECTIVE APPROACH WIDTH OF THE DRIVEWAY

This technique is a driveway design technique aimed at limiting the maximum deceleration requirements on the highway. The technique affects driveway operations by increasing the driveway turning speeds. Strategies for implementing this technique involve optimizing various driveway design parameters.

Conflict severity will be reduced with this technique by decreasing the maximum deceleration requirements for highway vehicles. Delay to through vehicles will also be reduced by increasing the turning speeds of ingress and egress vehicles.

Design and Operational Considerations

Effective approach width is a concept that helps to rationally relate the horizontal geometrics of the driveway to a design turning speed. It is defined as the maximum length parallel to the highway that practically can be used by a vehicle to perform a circular turning maneuver. The maneuver is tangent to paths that are parallel to the highway before turning and parallel to the driveway after turning. This path can depend on the driveway width, return radius, lateral offset, approach angle, approach flare, and usable driveway length. Within certain boundaries, both the effective approach width and the practical maximum turning radius increase with decreasing driveway angle and increase as all the other parameters increase.

Figure C-8.1 shows a schematic diagram of the driveway entrance maneuver. Also shown are the design components that effect a change in the approach width.

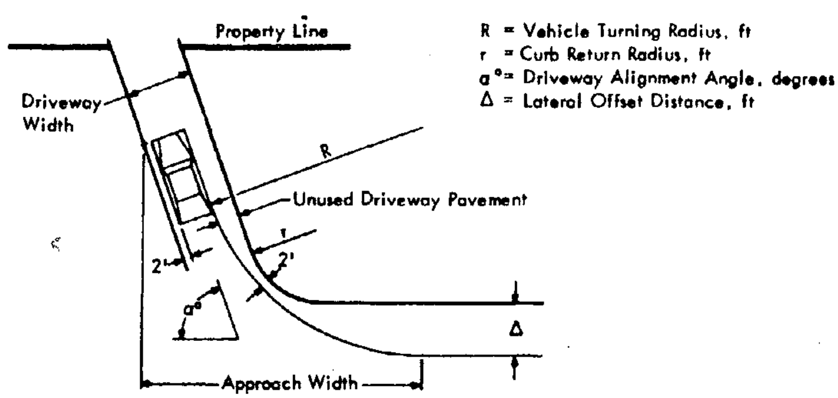


Figure C-8.1 - Driveway Design Elements

The relationship between the driveway turning maneuver and driveway design elements were examined, and the optimum combinations of design elements for various design turning speeds were developed. Tables C-8.1 through C-8.4 list the results of these calculations. It is recommended that the design element combinations appearing in these tables be utilized in a driveway design as part of an access control policy. The design turning speed should be maximized consistent with the technical feasibility of the resulting driveway design dimensions.

Warrants

This technique has general application to all driveways. It should always be a part of the design process for all planned or reconstructed driveways. Also, it should be considered as a general accident countermeasure for medium to high volume existing driveways.

Costs

The costs for this technique are highly site specific. The total cost for each site will involve construction costs for curbing, driveway pavement, and other appurtenances.

The cost used in this evaluation is based on the curb and pavement required to increase the curb return radius from 5 ft to 15 ft on both sides of the driveway. The cost for this alteration is $640.

The implementation cost will increase when design elements are more significantly altered, but the technique will generally cost less than $1,500 to implement. Also, driveway channelization techniques can be easily implemented with the driveway design with little additional cost.

Measures of Effectiveness

The application of this technique involves some important effects on the operational effectiveness of commercial driveways. The objective is to increase the driveway entrance speed in order to limit the maximum deceleration requirements for following vehicles. By increasing the effective approach width, and in turn the driveway entrance speed, the severity of conflicts should be reduced.

The literature revealed that a correlation exists between the incidence of rear-end two-vehicle accidents and speed differentials on rural highways. The results indicated a significant increase in accident potential with speed differentials above 10 mph. Design entry speeds for driveways along major urban roadways should be at least 10 to 15 mph. Therefore, if driveway entrance speeds of 15 mph can be provided for, speed differentials of less than 10 mph between through and turning vehicles will be possible on many urban roadways. If these conditions exist, reductions in both accidents and delay are likely to occur.

It was estimated that a 20% reduction in right-turn accidents could be realized by the implementation of this technique. The literature revealed that right-turn driveway maneuvers to comprise 30% of the total driveway accidents; therefore a reduction of 6% in total driveway accidents is expected to accompany this technique. Delay reductions were assumed only for right-turn entering maneuvers. These maneuvers were assumed to constitute 30% of the total driveway volume. Reductions of 3 sec and 4 sec per entering vehicle were used for medium and high highway volumes, respectively.

Table C-8.5 lists the estimated annual accident reductions and Table C-8.6 lists the estimated annual delay reduction caused by increasing driveway entrance speeds from 5 to 15 mph.

TABLE C-8.1

DRIVEWAY LANE WIDTHS AS A FUNCTION OF DRIVEWAY OFFSET AND RETURN RADIUS FOR A 90 DEGREE DRIVEWAY ANGLE AND VARIOUS DESIGN TURNING SPEEDS

Turning Speed = 6.6 mph				Driveway Length = 33 ft		
Driveway Offset	Driveway Return Radius (ft)					
(ft)	0	5	10	15	20	25
0	-	-	23	20	17	14
2	-	24	20	17	14	-
4	24	21	17	14	-	-
6	21	18	15	14	-	-
8	19	16	14	-	-	-
10	17	17	14	-	-	-

Turning Speed = 10 mph				Driveway Length = 51 ft		
Driveway Offset	Driveway Return Radius (ft)					
(ft)	0	5	10	15	20	25
0	-	-	-	23	20	16
2	-	-	24	21	18	14
4	-	-	23	20	17	14
6	-	25	21	18	15	14
8	25	22	19	16	14	-
10	23	20	17	15	14	-

Turning Speed = 15 mph					Driveway Length = 74 ft		
Driveway Offset	Driveway Return Radius (ft)						
(ft)	10	15	20	25	30	35	40
0	-	-	-	-	23	20	17
2	-	-	-	24	20	17	14
4	-	-	24	21	17	14	-
6	-	25	21	18	15	14	-
8	25	22	19	16	14	-	-
10	23	20	17	15	14	-	-

TABLE C-8.2

DRIVEWAY LANE WIDTHS AS A FUNCTION OF DRIVEWAY OFFSET AND RETURN RADIUS FOR A 60 DEGREE DRIVEWAY ANGLE AND VARIOUS DESIGN TURNING SPEEDS

Turning Speed = 15 mph						Driveway Length = 74 ft		
Driveway Offset (ft)	Driveway Return Radius (ft)							
	0	5	10	15	20	25	30	35
0	-	25	23	21	19	17	15	14
2	24	22	20	18	17	15	14	-
4	20	18	17	16	14	-	-	-
6	18	16	15	14	-	-	-	-
8	16	15	14	-	-	-	-	-
10	14	-	-	-	-	-	-	-

Turning Speed = 20 mph							Driveway Length = 137 ft		
Driveway Offset (ft)	Driveway Return Radius (ft)								
	0	5	10	15	20	25	30	35	40
2	-	-	-	-	-	-	-	-	24
4	-	-	-	-	-	25	23	22	20
6	-	-	-	25	23	22	20	19	18
8	-	25	24	22	21	20	18	17	16
10	24	23	22	20	19	18	16	15	14

TABLE C-8.3

DRIVEWAY LANE WIDTHS AS A FUNCTION OF DRIVEWAY OFFSET AND RETURN RADIUS FOR A 45 DEGREE DRIVEWAY ANGLE AND VARIOUS DESIGN TURNING SPEEDS

Turning Speed = 20 mph							Driveway Length = 73 ft		
Driveway Offset (ft)	Driveway Return Radius (ft)								
	0	5	10	15	20	25	30	35	40
0	-	-	-	24	23	22	21	20	18
2	25	24	23	21	20	19	18	17	16
4	21	20	19	18	17	16	15	15	14
6	18	17	17	16	15	14	-	-	-
8	16	15	15	14	-	-	-	-	-
10	15	14	-	-	-	-	-	-	-

Turning Speed = 25 mph							Driveway Length = 121 ft		
Driveway Offset (ft)	Driveway Return Radius (ft)								
	0	5	10	15	20	25	30	35	40
4	-	-	-	-	-	-	-	-	25
6	-	-	-	-	25	24	23	22	21
8	-	25	24	23	22	21	21	20	19
10	23	22	22	22	20	19	19	18	17

TABLE C-8.4

DRIVEWAY LANE WIDTHS AS A FUNCTION OF DRIVEWAY OFFSET AND RETURN RADIUS FOR A 30 DEGREE DRIVEWAY ANGLE AND VARIOUS DESIGN TURNING SPEEDS

Turning Speed = 25 mph									Driveway Length = 115 ft
Driveway Offset (ft)	Driveway Return Radius (ft)								
	0	5	10	15	20	25	30	35	40
0	23	23	22	21	20	20	19	19	18
2	20	20	19	19	18	18	17	17	17
4	17	16	16	16	15	15	15	14	-
6	15	15	14	-	-	-	-	-	-
8	14	-	-	-	-	-	-	-	-
10	14	-	-	-	-	-	-	-	-

Turning Speed = 30 mph					Driveway Length = 172 ft
Driveway Offset (ft)	Driveway Return Radius (ft)				
	0	10	20	30	40
0	-	-	-	-	-
2	-	-	-	25	24
4	23	23	22	21	20
6	20	20	19	18	17
8	18	18	17	16	16
10	16	16	15	15	14

(TECHNIQUE C-8)

TABLE C-8.5

ANNUAL ACCIDENT REDUCTION BY INCREASING THE EFFECTIVE APPROACH WIDTH OF A DRIVEWAY

DRIVEWAY ADT (Vehicles per Day)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 500	0.016	0.027	0.037
MEDIUM	500-1500	0.038	0.066	0.090
HIGH	> 1500	0.058	0.102	0.138

TABLE C-8.6

ANNUAL DECREASE IN DELAY (HR) BY INCREASING THE DRIVEWAY ENTRANCE SPEED FROM 5 TO 15 MPH

DRIVEWAY ADT (Vehicles per Day)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 500	-	22.8	30.4
MEDIUM	500-1500	-	91.2	121.6
HIGH	> 1500	-	182.4	243.2

Evaluation and Comparison

Table C-8.7 lists the estimated benefit/cost ratios for the construction condition described previously. It can be seen that this technique is always cost-beneficial except for low volume combinations of highway and driveway ADT.

TABLE C-8.7

BENEFIT/COST RATIOS FOR INCREASING THE EFFECTIVE APPROACH WIDTH

DRIVEWAY ADT (Vehicles per Day)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 500	-	3.0	4.0
MEDIUM	500-1500	1.8	10.0	13.0
HIGH	> 1500	2.7	18.0	25.0

C-9: IMPROVE THE VERTICAL GEOMETRICS OF THE DRIVEWAY

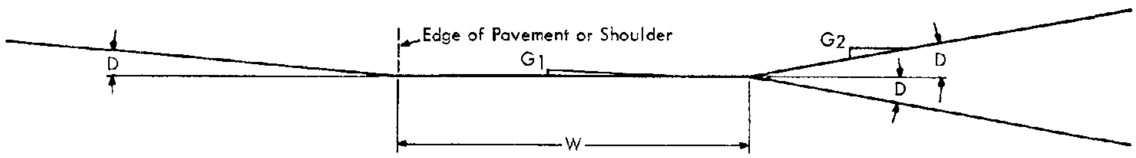
This technique is a general design standard for new and existing driveways in which driveway profile guidelines are specified. These guidelines allow vehicles to efficiently execute driveway maneuvers without the vehicle experiencing severe bouncing. Providing adequate driveway profiles will result in desirable driveway turning speeds only when the other driveway geometric characteristics will permit such speeds.

Increasing driveway turning speeds limits maximum deceleration requirements on the highway and therefore decreases conflict severity. Improvements to the driveway profile should not adversely affect utility installations or drainage requirements.

Design and Operational Considerations

Acceptable driveway profiles are generally influenced by the operating characteristics of highway traffic and the geometric characteristics of the site. The vertical geometrics of a driveway are also important in the basic operation of the vehicle itself. Satisfactory profiles can be provided by an infinite combination of slopes, tangent lengths, and vertical curves for a specified level-of-service. Profiles, which permit ingress and egress maneuvers at desirable speeds, depend on sufficient clearance between the vehicle underbody and the driveway surface. Normally, driveway profiles that permit maneuvers at acceptable speeds will satisfy clearance requirements.

Figure C-9.1 illustrates satisfactory driveway profile design. The figure shows the three basic sections of the profile to consider. These sections are the highway pavement or shoulder area, a tangent section at the driveway entrance, and the remaining length of driveway. The suggested maximum grade changes listed refer to the differences in grade between the tangent section and the edge of traveled way or the remaining driveway length.



DRIVEWAY VOLUME	SUGGESTED GRADE CHANGE (D) DESIRABLE	MAXIMUM
High	± 0%	± 3%
Medium	± 3%	± 6%
Low	± 6%	Controlled by Vehicle Clearance

Figure C-9.1 - Suggested Driveway Profile Design

Driveway profiles with the fewest and least severe grade changes are preferred. At certain locations where extreme grade changes are required, operations can be enhanced by connecting the tangents with a vertical curve. The length of vertical curve depends on the difference in grades. A 10-ft curve length (approximately the wheelbase of a passenger vehicle) will usually be satisfactory. Where mountable curbs are used, driveway construction should include curb removal because such discontinuities hinder driveway operations.

Space limitations may be present at many locations where improvements in driveway vertical geometrics are being planned. A relaxation of the design standards may be necessary in these cases.

Improvements to a driveway profile will benefit highway and driveway operations if other driveway geometrics permit desirable turning speeds. Driveway speeds will increase because a smoother profile is provided. Less severe grade transitions enable driveway maneuvers to be made more efficiently and with decreased interference to through vehicles.

Warrants

Application of this technique is desirable on all newly constructed or reconstructed driveways and on existing facilities where the driveway profile is adversely affecting traffic operations. Highway speeds should be at least 25 mph and driveways should accommodate greater than 100 vpd. High accident experience could also warrant this method (see Appendix B, Table B-I).

Costs

Two cost options have been evaluated. The first option involves partial driveway reconstruction. The estimated cost of $1,200 is based on 50 sq yards of pavement construction. The second option covers the removal of a mountable curb. Curb removal and patchback were estimated at $160 and $240, respectively, for a total estimated cost of $400.

No incremental costs are assessed to the highway agency when an improved driveway profile is provided in the permit authorization stage.

Measures of Effectiveness

Although a reduction in the severity of conflicts is anticipated because deceleration requirements are lessened, effects of driveway vertical geometrics on accidents were not found in the literature. Also, since the effects are highly site specific, no estimates were made.

Total delay will decrease where improved driveway vertical geometrics allow increased driveway turning speeds because interference to through traffic is reduced. Minimum delay reductions have been assumed in order to evaluate the operational effectiveness. Reductions of 1 sec, 2 sec, and 3 sec in total delay per driveway maneuver have been used for low, medium, and high highway volumes, respectively. Table C-9.1 lists the estimated reductions in total annual delay.

TABLE C-9.1

ANNUAL REDUCTION IN TOTAL DELAY (HR) FOR IMPROVEMENTS IN DRIVEWAY VERTICAL GEOMETRICS

DRIVEWAY ADT (Vehicles per Day)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 500	25.3	50.6	75.9
MEDIUM	500-1500	101.4	202.8	304.2
HIGH	> 1500	202.8	405.6	608.4

Evaluation and Comparison

The estimated costs and delay reductions were used in calculating the benefit/cost ratios for the two construction options. Table C-9.2 displays the estimated cost-effectiveness for the first option where partial driveway reconstruction is required. The cost-effectiveness of Option 2 is evident in Table C-9.3.

Both options involving improvements at existing driveways are cost-beneficial, particularly at higher driveway and highway volumes. The technique would exhibit even higher cost-effectiveness when implemented during the permit authorization stage since no costs are borne by the highway agency.

The technique is recommended on existing driveways when driveway speeds are restricted by the driveway profile and where interference to through traffic is caused by the restrictive driveway maneuvers. Also, application of the suggested driveway profile design standards should be required in the permit authorization stage. The application of other cost-effective driveway design and operations techniques should complement this measure when highway construction mandates driveway reconstruction.

TABLE C-9.2

BENEFIT/COST RATIOS FOR IMPROVING DRIVEWAY PROFILE
(PARTIAL DRIVEWAY RECONSTRUCTION)

DRIVEWAY ADT (Vehicles per Day)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 500	1.0	2.0	3.0
MEDIUM	500-1500	4.1	8.1	12.0
HIGH	> 1500	8.1	16.0	24.0

TABLE C-9.3

BENEFIT/COST RATIOS FOR IMPROVING DRIVEWAY PROFILE
(CURB REMOVAL AND PATCHBACK)

DRIVEWAY ADT (Vehicles per Day)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 500	2.9	6.1	8.9
MEDIUM	500-1500	12.0	24.0	36.0
HIGH	> 1500	24.0	48.0	72.0

C-10: REQUIRE DRIVEWAY PAVING

This technique is a general access control standard in which the structural integrity of the driveway is insured by using a hard-surface treatment.

Without driveway paving, desired driveway speeds are difficult to maintain because of potholing, ponding, and ill-defined maneuver paths (as shown in Figure C-10.1). With paving, interference to through vehicles and conflict severity are reduced because the maximum deceleration requirement is limited.

Figure C-10.1 - Unpaved Driveway with Potholing and Ill-Defined Maneuver Path

Design and Operational Considerations

The principal design consideration of this technique is the permanent hard-surfacing of a driveway. Portland-cement concrete or an asphaltic concrete with a bituminous surface treatment is desirable for the pavement design. Portland cement concrete is preferable at locations where fuel spillage is a problem and where heavy wheel loads are sustained for long periods such as at truck-loading docks. Gravel and other materials that do not provide a permanent surface are unsatisfactory for commercial driveways.

The pavement should be required to extend the length of the driveway on all newly constructed driveways and should provide a smooth transition between the highway and driveway. The highway agency should extend the pavement to the right-of-way line on existing driveways. Existing mountable curbs should be removed in order to achieve a more desirable profile. The driveway surface preferably should contrast with the surface of the through travel way, especially on high-speed highways.

The application of this technique enhances circulation paths for internal design in addition to benefiting highway-driveway operations. Other desirable characteristics include decreased highway and driveway maintenance, increased skid resistance and a more aesthetically pleasing design.

Warrants

This technique is warranted at all commercial driveways where excessive interference to highway-driveway operations results from the absence of driveway paving. Highway speeds should exceed 25 mph and driveway volume should exceed 100 vpd. High accident rates due to unpaved driveways will also warrant this technique (see Appendix B, Table B-I).

Costs

The estimated cost of this technique is $3,100 for existing driveways. This estimate is based on installing 130 sq yards of pavement. No costs to the highway agency are involved when implemented during the driveway permit process.

The application of other low-cost driveway design and operations techniques could result in increased benefits at locations where driveways are to be paved. Increasing the effective approach width and improving the vertical geometrics are possible supplementary techniques to consider.

Measures of Effectiveness

No operational studies on accidents or delay were found relating to this technique. However, driveway paving was assumed to reduce total delay the same amount as estimated in Technique C-9, "Improve the Vertical Geometrics of the Driveway." Accident severity is expected to decrease to a certain degree, however, no quantitative estimate was made.

Evaluation and Comparison

Table C-10.1, which lists the benefit/cost ratios for paving existing driveways, was developed by using the estimated delay reductions from Technique C-9 and the estimated cost for driveway paving.

TABLE C-10.1

BENEFIT/COST RATIOS FOR PAVING EXISTING DRIVEWAYS

DRIVEWAY ADT (Vehicles per Day)	HIGHWAY ADT (Vehicles per Day)		
	LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW < 500	-	-	1.2
MEDIUM 500-1500	1.6	3.1	4.7
HIGH > 1500	3.1	6.3	9.4

(TECHNIQUE C-10)

The cost-effectiveness for paving existing driveways is beneficial for combinations of medium and high driveway volumes and all highway volumes. A low driveway volume and a high highway volume is marginally cost-effective.

This technique is recommended for all newly constructed commercial driveways and for existing driveways where the lack of driveway pavement is detrimental to highway-driveway operations. Reconstruction or relocation of driveways should always include driveway paving.

C-11: REGULATE DRIVEWAY CONSTRUCTION (PERFORMANCE BOND) AND MAINTENANCE

This technique is an access control policy that insures a permanent and structurally adequate driveway surface. The strategy used in regulating construction is a performance bond that is required prior to construction. Maintenance is regulated by specifications included in the driveway permit, and regular enforcement of these regulations is needed to insure adequate operations. The functional objective of the technique is to increase driveway speeds which in turn limits the deceleration requirements of through vehicles. A reduction in the severity of conflicts is the anticipated result. Figure C-11.1 shows an example of a poorly maintained driveway.

Figure C-11.1 - The Result of Inadequate Driveway Construction and/or Maintenance

Design and Operational Considerations

Two elements necessary to the implementation of this policy are the performance bond and the maintenance regulations. The performance bond is required from the contractor or owner before construction. The amount of bond furnished should be large enough to assure compliance with the approved design, construction, and specifications. The amount may vary depending on the land use, the traffic volume served, and the operating characteristics of the site.

The maintenance regulations should be outlined in the driveway permit. Acceptable service levels should require that the original driveway profile be retained, that potholes or other surface irregularities be repaired, and that no damage to or deterioration of the highway pavement is caused by the lack of driveway maintenance. The quality of maintenance should also be adequate to ensure that drivers will not deviate from logical circulation patterns to avoid driveways in poor condition.

Improvements caused by regulating driveway construction and maintenance will certainly benefit highway and driveway operations. Driveway maneuvers are executed more efficiently because of increased speeds, and interference to through traffic is reduced because maximum deceleration requirements are lessened.

Warrants

This technique is warranted for all driveways during the driveway permit process. Highway speeds should be at least 25 mph and driveways should accommodate at least 100 vpd. This policy is most applicable to urban-suburban areas.

Costs

No incremental costs are borne by the highway agency since this technique is implemented in the permit authorization stage.

Measures of Effectiveness

No operational studies on accidents or delay were found that related to this technique. Implementation of this access control policy is estimated to decrease total delay and conflict severity. Total delay reductions are assumed to be the same as estimated in Technique C-9, "Improve the Vertical Geometrics of the Driveway." No quantitative estimate on accident reductions were made. Additional benefits are expected due to anticipated reductions in accident severity.

Evaluation and Comparison

Regulating construction and maintenance is a cost-beneficial measure since no cost is assumed by the highway agency and significant reductions in total delay are expected. The technique should be accompanied by other policy or design measures and is recommended for all newly-constructed commercial driveways or when reconstruction or relocation becomes necessary.

C-12: INSTALL RIGHT-TURN ACCELERATION LANE

This design technique reduces through lane deceleration requirements by facilitating higher speed driveway merge maneuvers. The merge maneuver is facilitated by a right-turn acceleration lane for use by right-turn egress driveway vehicles. This technique can be applied both during the permit-authorization stage or at existing facilities. Figure C-12.1 shows an application of this technique.

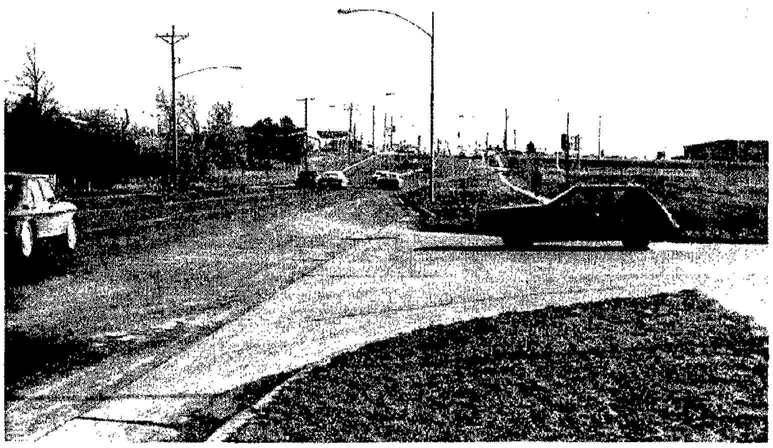


Figure C-12.1 - Right-Turn Acceleration Lane

The speed of driveway to highway merges is increased by allowing driveway vehicles the necessary length to accelerate. The merge maneuver can be accomplished safer when the speed is more compatible with highway running speeds.

Merge and rear-end conflicts are expected to decrease because of a reduction in the deceleration requirement of through vehicles. Increased perception times will also result.

Design and Operational Considerations

The proposed right-turn acceleration lane should be at least 14-ft wide at its initial point and immediately begin to taper into the through lane. The recommended lengths of the acceleration taper are listed in Table C-12.1.

TABLE C-12.1

ACCELERATION LANE LENGTHS

Highway Speed (mph)	Acceleration Lane Length (ft)
55	850
50	680
45	450
40	310
35	210
30	150

A driveway vehicle will be able to comfortably accelerate along the taper, and at the point where insufficient lane width remains, the vehicle should have achieved an adequate merge speed. The numbers listed in Table C-12.1 were derived by considering acceleration rates and distances for various highway speeds allowing for acceptable speed differentials for through vehicles.

The acceleration lane should be located totally along the frontage which it serves and it should not restrict access to neighboring properties. The downstream end of the acceleration lane should be at least the minimum driveway separation distance away from the nearest downstream access point. In some locations, right-of-way will need to be acquired to facilitate the additional roadway width.

Warrants

This technique is warranted on all highway types. Highway volumes should exceed 10,000 vpd and speeds should be greater than 35 mph. The technique should be implemented only at driveways that have at least 75 right-turn egress movements during peak demand periods. Property frontages should exceed the recommended length of the acceleration lane. High accident rates involving right-turn egress vehicles will also warrant this technique (see Appendix B, Table B-III).

Costs

The cost of implementing this technique was estimated for two construction options. The first option involves constructing 150 ft of acceleration lane, with appropriate curbing on existing right-of-way, at a cost of $5,060. The cost of the second option, which involves constructing the same facility but with additional right-of-way required, was estimated at $9,560.

Measures of Effectiveness

This technique is used to reduce the number of basic conflict points between right-turning vehicles and through vehicles on the highway. The severity of right-turn merge conflicts on the highway is reduced by allowing higher merge speeds for right-turning vehicles and thereby reducing maximum deceleration requirements for through vehicles.

The literature revealed that 15% of all driveway accidents involve right-turn exit maneuvers. It was assumed that this technique will eliminate 50% of the right-turn exit accidents, and these accident percentages were applied to the predicted annual accidents at commercial driveways. Table C-12.2 lists the annual accident reductions estimated for this technique.

TABLE C-12.2

ANNUAL ACCIDENT REDUCTION FOR INSTALLING RIGHT-TURN ACCELERATION LANE

DRIVEWAY ADT (Vehicles per Day)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 500	0.02	0.03	0.05
MEDIUM	500-1500	0.05	0.08	0.11
HIGH	> 1500	0.07	0.13	0.17

The literature revealed no specific effect on delays. It is possible that a decrease in total delay will occur due to the higher merge speeds.

Evaluation and Comparison

The estimated accident reductions and costs have been utilized to calculate benefit/cost ratios for the two construction options. Table C-12.3 lists the benefit/cost ratios for the first option where no right-of-way purchase is required. The table shows that the technique is cost-effective only for high-volume driveways located on high-volume highways. The benefit/cost ratios for the second construction option were all less than unity.

(TECHNIQUE C-12)

TABLE C-12.3

BENEFIT/COST RATIOS FOR INSTALLING RIGHT-TURN ACCELERATION LANE

DRIVEWAY ADT (Vehicles per Day)	HIGHWAY ADT (Vehicles per Day)		
	LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW < 500	-	-	-
MEDIUM 500-1500	-	-	-
HIGH > 1500	-	-	1.0

C-13: INSTALL CHANNELIZING ISLANDS TO PREVENT DRIVEWAY VEHICLES FROM BACKING ONTO THE HIGHWAY

This driveway design technique is aimed at reducing through lane deceleration requirements by preventing driveway vehicles from backing onto the highway from a parking area. The strategy for achieving this objective is to construct channelizing islands at existing locations to prohibit this maneuver. The islands can be located either on the right-of-way or inside commercial properties. Candidate locations for this technique are characterized by commercial parking areas flat-graded to the highway, with no physical distinction between the two areas. This method will define where access to a property should be made.

The technique will reduce the total area of conflict by controlling and defining driveway opernings. Conflict severity will be reduced by prohibiting uncontrolled access along property frontages. Possible detrimental effects may include an increase in through-vehicle conflicts with the installed island.

Design and Operational Considerations

The configuration of this technique is highly site-specific. The major design elements are the island sizes and locations. The islands should be large enough to command attention, but should not be so large as to limit driveway circulation. The minimum recommended island size is 100 sq ft. They should be at least 4 ft wide, to prevent parked vehicles from overhanging the through lanes. The island should be offset at least 4 ft from the through lanes to reduce the possibility of through vehicles striking the island.

This technique should always be considered when a highway is to be widened along uncontrolled access frontages. The effectiveness of this technique can be optimized if the other driveway location and design methods are also implemented.

Warrants

This technique is warranted on all highways where open access exists with ADT's greater than 10,000. Highway speeds should be less than 45 mph. Driveway volumes should exceed 200 vpd. High accident rates involving vehicles backing onto the highway will also warrant the technique.

Costs

The cost for implementing this technique was estimated for installing two channelizing islands, on existing right-of-way, one on each side of a driveway opening. The estimated cost is $1,920.

Measures of Effectiveness

The literature revealed that an annual accident reduction of 0.4 may be realized when access is controlled by this technique. This accident reduction is most representative for medium and high volume driveways located on medium and high volume highways.

Evaluation and Comparison

The estimated cost and predicted accident reductions were used to calculate the benefit/cost ratios for medium and high combinations of highway and driveway ADT's as shown in Table C-13.1

TABLE C-13.1

BENEFIT/COST RATIOS FOR INSTALLING CHANNELIZING ISLANDS TO PREVENT VEHICLES FROM BACKING ONTO THE HIGHWAY

DRIVEWAY ADT (Vehicles per Day)	HIGHWAY ADT (Vehicles per Day)		
	LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW < 500	--	--	--
MEDIUM 500-1500	--	6.2	6.2
HIGH > 1500	--	6.2	6.2

(TECHNIQUE C-13)

The technique exhibits a high level of cost-effectiveness. Additional benefits can be realized by implementing other techniques that optimize driveway location and design.

This technique compares favorably with other point location techniques aimed at limiting through lane deceleration requirements. In particular, this method can be used as a direct alternative to Technique A-8: "Install Physical Barrier to Prevent Uncontrolled Access Along Property Frontages."

C-14: INSTALL CHANNELIZING ISLAND TO MOVE INGRESS MERGE POINT LATERALLY AWAY FROM THE HIGHWAY

This driveway design technique is aimed at limiting the maximum deceleration requirements of the through lanes. The driveway channelizing island will move the ingress merge point laterally away from the highway enabling ingress vehicles to enter the driveway at higher speeds because other driveway vehicles will not interfere with the turning maneuver.

This technique is expected to reduce the severity of rear-end and merge conflicts. Possible trade-offs may accompany this technique due to through and driveway vehicles striking the channelizing island.

Design and Operational Considerations

The major design elements associated with this technique are the island area and location. The minimum recommended island size is 100 sq ft, which is sufficient to command driver attention and correctly channel the ingress vehicles into the driveway. The island should be offset at least 4 ft from the through lanes to reduce the possibility of through vehicles striking the island. At least 10 ft of one side of the triangular island should be parallel to the through lane and at least 20 ft of another side should be parallel to the driveway lane. These recommendations will move the ingress merge point approximately 24 ft from the through lanes. The turning lane width should be at least 14 ft. Figure C-14.1 shows an acceptable design.

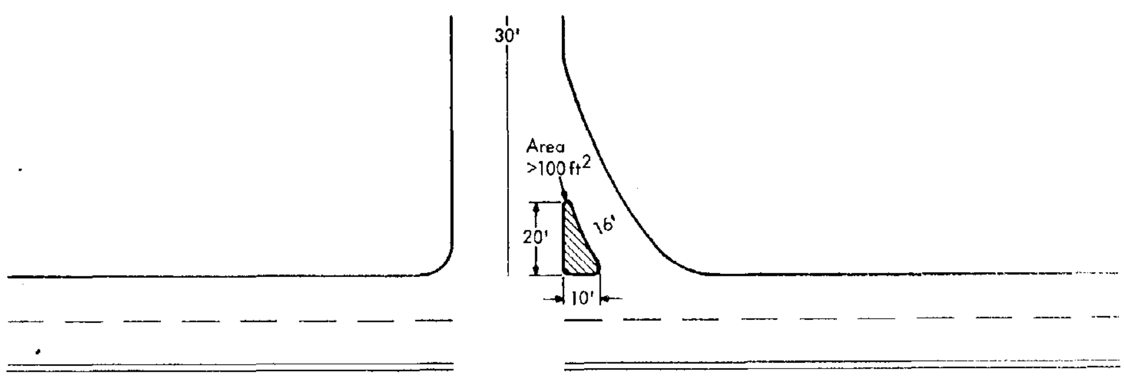


Figure C-14.1 - Channelizing Island to Move Ingress Merge Point Laterally Away from the Highway

Since the island extends at least 20 ft from the edge of the through lanes, sites with set-back distances that affect driveway geometrics may be eliminated from further considerations.

Warrants

This technique is warranted on all highway types. Highway volumes should exceed 10,000 vpd and speeds should be less than 45 mph. Driveway volumes should exceed 1,000 vpd and at least 40 right-turn ingress movements per hour should occur over peak use periods. Sites that have a history of frequent ingress conflicts will warrant special consideration.

Costs

The estimated cost for the design appearing in Figure C-14.1 is $1,770. The cost includes island construction and driveway widening.

Measures of Effectiveness

The literature revealed no specific effects on accidents or delay, however, an accident reduction estimation can be made. Rear-end accidents will decrease because the higher ingress speed will remove turning vehicles from the through lanes faster.

Right-turn ingress maneuvers are involved in 15% of total driveway accidents. For this technique it was conservatively estimated that 20% of these accidents would be reduced and, therefore, total driveway accidents will be reduced by 3%. Table C-14.1 lists the expected annual accident reductions.

TABLE C-14.1

ANNUAL ACCIDENT REDUCTIONS BY INSTALLING A RIGHT-TURN INGRESS CHANNELIZING ISLAND

DRIVEWAY ADT (Vehicles per Day)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 500	0.008	0.014	0.019
MEDIUM	500-1500	0.019	0.033	0.045
HIGH	> 1500	0.029	0.051	0.069

Evaluation and Comparison

Table C-14.2 lists the calculated benefit/cost ratios for this technique. The technique is only cost-beneficial for the higher combinations of driveway and highway ADT.

TABLE C-14.2

BENEFIT/COST RATIOS FOR INSTALLING A RIGHT-TURN INGRESS CHANNELIZING ISLAND

DRIVEWAY ADT (Vehicles per Day)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 500	--	--	--
MEDIUM	500-1500	--	--	1.2
HIGH	> 1500	--	1.4	1.8

(TECHNIQUE C-14)

This technique is thought to be most effective at locations where large numbers of vehicles attempt right-turns into driveways. A technique that may accompany the channelizing island is Technique C-17, Install Right-Turn Deceleration Lane. The two techniques, when used together, can be effective tools in reducing ingress conflicts.

C-15: MOVE SIDEWALK-DRIVEWAY CROSSING LATERALLY AWAY FROM HIGHWAY

This technique involves moving sidewalks, that are adjacent to driveways, laterally away from the highway. Interference between driveway ingress vehicles and through traffic will decrease because ingress vehicles are provided sufficient storage space on the driveway to avoid pedestrian conflicts. A reduction in conflict severity between through vehicles and driveway ingress vehicles is expected because the maximum deceleration requirements for through vehicles are lessened. Conflict severity between driveway ingress vehicles and pedestrians is also expected to be reduced because of the increased deceleration distance provided. Figure C-15.1 illustrates the general technique design.

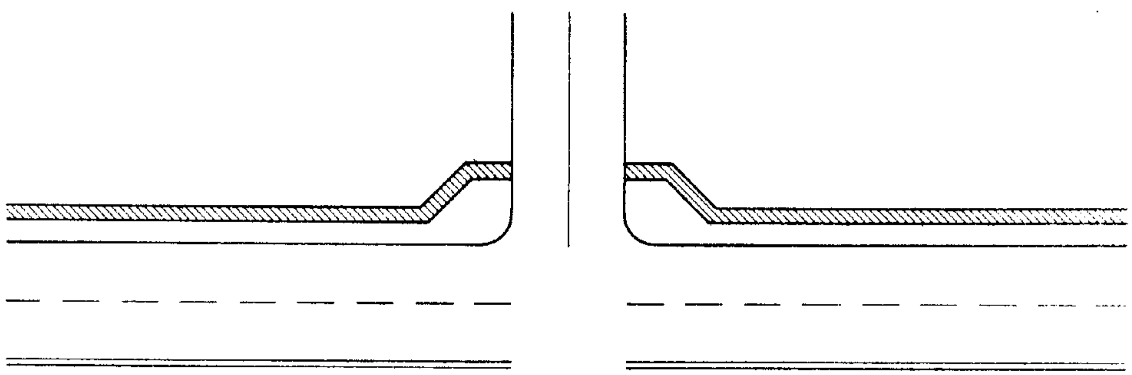


Figure C-15.1 - General Design for Moving Sidewalk-Driveway Crossing Laterally Away From Highway

Design and Operational Considerations

The lateral shift of the sidewalk is the most important design consideration for this technique. The sidewalk should be moved laterally along the driveway to a point on the driveway tangent length. The relocated sidewalk should be at least 25 ft from the edge of the traveled way. The 25 ft shift will yield a sufficient deceleration distance for acceptable driveway design speeds and will require about 100 ft of sidewalk improvement. The deceleration distance provides sufficient stopping distance for driveway speeds of 10-15 mph, assuming perception and reaction has already occurred.

The sidewalk shift will enable pedestrians a greater perception time in which to distinguish turning vehicles. Pedestrian exposure time on the driveway is also decreased because the driveway width is narrower at the relocated sidewalk crossing.

Warrants

This technique is applicable for all types of highways and at driveways where pedestrian crossings cause interference between highway and driveway vehicles. Highways with volumes and speeds greater than 5,000 vpd and 30 mph, respectively, are applicable. Driveway volume should exceed 100 during the peak hour and pedestrian crossings should total 50 or more during the same hour. The site layout must also provide adequate distance for the sidewalk shift.

Costs

Installing the relocated sidewalk was estimated at $1,200 and removing the original sidewalk and backfilling was estimated at $140 for a total implementation cost of $1,340.

Measures of Effectiveness

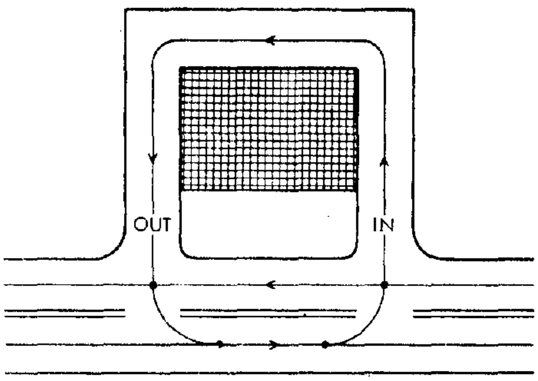
No measures of effectiveness relating to accidents or delay were available in the literature. Conflict severities between through vehicles and driveway ingress vehicles and between driveway ingress vehicles and pedestrians are expected to decrease. Total delay is also anticipated to decrease because interference between highway and driveway vehicles is reduced. Since the expected benefits for this technique are very site specific, no estimates have been made.

Evaluation and Comparison

The technique appears to merit only limited consideration in an overall access control program since it is very site specific. Implementation is recommended only at driveways where substantial interference to highway and driveway operations is caused by pedestrian crossings. Other techniques that remove turning vehicles or queues from the through lanes may be more cost-beneficial and should be considered as alternatives.

C-16: REVERSE ONE-WAY DRIVEWAY OPERATIONS FROM IN-OUT (PROCEEDING DOWNSTREAM) TO OUT-IN WHERE VEHICLES MUST USE HIGHWAY TO ACHIEVE INTERNAL CIRCULATION

This driveway operations technique involves reversing one-way driveway operations from in-out to out-in (proceeding downstream). It is used where internal circulation is inadequate at existing sites, and vehicles unable to park recirculate using the highway to re-enter the site. Changing to out-in driveway operations eliminates left turns for recirculating vehicles, thereby improving total driveway operations. This technique reduces the frequency of conflicts by reducing the number of basic conflict points that a recirculating vehicle encounters from four to two. Proper driveway signing will be required to reduce confusion to motorists and internal conflicts. Figure C-16.1 illustrates the operational differences between in-out and out-in driveway operations.



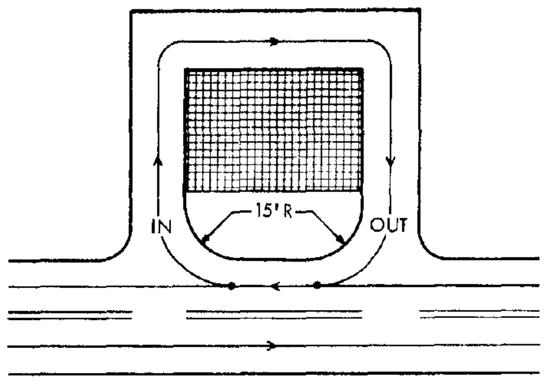


Figure C-16.1 - Reversed Driveway Operations

Design and Operational Considerations

Several driveway design and operational changes accompany the implementation of this technique. Signing of the one-way driveways needs to be reversed to inform motorists of the operational requirements. Signing must be visible from both directions and from a sufficient distance to insure ample time for drivers to make their decision (see Figure C-16.2). The inside curb return radii may need to be increased to provide more efficient turning movements. Minimum inside return radii of 15 ft should be provided. In addition, internal parking facilities might need to be modified to accompany the reversed circulation patterns.

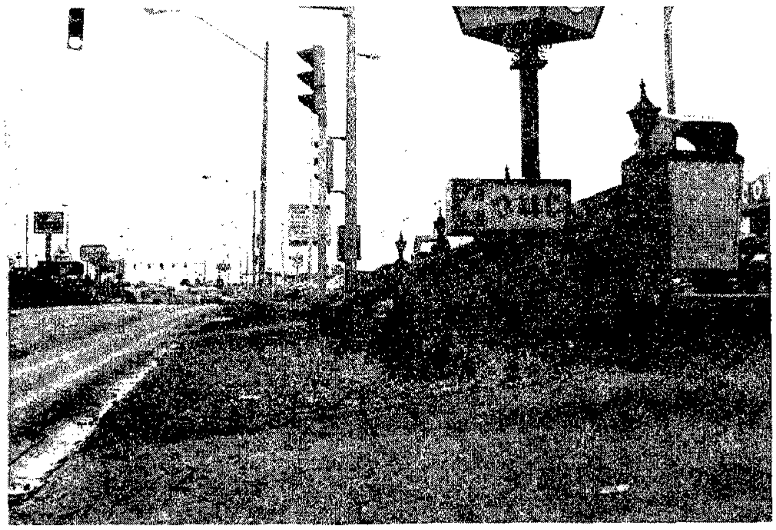


Figure C-16.2 - Example of Recommended Signing

Application of this technique eliminates crossing maneuvers on the highway that result from additional recirculation patterns. A decrease in interference to through traffic is therefore expected. Left-turn egress maneuvers are also facilitated by moving left-turn ingress queues to a point where they no longer can block the egress maneuver.

Warrants

This technique is applicable on all undivided highways where commercial establishments with one-way driveways lack adequate internal circulation. Highway ADT should exceed 10,000 vpd with speeds between 30 and 45 mph. More than 100 driveway vehicles should use the facility during peak demand periods. High accident rates involving recirculating vehicles will also warrant this technique (see Appendix B, Table B-I).

Costs

The estimated cost for implementing this technique is $740, based on curbing, pavement, and signing.

Measures of Effectiveness

No specific measures of effectiveness were available in the literature. Conflicts are expected to decrease slightly when utilizing this technique since conflict points are reduced from four to two for recirculating vehicles. A 2% reduction in total annual accidents was estimated since the additional recirculation maneuvers constitute only a small percentage of the total driveway volume. Table C-16.1 lists the estimated annual accident reductions for this technique.

TABLE C-16.1

ESTIMATED ANNUAL ACCIDENT REDUCTIONS BY REVERSING ONE-WAY DRIVEWAY OPERATIONS FROM IN-OUT TO OUT-IN

DRIVEWAY ADT (Vehicles per Day)	HIGHWAY ADT (Vehicles per Day)		
	LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW < 500	0.0052	0.009	0.0124
MEDIUM 500-1500	0.0126	0.022	0.030
HIGH > 1500	0.0194	0.034	0.046

Evaluation and Comparison

The estimated cost and accident reductions were used in calculating the benefit/cost ratios listed in Table C-16.2.

The technique appears to have a limited cost-effectiveness. It will be beneficial at existing locations where inadequate parking and internal circulation cause significant interference to through vehicles because of the additional circulation maneuvers. Increased cost-effectiveness will result when only signing is needed to implement the technique.

TABLE C-16.2

BENEFIT/COST RATIOS BY REVERSING ONE-WAY DRIVEWAY OPERATIONS FROM IN-OUT TO OUT-IN

DRIVEWAY VOLUME (Vehicles per Day)	HIGHWAY VOLUME (Vehicles per Day)		
	LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW < 500	-	-	-
MEDIUM 500-1500	-	-	1.2
HIGH > 1500	-	1.4	1.8

C-17: INSTALL RIGHT-TURN DECELERATION LANE

This driveway design technique is aimed at removing turning vehicles or queues from sections of the through lanes. The deceleration lane will reduce the severity of rear-end conflicts on the highway by allowing right-turn vehicles to leave the through lanes at a high speed.

Design and Operational Considerations

Figure C-17.1 diagrams an acceptable deceleration lane design. The deceleration lane should be at least 12 ft wide.

Taper lengths are determined by the speed of traffic on the highway.

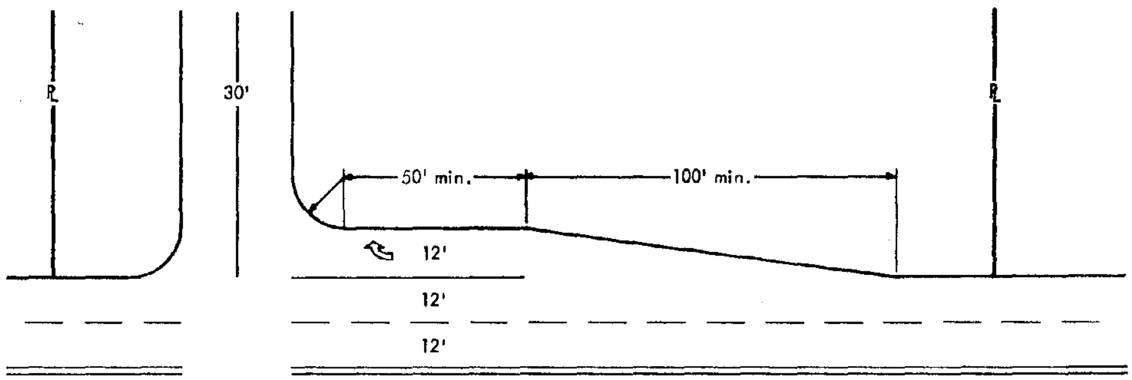


Figure C-17.1 - Right-Turn Deceleration Lane

Table C-17.1 lists the recommended deceleration lane lengths.

TABLE C-17.1

RECOMMENDED LENGTHS FOR RIGHT-TURN DECELERATION LANES

Highway Speed (mph)	Deceleration Lane Length
55	380
50	310
45	250
40	210
35	170
30	150

The recommended lengths will limit the frontage widths that are eligible for this technique. The deceleration lane should be located completely within the frontage of a particular property.

Warrants

This technique is applicable on all highway types. Highway ADT's should exceed 10,000 vpd, and highway speeds should be at least 35 mph. Driveway volume should exceed 1,000 vpd with at least 40 right-turn ingress movements during peak periods. This technique should not be applied on frontages less than 150 ft in width, or where the deceleration lane will restrict access to upstream properties. High accident rates involving right-turn ingress vehicles will also warrant this technique.

Costs

The costs for implementing this technique were estimated for two construction options. The cost of the first option, which involves constructing the deceleration lane on an existing right-of-way, is $4,400. The second option where additional right-of-way is required, is $8,000. Other driveway design techniques can also be implemented at little additional cost when included in the overall design plan for this technique.

Measures of Effectiveness

This technique reduces the frequency and severity of rear-end conflicts by removing right-turning vehicles from the through lanes. The deceleration lane also shadows and stores right-turning queues.

The literature revealed that 15% of all driveway accidents involve right-turn ingress movements. The deceleration lane is expected to eliminate 50% of these accidents. Thus, an overall annual accident reduction of 7.5% is expected by implementation of this technique. This reduction is shown in Table C.17.2.

TABLE C-17.2

ANNUAL ACCIDENT REDUCTION FOR INSTALLING RIGHT-TURN DECELERATION LANE

DRIVEWAY ADT (Vehicles per Day)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 500	0.02	0.03	0.05
MEDIUM	500-1500	0.05	0.08	0.11
HIGH	> 1500	0.07	0.13	0.17

The literature revealed a delay reduction of from 3 to 4 sec per right-turn ingress vehicle. Delay reductions per maneuver of 3 sec for medium volume highways and 4 sec reduction for high volume highways were used in estimating the total delay effect. No significant delay effect is expected at low volume locations. Right-turn ingress vehicles are assumed to comprise 30% of total driveway volume. The annual delay reduction in hours appears in Table C-17.3.

TABLE C-17.3

ANNUAL DELAY REDUCTION IN HOURS BY INSTALLING RIGHT-TURN DECELERATION LANE

DRIVEWAY ADT (Vehicles per Day)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 500	--	22.8	30.4
MEDIUM	500-1500	--	91.2	121.6
HIGH	> 1500	--	182.4	243.2

Evaluation and Comparison

Table C-17.4 lists the benefit/cost ratios for the first option, and Table C-17.5 lists the benefit/cost ratios for the second option.

The ratios in Table C-17.4 indicate that the option is cost-beneficial for medium and high combinations of highway and driveway ADT. The lower ratios in Table C-17.5 are attributed to the additional cost of right-of-way. Both options are cost-effective for medium and high combinations of highway and driveway ADT's.

This technique is effective when implemented at point locations where right-turning vehicles or queues cause conflict or delay problems. It compares marginally to other access control techniques aimed at removing turning vehicles from the through lanes. The benefits realized through implementing this technique can be optimized by including several other driveway location, design, and operations techniques in the overall design.

TABLE C-17.4

BENEFIT/COST RATIOS FOR INSTALLING RIGHT-TURN DECELERATION LANE

DRIVEWAY ADT (Vehicles per Day)	HIGHWAY ADT (Vehicles per Day)		
	LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW < 500	--	--	--
MEDIUM 500-1500	--	1.5	2.1
HIGH > 1500	--	2.9	3.9

TABLE C-17.5

BENEFIT/COST RATIOS FOR INSTALLING RIGHT-TURN DECELERATION LANE ON ADDITIONAL RIGHT-OF-WAY

DRIVEWAY ADT (Vehicles per Day)	HIGHWAY ADT (Vehicles per Day)		
	LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW < 500	--	--	--
MEDIUM 500-1500	--	--	1.1
HIGH > 1500	--	1.6	2.1

C-18: INSTALL ADDITIONAL EXIT LANE ON DRIVEWAY

This technique involves construction of an additional driveway exit lane to better facilitate egress maneuvers. Right-turn and left-turn egress maneuvers are made more efficiently because drivers are not delayed by egress vehicles wanting to turn in the opposite direction. The egress capacity of the driveway is also significantly increased. Figure C-18.1 shows a good example of this application.

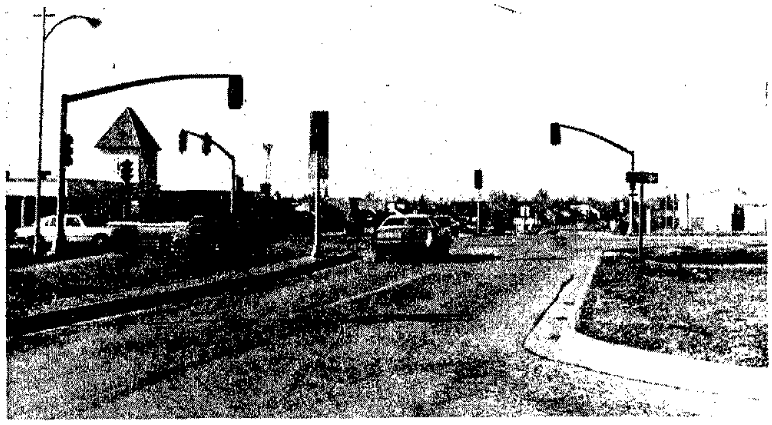


Figure C-18.1 - Additional Driveway Exit Lane

Total driveway delay should decrease significantly because of the increased capacity due to the separation of egress turning maneuvers. However, if insufficient approach length is available, a reduction in the capacity potential may result because of internal conflicts associated with considerable weaving at the exit.

Design and Operational Considerations

The design element of major importance to this access control measure is the driveway storage length required to permit assignment of exiting traffic. Sufficient building setback is needed in order to accommodate the driveway length. A driveway length of 100 ft is adequate in most cases with a minimum lane width of 11 ft. However, specific site conditions of traffic volumes, traffic control, site layout and internal circulation may necessitate a different design.

The additional exit lane increases right-turn egress capacity substantially because a left-turning vehicle does not obstruct all exit flow. On heavily traveled arterials, however, it is extremely difficult for left-turning vehicles to enter the main traffic stream unless traffic signal control is provided at the driveway.

If the exit driveway is located so that traffic signal control is feasible, its internal design should provide sufficient exit storage capacity to maintain continuous exit flow for the full green signal interval without interruption by weaving vehicles or internal conflicts. Together, proper internal design and traffic signal control can achieve high exit capacity.

Warrants

This technique is applicable for all highway types and at driveway locations where egress maneuvers are hindered because separate turning lanes are not provided. Highway speeds should normally exceed 30 mph with highway volumes surpassing 5,000 vpd. Existing driveway volumes should exceed 1,000 vpd (approximately 500 egress vehicles).

Costs

The cost for this technique is based on constructing an additional 12-ft x 100-ft driveway exit lane. The estimated cost includes pavement ($3,240) and curbing ($1,000) for a total construction cost of $4,240. Increasing the effective approach width and driveway channelization are low-cost measures which could supplement this technique.

Evaluation and Comparison

Application of this access control measure is limited to high driveway volume locations and would only be cost-effective where total driveway delay could be decreased significantly. Driveway delay would have to be reduced by 90 hr/year for the measure to be cost-beneficial.

C-19: ENCOURAGE CONNECTIONS BETWEEN ADJACENT PROPERTIES

This driveway operation technique is aimed at removing turning vehicles or queues from the through lanes. The strategy for achieving this objective is to encourage adjacent property owners to permit property-to-property movements away from the highway. Figure C-19.1, although not a good example of internal design, shows the interconnection between properties.

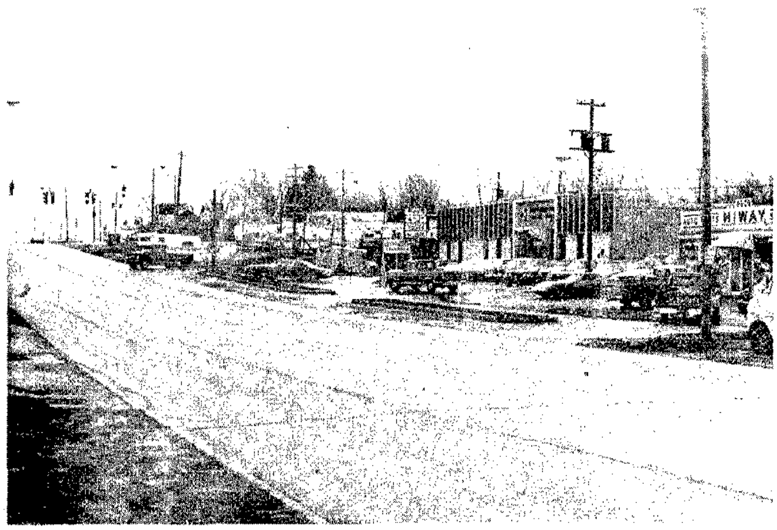


Figure C-19.1 - Connections Between Adjacent Properties

A prime example of this access control measure is the neighborhood shopping center, where several adjacent properties are served by one open parking lot area. The patrons frequenting nearby establishments do not need to exit onto the highway and then enter the neighboring driveway.

Highway conflicts will be reduced because the highway will no longer be used in traversing from one property to the next.

Design and Operational Considerations

The design consideration here is that the access is to be provided for neighboring properties through intra-parking area connections. This may require some alteration of existing parking patterns. Also, the internal circulation plans of neighboring properties may change. Technique C-21, "Require Adequate Internal Design and Circulation Plan" details criteria for acceptable parking area design.

Warrants

This technique is warranted on all highway types. Of particular interest are adjacent properties with small frontage widths. All highway ADT volumes and highway speeds from 25 to 45 mph will exist at the candidate locations. Driveway volumes should exceed 500 vpd.

Costs

The cost for installing a connecting roadway between two adjacent properties has been estimated by assuming a short connecting pavement slab with appropriate curbing. The cost of this installation is $980.

Measures of Effectiveness

Although the literature reveals no specific effects on accidents, reductions should occur. Accident frequencies should decrease because vehicles no longer use the highway in moving from one property to the next. Accident severities should also be reduced because parking lot speeds are lower than the speeds occurring on the highway.

Evaluation and Comparison

No cost effectiveness evaluation was possible because no specific accident or delay reduction estimates were available. Encouraging connections between adjacent properties is thought to be effective in maintaining the integrity of the highway. This particular technique will be especially significant when used as an alternative to implementing Technique B-10, "Consolidate Access to Adjacent Properties."

C-20: REQUIRE TWO-WAY DRIVEWAY OPERATION WHERE INTERNAL CIRCULATION IS NOT AVAILABLE

This driveway design and operations technique is aimed at removing recirculating driveway vehicles or queues from the through lanes. The strategy for implementing this technique is to require two-way driveway operations in lieu of one-way operations at locations where internal circulation is not available. This technique is intended to be implemented in the permit stage, however, it may be implemented at existing locations to alleviate specific problems.

The number of conflict points will be minimized by implementing this technique, because recirculating vehicles will not use the highway; however, total conflicts will not necessarily be reduced. Increased congestion and delay may result internally or at the driveway entrance.

Design and Operational Considerations

Two designs may be implemented where this technique is applied. The first requires a signing scheme to inform drivers of the two-way operations. The second design closes one driveway at locations where two driveways exist. The internal design is then altered to compliment the remaining driveway location. Both designs require the implementation of adequate driveway design methods.

Warrants

The technique is warranted on all highway types. The internal circulation of the parking area must be shown to be inadequate for one-way operation. Particular attention should be paid to properties whose frontage widths are less than 100 ft. Driveway volumes should be less than 250 vpd. This technique is not recommended on higher volume driveways.

Costs

The costs for implementing this technique are highly site specific. The cost can range from approximately a few hundred dollars for signing to thousands of dollars for an extensive parking lot design. No incremental cost is assumed by the highway agency when the internal design is optimized in the permit stage. However, the cost of redesigning the internal circulation at an existing site could be high.

Measures of Effectiveness

The literature revealed no specific accident or delay reduction figures for this technique. Changes in total conflicts are difficult to predict. Conflicts on the highway are expected to decrease, however, internal conflicts may increase. If one existing driveway is closed, then accidents at the remaining driveway are expected to increase. Changes in total accidents are very site specific and no estimates were possible.

Evaluation and Comparison

No cost-effectiveness evaluation was possible because accident and delay reductions, and estimated costs, are highly site specific. This technique appears to be effective on existing facilities when used to mitigate conflict occurrence at low volume locations where frequent recirculation maneuvers occur. If this technique can be implemented during the permit stage, or for a low cost, it should be cost-beneficial.

This technique does not appear to be a strong access control tool. Its effectiveness and applicability as a primary access control technique is questionable. A more acceptable approach would be to require an adequate circulation plan as detailed in Technique C-21, "Require Adequate Internal Design and Circulation Plan."

This is a general access control policy that may be utilized on existing facilities or in the driveway permit stage. An adequate internal design and circulation plan is intended to insure harmony between highway, driveway, and internal operations. Driveway and internal operations will be improved by providing adequate internal property design and controls. Through traffic will experience a decrease in interference because the internal design will minimize queuing on the highway and vehicles searching for parking places are able to recirculate internally. Conflict frequency and severity are expected to decrease because deceleration requirements are lessened for through vehicles.

Design and Operational Considerations

The important design and operational elements associated with this technique are dependent on the site location, land-use served, internal circulation patterns and traffic volumes on the driveway and highway. Two distinct situations are evident when dealing with this technique. The first case involves commercial establishments with limited area, parking space, and traffic volumes. The design for these establishments is primarily concerned with enabling vehicles to recirculate internally instead of using the highway. A general application of the technique to this situation is shown in Figure C-21.1.

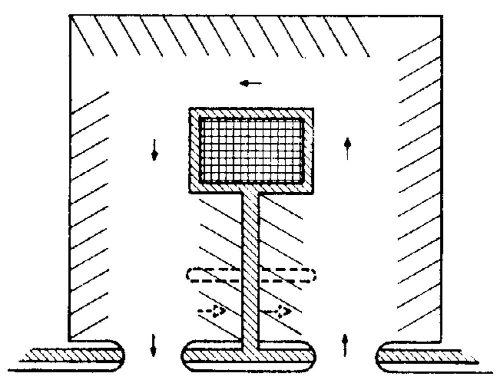


Figure C-21.1 - Internal Circulation Plan for Small Properties

The second situation involves large commercial establishments such as shopping centers that contain substantial area, parking space, and traffic volume. The major design consideration for this case is the driveway interior design and internal circulation. Optimizing these design elements will minimize vehicle queuing on the highway and enhance all operations. Figure C-21.2 illustrates the application of the technique for the larger commercial establishments. In particular, the figure exemplifies adequate driveway interior design and control.

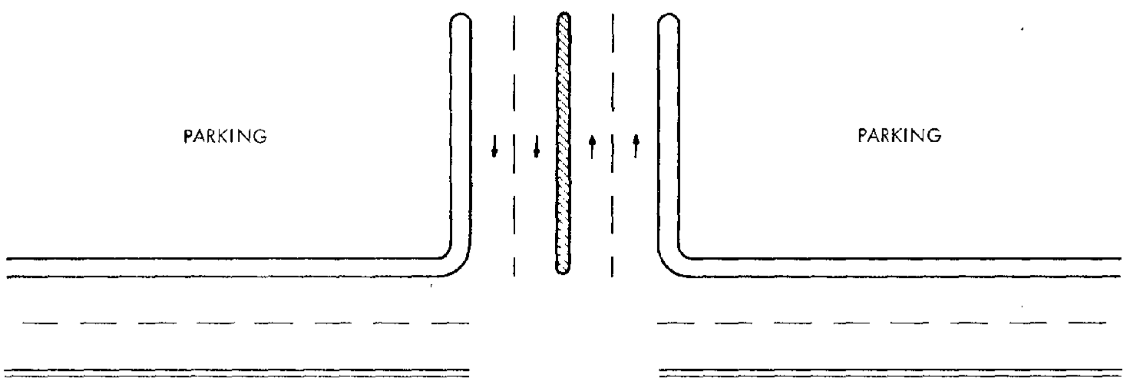


Figure C-21.2 - Large Property Driveway Design and Parking Layout

The specific design elements important to adequate site design and circulation include driveway entrance design and internal control, internal circulation patterns, and parking layout. The extent to which these elements are considered for a particular location is mainly dependent on the size of the facility and the traffic volumes.

The critical portion of the site circulation system is the immediate area surrounding the driveway. The entrance must be designed to absorb the maximum rate of inbound flow. This implies an entrance wide enough and deep enough for traffic to enter the facility without interruption and clear of disruptive marginal interference. Technique C-7 should be referred to when considering driveway width. The building set-back will dictate the available driveway length on existing facilities. In the permit stage, a driveway length which will reinforce the intended operations should be provided. A minimum controlled driveway length of 50 ft (not including curb return) is desirable for large commercial establishments.

The internal design must facilitate the distribution of entering vehicles by providing clearly defined circulation patterns. Such patterns result in a minimum of hesitation and confusion at the entrance to distract the driver and reduce the continuity of entering flow. There should also be minimal interference from crossing conflicts, from parking or loading vehicles, and from other disruptive influences. Crossing conflicts can be minimized by installing a driveway medial channelizing island.

Sufficient storage space for egress vehicles is essential at the larger establishments. Egress flow is generally subject to more intensive peaks than is ingress flow. The exit reservoir must be adequate to enable vehicles to enter the arterial highway at a continuous, uninterrupted rate during the time interval provided by external traffic controls.

Internal circulation within the development site is subject to design criteria similar to those governing vehicular circulation elsewhere. A small parking facility may be inconsequential in its effect on the external circulation network. However, in a large parking facility, the efficiency of internal design has a significant effect on the adjacent external network.

Conventional internal design should provide flexible and continuous interior circulation so that vehicles can reach any parking space without re-entering the highway. This requires that the internal circulation system be highly interconnected.

The aisles should be sufficiently wide to allow for comfortable one- or two-way movement, according to the design used, and should permit a vehicle to enter a parking space in a single maneuver whenever possible. The parking aisle pattern should provide adequate opportunities for internal recirculation. If the stalls are angled this can be facilitated by reversing the direction of flow in alternate parking aisles.

Individual parking bays can lead to an internal collector that combines the traffic from the aisles and carries it to the arterial access driveway. In larger parking facilities there may also be a major interior circulation road around the perimeter to combine the traffic from several collectors, provide general circulation opportunities to all parking areas, and equalize parking area use. This circulation road leads directly to the principal access driveways on the arterial.

Although site parking is not normally considered to be an element of the circulation network, the adequacy of parking can vitally effect the operation of the entire system. If parking is inadequate, adverse effects extend out to other elements of the system and cause them to break down. Motorists continue to enter the parking facility even when it is filled and no spaces are available. They circle endlessly in seeking a parking space and if not successful, merely stand in an aisle and wait for someone to leave. The line of waiting vehicles may extend beyond the parking aisles and into the circulation roadways. Ultimately it may reach out into the street or arterial highway.

A list of general guidelines for increased parking capacity with additional benefits to traffic control, efficiency and aesthetics are given below:

1. General location of driveway entrances should be approved by code authorities before the major effort toward maximum capacity planning begins.

2. Rectangularly shaped parking areas are the most efficient.

3. Wherever possible, the long sides of parking areas should be parallel.

4. Curved, triangular, and other irregularly shaped parking areas should be avoided.

5. Traffic aisles should be aligned parallel to the long dimension of the parking areas wherever feasible.

6. Irregularly shaped areas should be designed with the traffic aisles parallel to the longest side.

7. Traffic aisles should serve two rows of stalls, that is, they should be double-loaded.

8. The perimeter of the parking area should be lined with parking stalls to the maximum extent.

9. Parking areas serving combined parking use functions, such as combined customer and employee parking, should be designed to provide distinctly separate areas and traffic control for each use function.

10. Traffic flow and control should be analyzed carefully for optimum efficiency.

11. Landscaping and lighting should be designed after the optimum maximum capacity design has been achieved. If the maximum capacity design is altered to suit other criteria (such as an owner's request for greater stall width, changes in direction of traffic aisles, etc.), lighting fixtures should be located so the parking area may be converted to the maximum capacity design without requiring relocation of the lighting standards. Where feasible, landscaping should be planned in the same manner, especially where irrigation and sprinkler systems with underground water piping are included.

12. More than one design should be prepared and evaluated. Only good fortune would produce the optimum design on the first attempt.

Any set of design standards that are decided upon should be used in working toward a functional overall plan, including circulation within the lot, access to the street, and relationships of aisles, driveways, and optimum parking areas.

Warrants

This technique is applicable on all types of highways. Implementation is feasible on existing facilities but primary consideration should be given this policy during site plan approval. Highway speeds should equal at least 25 mph and highway volumes should exceed 5,000 vpd. For small commercial establishments, driveway volume should exceed 100 vpd. Peak-hour driveway volume for large commercial establishments, such as shopping centers, should number at least 150 vehicles.

Costs

No incremental costs are included with this policy if implementation occurs during site plan approval. Costs will vary significantly if this technique is utilized on existing facilities. The costs will be highly site specific and will depend primarily on planned design and operational changes.

Measures of Effectiveness

Substantial benefits are expected at locations where this policy has been implemented because of the increased efficiency of highway, driveway, and internal operations. Total delay should decrease significantly and safety benefits are expected to increase since conflict severity on the highway will decrease and internal conflict areas will be better defined by the proposed circulation patterns. Specific measures of effectiveness were not found in the literature. Reductions are felt to be very sensitive to site conditions and location and for these reasons no estimates were made.

Evaluation and Comparison

Utilization of this access control policy is desirable in a comprehensive access control program. It is recommended that consideration of this technique be required on all newly developed sites. High costs will prohibit implementation on existing facilities where significant design and operational changes are needed. The use of other driveway location or design and operations techniques is desirable in achieving a greater cost-effectiveness during the site planning stage.

APPENDIX A

COMMON GEOMETRIC DESIGN ELEMENTS

COMMON GEOMETRIC DESIGN ELEMENTS

The common geometric design elements are the minimum acceptable dimensions of major components of the 70 access control techniques. These dimensions are based on either: (1) widely accepted geometric design standards; or (2) the operational controls and criteria recommended by AASHTO publications.1/

The major geometric elements which affect access control include the following: (1) lane widths; (2) median dimensions; (3) deceleration lane lengths; (4) acceleration lane lengths; (5) driveway spacing; (6) driveway dimensions; and (7) channelizing island dimensions. Figure A-1 delineates these elements.

a. Lane widths (K): The desirable width for all highway through lanes and speed-change lanes is 12 ft. The minimum allowable lane width should be 11 ft.2/

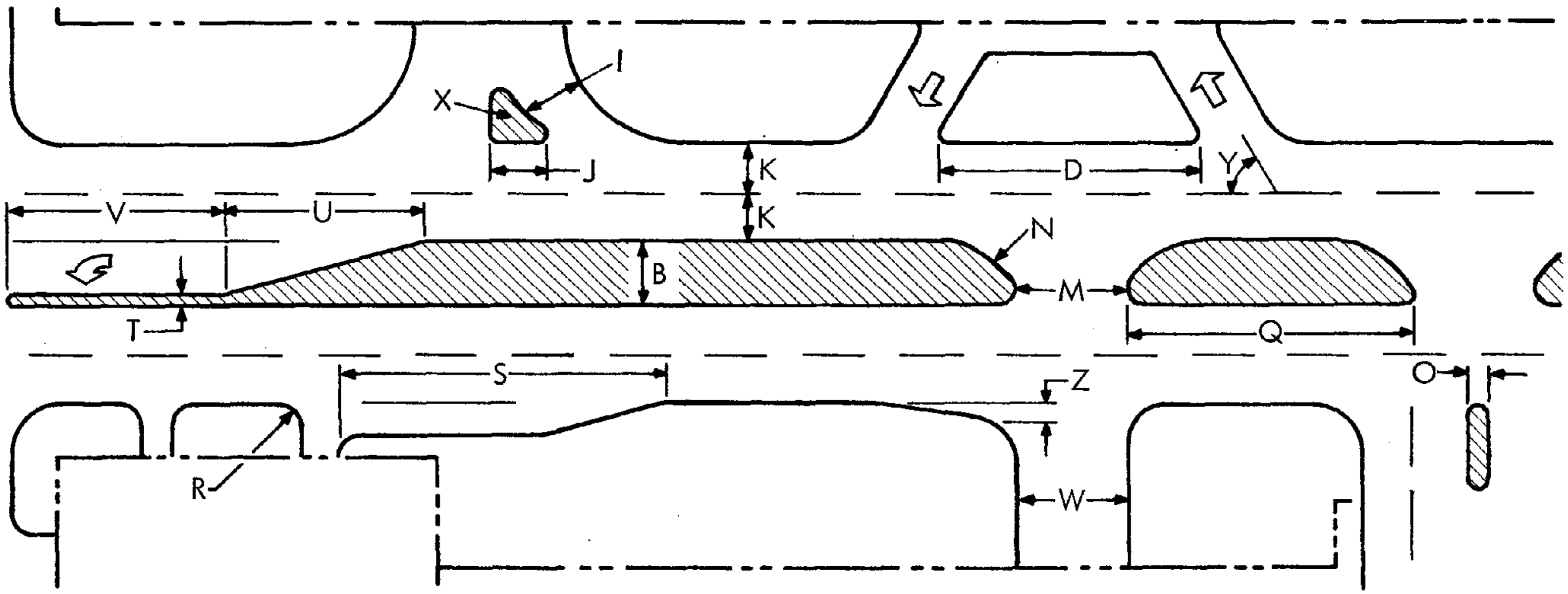
b. Median dimensions: A median is a desirable element on all arterial highways carrying four or more traffic lanes. The principal functions of medians are to provide for the separation of opposing traffic, to provide the necessary storage and shadowing areas for turning vehicles, and to reduce oncoming headlight glare. Median designs vary from areas of grass, to flush paved areas, to curbed islands. Curbs are preferred on highways where it is desirable to physically control left-turning movements.

The median width (B) is paramount to all other medial design considerations. A median must be wide enough to accomplish the primary functions listed above. A very narrow flush median will not effectively separate opposing traffic, and an extremely wide median will be very expensive to construct in most urban areas. The median width must be sufficient to satisfy both operational requirements and spatial restrictions. Recommended median widths3/ are given below:

1/ A Policy on Design of Urban Highways and Arterial Streets - 1973, American Association of State Highway Officials.

2/ A Policy on Geometric Design of Rural Highways - 1965, American Association of State Highway Officials.

3/ Stover, Vergil G., et al., "Guidelines for Medial and Marginal Access Control on Major Roadways," NCHRP Report 93 (1970).



B - Median Width - 4 ft Minimum
D - Driveway Separation Distance - 85 ft Minimum
I - Turning Lane Width - 14 ft Minimum
J - Triangular Island Length - 12 ft Minimum
K - Through Lane Width - 11 ft Minimum
M - Median Opening Length - 40 ft Minimum
N - Blunted Bullet Nose Median End Treatment
O - Elongated Island Width - 4 ft Minimum
Q - Divisional Island Length - 100 ft Minimum
R - Driveway Curb Return Radius
S - Acceleration Length - 150 ft Minimum
T - Narrowed Median End Width - 2 ft Minimum
U - Taper/Deceleration Length - 300 ft Minimum
V - Storage Length - 50 ft Minimum
W - Driveway Width
X - Channelizing Island Area - 75 sq ft Minimum
Y - Driveway Angle
Z - Offset Distance

Median Function	Minimum Width (ft)	Desired Width (ft)
Separation of opposing traffic streams	4	10
Provide pedestrian refuge and room for signs or appartenances	6	14
Provide storage for left-turning vehicles	16	20
Provide protection for vehicles crossing the through lanes	25	30
Provide for U-turns, inside lane to outside lanes	16	20
Provide for U-turns, inside lane to inside lanes	26	30

Turning movements at median openings (M) can be influenced by the physical geometrics of that opening. The width and radii of the opening define the area available for left-turning vehicles. If the median opening is small, a turning vehicle may be severely restricted in its ability to negotiate the opening. Large median openings, on the other hand, do not provide an adequate channelizing effect for turning vehicles. Thus, the recommended median opening must be large enough to allow for turning movements, but small enough to provide an adequate channelization effect. Recommended median opening widths are given below:[3/]

Median Width (ft)	Width of Median Passenger Car	Opening (ft) Tractor-Trailer Combinations
6	60	93
8	53	85
10	47	77
12	43	73
16	40	64
20	40	57
24	40	51
28	40	45

At locations where turning lanes are provided within the median, a narrowed median end tongue (T) is installed.[1/] The narrowed median end must be at least 2 ft wide. This width can be easily realized with a 14-ft wide median. For wider medians, it is recommended that the turning lane be located in a position that leaves 6 to 8 ft for a narrowed median end. This location will increase the separation distance between the storage lane and through traffic. Also, vehicle operators will have a better view of on-coming traffic.

A median opening's channelizing effect can be optimized by shaping the median end to facilitate turning movements. The shape of the median end depends upon the available median width.

The minimum spacing of median openings (Q) is dependent on the type of median. For wide medians with right-angle crossovers, median opening spacing should exceed 1/4 mile. For medians with left-turn deceleration lanes the minimum spacing is dependent only on meeting the required dimensions for the deceleration lane.

c. Deceleration lane lengths: The adequate length of deceleration lanes is the sum of the following three requirements: (1) taper length (U); (2) deceleration length; and (3) storage length (V). The taper is designed to provide for the normal lateral speed of vehicles using transitional sections. AASHTO,[2/] using 3-1/2 sec for a vehicle to move laterally from one lane to another, recommends the following taper lengths:

Highway Speed (mph)	Taper Length (ft)
30	150
40	190
50	230
60	270

The minimum length of deceleration lane (minus storage) for various highway speeds, is based on two conditions: (1) the turning-lane vehicle has a speed differential of 15 mph less than highway speed before deceleration in the lane begins; and (2) the deceleration in the lane begins when the taper has two-thirds (8/12) of its full width. The following deceleration lengths are recommended:

Highway Speed (mph)	Deceleration Lane Length (ft)
55	380
50	310
45	250
40	210
35	170
30	150

In addition to the above lengths, the deceleration lane design should provide an additional vehicle storage length. The storage length should be sufficient to accommodate the maximum vehicle queue during a critical period. Ideally, the storage length should insure that no turning queues interfere with through-traffic flow.

At unsignalized driveway locations, the additional length to be provided for queue storage is designed to completely shadow the average number of vehicles expected to use the deceleration facility in a 2-min period. As a minimum, enough length should be provided for two passenger vehicles, or, when there is at least 10% truck turning movements, space for one passenger vehicle and one WB-50 truck.[1/] The table below lists the minimum recommended storage lengths for various numbers of left-turn deceleration lane vehicles per hour. If the deceleration lane is located on the right of the through lanes, little storage length is required because right-turning vehicles are not normally delayed in their turning movements. The minimum recommended storage lengths are listed below:

Left-Turning Passenger Vehicles Per Hour	30	60	100	200	300
Minimum Recommended Storage Length (ft)	50	50	75	175	250

d. Acceleration lane length: The total length of acceleration lane depends on speed differential (15 mph), and the point of completed acceleration. These considerations are the same as those used for the design of deceleration lengths. Using these conditions and the relation between acceleration rate and attained speed, the following minimum acceleration lane lengths are recommended:

Highway Speed (mph)	Acceleration Lane Length (ft)
55	850
50	680
45	450
40	310
35	210
30	150

e. Driveway Spacing (D): The distance between driveways must allow vehicles using driveways to safely accelerate, decelerate, and cross traffic streams without excessive interference to through traffic or traffic using adjacent driveways. Thus, the minimum spacing is related to the operational characteristics of the highway and interactions between adjacent driveways. Such interactions include conflicts between vehicles entering the traffic stream simultaneously from adjacent driveways, blocking of driveways as a result of queueing and sight restrictions.

The minimum spacing is specifically related to the movement permitted and type of highway. Each site is unique with regard to minimum spacing.

The following table lists the acceleration rate of driveway vehicles, the deceleration rate of through vehicles, and the recommended driveway separation distances for varying highway speeds.

Highway Speed (mph)	Acceleration Rate (fps^2)	Deceleration Rate (fps^2)	Driveway Spacing (ft)
20	3.0	8.5	85
25	2.5	8.5	105
30	2.1	8.5	125
35	1.7	8.5	150
40	1.7	8.5	185
45	1.7	8.5	230
50	1.7	8.5	275

f. Driveway Dimensions: Driveway dimensions consist of several geometric elements. These elements are, width (W), return radii (R), angle (Y) and offset (Z). Specific values for these elements can not be suggested because the differing values can be joined into endless combinations. The reader is referred to technique C-8 for the recommended values of driveway width based on turning radii, offset and angle.

g. Channelizing island dimensions: Channelizing islands constitute an important element in the geometric design of driveways on arterial highways. A channelizing island is a defined area intended to control vehicle movements or provide a pedestrian refuge area. An island may be designated by paint, raised bars, mushroom buttons, curbs, guideposts, pavement edges, or other devices, and they should be included in a project whenever possible.

Islands are classified in three categories: pedestrian refuge, traffic divisional, and traffic channelizing. In driveway design, the last two island types are primarily considered, however, island purposes frequently overlap and little difference between design parameters can be discerned.

The need for islands should be determined by diligent site examination because they are located in an area usually occupied by traffic. Islands are generally elongated or triangular in shape. The island location should be such as to offer little hazard to vehicles. General guidelines[2/] for islands are:

1. Islands should be placed so that the desired vehicle path is immediately obvious, easy to follow, and of unquestionable continuity.

2. Islands should allow converging vehicle paths to merge at small angles, and they should align crossing movements to nearly right angles.

3. The island outline should consist of gently flowing curved lines or straight lines parallel to the direction of travel.

4. To separate turning movements, the radii of curved islands should equal or exceed the minimum radii for the turning speeds expected.

5. Approach ends should be indicated by a gradually widening contrast area that directs traffic to one side of the approaching island.

The following minimum island design standards[2/] should be implemented when possible:

1. Minimum island area = 75 sq ft.

2. Triangular islands must be at least 12 ft on a side after rounding corners.

3. Elongated islands should be at least 4 ft wide and 12 ft long.

4. Divisional islands should be at least 100 ft long.

5. Island corner radii should be at least 2 ft.

6. Islands should be offset from roadway lanes by at least 2 ft.

7. Large island noses shall be offset 4 ft minimum from traffic lanes.

At locations where channelizing islands are employed to facilitate turning movements, a turning lane width of at least 14 ft should be maintained. This minimum width will provide sufficient area for the efficient completion of all turning movements around the island.

APPENDIX B

ACCIDENT WARRANTS

TABLE B-I

TOTAL ACCIDENT WARRANTS FOR ACCESS CONTROL TECHNIQUES

Route Techniques
(Annual Number of Driveway-Related Accidents per Mile)

LEVEL OF DEVELOPMENT (Driveways per Mile)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 30	3.8	7.4	11.0
MEDIUM	30-60	11.3	22.1	32.9
HIGH	> 60	18.8	36.8	54.8

Point Techniques
(Annual Number of Accidents)

DRIVEWAY ADT (Vehicles per Day)		HIGHWAY ADT (Vehicles per Day)		
		LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW	< 500	0.26	0.45	0.62
MEDIUM	500-1500	0.63	1.10	1.50
HIGH	> 1500	0.97	1.70	2.30

TABLE B-II

LEFT-TURN ACCIDENT WARRANTS FOR ACCESS CONTROL TECHNIQUES

Route Techniques
(Annual Number of Driveway-Related Accidents per Mile)

LEVEL OF DEVELOPMENT (Driveways per Mile)	HIGHWAY ADT (Vehicles per Day)		
	LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW <30	2.66	5.18	7.70
MEDIUM 30-60	7.91	15.47	23.03
HIGH >60	13.16	25.76	38.36

Point Techniques*
(Annual Number of Accidents)

DRIVEWAY ADT (Vehicles per Day)	HIGHWAY ADT (Vehicles per Day)		
	LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW < 500	0.18	0.31	0.43
MEDIUM 500-1500	0.44	0.77	1.05
HIGH > 1500	0.68	1.19	1.61

* Left-turn ingress accidents total 61% of the listed accidents; left-turn egress accidents comprise the remaining 39%.

TABLE B-III

RIGHT-TURN ACCIDENT WARRANTS FOR ACCESS CONTROL TECHNIQUES

Route Techniques
(Annual Number of Driveway-Related Accidents per Mile)

LEVEL OF DEVELOPMENT (Driveways per Mile)	HIGHWAY ADT (Vehicles per Day)		
	LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW < 30	1.14	2.22	3.30
MEDIUM 30-60	3.39	6.63	9.87
HIGH > 60	5.64	11.04	16.44

Point Techniques*
(Annual Number of Accidents)

DRIVEWAY ADT (Vehicles per Day)	HIGHWAY ADT (Vehicles per Day)		
	LOW <5,000	MEDIUM 5-15,000	HIGH >15,000
LOW < 500	0.08	0.13	0.19
MEDIUM 500-1500	0.19	0.33	0.45
HIGH > 1500	0.29	0.51	0.69

* Right-turn ingress and egress accidents each comprise 50% of the listed accident rates.

APPENDIX C

CLASSIFICATION OF ACCESS CONTROL TECHNIQUES

TECHNIQUES TO CONTROL CONFLICTS AT COMMERCIAL DRIVEWAYS

MRI

FUNCTIONAL OBJECTIVES

A - HIGHWAY DESIGN AND OPERATIONS TECHNIQUES

Functional Objective		Techniques
LIMIT NUMBER OF CONFLICT POINTS	Limit Number of Basic Crossing Conflict Points	A-1: Install median barrier with no direct left-turn access A-2: Install raised median divider with left-turn deceleration lanes A-3: Install one-way operations on the highway A-4: Install traffic signal at high-volume driveways A-5: Channelize median openings to prevent left-turn ingress and/or egress maneuvers
	Limit Encroachment Conflicts	A-6: Widen right through lane to limit right-turn encroachment onto the adjacent lane to the left A-7: Install channelizing islands to prevent left-turn deceleration lane vehicles from returning to the through lanes
	Reduce Area of Conflict	A-8: Install physical barrier to prevent uncontrolled access along property frontages A-9: Install medial channelization to control the merge of left-turn egress vehicles
LIMIT MAXIMUM DECELERATION REQUIREMENTS	Reduce Highway Speeds	A-10: Regulate highway speed limit consistent with driveway operations A-11: Install traffic signals to slow highway speeds and meter traffic for larger gaps
	Increase Driveway Speeds	A-12: Restrict parking on the roadway next to driveways to increase driveway turning speeds
	Increase Driver Perception Time	A-13: Install visual cues of the driveway A-14: Alter terrain or highway geometrics for increased sight distance A-15: Improve sight distance by preventing parking on the highway, either totally or partially A-16: Improve sight distance by preventing parking on the right-of-way
REMOVE TURNING VEHICLES OR QUEUES FROM SECTIONS OF THE THROUGH LANES	Improve Left-Turn Operations	A-17: Install two-way left-turn lane A-18: Install continuous left-turn lane A-19: Install alternating left-turn lane A-20: Install isolated median and deceleration lane to shadow and store left-turning vehicles A-21: Install left-turn deceleration lane in lieu of right-angle crossover A-22: Install medial storage for left-turn egress vehicles A-23: Increase storage capacity of existing left-turn deceleration lane A-24: Increase the turning speed of right-angle median crossovers by increasing the effective approach width
	Improve Right-Turn Operations	A-25: Install continuous right-turn lane
	Completely Separate Driveway Maneuvers From Through Traffic	A-26: Construct a local service road A-27: Construct a bypass road A-28: Reroute through traffic

A

B - DRIVEWAY LOCATION TECHNIQUES

Functional Objective		Techniques
LIMIT NUMBER OF CONFLICT POINTS	Limit Number of Basic Crossing Conflict Points	B-1: Offset opposing driveways B-2: Locate driveway opposite a 3-leg intersection or driveway and install traffic signals where warranted B-3: Install two one-way driveways in lieu of one two-way driveway B-4: Install two two-way driveways with limited turns in lieu of one standard two-way driveway
SEPARATE BASIC CONFLICT AREAS	Increase Minimum Spacing Of Access Points	B-5: Regulate minimum spacing of driveways B-6: Regulate minimum corner clearance B-7: Regulate minimum property clearance B-8: Optimize driveway spacing in the permit authorization stage
	Increase Average Spacing Of Access Points	B-9: Regulate maximum number of driveways per property frontage B-10: Consolidate access for adjacent properties B-11: Require highway damages for extra driveways B-12: Buy abutting properties B-13: Deny access to small frontage B-14: Consolidate existing access whenever separate parcels are assembled under one purpose, plan, entity, or usage B-15: Designate the number of driveways permitted to each existing property and deny additional driveways regardless of future subdivision of that property B-16: Require access on collector street (when available) in lieu of additional driveway on highway
LIMIT MAXIMUM DECELERATION REQUIREMENTS	Increase Driver Perception Time	B-17: Regulate minimum sight distance B-18: Optimize sight distance in the permit authorization stage
REMOVE TURNING VEHICLES OR QUEUES FROM SECTIONS OF THE THROUGH LANES	Provide Supplementary Access To a Single Property	B-19: Install supplementary one-way right-turn driveways to divided highway (noncapacity warrant) B-20: Install supplementary access on collector street when available (noncapacity warrant) B-21: Install additional driveway when total driveway demand exceeds capacity

B

C - DRIVEWAY DESIGN AND OPERATIONS TECHNIQUES

Functional Objective		Techniques
LIMIT NUMBER OF CONFLICT POINTS	Limit Number of Basic Crossing Conflict Points	C-1: Install two one-way driveways in lieu of two two-way driveways C-2: Install two two-way driveways with limited turns in lieu of two standard two-way driveways C-3: Install driveway channelizing island to prevent left-turn maneuvers
	Limit Encroachment Conflict Points	C-4: Install driveway channelizing island to prevent driveway encroachment conflicts C-5: Install channelizing island to prevent right-turn deceleration lane vehicles from returning to the through lanes
	Reduce Area of Conflict	C-6: Install channelizing island to control the merge area of right-turn egress vehicles C-7: Regulate the maximum width of driveways
LIMIT MAXIMUM DECELERATION REQUIREMENTS	Increase Driveway Speeds	C-8: Increase the effective approach width of the driveway (horizontal geometrics) C-9: Improve the vertical geometrics of the driveway C-10: Require driveway paving C-11: Regulate driveway construction (performance bond) and maintenance C-12: Install right-turn acceleration lane C-13: Install channelizing islands to prevent driveway vehicles from backing onto the highway C-14: Install channelizing islands to move ingress merge point laterally away from the highway C-15: Move sidewalk-driveway crossing laterally away from highway
REMOVE TURNING VEHICLES OR QUEUES FROM SECTIONS OF THE THROUGH LANES	Improve Left-Turn Operations	C-16: Reverse one-way driveway operations from in-out (proceeding downstream) to out-in where vehicles must use highway to achieve internal circulation
	Improve Right-Turn Operations	C-17: Install right-turn deceleration lane C-18: Install additional exit lane on driveway
	Improve Driveway Operations With Internal Property Design and Controls	C-19: Encourage connections between adjacent properties (even when each has highway access) C-20: Require two-way driveway operation where internal circulation is not available C-21: Require adequate internal design and circulation plan

C

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