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TECHNICAL GUIDELINES FOR THE CONTROL OF DIRECT ACCESS TO ARTERIAL HIGHWAYS

FEDERAL HIGHWAY ADMINISTATION
WASHINGTON, DC

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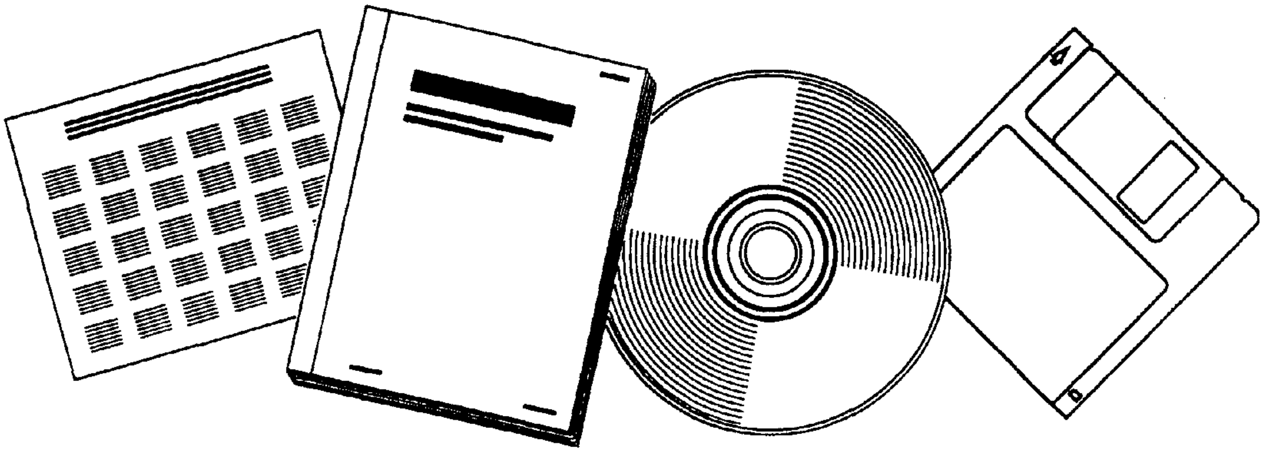

Report No. FHWA-RD-76-86

TECHNICAL GUIDELINES FOR THE CONTROL OF DIRECT ACCESS TO ARTERIAL HIGHWAYS

Vol. I. General Framework for Implementing Access Control Techniques

DEPARTMENT OF TRANSPORTATION
UNITED STATES OF AMERICA

August 1975
Final Users' Manual

Prepared for
FEDERAL HIGHWAY ADMINISTRATION
Offices of Research & Development
Washington, D.C. 20590

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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.

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I. INTENT AND SCOPE OF GUIDELINES

These guidelines represent the results of a comprehensive research program that attempted to evaluate all techniques that can be applied to control direct access on arterial highways. The term "access control," as considered here refers to all techniques intended to minimize the traffic interference associated with commercial driveways. The techniques include locational controls, geometric design aspects, and traffic operational controls.

The scope of these guidelines is limited to the control of direct access to commercial properties on two-lane and multilane highways with unlimited access, where traffic volumes are high enough to produce a hazardous situation. It is not concerned with residential driveways or with highways designed primarily for land access. Also, the basic orientation is toward the control of direct access on existing urban and suburban routes under state highway department jurisdiction.

The information presented here provides highway agencies with a basic orientation toward developing a more comprehensive access control policy as a means of protecting the functional integrity of their arterial highways. More specifically, the topic areas covered are:

Volume II: Detailed Description of Access Control Techniques

A detailed discussion of design and operational considerations, warrants, direct costs, measures of effectiveness, and comparative evaluations for each of the 70 access control techniques

II. PROBLEM DIMENSION

Traffic service and land access are necessary but conflicting functions of a highway system. To adequately satisfy both functions, requires a variety of highway types. At one extreme, the freeway limits access points and most effectively provides for high design speed. At the other extreme, the local street provides maximum access to abutting properties at the expense of traffic service. Figure 1 schematically illustrates the division of these two functions for various functional classes of roadway.1/

Many studies2-4/ document the safety benefits of access control. As shown in Figure 2, accident rates are lowest for freeways and highest for arterial streets and highways* with unlimited access.5/ Also, several reports show that arterial highways have a definite increase in accident rates with increasing numbers of intersections and commercial driveways per mile.5-7/

The sequence of events that produces high accident rates on arterial highways can be characterized as a spiraling effect. Initially, a new highway is constructed on new right-of-way but without access control. At this stage, there are few if any driveways, and accident rates are relatively low. Over time, because of these favorable operational conditions, more and more traffic is attracted to the highway. Then, because of increased traffic volumes, businesses begin to locate along the highway. These businesses generate more traffic, which attracts more businesses. And so the sequence goes, creating conditions that cause the accident rate to become two, three, or even four times the initial rate.

A. Driveway Conflict Circumstances

Driveway connections to public highways are actually intersections. Therefore, like intersections, the efficiency and safety of driveways depend on traffic volumes, geometric design, and traffic control systems. Unfortunately, many highway agencies tend to disregard these factors that influence driveway operations and safety. The general practice is to pay more attention to the design, location, and control of intersections even though some driveways carry more traffic than many intersections.

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* Definition of this and other terms are given in Appendix A, Glossary of Terms.

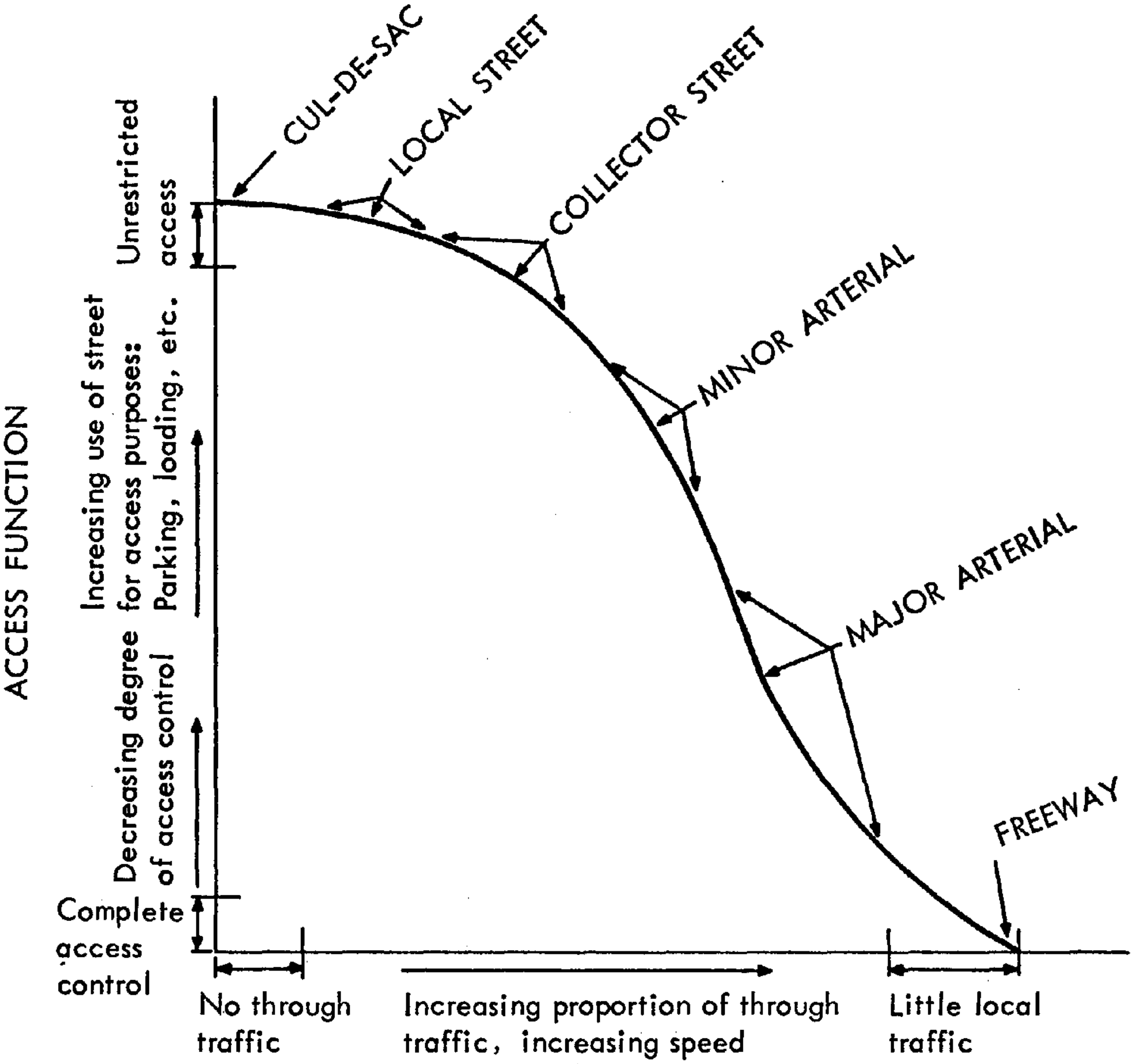


Figure 1 - Relationship Between Control of Access and Traffic Movement

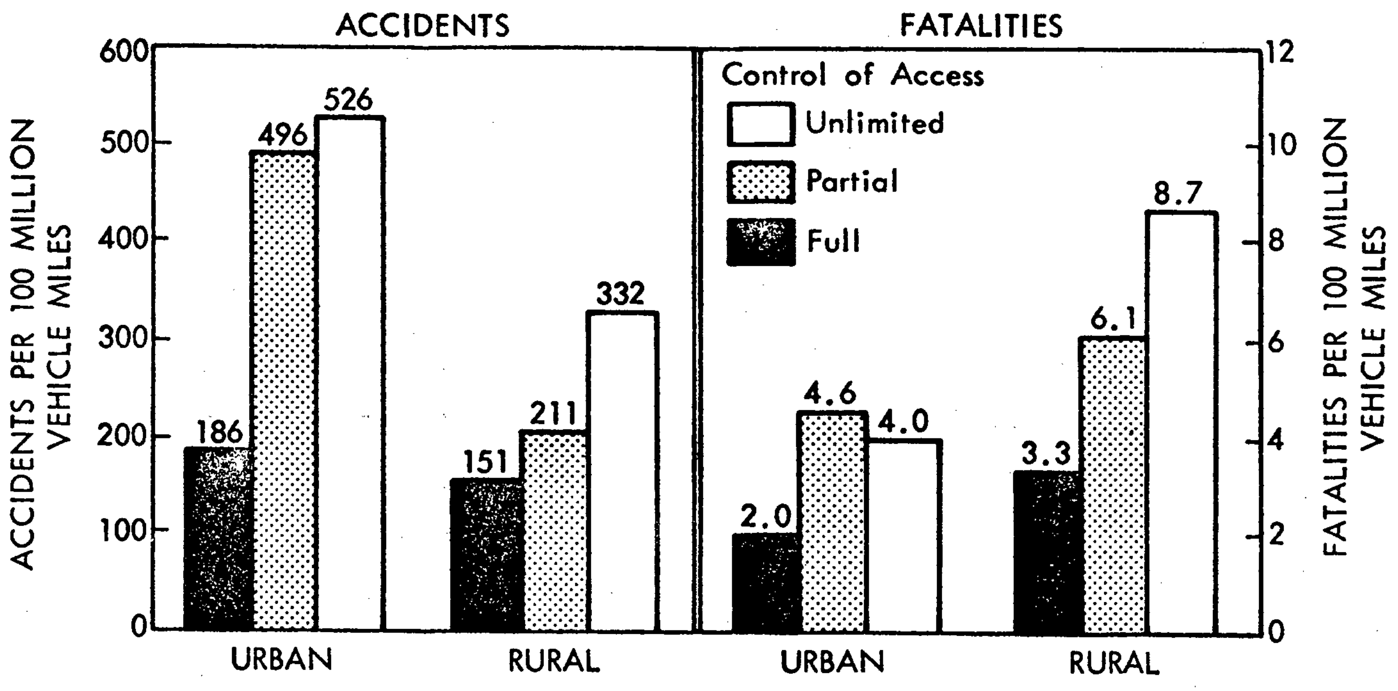


Figure 2 - Effect of Control of Access on Accidents and Fatalities in Urban and Rural Areas

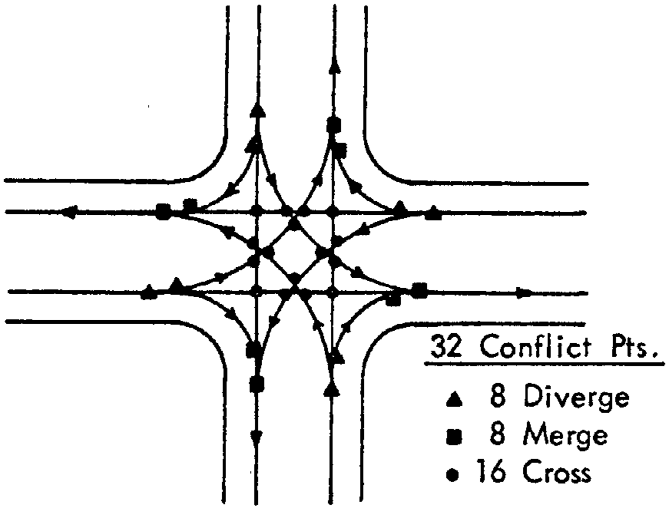
The vehicle-to-vehicle conflicts at driveway entrances are analogous to conflicts at intersections. Quite often sight-distance is restricted. Sometimes distracting elements are present. With reasonably heavy traffic opposing uncontrolled left-turning vehicles, drivers are forced to accept small gaps. Then too, driver perception of an ensuing conflict is difficult at night. But the most critical factor is relative speed.

Large speed differentials between through vehicles and maneuvering driveway vehicles create traffic inefficiency and its by-product, increased accident potential. Well-designed acceleration and deceleration lanes or well-designed frontage roads can minimize this factor by allowing driveway vehicles to enter and leave the arterial roadway at close to average running speed. Where these transitional facilities are infeasible, the design speed of the driveway entrance should be as high as possible consistent with minimizing conflicts with pedestrians and other driveway vehicles.

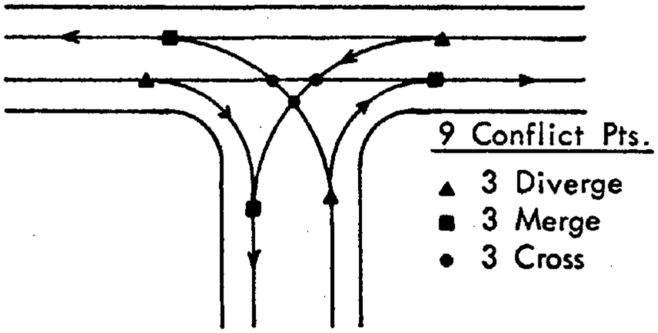
A study[8/] by Stover, Adkins, and Goodknight shows a distinct relation between driveway entrance speed and the efficiency and safety of driveway operations. To quantify the effects of entrance speed, they used time-space data for driveway entrance maneuvers and the speed adjustment of following vehicles obtained from time-lapse aerial photographs of a 45-mph roadway. They found that as driveway entrance speed increased from 2 to 10 mph, the traffic interference falls off rapidly. For the increase from 10 to 15 mph some additional reduction is realized, but for higher entrance speeds, the additional benefit is small.

For rural roadways and some urban roadways, entrance speeds of 15 mph may be too low. Solomon[9/] has shown a strong correlation between the involvement rate for two-car, rear-end collisions and speed differential for main rural highways. His findings indicate that, for minimizing rear-end collisions, a differential of less than 10 mph between through speed and driveway speed is desirable.

In analyzing driveway conflicts, the classical method of conflict-point analysis is pertinent. Figure 3 shows the description of conflict points for a four-leg intersection and, like the conventional driveway, a three-leg intersection. Comparison of these two descriptions gives a good indication of the potential to improve the conflict situation. By eliminating one leg of the intersection, the number of conflict points is reduced from 32 to 9. More important, the more severe conflict points are reduced from 16 to 3.



COMMON FOUR-WAY INTERSECTION



T OR Y INTERSECTION

Figure 3 - Intersection Conflict Points

To improve the conflict conditions at intersections, the engineer uses the principles of geometric design (including channelization) to physically separate movements, to define maneuver paths, to reduce conflict areas, to shadow and store turning vehicles, to merge vehicles at flat angles, to provide adequate sight distances, to prohibit certain movements, and to minimize speed differentials. He also uses the principles of traffic control to separate opposing movements, prohibit certain maneuvers, and reduce speed differentials.

B. Driveway Accident Statistics

Accident data on commercial driveways is a helpful tool in diagnosing the problems of conflicting traffic maneuvers. However, obtaining consistent and meaningful data on driveway accidents is complicated by the classical problems of accident reporting. These are: overgeneralization of report forms; difficulty in identifying causal factors; difficulty in assigning collision locations; incompleteness of reporting; and the high proportion of unreported accidents.

The 1970 National Safety Council statistics[10] show 4.9% of urban accidents and 6.0% of rural accidents involving driveway vehicles. From these statistics, 63% of the urban driveway accidents involve vehicles leaving the driveway and 58% of the rural driveway accidents involve vehicles entering the driveway.

Marks[11] reported that 6.5% of Los Angeles County accidents involved "uncontrolled" driveway access. In a 2-year study,[12] Michaels and Petty found that 14.4% of two-vehicle accidents on Indiana county roads involved driveways. Driveway accidents were reported in 6.8% of all Indiana accidents. Box[5] found 11.2% of all accidents in Skokie, Illinois, involved driveways.

Several studies indicate that driveway accidents are much more frequent than national figures suggest. Two studies indicate that rural driveway accidents are more prevalent than the National Safety Council figures would indicate. Box[13] reported 11% and Cribbins et al., [14] reported 13% of all rural accidents involve driveway maneuvers. Also, Marconi[15] reported conflicting evidence on urban driveway accidents. He found that only 1.3% of San Francisco accidents involved driveways.

Box[5] has conducted the most complete study of driveway accidents by type of maneuver and collision. His studies in Skokie, Illinois, show the following percentage breakdown on driveway accidents:

Maneuver	Turn	Collision	Percent of Total Driveway Accidents
Entering	Left	Rear-end	26
Leaving	Left	Right-angle	24
Entering	Left	Head-on angle	15
Entering	Right	Rear-end	12
Leaving	Right	Right-angle	7
Leaving	Right	All other	8
Leaving	Left	All other	3
Entering	Right	All other	3
Entering	Left	All other	2
			100

These statistics show 58% of all driveway accidents involve entering vehicles and 70% involve left-turns. Again, though, there is good reason to question these statistics. Four types of accidents, in particular, are hard to identify and are probably underrepresented in these statistics. These are:

1. The rear-end accident that happens upstream from the driveway because of a vehicle slowing down to enter the driveway;

2. The sideswipe accident caused by vehicles changing lanes behind a vehicle preparing to enter a driveway;

3. The rear-end accident that happens downstream from the driveway involving a vehicle from the driveway that has not yet gained enough speed; and

4. Collisions involving two vehicles using closely spaced adjacent driveways and collisions of driveway vehicles with intersection vehicles when the driveway is close to the intersection.

C. Current Practices in Direct Access Control

Observation of almost any urban or suburban arterial highway in the nation will show the process of sequential degradation of the traffic service function (see Figure 4). In other words, each new driveway opening was allowed by the authorizing agency without due concern until the traffic service function of the highway was seriously jeopardized. Although each driveway opening in the sequence only degraded the traffic service a small amount, the cumulative effect was a significant degradation of the travel time, capacity, and safety of the highway.

Major highway and traffic engineering references almost completely ignore the subject of direct access control on arterial highways. Because of the lack of a unified body of information, standards for the location, design, and traffic control of driveways vary considerably among jurisdictions.

D. Legal Aspects of Access Control

Access to property from roadways is normally a right of the property owner. The degree of access, however, can be limited by the public agency responsible for the route. Limitations may include denial of left-turn exit or entry, denial of closest approach access by using one-way roadways, and restriction of driveways. These controls are mostly exercised within the highway right-of-way. They are usually reinforced with land-use planning and zoning, including traffic zoning.

Regulating the number of direct access driveways faces no legal obstacles. But the allocation of a limited number among abutting properties through spacing and locating often stirs controversy on the authority and equity of the law. The "rule of reason" often determines whether access restriction is valid and whether compensation is required. What is "reasonable and proper" depends on abutter's customary rights and on local situations, including the attitude of the public and of public authorities.[16/] Also, existing land use may affect how the law relates to denying access at a particular point. What constitutes sufficient and suitable access varies among land uses.

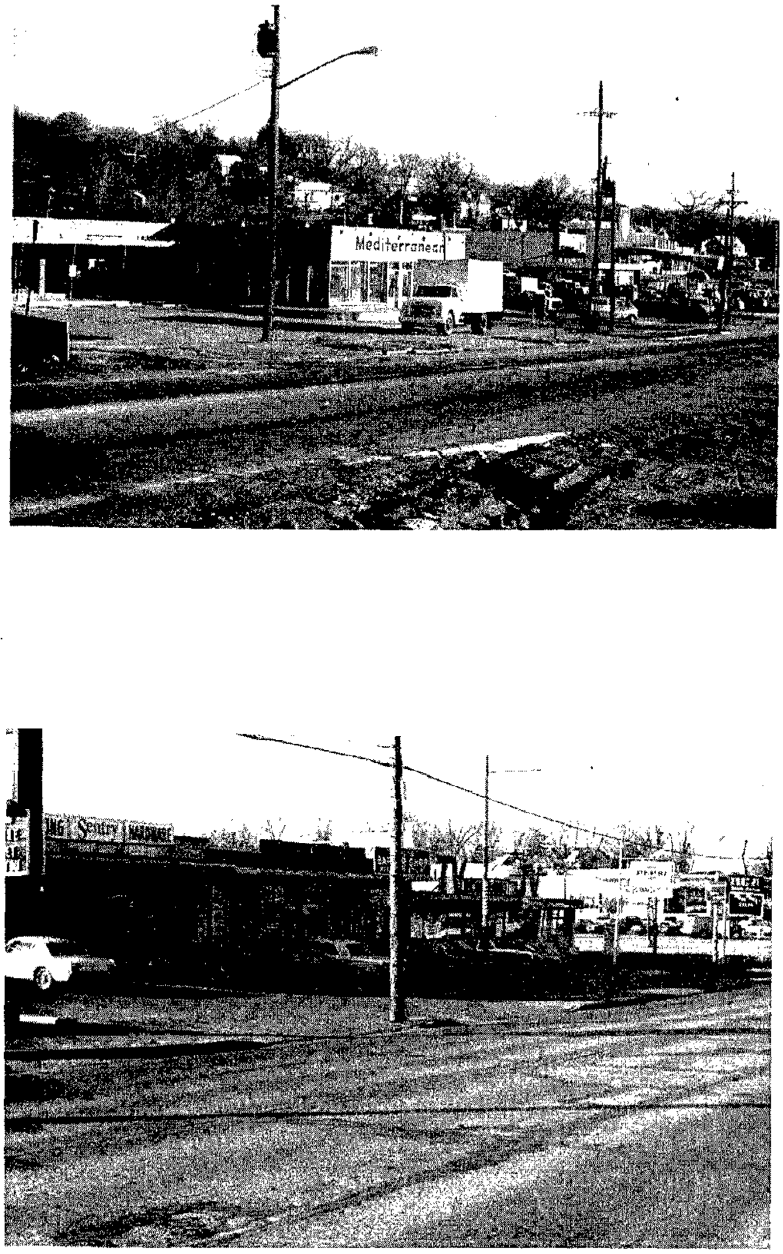


Figure 4 - Strip Commercial Development Degrades the Traffic Service Function of the Arterial Highway

The current body of access control policy, as documented in the reports of the Committee on Land Acquisition and Control of Highway Access and Adjacent Areas (Highway Research Board), is a result of judgment in individual cases before state courts between the early 1950's and late 1960's.[17] Access control policies have been developed in pieces rather than as a comprehensive plan. Often, the regulatory policy to implement specific access control techniques does not exist, and the subsequent disputes between abutter and state require court action.

Court action establishes precedent for future access disputes. Unfortunately, legal procedures based on precedent have a disadvantage; a ruling made in favor of an abutting landowner or at least a lenient compromise in access control policy may be an opportunity to set precedent for lenient rulings in other cases.

If a state does not have a comprehensive access control policy that is sensitive to optimizing the trade-off between safe and efficient highway operations and suitable and sufficient access, then the courts must decide many cases individually. But this procedure requires time, money, and court action. Although the courts are presently deciding in favor of access control in most reasonable cases,[16] a state highway department has no advance guarantee that an untested access control technique will be implemented through court action. The difficulty that highway departments face in implementing control techniques discourages the clear-cut standards needed to eliminate present and future access problems.

E. Highway Agency Needs

Although major arterial highways must provide both traffic service and land access, access is a secondary function that should be controlled to avoid jeopardizing the primary traffic service function. Failure to exert comprehensive standards for the design, operation, and regulation of direct access driveways leads to inefficient and hazardous traffic operations, which are detrimental to both the road user and the abutting property owner.

Without a comprehensive and objective approach to access control, there is little wonder of the continuing failure to preserve the functional integrity of arterial highways. The congested strip development is the typical result. Highway agencies have almost given up trying to control this kind of development because, when they have made a concerted effort, they have ended up in court and lost. But why have the highway agencies lost these court battles? They have consistently been unable to operationally define what is safe and efficient traffic operation and what is suitable and sufficient access.

Although available studies show a strong relationship between increased commercial access and increased accident rates on arterial roadways, they do not adequately define the relationship of accident hazard to specific elements of driveway location, design, and traffic control. More detailed information relating traffic safety and service to specific elements such as driveway spacing, driveway width and turning radii, and maneuvering speed are desirable. With these data and a more precise description of implementation costs, highway agencies will be able to formulate comprehensive access control policies based on valid cost-effectiveness comparisons of feasible alternative access control techniques.

III. SUMMARY OF THE IDENTIFICATION AND BASIC EVALUATION OF ACCESS CONTROL TECHNIQUES

This part of the guideline is intended to orient the reader to the identification and analysis of access control techniques detailed in the companion research document, "Evaluation of Techniques for the Control of Direct Access to Arterial Highways." The research was undertaken to identify, analyze the applicability of, and comparatively evaluate alternative techniques for the control of direct access to arterial highways.

The total evaluation consisted basically of a synthesis of the state of the art in locational controls, geometric design techniques, and traffic operational measures that can be applied to reduce the traffic interference associated with commercial driveways. A summary of the various elements of the evaluation is given below.

A. Review of Current Practices

The first part of the evaluation took a critical look at current practices in access control. Although this review indicated the lack of a well-defined body of knowledge on the control of direct access to arterial highways, it did provide a basic orientation to specific aspects of the subject that were helpful to other parts of the evaluation.

Because driveway operations can so seriously affect the efficiency and safety of the highway, the dearth of unified information on the location, design, and traffic control of direct access driveways is surprising. Major references such as the Traffic Engineering Handbook[18/] and the AASHTO design policies[1,19/] treat the subject of direct access control with such broad generalities that they provide little practical guidance for highway agencies. Although AASHTO[20/] does have a separate guide for driveway regulation, that guide is not very comprehensive and seems more concerned with national standardization than with optimizing the traffic service and safety of arterial highways.

Standards for the location, design, and traffic control of driveways vary considerably among jurisdictions, as demonstrated by a review of 49 state highway agency driveway manuals. Besides demonstrating an extremely wide variance of current access regulations and standards, this review gave a very clear indication that most agencies treat direct access control more strictly as an enforcement of policies than as a comprehensive attempt to protect the functional integrity of the highway.

B. Identification and Classification of Techniques

One of the early phases of the research was to define access control objectives and thereby develop a scheme for the identification and functional classification of potential techniques.

The goals of all highway design and operational measures are the safe and efficient movement of traffic. The operational objectives to satisfy these goals are the minimization of the frequency and severity of traffic conflicts. A traffic conflict is defined as an event involving two vehicles where evasive action is required by one or both drivers to avoid collision. This corrective action can involve acceleration, deceleration, path correction, or any combination of the three. The severity of the conflict depends on the degree of the evasive action required, which in turn, is a function of the relationships between closing rate, separation distance, and driver and vehicle performance limitations.

The initial step in the process was to list all of the techniques identified in the review of current practices or otherwise known to the research team. This activity resulted in the initial identification of 40 techniques. These techniques were then used as the basis for developing a structure for classification of alternative techniques. This development was important for three reasons. First, the rational process of development helped identify many additional alternative techniques. Second, the classification scheme provided a logical framework for the technical, economic, legal, and operational effectiveness evaluations of the techniques. And third, the classification scheme provides an effective decision tool for highway agencies to delineate and compare feasible alternative techniques.

The classification process resulted in identifying a total of 70 alternative techniques for the control of access on arterial highways. The classification table, shown on the last page of this volume, conveniently folds out to serve as a ready reference to the reader. Also, Volume II of this document gives a detailed description of each of the techniques.

Although all of the techniques identified are believed to contribute to the minimization of the frequency and severity of conflicts, the classification scheme uses a further subdivision of objectives that more closely explains the direct operational functions and applicational similarities of the alternative techniques.

The techniques with similar application are grouped into three categories as follows:

a. Highway design and operations techniques: Highway design and operational measures generally applied within the limits of the highway traveled way.

b. Driveway location techniques: Access control regulations that limit the number and location of driveways.

c. Driveway design and operations techniques: Driveway design standards and operational measures applied outside the edge of the highway traveled way.

Within each application category, the techniques are further grouped under one or more functional objectives as follows:

1. Limit the number of conflict points: These techniques directly reduce the frequency of either basic conflicts, or encroachment conflicts, or reduce the area of conflict at some or all driveways on the highway by limiting or preventing certain kinds of maneuvers. The standard uncontrolled T-driveway (three-leg intersection) has nine basic conflict points--three merge, three diverge, and three crossing.

2. Separate basic conflict areas: These techniques either reduce the number of driveways or directly increase the spacing between driveways or between driveways and intersections. They indirectly reduce the frequency of conflicts by separating turning vehicles at adjacent access points and by increasing the decision-process time for the through driver between successive conflicts with driveway vehicles at successive driveways.

3. Reduce maximum deceleration requirements: These techniques reduce the severity of conflicts by increasing driveway turning speeds, by decreasing through highway speeds, or by increasing driver perception time.

4. Remove turning vehicles or queues for certain portions of the through lanes: These techniques directly reduce both the frequency and severity of conflicts by providing separate paths and storage areas for turning vehicles and queues.

In reality, each of the 70 techniques listed in the classification table has several forms of application. For clarity of the total presentation, however, the techniques are stated in general terms with knowledge of the following two implicit characteristics.

First: The classification assumes that all techniques are applied with certain desirable standards or criteria. Therefore, where a certain technique has been previously applied and is now substandard for existing conditions, upgrading that particular application is implicitly considered as part of the described technique. For example, where a 10-ft, two-way-left-turn lane exists, a potential application may be to widen that lane.

Second: The classification also assumes that some techniques apply to the location, design, or operation of both existing driveways and future driveway openings. For future driveway openings, the techniques take the form of regulatory standards intended to limit the future sequential degradation of highway operations. For existing driveways, the techniques are intended to improve current highway operations through the application of redesign and the closing and/or relocating of driveways.

C. Legal Evaluation of Techniques

Access control techniques can be implemented with two basic legal powers: police power and eminent domain. The first power allows a state to restrict individual actions for public welfare. The second power allows a state to take property for public use provided an owner is compensated for his loss. Police power is sufficient authority for most access control techniques associated with highway operations, driveway location, and driveway design. Eminent domain, on the other hand, is the authority a state must cite when constructing local service roads, buying abutting property, taking additional right-of-way, and denying direct access.

Most of the access control techniques cited in this report are legally feasible. However, three questions should be asked when evaluating access control techniques for a particular state. What access control policies does a state presently have? Will the state enforce existing legislation? Are the courts receptive to particular access control techniques? It is futile to propose a technique that, while theoretically feasible, will not or cannot be implemented by a state highway department because of lack of legislation, reluctance to participate in legal struggles, or lack of support in the courts.

Certain public protection from negligent use of access control does exist. The authority to construct, maintain, and protect state highways delegated to state highway departments is necessary but not always sufficient for implementing access control techniques. Police power gives a state ability to legislate restrictions for public welfare, but these restrictions must be part of general policy and should be reasonably consistent. Eminent domain requires a state to prove that taking property or property rights is necessary for public use.

Generally, states should consult their code books for access control policy. Legislation contributing to police power can be reviewed and subsequently replaced or reinforced by additional standards. For effective use of police power, consistent, consolidated, clear and forceful regulatory policies should be enacted. Coordinating access policy into a definitive, unambiguous code is necessary. Providing concrete evidence (traffic counts, accident counts, visual accounts of site conditions) confirming the hazards of access points or the improvements made by access control techniques will promote additional legislation and aid legal struggles for access control.

Whether a state is fully exercising its legal powers to control access should be evaluated within each state highway department. Often techniques that can be implemented legally cannot be implemented practically. Abutters may challenge the legality of a technique to the extent that its benefits do not outweigh costs of legal struggles. Furthermore, all of the techniques discussed may be legally feasible according to a state's legislated authority to safely maintain its highways; however, the techniques may not be legally feasible in a state which does not have a policy or the legal precedent to uphold them.

The states have adequate power to practice effective access control. Generally, as long as reasonable access is given to an abutter, reasonable access regulation can be implemented. However, the control of future access points is relatively simple in comparison to the control of existing access points. Deliberate utilization of the law, of existing access legislation, of traffic safety concepts, and attempts both to educate the public on the values of access control and to negotiate with property owners could result in an improved access control policy.

D. Technical Evaluation of Techniques

The technical evaluation included: (1) the development of operational controls and criteria; (2) the derivation of geometric design requirements; and (3) a general analysis of the technical feasibility of each technique.

The development of operational controls and criteria considered the static and dynamic characteristics of drivers, vehicles, and traffic that bear on safe and efficient highway operations. The characteristics considered in the development of operational controls and criteria for the 70 access control techniques are: (1) design vehicle dimensions; (2) vehicular acceleration rates; (3) vehicle deceleration rates; (4) driver perception-reaction time; (5) vehicular turning path and speed; and (6) speed differentials between vehicles.

The development of geometric design requirements focused on determining the minumum acceptable dimensions of major geometric components of the 70 access control techniques. These dimensions were based on either: (1) widely accepted geometric design standards; or (2) the developed operational controls and criteria.

The major geometric aspects of access control that were considered include: (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. The geometric design requirements for these elements are included where appropriate in the detailed discussion of each technique given in Volume II of this document.

The technical feasibility analysis was limited to a determination of the ease with which each individual technique can be implemented dependent on the number and type of site paramters that pose possible major constraints to implementation. Physical restrictions to implementation will appear as longitudinal or transverse constraints. Major longitudinal constraints include insufficient property frontage widths, driveway spacing, corner clearances, major intersection spacings, and median opening spacings. Major transverse constraints include insufficient right-of-way width, median width, or setbacks (to buildings or parking areas). The summary of this analysis is given in Appendix B.

E. Economic Evaluation of Techniques

The economic evaluation considered the economic impact and direct costs of implementing the 70 access control techniques. The purpose of the evaluation was to provide the cost basis for relating the benefit-cost ratios of the alternative techniques.

The economics of implementing the access control techniques on unlimited access highways are highly variable because of many aspects that are either locational or activity dependent. First are the direct costs of implementation that usually accrue to the highway agency, but sometimes represent costs to the abutter. Included are the costs of construction and right-of-way. The costs of construction for a particular technique vary with existing highway geometrics, the physical specifications of the technique, the size of the construction job, and locality-dependent unit costs. Right-of-way costs depend on the existing availability of right-of-way required for the technique and the value of land.

The analysis of the direct costs of implementation examined one or more cost options for each technique based on implementing the technique for typical site conditions. A summary of these costs is given in Appendix C.

The other major category of the evaluation dealt with the economic impact of highway improvements. Here the prime considerations were the effects of the improvement on access values, land values, and the gain or loss of business revenue. These economic factors tend to be highly unpredictable for particular parcels because of the many temporal variables that affect the economic scene.

F. Operational Effectiveness Evaluation of Techniques

With respect to direct access control, the goals of safe and efficient highway operations are satisfied by the minimization of the frequency and severity of traffic conflicts. Although it may appear that the frequency and severity of conflicts are only related to the safe movement of traffic, these operational objectives are also directly related to the efficient movement of traffic. Reducing total frequency and severity of conflicts will necessarily improve the efficiency of traffic operations.

The response variables used in evaluating the effects of the access control techniques on traffic operations were traffic accidents and vehicle delay. These two measures were chosen because of their practicality and general data availability. Also, they are measures of safe and efficient traffic movement that allow direct comparison of access control techniques on the basis of their operational effectiveness.

An exhaustive review of literature was undertaken to develop the basic operational data on traffic accidents and delay. The accumulated information from the literature review was examined and material pertinent to the operational evaluation was extracted. Often portions of the total data base were not directly applicable to any specific technique or group of techniques. Sometimes, simplifying assumptions were used to indirectly relate the available information to the techniques. Some techniques were also quantitatively evaluated on the sole basis of engineering judgment. Other techniques could not be operationally quantified because of the lack of data and because of the complexity of their traffic operations.

A summary of the measures of effectiveness is given in Appendix D. The combinations of site parameters used in quantifying and classifying the effectiveness measures are: (1) highway volume and level of development; (2) highway volume and driveway volume; or (3) highway volume alone.

G. Cost-Effectiveness Evaluation of Techniques

The cost-effectiveness evaluation was undertaken to arrive at a comparative basis on the cost efficiency of the alternative techniques. This evaluation used the developed direct costs and measures of effectiveness to compute benefit-cost ratios for various site-condition categories pertinent to each technique.

A complete cost-effectiveness analysis for all the identified access control techniques is useful and essential for the comparison process. In many instances, however, the lack of effectiveness data hindered this overall effort. Quantitatively, 44 techniques were evaluated. The benefit/cost ratios of these techniques, and their options, are presented in Appendix E for all appropriate combinations of site parameters.

As might be expected most of the evaluated techniques were not cost-effective for low highway volumes, low driveway volumes, and low levels of development. Another general observation of the evaluation is that the lower cost techniques tend to have the higher benefit-cost ratios.

H. Development of Warrants for Implementing Techniques

To aid highway agencies in determining the applicability of each access control technique to specific sites, warrants for implementation are suggested in the detailed discussion of each technique found in Volume II of this document. A summary of warrants is given in Appendix F.

The suggested warrants are an attempt to quantify the site conditions that should be met to justify implementation of a technique. These minimum site conditions should insure that the technique will be both operationally effective and cost efficient. The suggested warrants do not, however, give any indication of the best alternative technique. That comparison must be made on a differential cost-effectiveness basis.

Where possible, the suggested warrants are compatible with nationally recognized warrants. For example, the existing national warrants for intersection signalization stated in the Manual on Uniform Traffic Control Devices[21] were suggested as warrants for driveway signalization. Other warrants were derived from the cost-effectiveness analysis, from data on expected accident rates[6,22] and by using engineering judgment.

IV. DECISION FRAMEWORK FOR THE IMPLEMENTATION OF ACCESS CONTROLS

Since the lack of proper access controls can seriously degrade the traffic service and safety of the arterial highway system, highway agencies should dedicate a considerable amount of resources toward the development and application of a comprehensive and systematic approach to direct access control. The following discussion is designed to give highway agencies an orientation toward using the research developments summarized earlier as the basis for developing a comprehensive and systematic approach to the application of direct access controls on arterial highways.

Access control is considered at two levels of application. First, in order to guarantee the future adequacy of traffic service and safety on arterial highways, it is imperative that highway agencies develop comprehensive access control policies that will provide the machinery to preserve the functional integrity of highways through comprehensive planning and the proper administration of driveway permit authorization. Some broad guidelines are presented for the development of appropriate comprehensive policies.

Also, at a time when the basic scenario of the highway transportation community is rapidly changing from a massive highway-building campaign to an attempt to improve the quality of existing highways, a second and equally important level of application is the implementation of access control techniques to counteract current or anticipated traffic service and safety problems on existing highways. Here, selection processes are described for the priority ranking of access control techniques applied to specific site conditions and operational problems.

A. General Considerations for Comprehensive Policy Development

These guidelines take a more comprehensive look at the control of direct access on "unlimited-access" highways than is expounded in the policy documents of most state highway agencies. These documents generally treat access control on these highways mostly from the viewpoint of the legal sanctioning of abutter's access rights.

Actually the commonly used term "unlimited access" appears as an admission of the inability to "control" direct access. Although "unlimited" may be true in a relative sense when at-grade highways are compared with freeway facilities, the term is a misnomer when speaking of the highway agency's ability to protect the traffic service function of a highway. With these thoughts in mind, these guidelines define direct access control as all locational controls, geometric design aspects, and traffic operational measures that minimize the traffic interference associated with direct access driveways.

Although the research developments were oriented toward access control improvements on existing highways, they lend some ideas toward the development of comprehensive access control policies. In this regard, the discussion centers around two basic applications (1) the planning of access control on future highways, and (2) the administration of driveway permits.

The classification table (last page of this volume) of access control techniques is the basic building block in the development process. This table is not necessarily the only way to classify techniques, nor does it necessarily list all feasible techniques. It is, however, one way to conceptualize a systematic and comprehensive approach to the problem. By classifying, based on applicational similarities and functional, objectives, not only can the techniques be conceptually compared but also direct alternatives can be identified for the purposes of choosing one technique over another because of general practicality or feasibility within a particular state.

The highway planning and preliminary design stage is the first important opportunity to take steps toward preserving the functional integrity of the highway. Here the access control policy should include procedures that systematically evaluate every opportunity to optimize access control. The level of access control should be compatible with the functional classification of the highway, the anticipated traffic volumes, and planned traffic speed control. The major aspects that affect the general level of access control at this stage are: (1) zoning and subdivision regulations; (2) application and design of medial treatments; (3) building setback regulations; and (4) driveway spacing regulations.

Zoning and subdivision regulations are the most positive controls on the number of commercial driveways. These land use regulations can be used to control the type and amount of commercial activity along the highway. Although these regulations are not usually under the direct control of state highway agencies, the access control policy should contain regulations and procedures to insure their optimum use through specified coordination processes with local jurisdictions.

Because left-turn driveway maneuvers are a major operational characteristic that can degrade the traffic service function of the highway, median design alternatives should be a major aspect of the access control policy. The classification table lists several median alternatives, which apply to varying operational conditions. The specific application of the individual techniques is given in Volume II. In the planning and preliminary design stage, detailed analysis of anticipated traffic volumes and levels and types of commercial development will aid in determining the need for and type of median treatment. If the need for a median is not anticipated in the early years of the highway operation, but is projected for some future year, then the right-of-way acquisition should provide space for future installation of the median.

Building setback regulations are important because they can insure that adequate space is available for proper driveway and internal circulation designs and for future highway widening. As seen in Appendix B, the technical feasibility of several access control techniques depends on adequate building setbacks.

Driveway spacing regulations can take several forms as seen by the several techniques listed under Driveway Location Techniques in the classification table. The function of these regulations is to limit the number of driveways and minimize the traffic interference between adjacent driveways. Driveway spacing regulations should be compatible with the functional classification of highways. Therefore, the level of access control on a proposed highway will be set when the functional class is decided.

The driveway permit authorization process is another important level of application in protecting the functional integrity of the highway. This process, which continues throughout the life of the highway, is concerned with minimizing the traffic interference associated with each new driveway opening. Driveway permit authorization deals mainly with the location, design, and operation of proposed driveways. The classification table lists 42 techniques that have some degree of pertinence to the driveway permit process.

In the driveway permit authorization process, every avenue should be investigated to optimize the safety and efficiency of proposed driveways subject to providing suitable and sufficient access to the property. The key issue in the review of driveway permit applications is to insure that the proposed driveway(s) and site plan are operationally compatible with the surrounding highway environment. This requires review by competent staff personnel and a comprehensive set of procedures and standards that are keyed to expected operational characteristics.

Many of the considerations pertinent to these requirements for the permit authorization process are discussed under the Driveway Location Techniques and Driveway Design and Operation Techniques given in Volume II. The basic considerations include: (1) minimizing the number of driveways; (2) maximizing the spacing of driveways; (3) maximizing driveway turning speed; (4) minimizing driveway traffic queues; (5) preventing internally circulating vehicles from using the highway as part of their circulating path; and (6) limiting conflict points by restricting certain turning maneuvers.

B. Selection of Techniques to Counteract Operational Problems on Existing Highways

Programming access control techniques to counteract operational problems on existing highways is another important avenue for protecting the functional integrity of a highway. Identifying the need for access control improvements can be approached by two different procedures depending on the level of funding allocations.

The first procedure warrants implementation of access control techniques only when specified operational problems have been observed. The operational problems that best identify the need for implementation are high-accident rates and frequent delays to highway or driveway vehicles.

The second procedure warrants implementation by predicting the potential operational effectiveness of access control techniques knowing site parameters that are associated with high-accident rates or frequent delays. This procedure presupposes a jurisdiction-wide focus on access control problems where all possible access control improvements are implemented, and programming is prioritized based on the levels of site parameters such as highway volume, driveway volume, and level of development (driveways/mile).

1. Techniques to Counteract Accident Problems

In relating to the implementation of access control techniques, two characteristics of accidents are appropriate--accident rates and accident patterns. The important accident rates to identify are those associated with mid-block locations. Intersection accidents do not directly indicate access control problems and therefore should not be included in tabulations. Representative average accident rates for various levels of site parameters are given in Table I for highway sections and driveway locations. These average rates serve as warranting conditions.

TABLE I

GENERAL 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

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* These table values represent average total accident rates. The average rates for left-turn accidents and right-turn accidents are 70% and 30% of these values, respectively.

When an accident rate at an existing location is above the appropriate warranting value, access control improvements should be considered. For example, if an accident rate of 3.0 accidents per year was observed for a driveway with 1,600 driveway vehicles per day and 17,000 highway vehicles per day, the site would warrant access control improvements.

Since many of the access control techniques apply specifically to the reduction of accidents associated either with left-turns or right-turns, these patterns provide a more precise analysis for warranting problems. In this case, the average or warranting rates are 70% of the Table I values for left-turn techniques and 30% of the values for right-turn techniques. These are the proportions of accidents associated with these maneuvers.

a. Procedures for ranking application techniques: A partial decision tree for delineating applicable access control techniques based on prevalent accident patterns is shown in Figure 5. One main branch is used to determine applicable access control for a warranting left-turn accident rate; the other main branch is similar for those locations with warranting right-turning accident rates. The same basic decision tree can be used for the second procedure that predicts accident rates and operational effectiveness based only on site parameters.

Using the complete decision tree, all techniques were tested to see which of the 108 branches they applied to. Some branches did not have any cost-beneficial techniques and other branches had identical lists of techniques and were therefore grouped together. The result of this phase was 46 groupings of techniques.

The next stage in the decision process was to rank the techniques within each group. This step was accomplished using differential benefit-cost analysis, which is a technique used to rank alternatives when more than two are available. It systematically looks at incremental benefits and costs to maximize the benefit given that all incremental benefit-cost ratios are greater than one.

To obtain a priority ranking for a group of cost-beneficial solutions, every solution must be ranked with respect to every other solution. Proving that solution A is better than solution B, and solution A is also better than soluction C does not prove anything regarding solutions B and C. Thus, in the procedure used to rank the techniques, each solution was compared with every other solution. The basic ranking criterion used was to determine the solution with the greatest benefit given that the benefit/cost ratio was greater than unity and that the

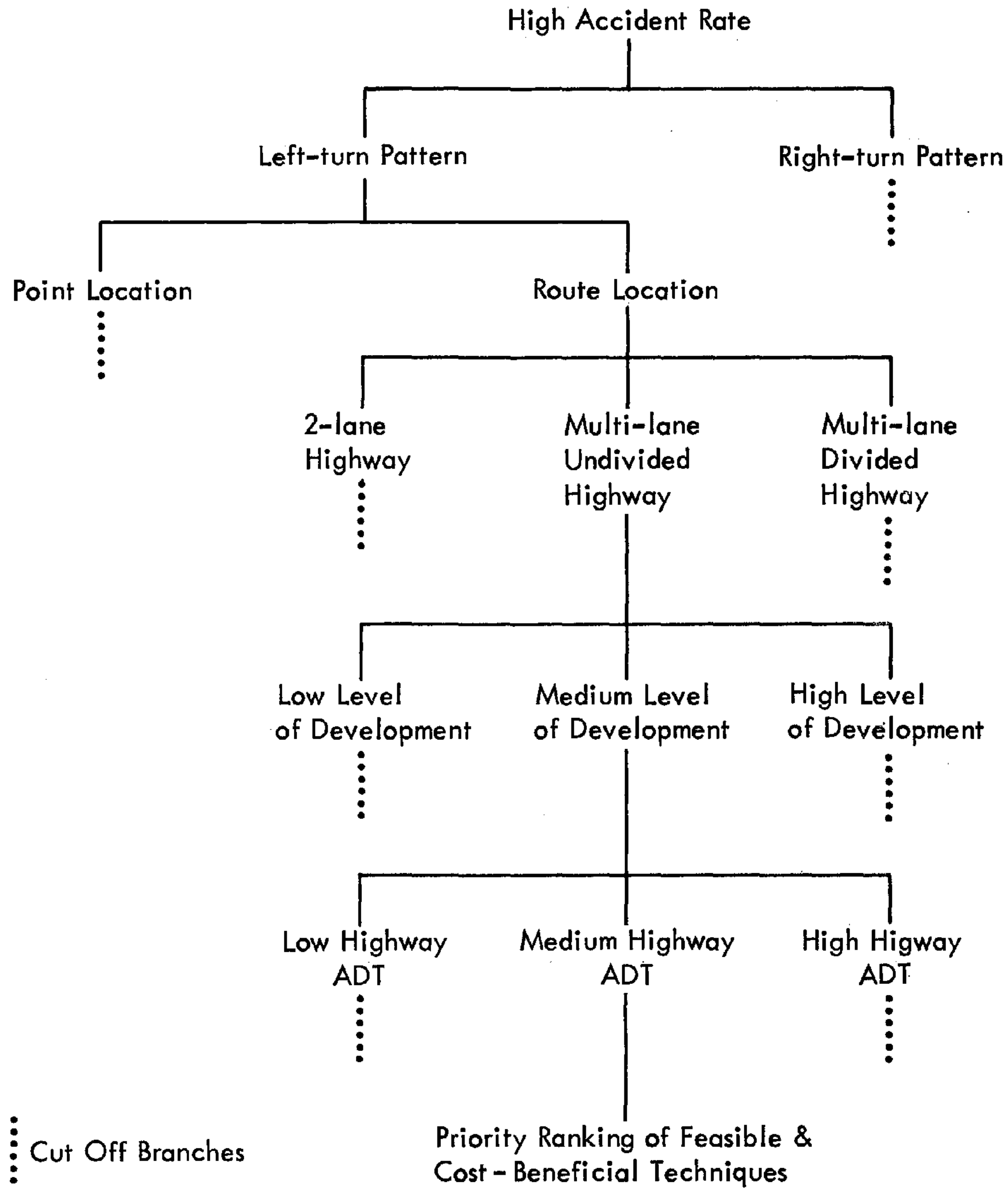

Figure 5 - Partial Decision Tree for Delineating Access Control Techniques

differential benefit/cost ratios (comparing the relative benefit/cost of each solution against the other solution) was also greater than one.

For some highway agencies, because of constraints imposed by competing programs, the basic ranking criterion may be set higher than unity. Also, since differential analysis is not a rigorous optimization strategy, care should be taken to insure that its use does not degrade the effectiveness of the total access control program that is constrained by limited funding. For example, if available fiscal funds only allow implementing 1% of the total improvements needed, then only the highest ranked alternatives (without considering lower cost-effective differentials) should be considered during the early years of program implementation.

b. Ranking of techniques to counteract left-turn accidents: Tables II through VI show the priority ranking of techniques to counteract left-turn accidents dependent on type of highway and location (route or point). Within each cell of each table the techniques are ranked from top to bottom based on the differential benefit/cost analysis. In revising these tables, the reader is advised to consult the pull-out classification table (last page of this volume) for technique titles. Also, reference to the detailed description of techniques in Volume II may be helpful.

Table II ranks the applicable route techniques for reducing left-turn accidents on multilane divided highways. These techniques include the various construction options of Techniques A-1, A-2, A-17, and A-19. The application of these techniques on highways that are already divided is limited to two specific situations. Option 1 applies only to highways with narrow paved medians with no left-turn channelization, but with at least 56 ft of total pavement width. Options 2 and 3 apply to highways with narrow paved medians where pavement widening and/or right-of-way are needed to achieve adequate widths.

A glance at Table II reflects the general preferences of Technique A-17, Install Two-Way Turn Lane. The user, however, is cautioned against the indiscriminate use of this measure. This technique applies only to sections of highway having frequent driveways on both sides with evenly distributed moderate left-turn volumes. In contrast, Technique A-2, Install Raised Median Divider with Left-Turn Deceleration Lane, applies to sections of highway with a significant number of medium and high highway volume driveways. Technique A-19 is applicable to highways with a higher concentration of driveways on one side. Technique A-1 applies to high-speed arterials at the suburban fringe where space for the median is limited. This technique has limited feasibility because of the large areas of right-of-way needed for indirect left-turn loops.

TABLE II

PRIORITY RANKING OF ROUTE TECHNIQUES TO REDUCE LEFT-TURN ACCIDENTS ON MULTILANE DIVIDED HIGHWAYS

Level of Development (Driveways per Mile)	Highway ADT (Vehicles per Day)		
	Low < 5,000	Medium 5 - 15,000	High > 15,000
Low < 30	A-17(1)* A-19(1)	A-17(1) A-19(1) A-2(1)	A-17(1) A-19(1) A-17(2) A-2(1)
Medium 30-60	A-17(1) A-19(1) A-2(1)	A-17(1) A-19(1) A-2(1) A-17(2) A-2(2) A-19(2) A-17(3)	A-17(1) A-2(1) A-17(2) A-19(1) A-2(2) A-19(2) A-17(3) A-2(3) A-19(3) A-1(1)
High > 60	A-17(1) A-2(1) A-19(1) A-1(1)	A-17(1) A-2(1) A-17(2) A-17(1) A-2(2) A-19(2) A-17(3) A-2(3) A-1(1) A-19(3) A-1(2) A-1(3)	A-17(1) A-2(1) A-19(1) A-2(2) A-17(2) A-2(3) A-17(3) A-19(2) A-19(3) A-1(1) A-1(2) A-1(3)

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* Number in parentheses denotes construction option delineated in Appendix C.

TABLE III

PRIORITY RANKING OF TECHNIQUES TO REDUCE LEFT-TURN ACCIDENTS AT SINGLE DRIVEWAYS ON MULTILANE DIVIDED HIGHWAYS

Driveway Volume (Vehicles per Day)	Highway ADT (Vehicles per Day)		
	Low < 5,000	Medium 5 - 15,000	High > 15,000
Low < 500	A-5(3) A-5(2) A-5(1)	A-5(3) A-5(2) A-5(1) B-4(1) A-24(2) A-24(3) A-24(4)	A-5(3) A-5(2) A-5(1) B-4(1) A-21 A-24(2) A-24(3) A-24(4) A-24(1)
Medium 500 - 1500	A-5(3) A-5(2) A-5(1) A-21 B-4(1) A-24(2) A-24(3) A-24(4) A-24(1)	A-5(3) A-5(2) A-21 B-4(1) A-5(1) A-23(1) A-23(2) B-4(2) A-24(2) A-24(3) A-24(4) A-24(1) A-4(1)	A-23(1) A-23(2) A-23(3) A-5(3) A-5(2) A-21 B-4(1) A-5(1) B-4(2) A-4(1) A-23(4) A-24(2) A-24(3) A-24(4) A-24(1) A-4(2) C-16
High > 1500	A-5(3) A-5(2) A-21 B-4(1) A-5(1) B-4(2) A-24(2) A-24(3) A-24(4) A-24(1)	A-5(3) A-21 A-23(1) A-5(2) B-4(1) A-5(1) B-4(2) A-23(2) A-23(3) A-24(2) A-24(3) A-24(4) A-4(1) A-4(2) A-24(1) C-16	A-23(1) A-23(2) A-23(3) A-5(3) A-21 A-5(2) A-4(2) B-4(1) A-23(4) A-4(1) B-4(2) A-5(1) A-24(2) A-24(3) A-24(4) A-24(1) C-16 A-22

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* Number in parentheses denotes construction option delineated in Appendix C.

TABLE IV

PRIORITY RANKING OF ROUTE TECHNIQUES TO REDUCE LEFT-TURN ACCIDENTS ON MULTILANE UNDIVIDED HIGHWAYS

Level of Development (Driveways per Mile)	Highway ADT (Vehicles per Day)		
	Low < 5,000	Medium 5 - 15,000	High > 15,000
Low < 30			A-17(2)*
Medium 30-60		A-3 A-17(2) A-2(2) A-19(2) A-17(3)	A-3 A-17(2) A-2(2) A-19(2) A-17(3) A-2(3) A-19(3)
High > 60		A-3 A-17(2) A-2(2) A-19(2) A-17(3) A-2(3) A-19(3) A-1(2) A-1(3)	A-3 A-2(2) A-17(2) A-2(3) A-17(3) A-19(2) A-19(3) A-1(2) A-1(3)

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* Number in parentheses denotes construction option delineated in Appendix C.

TABLE V

PRIORITY RANKING OF TECHNIQUES TO REDUCE LEFT-TURN ACCIDENTS AT SINGLE DRIVEWAYS ON MULTILANE AND TWO-LANE UNDIVIDED HIGHWAYS

Driveway Volume (Vehicles per Day)	Highway ADT (Vehicles per Day)		
	Low < 5,000	Medium 5 - 15,000	High > 15,000
Low < 500	C-3(2)* C-3(3)	C-3(3) C-3(2) C-3(1)	C-3(3) C-3(2) C-3(1)
Medium 500 - 1500	C-3(3) C-3(2) C-3(1)	C-3(3) C-3(2) C-3(1) A-4(1)	C-3(3) C-3(2) C-3(1) A-20(1) A-4(1) A-4(2) C-16
High > 1500	C-3(3) C-3(2) C-3(1)	C-3(3) C-3(2) C-3(1) A-20(1) A-4(1) A-4(2) C-16	C-3(3) C-3(2) C-3(1) A-20(1) A-20(2) A-4(2) A-4(1) C-16

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* Number in parentheses denotes construction option delineated in Appendix C.

TABLE VI

PRIORITY RANKING OF ROUTE TECHNIQUES TO REDUCE LEFT-TURN ACCIDENTS ON TWO-LANE HIGHWAYS

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		A-3	A-3
High > 60		A-3	A-3

Other techniques that will reduce left-turn accidents on multilane divided highways are A-10 and A-11. Although these techniques were not evaluated, they should be effective for counteracting untolerable left-turn accident patterns when none of the ranked techniques is feasible.

Table III ranks techniques to reduce left-turn accidents and/or conflicts for single driveways on multilane divided highways. These techniques are A-4, A-5, A-21, A-22, A-23, A-24, B-4, and C-16. Technique A-4 is an operational measure and requires satisfaction of MUTCD warrants for traffic volumes. Technique A-5 restricts either egress (Option 1), ingress (Option 2), or both left-turn (Option 3) maneuvers when the volume of turns are low. In most cases, driveway islands (Technique C-3) are constructed in conjunction with this improvement. Techniques A-21, A-22, A-23, and A-24 aim at improving left-turn operation and therefore are less restrictive than Technique A-5. These techniques treat egress and ingress maneuvers with the exception of Technique A-22 where it exclusively treats egress maneuvers. Techniques B-4 and C-16 are generally applicable to frontages with at least two driveways. Both techniques facilitate left-turn movements through operational restrictions with a minimum change in the physical characteristics of driveways.

Other techniques that may reduce left-turn accidents for a single driveway on multilane divided highways are A-7, A-9, C-1 and C-2. Techniques A-7 and A-9 require a median width of at least 18 ft. Techniques C-1 and C-2 are generally applicable to frontages with at least two driveways.

Table IV ranks route techniques to reduce left-turn accidents on multilane undivided highways. These techniques are A-1, A-2, A-3, A-17, and A-19. Evident from examining this table is the absence of any cost-beneficial techniques for low highway ADT's and low levels of development. In the remaining categories, technique A-3 heads the list of cost-effective techniques. This technique, of course, is limited by the requirement of a parallel facility to carry the opposing traffic stream. Techniques A-1, A-2, A-17, and A-19 require widening and/or right-of-way acquisition. The selection of these techniques depends on specific site conditions and traffic operations as described for Table II.

Other techniques that may reduce left-turn conflicts on multilane undivided highways are A-10 and A-11. Consideration of these techniques was included in the discussion for Table II.

Table V ranks techniques to reduce left-turn accidents at a single driveway on both multilane and two-lane undivided highways. These techniques are A-4, A-20, C-3 and C-16. Technique A-4 requires satisfaction of MUTCD warrants for signals, with minimum change in the physical characteristics of the site. Technique A-20 requires highway widening and/or right-of-way acquisition for the medial treatment. Technique C-3 requires the availability of additional frontage width. Technique C-16 is an operational measure and requires the least physical change. Obvious from this table, Technique C-3 ranks the highest.

Other techniques that may reduce left-turn accidents for a single driveway on two-lane and multilane undivided highways are A-13 an and C-1. Technique A-13 is applicable on relatively high-speed arterials with insufficient sight distances. Technique C-1 is applicable to frontages with at least two two-way driveways. The application of these techniques should be considered either in combination with other cost-effective techniques or separately when all of the ranked techniques are infeasible.

Table VI shows only one cost-beneficial route technique to reduce left-turn accidents on two-lane highways. The areas of application of Technique A-3 are medium and high levels of developments and highway ADT. A nearby parallel facility must exist to facilitate the movement of the opposing diverted traffic stream.

Other techniques that may reduce left-turn conflicts on two-lane highways are A-10 and A-11. Consideration of these techniques was included in the discussion for Table II.

c. Ranking of techniques to counteract right-turn accidents: Tables VII and VIII show the priority ranking of techniques to counteract right-turn accidents dependent on the location (route or point). The type of highway was not a determinant. Most of these techniques are implemented directly on driveways.

Table VII shows Technique A-25, Install Continuous Right-Turn Lane, as the only cost-beneficial route technique to reduce right-turn accidents on all highways. This technique usually requires widening and/or right-of-way acquisition. Insufficient building setbacks could present a physical constraint to implementation.

Other route techniques that will reduce right-turn accidents on all highways are A-10 and A-11. Although these techniques were not evaluated, they should be effective for counteracting intolerable right-turn accident patterns when Technique A-25 is infeasible.

TABLE VII

PRIORITY RANKING OF ROUTE TECHNIQUES TO REDUCE RIGHT-TURN ACCIDENTS ON ALL HIGHWAYS

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			A-25

TABLE VIII

PRIORITY RANKING OF TECHNIQUES TO REDUCE RIGHT-TURN ACCIDENTS AT SINGLE DRIVEWAYS ON ALL HIGHWAYS

Driveway Volume (Vehicles per Day)	Highway ADT (Vehicles per Day)		
	Low < 5,000	Medium 5 - 15,000	High > 15,000
Low < 500	C-2(3)* C-2(1) A-12	C-2(3) C-2(1) A-12 C-8 C-2(2)	C-2(3) C-2(1) C-8 C-2(2) A-12
Medium 500 - 1500	C-2(3) C-2(1) C-2(2) A-12 C-8	C-2(3) C-2(1) C-2(2) A-12 C-8 C-17(1)	C-2(3) C-2(1) C-2(2) A-12 C-8 A-4(1) C-17(1) C-17(2) A-4(2)
High > 1500	C-2(3) C-2(1) C-2(2) A-12 C-8	C-2(3) C-2(1) C-2(2) A-12 C-8 C-17(1) A-4(1) C-17(2) A-4(2)	C-2(3) C-2(1) C-2(2) A-12 A-4(2) A-4(1) C-8 C-17(1) C-17(2) C-6 C-14 C-12

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* Number in parentheses denotes construction option delineated in Appendix C.

Table VIII ranks techniques to reduce right-turn accidents at a single driveway on all highways. These techniques include A-4, A-12, C-2, C-6, C-8, C-12, C-14 and C-17. Techniques A-4 and A-12 require the least physical change. Technique A-4 requires satisfying MUTCD warrants for signal installation. Technique C-2 is usually applicable to frontages for signal installation. Technique C-2 is usually applicable to frontages with at least two driveways. Techniques C-6 and C-14 are channelization measures to improve right-turn egress and ingress, respectively. Their effectiveness is marginal. Techniques C-8, C-12, and C-17 require physical changes of the site under consideration. Technique C-8 requires the least and should be considered before C-12 and C-17. Techniques C-12 and C-17 require pavement widening and/or right-of-way acquisition.

Although Technique C-2 ranks highest, its application is mainly preferred on multilane divided highways with median designs to restrict certain maneuvers. However, this technique is effective on wide frontages where angle driveways can be constructed.

Other techniques which may reduce right-turn conflicts for single driveways on all highways are A-13, B-6, B-19, C-1 and C-15. Technique A-13 is an operational measure applicable to highways with relatively high speeds and insufficient sight distances. Technique B-6 is a regulatory measure applicable to corner lots. Technique B-19 requires wide frontage width and is mainly preferred on divided highways. Technique C-1 is applicable to frontages with at least two two-way driveways. Technique C-15 is a relatively inexpensive measure and applicable to driveways with insufficient sight distances and high pedestrian traffic.

d. <u>Summary of the application of techniques to counteract accidents</u>: Tables II-VIII are not intended to give the total solution to the application of access control techniques to counteract accidents. Actually, all they represent is the first step in the process. As such, they do highlight the reasonably small list of techniques that are aplicable.

Although some of the situations shown in the tables have several alternative techniques (and several options), not all techniques can be implemented at all locations. The user must still determine the technical feasibility of the selected alternatives to meet the specific physical or operational constraints of the site.

Accident problems are identified by examining accident records to determine accident rates, the prevalent accident pattern (left-turn or right-turn), and whether the accident problem occurs at individual locations (point) or at many locations (route). This data, together with information on the type of highway, highway volume, and either driveway volume (for point locations) or level of development (for route locations), will determine whether an accident problem (warranting level) exists.

When a total accident problem is identified but left- or right-turn accident patterns cannot be determined or if accident records are not available and the predictive procedure (discussed earlier) is appropriate, then consideration of both left-turn and right-turn techniques is dictated. To consider left- and right-turn techniques as alternatives, though, requires another step in the differential analysis to rank the combinations of left- and right-turn techniques. Without doing this step, however, it can be said that the left-turn techniques will generally rank higher than the right-turn techniques because of their generally higher effectiveness.

The other major step in the analysis is the comparison of route techniques with various combinations of point techniques as direct alternatives. At this stage, the analysis becomes very complex, because, ideally, the user would want to incrementally rank all feasible combinations of techniques to decide which combination is best. This step would also include another consideration, which has not been mentioned previously. That is, all techniques which relate to closing driveways, should be considered as route alternatives. The reason that driveway closing could not be ranked in the route tables is because the ranking would depend on the specific number of closings per mile.

Two other points are important to the application. First, most techniques listed in the accident countermeasure tables will also effect some delay reduction. This effect can be considerable for techniques like A-2. The other point which is very important is that whenever a proposed route technique will necessitate pavement widening, all feasible driveway locations, design and operation techniques should be considered in combination with the route technique because their cost will be substantially reduced by the reconstruction cost already associated with the route technique.

2. Selection of Techniques to Counteract Vehicle Delay

Vehicular delay is a major factor indicating the quality of traffic services on the highway and driveways. Delay is defined as the time consumed while traffic is impeded in its movement by some element over which it has no control. There are two types of delay, fixed delay and operational delay. The delays experienced by individual vehicles as a result of traffic signals or stop signs are considered to be fixed delays. Operational delay is caused by the interference between components of the traffic and the driving environment.

Delay on highway sections and driveways can be measured by using a test car and stopwatches. With this information, areas with inadequate traffic operations can be identified. Unfortunately, little current information is available regarding what is a normal or acceptable amount of delay to through or driveway vehicles.

Traffic volumes are utilized to approximate delay for both highway and driveway vehicles. It is assumed that as traffic volumes increase, the amount of total delay experienced by highway and driveway vehicles increases. Since most of the mid-block delay experienced by highway traffic is due to left-turning driveway vehicles, a technique that improves left-turn movements will reduce highway delay times. Similarly, since the delay experience by exiting driveway vehicles is primarily due to high driveway volume and lack of sufficient traffic gaps on the highway, a technique that increases or regulates the length of highway gaps or separates exiting driveway vehicle by maneuver will reduce driveway delay times. Care must be taken when considering a delay reducing technique, because a technique that will decrease delay on the driveway may increase delay on the highway.

a. Selection of techniques to reduce highway delay: The delay experienced by through vehicles due to turning vehicles or queues is indicated by the relationship between the number of vehicles that desire access to a driveway, the opposing volume, and the advancing volume. Right-turns are not as critical as left-turns because no opposing volume is present and, even though some queues may accumulate behind turning vehicles, the queue length is generally short and it dissipates rapidly as the lead vehicle enters the driveway.

The obvious method to reduce delay caused by turning vehicles is to separate those vehicles from the through lanes. This indicates the use of special turning lanes. Volume warrants[23] for left-turns have been altered to allow their use in access control situations.

Figure 6 shows the graph for determining whether a left-turn lane is warranted based directly on volumes, but indirectly on delay. The user must determine the advancing, opposing, and left-turning volumes at either a point or along a route, and then enters the graph with these parameters to determine if the volumes warrant a left-turn lane. If a specialized left-turn lane is not warranted, then the delay associated with the left-turn movement is not critical.

Highway delay caused by right-turning movements are generally not as critical as those caused by left-turning movements. Engineering judgement must be used to determine whether a delay caused by right-turning vehicles is excessive enough to merit a special turning lane. Generally, if several vehicles are delayed by each right-turning vehicle, then a delay problem probably exists. If the queues are short or occur infrequently, then the delay does not constitute a major problem.

Table IX lists the techniques that will generally reduce highway delay. Since the delay reduction was not explicitly evaluated, these techniques are not ranked.

b. <u>Selection of techniques to reduce driveway delay</u>: The interaction that causes the driveway delay takes place when a driveway vehicle attempts to merge into the traffic stream or crosses a traffic stream. Inherent in the traffic operation and interaction associated with driveway exit maneuvers is the concept of gap acceptance. The lack of frequent-long gaps coupled with high driveway volumes are the most critical elements that contribute to driveway delay.

The frequency and distribution of accepted gaps on a highway depends largely on the physical geometrics of the highway and the traffic operational characteristics. For example, two-lane highways with fairly high traffic volumes have a lesser number of acceptable gaps than four-lane highways with the same traffic volumes. Therefore, the improvements of traffic operations which aim at decreasing the driveway delay are warranted at highway sections with infrequent traffic gaps.

The techniques listed in Table X are desirable for reducing delay on the driveway. The effects of these techniques on highway delay should be investigated for each location.

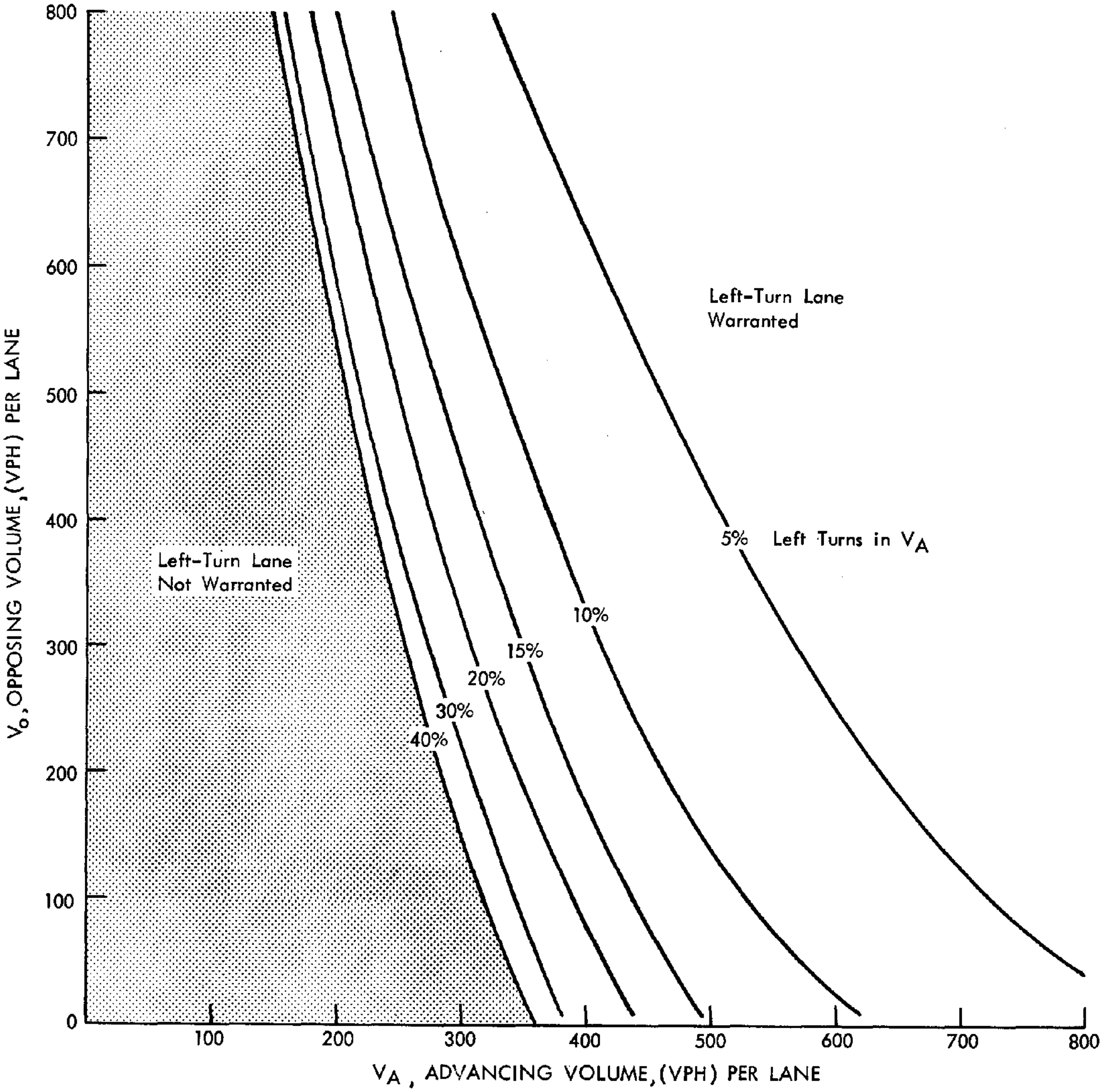

Figure 6 - Volume Warrants for Left-Turn Lanes

TABLE IX

TECHNIQUES THAT REDUCE DELAY TO HIGHWAY VEHICLES

A-2	Install raised median divider with left-turn deceleration lanes
A-17	Install two-way left-turn lane
A-19	Install alternating left-turn lane
A-20	Install insolated 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-23	Increase storage capacity of existing left-turn deceleration lane
A-25	Install continuous right-turn lane
A-26	Construct a local service road
A-27	Construct a bypass road
A-28	Reroute through traffic
C-17	Install right-turn deceleration lane

TABLE X

TECHNIQUES THAT REDUCE DELAY TO DRIVEWAY VEHICLES

A-4	Install traffic signal at high-volume driveways
B-16	Require access on collector street (when available) in lieu of additional driveway on highway
B-21	Install additional driveway when total driveway demand exceeds capacity
C-18	Install additional exit lane on driveway

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APPENDIX A

GLOSSARY OF TERMS

GLOSSARY OF TERMS

1. Acceleration Lane: The portion of the roadway adjoining the traveled way for the purpose of enabling a vehicle entering a roadway to increase its speed to a rate at which it can more safely merge with through traffic.

2. Access: The vehicular movement to and from an abutting property to a highway. Includes only that part of the driveway that lies within the established right-of-way limits of the highway.

3. Access, Control of: The condition where the right of vehicular traffic to abutting property to the highway is fully or partially controlled by public authority.

4. Access, Full Control of: The authority to control access if exercised to give preference to through traffic by providing access connections with selected public roads only and by prohibiting crossings at grade or direct private driveway connections.

5. Access, Partial Control of: The authority to control access is exercised to give preference to through traffic to a degree that, in addition to access connections with selected public roads, there may be some crossings at grade and some private driveway connections.

6. Access, Right of: The right of an abutting property owner to vehicular movement to and from the highway to his property.

7. Access, Uncontrolled: The authority having jurisdiction over a highway, street, or road, does not limit the number of points of ingress or egress except through the exercise of control over the placement and the geometrics of connections as necessary for the safety of the traveling public.

8. Access Point: The connection of a driveway at the right-of-way line to the highway.

9. Arterial Highway: A highway primarily for through traffic, usually on a continuous route.

10. Buffer Area (Border Area): The area between the outside edge of shoulder or curb line and the right-of-way line.

11. Channelizing Island: An area within the roadway not for vehicular movement, designed to control and direct specific movements of traffic to definite channels. The island may be defined by paint, raised bars, curbs or other devices.

12. Condemnation: The process by which property is acquired for highway purposes through legal proceedings based on the power of eminent domain.

13. Conflict: A traffic event that causes evasive action by a driver to avoid collision with another vehicle, usually designated by a brake light application or evasive lane change.

14. Conflict Area: An area where intersecting traffic either merges, diverges, or crosses.

15. Corner Clearance (C):* The minimum dimension parallel to a highway between the curb, pavement, or shoulder lines of an intersecting highway and the nearest edge of a driveway.

16. Deceleration Lane: The portion of the roadway adjoining the traveled way for the purpose of enabling a vehicle that is to make an exit turn from a roadway to slow to the safe speed on the curve ahead after it has left the mainstream of faster moving traffic.

17. Dedication: The setting apart by the owner and acceptance by the public of property for highway use, in accordance with statutory or common law procedures.

18. Delay: The time consumed while traffic or a specified component of traffic is impeded in its movement by some element over which it has no control.

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* Letter in parenthesis corresponds with dimensions shown on Figure 3.

19. Diverging: The dividing of a single stream of traffic into separate streams.

20. Divided Highway: A two-way road on which traffic in opposite directions is separated by a physical median.

21. Downstream: The direction along the roadway toward which the vehicle flow under consideration is moving.

22. Driveway: Every entrance or exit used by vehicular traffic to or from properties abutting a highway.

23. Driveway, Commercial: A driveway serving a commercial establishment, industry, governmental or educational institution, office building, hospital, church, apartment building, or other comparable traffic generator.

24. Distance Between Double Driveway (D): The distance measured along the right-of-way line between the inside edges of two adjacent driveways to the same frontage.

25. Driveway, Divided: A driveway so designed that traffic entering it is separated from traffic leaving it by a raised median or physical barrier.

26. Driveway, Joint Use: A driveway shared by two adjacent properties for connection to both properties.

27. Driveway, Major Commercial: Any commercial driveway where the actual or anticipated traffic volume is 500 or more vehicles entering and leaving during a 24-hr period.

28. Driveway, Minor Commercial: Any commercial driveway where the actual or anticipated traffic volumes on a typical day are less than the values stipulated for major commercial driveway.

29. Driveway Angle (Y): The angle between the highway centerline and the driveway centerline measured in a clockwise direction.

30. Driveway Approach Width (A): The maximum length parallel to the highway that practically can be used by a vehicle to perform a circular turning maneuver that is tangent to paths that are parallel to the highway before turning and parallel to the driveway after turning.

31. Driveway Flare: A triangular pavement surface that transitions the driveway pavement where it intersects the highway pavement for facilitating turning movements.

32. Driveway Return Radius (R): A circular pavement transition between the driveway and the highway for facilitating turning movements.

33. Driveway Turning Speed: The maximum speed at which a vehicle can negotiate a turn from the highway into the driveway.

34. Driveway Width (W): Narrowest width of driveway measured perpendicular to centerline of driveway.

35. Egress: The exit of vehicular traffic from abutting properties to a highway.

36. Eminent Domain: The power to take private property for public use with just compensation.

37. Frontage Road (Local Service Road): A local street or road located parallel to an arterial highway for service to abutting properties for the purpose of controlling access to the arterial highway.

38. Frontage Boundary Line (FB line): A line perpendicular to the highway centerline that passes through the point of intersection of the property line and the highway right-of-way line.

39. Frontage Width (F): The distance along the highway right-of-way line in front of an abutting property.

40. Highway Taper: A triangular pavement surface that transitions the highway pavement to accommodate an auxiliary lane.

41. Ingress: The entrance of vehicular traffic to abutting properties from a highway.

42. Level of Service: A qualitative measure of the effect of a number of factors which include speed and travel time, traffic interruptions, freedom to maneuver, safety, driving comfort and convenience, and operating costs.

43. Median: The physical portion of a highway separating the traveled ways for traffic in opposite directions.

44. Median Opening: A gap in a median provided for crossing and turning traffic.

45. Merging: The process by which two separate traffic streams moving in the same general direction combine or unite to form a single stream.

46. Peak-Hour Traffic: The highest number of vehicles found to be passing over a section of a lane or roadway during any 60 consecutive minutes.

47. Phase: That portion of a traffic signal cycle allocated to a specific traffic movement or combination of movements.

48. Pretimed Signal: A traffic control signal that directs traffic to stop and permits it to proceed in accordance with predetermined time schedules.

49. Property Acquisition or Taking: The process of obtaining land for highway right-of-way or other highway purposes. The methods of acquisition customarily available to public agencies include condemnation, purchase, and private dedication.

50. Property Line Clearance (E): The distance measured along the edge of the traveled way between the frontage boundary line and the nearest point of the driveway, including the flare or radius.

51. Remainder: The portion of a land parcel retained by the owner after a part of such parcel has been acquired for public use.

52. Right-of-Way: The land within legally-defined property boundaries vested in the State and designated for highway purposes.

53. Rural: Any area not included in a business, industrial, or residential zone of moderate or high density, whether or not it is within the boundaries of a municipality.

54. Set-Back (G): The lateral distance between the right-of-way line and the roadside business building, gasoline pump, display stand, or other object, the use of which will result in space for vehicles to stop or park between such facilities and the right-of-way line.

55. Stopping Sight Distance: The distance required by a driver of a vehicle, traveling at a given speed, to bring his vehicle to a stop after an object on the roadway becomes visible.

56. Traffic-Actuated Signal: A traffic control signal in which the phases are varied in accordance with the demands of traffic as registered by the actuation of vehicle detectors.

57. Traffic Control Device: Any sign, signal, marking, or device placed or erected for the purpose of regulating, warning, or guiding vehicular traffic and/or pedestrians.

58. Traffic Gap: The clearance interval in time or distance between individual vehicles.

59. Traveled Way: The portion of the roadway for the movement of vehicles, exclusive of shoulders and auxiliary lanes.

60. Turning Radius: The radius of an arc which approximates the turning path of a vehicle.

61. Undivided Highway: A road that has no directional separator, either natural or structural, separating traffic moving in opposite directions.

62. Urban: Any territory within an incorporated area or with frontage on a highway which is at least 50% built-up with structures devoted to business, industry, or dwelling houses for a distance of a quarter of a mile or more.

63. Weaving Maneuvers: The crossing of traffic streams moving in the same general direction accomplished by merging and diverging.

64. Zoning: The division of a geographic area into districts, and the public regulation of the character and intensity of use of the land and improvements thereon.

APPENDIX B

GENERAL TECHNICAL FEASIBILITY OF TECHNIQUES

GENERAL TECHNICAL FEASIBILITY OF TECHNIQUES

	POSSIBLE MAJOR PHYSICAL CONSTRAINTS TO IMPLEMENTATION									
TECHNIQUE	No Constraint	Available ROW for Widening	Median Width	Property Frontage Width	Setback to Buildings and Parking Areas	Driveway Spacing	Corner Clearance	Major Intersection Spacing	Spacing of Median Openings	Other
A-1		●			●			●		
A-2		●			●			●		
A-3										●
A-4							●			
A-5			●							
A-6		●			●					
A-7			●							
A-8					●					
A-9			●							
A-10	●									
A-11								●		
A-12	●									
A-13	●									
A-14										●
A-15	●									
A-16	●									
A-17		●			●			●		
A-18		●			●			●		
A-19		●			●					
A-20		●			●					
A-21			●						●	
A-22			●							
A-23					●				●	
A-24	●									
A-25		●			●					
A-26		●						●		
A-27										●
A-28										●
B-1				●	●	●	●			
B-2				●	●	●		●		
B-3				●	●	●	●			
B-4				●	●				●	
B-5				●		●				
B-6				●		●				
B-7				●						
B-8	●									
B-9	●									
B-10					●				●	
B-11	●									
B-12	●									
B-13	●									
B-14	●									
B-15	●									
B-16					●					
B-17				●	●	●	●			
B-18	●									
B-19				●	●					
B-20					●					
B-21				●	●	●				
C-1	●									
C-2				●	●	●			●	
C-3				●	●	●				
C-4					●					
C-5		●								
C-6				●			●			
C-7					●					
C-8				●	●	●				
C-9										●
C-10	●									
C-11	●									
C-12		●		●		●	●			
C-13										●
C-14				●	●	●				
C-15		●			●					
C-16	●									
C-17		●		●	●	●	●			
C-18				●	●	●				
C-19										●
C-20	●									
C-21										●

APPENDIX C

DIRECT IMPLEMENTATION COSTS OF ACCESS CONTROL TECHNIQUES

DIRECT IMPLEMENTATION COSTS OF ACCESS CONTROL TECHNIQUES

Technique	Construction Option	Total Construction Cost
A-1: Install Median Barrier With No Direct Left-Turn Access	1. Basic construction - median barrier on existing paved median and jug-handle or cloverleaf construction	$185,200
	2. Basic construction plus additional pavement widening	$304,000
	3. Basic construction plus additional pavement widening and right-of-way acquisition	$398,800
A-2: Install Raised Median Divider With Left-Turn Deceleration Lanes	1. Basic construction - raised median with openings on existing paved median	$ 97,600
	2. Basic construction plus additional pavement widening	$369,600
	3. Basic construction plus additional pavement widening and right-of-way acquisition	$590,400
A-3: Install One-Way Operations on the Highway	1. Signing and striping	$ 7,700
A-4: Install Traffic Signal at High-Volume Driveways	1. Two-phase pre-timed signal installation	$ 15,000
	2. Three-phase semi-actuated signal installation	$ 30,000

Technique	Construction Option	Total Construction Cost
A-5: Channelize Median Openings to Prevent Left-Turn Ingress and/or Egress Maneuvers	1. Channelizing island to prevent left-turn egress maneuvers	$ 1,140
	2. Channelizing island to prevent left-turn ingress maneuvers	$ 980
	3. Close median opening to prevent all left-turn maneuvers	$ 1,260
A-6: Widen Right Through-Lane to Limit Right-Turn Encroachments onto the Adjacent Lane to the Left	1. Highway widening	$ 93,200
	2. Highway widening and right-of-way acquisition	$140,800
A-7: Install Channelizing Island to Prevent Left-Turn Deceleration Lane Vehicles From Returning to Through Lanes	1. Channelizing island on existing median	$ 1,600
A-8: Install Physical Barrier to Prevent Uncontrolled Access Along Property Frontages	1. Barrier curb	$ 72,000

Technique		Construction Option	Total Construction Cost
A-9: Install Median Channelization to Control Merge of Left-Turn Egress Vehicles	1.	Channelizing island on existing median	$ 460
A-10: Regulate Highway Speed Limit Consistent With Driveway Operations	1.	Signing	$ 300
A-11: Install Traffic Signals to Slow Highway Speeds and Meter Traffic for Larger Gaps	1.	Two-phase pre-timed signal installation	$ 15,000
A-12: Restrict Parking on the Roadway Next to Driveways to Increase Driveway Turning Speeds	1.	Signing	$ 100
A-13: Install Visual Cues of the Driveway	1.	Suspended red-yellow flashing beacon	$ 3,000
	2.	Advance warning sign and flashing beacon	$ 500
	3.	Driveway illumination	$ 2,000

Technique	Construction Option	Total Construction Cost
A-14: Alter Terrain or Highway Geometrics for Increased Sight Distance	1. Basic construction - costs are highly dependent on site-specific conditions	NC[1/]
A-15: Improve Sight Distance by Preventing Parking on the Traveled Way, Either Totally or Partially	1. Signing	$ 5,300
A-16: Improve Sight Distance by Preventing Parking on the Right-of-Way	1. Basic construction - costs are highly variable and dependent on degree of enforcement	NC[1/]
A-17: Install Two-Way Left-Turn Lane	1. Basic construction - median striping on existing median	$ 8,200
	2. Basic construction plus additional pavement widening	$280,200
	3. Basic construction plus additional pavement widening and right-of-way acquisition	$501,000

[1/] No direct cost estimate.

Technique	Construction Option	Total Construction Cost
A-18: Install Continuous Left-Turn Lane	1. Basic construction - median striping on existing median	$ 12,800
	2. Basic construction plus additional pavement widening	$403,200
	3. Basic construction plus additional pavement widening and right-of-way acquisition	$783,600
A-19: Install Alternating Left-Turn Lane	1. Basic construction - median striping on existing median	$ 10,200
	2. Basic construction plus additional pavement widening	$282,200
	3. Basic construction plus additional pavement widening and right-of-way acquisition	$503,000
A-20: Install Isolated Median and Deceleration Lane to Shadow and Store Left-Turning Vehicles	1. Basic construction - median installation and highway widening	$ 36,500
	2. Basic construction plus right-of-way acquisition	$ 58,700
A-21: Install Left-Turn Deceleration Lane in Lieu of Right-Angle Crossover	1. Deceleration lane installation	$ 7,600
A-22: Install Medial Storage for Left-Turn Egress Vehicles	1. Channelizing island and existing median alteration	$ 4,890

Technique	Construction Option	Total Construction Cost
A-23: Increase Storage Capacity of Existing Left-Turn Deceleration Lane	1. Storage increase for a continuous curbed median	$ 6,400
	2. Storage increase for an isolated curbed median	$ 14,000
	3. Storage increase for an isolated curbed median plus additional right-of-way acquisition	$ 19,400
	4. Highway widening for two-lane left-turn bay at an isolated curbed median	$ 35,200
	5. Highway widening plus additional right-of-way acquisition for two-lane left-turn bay at an isolated curbed median	$ 64,900
A-24: Increase the Turning Speed of Right-Angle Median Crossovers by Increasing the Effective Approach Width	1. Uniformly widened crossover lane	$ 880
	2. Flared crossover lane	$ 320
	3. Increased return radius of median opening	$ 320
	4. Increased median opening width	$ 340
A-25: Install Continuous Right-Turn Lane	1. Basic construction - continuous right-turn lane	$ 49,700
	2. Basic construction plus additional right-of-way acquisition	$ 97,100
A-26: Construct a Local Service Road	1. Frontage road	$3,000,000

Technique	Construction Option	Total Construction Cost
A-27: Construct a Bypass Road	1. Bypass road	$1,000,000
A-28: Reroute Through Traffic	1. Basic construction - costs are highly variable and location dependent	NC[1/]

1/ No direct cost estimate.

Technique	Construction Option	Total Construction Cost
B-1: Offset Opposing Driveways	1. Close and relocate driveway	$ 4,300
B-2: Locate Driveway Opposite a Three-Leg Intersection or Driveway and Install Traffic Signals Where Warranted	1. Two-phase pre-timed signal installation	$ 15,000
	2. Signal installation plus closing and relocating driveway	$ 19,300
B-3: Install Two One-Way Driveways in Lieu of One Two-Way Driveway	1. Convert two-way driveway to one-way operation and construct additional one-way driveway	$ 3,200
	2. Close two-way driveway and construct two one-way driveways	$ 7,500
B-4: Install Two Two-Way Driveways with Limited Turns in Lieu of One Standard Two-Way Driveway	1. Construct one driveway and channelize both driveways	$ 3,940
	2. Close one driveway and construct two channelized driveways	$ 8,240
B-5: Regulate Minimum Spacing of Driveways	1. Close one driveway	$ 1,200
	2. Close and relocate one driveway	$ 4,300

Technique		Construction Option	Total Construction Cost
B-6: Regulate Minimum Corner Clearance	1.	Close one driveway	$ 1,200
	2.	Close and relocate one driveway	$ 4,300
B-7: Regulate Minimum Property Clearance	1.	Close one driveway	$ 1,200
	2.	Close and relocate one driveway	$ 4,300
B-8: Optimize Driveway Spacing in the Permit Authorization Stage	1.	Implemented during the permit authorization stage	NC[2/]
B-9: Regulate Maximum Number of Driveways per Property Frontage	1.	Close one driveway	$ 1,200
B-10: Consolidate Access for Adjacent Properties	1.	Close two driveways and construct one driveway on property line	$ 5,500
	2.	Close one driveway and construct one driveway on property line	$ 4,300
B-11: Require Highway Damages for Extra Driveways	1.	Basic construction - costs are highly variable	NC[1/]

[1/] No direct cost estimate.
[2/] No incremental cost.

Technique	Construction Option	Total Construction Cost
B-12: Buy Abutting Properties	1. Basic construction - costs are highly site specific	NC1/
B-13: Deny Access to Small Frontage	1. Basic construction - costs are highly variable and dependent on land value	NC1/
	2. Construct connection between properties	$ 980
	3. Close one driveway and construct one driveway on property line	$ 4,300
B-14: Consolidate Existing Access Whenever Separate Parcels are Assembled Under One Purpose, Plan, Entity, or Usage	1. Close one driveway	$ 1,200
B-15: Designate the Number of Driveways Permitted to Each Existing Property and Deny Additional Driveways Regardless of Future Subdivision of that Property	1. Implemented during the permit authorization stage	NC2/

1/ No direct cost estimate.
2/ No incremental cost.

Technique		Construction Option	Total Construction Cost
B-16: Require Access on Collector Street (when available) in Lieu of Additional Driveway on Highway	1.	Construct one driveway	$ 3,100
B-17: Regulate Minimum Sight Distance	1.	Close and relocate one driveway	$ 4,300
B-18: Optimize Sight Distance in the Permit Authorization Stage	1.	Implemented during the permit authorization stage	NC2/
B-19: Install Supplementary One-Way Right-Turn Driveways to Divided Highway (noncapacity warrant)	1.	Construct one one-way supplementary driveway	$ 3,100
B-20: Install Supplementary Access on Collector Street When Available (noncapacity warrant)	1.	Construct one supplementary driveway at no cost to highway agency	2/

2/ No incremental cost.

Technique	Construction Option	Total Construction Cost
B-21: Install Additional Driveway When Total Driveway Demand Exceeds Capacity	1. Construct additional driveway	$ 3,100

Technique		Construction Option	Total Construction Cost
C-1: Install Two One-Way Driveways in Lieu of Two Two-Way Driveways	1.	Signing	$ 100
C-2: Install Two-Two-Way Driveways with Limited Turns in Lieu of Two Standard Two-Way Driveways	1.	Channelize two angled driveways	$ 840
	2.	Close two driveways and construct two angled limited-turn driveways and medial turning bays	$ 16,940
	3.	Channelize two t-driveways	$ 840
C-3: Install Driveway Channelizing Island to Prevent Left-Turn Maneuvers	1.	Driveway widening and channelization to prevent left-turn egress vehicles	$ 1,850
	2.	Driveway widening and channelization to prevent left-turn egress vehicles	$ 1,850
	3.	Driveway widening and channelization to prevent both left-turn ingress and egress vehicles	$ 3,660
C-4: Install Driveway Channelizing Island to Prevent Driveway Encroachments Conflicts	1.	Medial channelizing island and driveway widening	$ 1,060
	2.	Driveway curbing (one side)	$ 320
	3.	Medial channelizing island, driveway widening, and driveway curbing (one side)	$ 1,380
C-5: Install Channelizing Island to Prevent Right-Turn Deceleration Lane Vehicles from Returning to the Through Lanes	1.	Channelizing island	$ 1,600
	2.	Channelizing island and deceleration lane widening	$ 3,760
	3.	Channelizing island, deceleration lane widening, and additional right-of-way acquisition	$ 4,960

Technique	Construction Option	Total Construction Cost
C-6: Install Channelizing Island to Control the Merge Area of Right-Turn Egress Vehicles	1. Channelizing island and driveway widening	$ 1,770
C-7: Regulate the maximum Width of Driveways	1. Curbing	$ 480
C-8: Increase the Effective Approach Width of the Driveway	1. Increase return radii on both sides of driveway	$ 640
C-9: Improve the Vertical Geometrics of the Driveway	1. Partial driveway reconstruction	$ 1,200
	2. Mountable curb removal	$ 400
C-10: Require Driveway Paving	1. Driveway paving	$ 3,100
C-11: Regulate Driveway Construction (performance bond) and Maintenance	1. Implemented during the permit authorization stage	NC2/

2/ No incremental cost.

Technique	Construction Option	Total Construction Cost
C-12: Install Right-Turn Acceleration Lane	1. Acceleration lane	$ 5,060
	2. Acceleration lane and additional right-of-way acquisition	$ 9,560
C-13: Install Channelizing Islands to Prevent Driveway Vehicles from Backing onto the Highway	1. Channelizing islands	$ 1,920
C-14: Install Channelizing Islands to Move Ingress Merge Point Laterally Away from the Highway	1. Channelizing island and driveway widening	$ 1,770
C-15: Move Sidewalk - Driveway Crossing Laterally Away from Highway	1. Sidewalk relocation	$ 1,340
C-16: Reverse One-Way Driveway Operations from In-Out (proceeding downstream) to Out-In Where Vehicles Must Use Highway to Achieve Internal Circulation	1. Driveway return radii alteration and signing	$ 740

Technique		Construction Option	Total Construction Cost
C-17: Install Right-Turn Deceleration Lane	1.	Deceleration lane	$ 4,400
	2.	Deceleration lane and additional right-of-way acquisition	$ 8,000
C-18: Install Additional Exit Lane on Driveway	1.	Additional driveway lane construction	$ 4,240
C-19: Encourage Connections Between Adjacent Properties (even when each has highway access)	1.	Connection between properties	$ 980
C-20: Require Two-Way Driveway Operation Where Internal Circulation is Not Available	1.	Basic construction - costs are site specific	NC[1/]
C-21: Require Adequate Internal Design and Circulation Plan	1.	Basic construction - costs are highly variable and location dependent	NC[1/]

1/ No direct cost estimate.

APPENDIX D

SUMMARY OF OPERATIONAL EFFECTIVENESS

SUMMARY OF OPERATIONAL EFFECTIVENESS MEASURES

FUNCTIONAL OBJECTIVE		Technique	Basis for Evaluation a/	Operational Parameter b/ \ Operational Parameter Level	ANNUAL ACCIDENT REDUCTION AND/OR (ANNUAL HOURS OF DELAY REDUCTION)								
					Highway Volume								
					Low			Medium			High		
					Low	Medium	High	Low	Medium	High	Low	Medium	High
Limit Number of Conflict Points	Limit Number of Basic Crossing Conflict Points	A-1	1	2	-2.7	1.8	6.3	-4.0	4.7	13.6	-5.0	8.1	21.3
		A-2	1	2	2.2	5.8	10.7	4.1	11.2(2628)	20.7(6059)	6.3	17.2(6935)	31.2(17046)
		A-3	1	2	-	-	-	-	9.9(30405)	13.6(36500)	-	14.9(73000)	20.4(91250)
		A-4: Option 1	1	3	(-358)	(-358)	(-358)	(-3975)	0.49(-3975)	0.76(-3975)	(-15735)	0.67(-15735)	1.02(-15735)
		Option 2	1	3	(-358)	(-358)	(-358)	(-3975)	0.74(-3975)	1.14(-3975)	(-15735)	1.00(-15735)	1.53(-15735)
		A-5: Option 1	1	1	0.08	0.19	0.29	0.14	0.33	0.51	0.19	0.45	0.69
		Option 2	1	1	0.05	0.13	0.19	0.09	0.22	0.34	0.12	0.30	0.46
		Option 3	1	1	0.13	0.31	0.49	0.23	0.55	0.85	0.31	0.75	1.15
	Limit Encroachment Conflicts	A-6	2	2	0.25	0.40	0.55	0.50	0.79	1.09	0.76	1.20	1.63
		A-7	3	x	x	x	x	x	x	x	x	x	x
	Reduce Area of Conflict	A-8	1	1	-	-	-	-	0.4	0.4	-	0.4	0.4
		A-9	3	x	x	x	x	x	x	x	x	x	x
Limit Maximum Deceleration Requirements	Reduce Highway Speeds	A-10	3	x	x	x	x	x	x	x	x	x	x
		A-11	3	x	x	x	x	x	x	x	x	x	x
	Increase Driveway Speeds	A-12	1	1	0.016	0.038	0.058	0.027(23)	0.066(91)	0.102(183)	0.037(30)	0.090(122)	0.138(243)
		A-13: Option 1	1	1	0.05	0.13	0.20	0.09	0.23	0.36	0.13	0.32	0.48
	Increase Driver Perception Time	Option 2	1	1	0.02	0.06	0.09	0.04	0.11	0.16	0.06	0.14	0.22
		Option 3	1	1	0.04	0.11	0.16	0.08	0.18	0.29	0.10	0.25	0.39
		A-14	3	x	x	x	x	x	x	x	x	x	x
		A-15	1	2	1.9	3.0	4.2	3.8	6.0	8.2	5.7	9.0	12.3
		A-16	3	x	x	x	x	x	x	x	x	x	x
Remove Turning Vehicles or Queues from Sections of the Through Lanes	Improve Left-Turn Operations	A-17	1	2	4.4	7.1	9.7	8.8	13.9(2628)	19.0(6059)	13.3	20.9(6935)	28.6(17046)
		A-18	1	2	4.4	7.1	9.7	8.8	13.9(2628)	19.0(6059)	13.3	20.9(6935)	28.6(17046)
		A-19	1	2	1.7	3.5	6.4	3.2	7.1(2628)	13.3(6059)	5.1	11.6(6935)	21.0(17046)
		A-20	1	1	-	-	-	-	0.55(263)	0.85(606)	-	0.75(694)	1.15(1705)
		A-21	1	1	0.13	0.32	0.49	0.23	0.55	0.85	0.31	0.75	1.15
		A-22	1	1	0.02	0.04	0.07	0.03	0.07	0.11	0.04	0.10	0.16
		A-23	1	1	-	-	-	-	0.11(263)	0.17(345)	-	0.15(694)	0.23(973)
	Improve Right-Turn Operations	A-24	2	1	0.01	0.03	0.04	0.02	0.04	0.07	0.03	0.06	0.09
		A-25	1	2	-	0.35	0.52	-	0.60	0.90	-	0.82	1.23
	Completely Separate Driveway Maneuvers from Through Traffic	A-26	3	x	x	x	x	x	x	x	x	x	x
		A-27	3	x	x	x	x	x	x	x	x	x	x
		A-28	3	x	x	x	x	x	x	x	x	x	x

a/ Basis for Evaluation
1. Data from Literature and/or Assumptions
2. Engineering Judgement
3. No Evaluation

b/ Operational Parameter Code
1. Driveway Volume
2. Level of Development (Commercial Driveways per Mile)
3. Accidents Dependent on Driveway Volume and Delay Dependent only on Highway Volume

SUMMARY OF OPERATIONAL EFFECTIVENESS MEASURES

FUNCTIONAL OBJECTIVE			Technique	Basis For Evaluation a/		ANNUAL ACCIDENT REDUCTION								
						Highway Volume								
						Low			Medium			High		
					Operational Parameter Level / Operational Parameter b/	Low	Medium	High	Low	Medium	High	Low	Medium	High
	Limit Number Of Conflict Points	Limit Number Of Basic Crossing Conflict Points	B-1	1	1	0.43	0.90	1.60	0.7	1.7	2.6	1.0	2.3	3.6
			B-2	1	1	-0.58	-0.60	-0.60	-1.0	-1.0	-0.8	-1.4	-1.4	-1.2
			B-3	1	1	0.02	0.07	0.11	0.05	0.12	0.18	0.06	0.16	0.26
			B-4	1	1	0.09	0.21	0.32	0.15	0.37	0.57	0.21	0.50	0.77
	Separate Basic Conflict Areas	Increase Minimum Spacing of Access Points	B-5	3	X	X	X	X	X	X	X	X	X	X
			B-6	3	X	X	X	X	X	X	X	X	X	X
			B-7	3	X	X	X	X	X	X	X	X	X	X
			B-8	3	X	X	X	X	X	X	X	X	X	X
		Increase Average Spacing of Access Points	B-9	1	2	0.25	0.25	0.25	0.49	0.49	0.49	0.73	0.73	0.73
			B-10	1	1c/	0.10	0.33	-	0.17	0.50	-	0.20	0.70	-
			B-11	3	X	X	X	X	X	X	X	X	X	X
			B-12	3	X	X	X	X	X	X	X	X	X	X
			B-13	1	1	0.26	-	-	0.45	-	-	0.62	-	-
			B-14	1	2	0.25	0.25	0.25	0.49	0.49	0.49	0.73	0.73	0.73
			B-15	3	X	X	X	X	X	X	X	X	X	X
			B-16	1	1	-	-	-	0.19	0.47	0.73	0.36	0.87	1.33
	Limit Maximum Deceleration Requirements	Increase Driver Perception Time	B-17	3	X	X	X	X	X	X	X	X	X	X
			B-18	3	X	X	X	X	X	X	X	X	X	X
	Remove Turning Vehicles Or Queues From Sections Of The Through Lanes	Provide Supplementary Access To A Single Property	B-19	3	X	X	X	X	X	X	X	X	X	X
			B-20	1	1c/	-	-	-	-	-0.15	-0.03	-	-0.03	-0.03
			B-21	3	X	X	X	X	X	X	X	X	X	X

a/ Basis for Evaluation
1. Data from literature and/or assumptions
2. Engineering judgment
3. No evaluation

b/ Operational Parameter Code
1. Driveway Volume
2. Accidents dependent only on highway volume

c/ The level of driveway volume refers to the volume of each driveway before technique implementation.

SUMMARY OF OPERATIONAL EFFECTIVENESS MEASURES

			Technique	Basis for Evaluation a/	ANNUAL ACCIDENT REDUCTION AND/OR (ANNUAL HOURS OF DELAY REDUCTION)									
					Highway Volume									
					Low				Medium			High		
					Oper-ational Parameter b/ \ Operational Parameter Level	Low	Medium	High	Low	Medium	High	Low	Medium	High
FUNCTIONAL OBJECTIVE	Limit Number of Conflict Points	Limit Number of Basic Crossing Conflict Points	C-1	1	1	0.28	0.70	1.08	0.50	1.22	1.88	0.68	1.66	2.56
			C-2	1	1	0.34	0.84	1.30	0.60	1.46	2.26	0.82	2.00	3.06
			C-3;Option 1	1	1	0.05	0.13	0.19	0.09	0.22	0.34	0.12	0.30	0.46
			Option 2	1	1	0.08	0.19	0.29	0.14	0.33	0.51	0.19	0.45	0.69
			Option 3	1	1	0.13	0.31	0.49	0.23	0.55	0.85	0.31	0.75	1.15
		Limit Encroachment Conflict Points	C-4;Option 1	2	1	0.010	0.025	0.039	0.018	0.044	0.068	0.025	0.060	0.092
			Option 2	2	1	0.008	0.019	0.029	0.014	0.033	0.051	0.019	0.045	0.069
			Option 3	2	1	0.013	0.032	0.049	0.023	0.055	0.085	0.031	0.075	0.115
			C-5	3	x	x	x	x	x	x	x	x	x	x
		Reduce Area of Conflict	C-6	2	1	0.08	0.19	0.29	0.14	0.33	0.51	0.19	0.45	0.69
			C-7	1	1	-	-	-	-	0.4	0.4	-	0.4	0.4
	Limit Maximum Deceleration Requirements	Increase Driveway Speeds	C-8	1	1	0.016	0.038	0.058	0.027(23)	0.066(91)	0.102(183)	0.037(30)	0.090(122)	0.138(243)
			C-9	2	1	(25.3)	(101.4)	(202.8)	(50.6)	(202.8)	(405.6)	(75.9)	(304.2)	(608.4)
			C-10	2	1	(25.3)	(101.4)	(202.8)	(50.6)	(202.8)	(405.6)	(75.9)	(304.2)	(608.4)
			C-11	2	1	(25.3)	(101.4)	(202.8)	(50.6)	(202.8)	(405.6)	(75.9)	(304.2)	(608.4)
			C-12	1	1	0.02	0.05	0.07	0.03	0.08	0.13	0.05	0.11	0.17
			C-13	1	1	-	-	-	-	0.4	0.4	-	0.4	0.4
			C-14	2	1	0.008	0.019	0.029	0.014	0.033	0.051	0.019	0.045	0.069
			C-15	3	x	x	x	x	x	x	x	x	x	x
	Remove Turning Vehicles or Queues from Sections of the Through Lanes	Improve Left-Turn Operations	C-16	2	1	0.0052	0.0126	0.0194	0.009	0.022	0.034	0.0124	0.030	0.046
		Improve Right-Turn Operations	C-17	1	1	0.02	0.05	0.07	0.03	0.08(91)	0.13(183)	0.05	0.11(122)	0.17(243)
		Improve Driveway Operations with Internal Property Design and Controls	C-18	3	x	x	x	x	x	x	x	x	x	x
			C-19	3	x	x	x	x	x	x	x	x	x	x
			C-20	3	x	x	x	x	x	x	x	x	x	x
			C-21	3	x	x	x	x	x	x	x	x	x	x

a/ Basis for Evaluation
1. Data from literature and/or assumptions
2. Engineering judgment
3. No evaluation

b/ Operational Parameter Code
1. Driveway volume

APPENDIX E

COST-EFFECTIVENESS TABULATION

TABLE XIX-A

COST EFFECTIVENESS TABULATIONS FOR ROUTE TECHNIQUES

		Highway ADT								
	Level of	Low			Medium			High		
Technique ↓	Development →	Low	Med	High	Low	Med	High	Low	Med	High
A-1 Opt.	1	-*	-	1.0	-	-	2.2	-	1.3	3.4
	2	-	-	-	-	-	1.3	-	-	2.1
	3	-	-	-	-	-	1.0	-	-	1.6
A-2	1	-	1.8	3.3	1.3	4.7	9.3	1.9	8.7	17.9
	2	-	-	-	-	1.2	2.5	-	2.3	4.7
	3	-	-	-	-	-	1.5	-	1.4	3.0
A-3		-	-	-	-	230	290	-	530	660
A-6		-	-	-	-	-	-	-	-	-
A-8		-	-	-	-	1.6	1.6	-	1.6	1.6
A-15		11	17	24	21	34	46	32	50	69
A-17	1	16	26	35	32	66	105	48	116	203
	2	-	-	1.0	-	1.9	3.1	1.4	3.4	5.9
	3	-	-	-	-	1.1	1.7	-	1.9	3.3
A-18	1	10	17	23	21	42	67	31	74	130
	2	-	-	-	-	1.3	2.1	1.0	2.4	4.1
	3	-	-	-	-	-	1.1	-	1.2	2.1
A-19	1	5	10	19	9	33	67	15	55	141
	2	-	-	-	-	1.2	2.4	-	2.4	5.1
	3	-	-	-	-	-	1.4	-	1.3	2.9
A-25	1	-	-	-	-	-	-	-	-	1.3
B-9		6.4	6.4	6.4	12.0	12.0	12.0	19.0	19.0	19.0

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* Dash (-) indicates that the B/C ratio is less than 1.0 or not applicable.

TABLE XIX-B

COST-EFFECTIVENESS TABULATION FOR POINT LOCATION TECHNIQUES

		Highway ADT								
	Driveway	Low			Medium			High		
Technique ↓	Volume →	Low	Med	High	Low	Med	High	Low	Med	High
A-4 Opt.	1	-*	-	-	-	1.0	1.5	-	1.3	2.1
	2	-	-	-	-	-	1.3	-	1.2	1.7
A-5	1	2.0	4.7	7.3	3.5	8.2	13	4.7	11	17
	2	1.2	3.2	4.7	2.2	5.5	8.4	3.0	7.4	11
	3	2.6	6.3	9.9	4.7	11	17	6.3	15	23
A-12		5	12	18	20	66	123	27	89	164
A-13	1	-	1.3	2.0	-	2.3	3.6	1.3	3.2	4.8
	2	1.3	3.6	5.3	2.3	6.6	9.6	3.6	8.3	13.2
	3	-	1.6	2.4	1.2	2.7	4.3	1.5	3.7	5.8
A-20	1	-	-	-	-	-	1.5	-	1.5	3.2
	2	-	-	-	-	-	-	-	-	2.0
A-21		-	1.3	1.9	-	2.2	3.4	1.2	3.0	4.5
A-22		-	-	-	-	-	-	-	-	1.0
A-23	1	-	-	-	-	2.5	3.4	-	5.9	8.3
	2	-	-	-	-	1.1	1.6	-	2.7	3.8
	3	-	-	-	-	-	1.1	-	1.9	2.8
	4	-	-	-	-	-	-	-	1.1	1.5
	5	-	-	-	-	-	-	-	-	-
A-24	1	-	1.0	1.3	-	1.3	2.4	1.0	2.0	3.0
	2 & 3	-	2.8	3.7	1.9	3.7	6.5	2.8	5.6	8.4
	4	-	2.6	3.5	1.8	3.5	6.1	2.6	5.1	7.9
B-1		3.0	6.3	11	4.9	12	18	7.0	16	25
B-2		-	-	-	-	-	-	-	-	-
B-3	1	-	-	1.0	-	1.1	1.7	-	1.5	2.4
	2	-	-	-	-	-	-	-	-	1.0

TABLE XIX-B (continued)

		Highway ADT								
	Driveway	Low			Medium			High		
Technique ↓	Volume →	Low	Med	High	Low	Med	High	Low	Med	High
B-4 Opt.	1	-	1.6	2.4	1.1	2.8	4.3	1.6	3.8	5.8
	2	-	-	1.2	-	1.3	2.1	-	1.8	2.8
B-10	1	-	1.8	-	-	2.7	-	1.1	3.8	-
	2	-	2.3	-	1.2	3.5	-	1.4	4.9	-
B-14		6.4	6.4	6.4	12	12	12	19	19	19
B-16		-	-	-	1.8	4.6	7.0	3.5	8.4	13
C-1		84	208	320	148	364	560	204	496	764
C-2	1	12	29	46	21	51	79	29	70	107
	2	-	1.5	2.3	1.1	2.6	4.0	1.4	3.5	5.3
	3	12	29	46	21	51	79	29	70	107
C-3	1	-	2.1	3.1	1.5	3.6	5.5	2.0	4.9	7.5
	2	1.3	3.1	4.7	2.3	5.4	8.3	3.1	7.3	11.0
	3	1.1	2.5	4.0	1.9	4.5	6.9	2.5	6.1	9.4
C-4	1	-	-	1.1	-	1.2	1.9	-	1.7	2.6
	2	-	1.8	2.7	1.3	3.1	4.8	1.8	4.2	6.4
	3	-	-	1.1	-	1.2	1.8	-	1.6	2.5
C-6		-	-	-	-	-	-	-	-	1.2
C-7		-	-	-	-	25	25	-	25	25
C-8		-	1.8	2.7	3.0	10	18	4	13	25
C-9	1	1.0	4.1	8.1	2.0	8.1	16	3.0	12	24
	2	2.9	12	24	6.1	24	48	8.9	36	72
C-10		-	1.6	3.1	-	3.1	6.3	1.2	4.7	9.4
C-12	1	-	-	-	-	-	-	-	-	1.0
	2	-	-	-	-	-	-	-	-	-

TABLE XIX-B (concluded)

		Highway ADT								
	Driveway	Low			Medium			High		
Technique ↓	Volume →	Low	Med	High	Low	Med	High	Low	Med	High
C-13		-	-	-	-	6.2	6.2	-	6.2	6.2
C-14		-	-	-	-	-	1.4	-	1.2	1.8
C-16		-	-	-	-	-	1.4	-	1.2	1.8
C-17 Opt. 1		-	-	-	-	1.5	2.9	-	2.1	3.9
2		-	-	-	-	-	1.6	-	1.1	2.1

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* Dash (-) indicates a B/C ratio less than 1.0 or not applicable.

APPENDIX F

WARRANTS FOR IMPLEMENTATION OF ACCESS CONTROL TECHNIQUES

WARRANTS FOR IMPLEMENTATION OF ACCESS CONTROL TECHNIQUES

Warrants for technique implementation are suggested in the detailed discussion of each access control technique. The proposed warrants will aid highway agencies in determining the applicability of each technique to specific site conditions. This appendix collectively summarizes these warrants.

The warrants attempt to quantify the site conditions that must be met to justify a technique's implementation. These minimum site conditions (accident rates, highway ADT, driveway ADT, and level of development) should insure that the technique will be both operationally effective and cost-effective. The suggested warrants do not indicate the optimum technique, for this must be determined by a differential cost-effectiveness evaluation.

Where possible, the values of these warrants are compatible with nationally recognized warrants. For example, the existing national warrants for intersection signalization stated in the Manual on Uniform Traffic Control Devices are suggested as warrants for driveway signalization. Other warrants are derived from the cost-effectiveness analysis, from data on expected accident rates[6,22], and by using sound engineering judgement.

It is not a good engineering practice to warrant technique application at sites where detrimental economic and operational effects would result. More specifically, no technique is warranted under conditions that lead to a non-cost effective remedy, and no technique is warranted under conditions that will lead to an increase in operational problems. The only warrants that are recommended are those that will result in a cost-beneficial and hazard reducing access control remedy.

Based on the cost-effectiveness analysis, the basic warrants for each route technique are stated as minimum highway volumes and levels of development. The values for these warrants were generally taken as the lower boundry of the lowest parameter category that exhibited a cost-benefit ratio greater than one. Similarly developed warrants for point techniques list highway and driveway volume as determinants. The volume ranges and averages for these parameters are listed below.

	Driveway ADT (ave)	Highway ADT (ave)	Level of Development (Driveways per Mile)(ave)
LOW	0-500 (250)	0-5,000 (3,000)	0-30 (15)
MEDIUM	501-1,500 (1,000)	5,001-15,000 (10,000)	31-60 (45)
HIGH	> 1,500 (2,000)	> 15,000 (20,000)	> 60 (75)

The warrants based on the cost-effectiveness analysis have a predictive base. In other words, the value for traffic operational effectiveness was based on the calculated difference of expected values of accidents and delays between the periods before and after implementation. This kind of warrant presupposes a jurisdiction-wide focus on existing access control problems. On the other hand, if access control improvements on existing highways are implemented as a reaction to specific traffic problems, then the warrants should relate to measurable operational characteristics such as accident experience and traffic congestion.

For traffic congestion or delay considerations, the lack of empirical data precluded the development of precise values, so suggested warrants are stated in generally qualitative terms leaving the judgement of justifying the techniques up to the user. In regard to accident considerations, the suggested warrants are met when the accident experience exceeds the average expected rate for each of the spcified site parameter combinations. These warrants, are shown in the Tables F-1 and F-2.

If the technique under consideration is aimed at reducing either right-turn or left-turn driveway accidents then 30% or 70% of the suggested values should be used as warranting rates, respectively.

Several techniques involve the construction of a left-turn lane within a medial area. While no uniform warrant is universally acceptable for left-turn lanes, the literature did reveal one method that is applicable in urban and suburban areas.[23/] The proposed left-turn lane warrants are based on the turning volume as well as the through and opposing volumes. Thus, applications to a variety of site conditions is feasible. The following Figure F-1 is a graphical representation of the proposed left-turn volume warrant.

TABLE F-I

GENERAL ACCIDENT WARRANTS FOR ROUTE TECHNIQUES

(Annual Number of 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

TABLE F-II

GENERAL ACCIDENT WARRANTS FOR 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

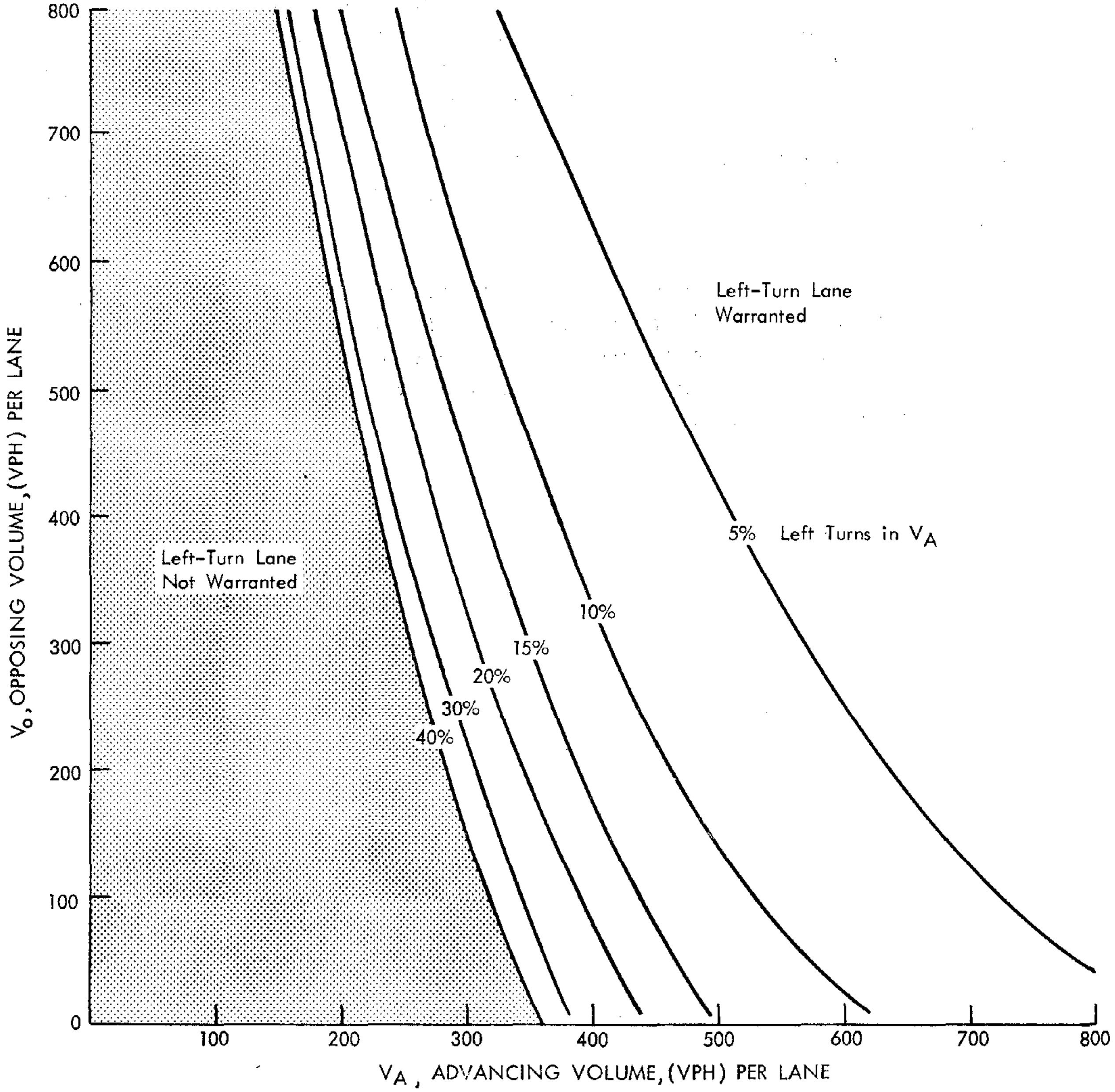

Figure F-1 - Left-turn lane volume warrant

The only site data required to determine whether a left-turn lane is warranted at a location are the advancing and opposing volumes per lane during the peak hour and the percentage of left-turning vehicles in the advancing volume. These data are easily obtainable through manual traffic counts. It is important that traffic operations during peak hours be observed since a delay occurring during this period due to improper or neglected medial features will be magnified by the volume using the facility.

In addition to the warrants discussed above, and where appropriate to a particular technique, other warranting conditions are based on engineering judgement. These conditions relate specifically to highway speed ranges, delays, and the level of traffic volume for particular driveway turning movements.

TE

FUNCTIONAL OBJECTIVES		A - HIGHWAY DESIGN AND OPERATIONS 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

ECHNIQUES TO CONTROL CONFLICTS AT COMMERCIAL DRIVEWAYS

B - DRIVEWAY LOCATION 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

C - DRIVEWAY DESIGN AND OPERATIONS 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

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