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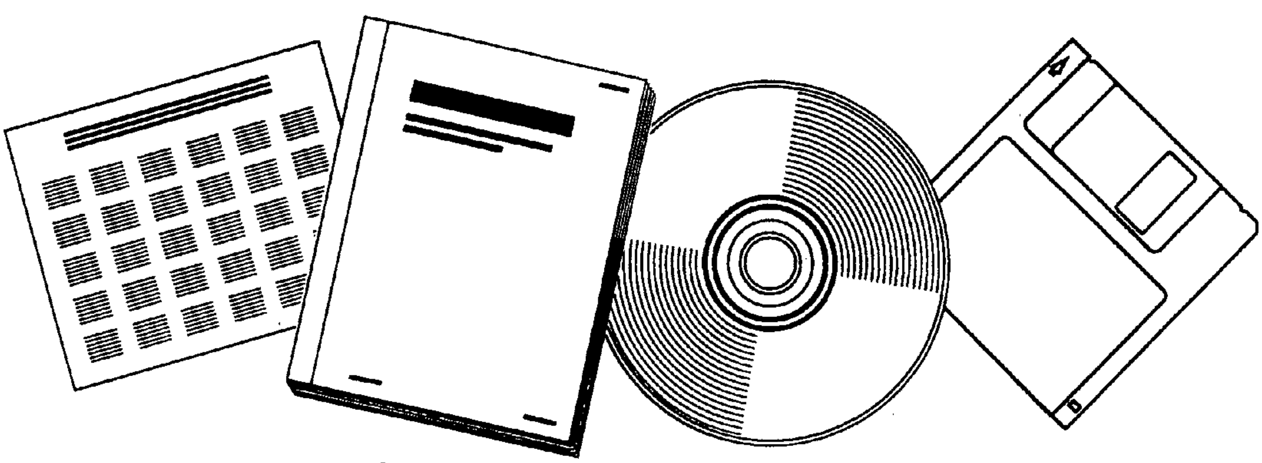
ACCESS, LOCATION, AND DESIGN PARTICIPANT NOTEBOOK

SEPTEMBER 1993



U.S. DEPARTMENT OF COMMERCE
National Technical Information Service

U.S Department
of Transportation
**Federal Highway
Administration**

Publication No. FHWA-HI-93-055
September 1993

PB98-106982

NHI Course No. 15255

Access, Location, and Design

Participant Notebook

National Highway Institute

REPRODUCED BY: NTIS
U.S. Department of Commerce
National Technical Information Service
Springfield, Virginia 22161

CHAPTER 1

INTRODUCTION TO ACCESS MANAGEMENT

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INTRODUCTION

Objectives

CHAPTER 1

INTRODUCTION TO ACCESS MANAGEMENT

The objectives of this chapter/session is to introduce the topic of access management and to present an overview of the issues involved.

Introduction

- **General Benefits**
- **Social, Economic, and Political Problems**
- **Administrative and Legal Considerations**

GENERAL BENEFITS

Introduction

Traffic engineers have long recognized that the elimination of unexpected events and the separation of decision points simplifies the driving task. Since access control reduces the number and complexity as well as increases the spacing of events to which the driver must respond, it will result in improved traffic operations and reduced accident experience. Various research efforts have explored the general relationships between accidents and medial and marginal access control.

> **General Benefits**
>
> **Elimination Of Unexpected Events And Separation Of Decision Points Result In:**
>
> - **Improved Traffic Flow**
> - **Fewer Accidents**
> - **Reduced Delay**
> - **Improved Fuel Economy**
> - **Increased Capacity**
> - **Reduced Vehicle Emissions**

Access, Traffic Flow, And Accidents

With a notable exception of freeways, urban arterials and highways in the developing urban fringe commonly experience a deterioration in their ability to accommodate traffic in a safe and efficient manner as travel demand increases. This problem results from the requirement that the facility must serve the conflicting functions of providing for land access and vehicular movement. Solomon (*1*) reflected the observations of many engineers and planners when he stated:

> "When conventional highways are constructed on new rights-of-way, initially there are few commercial driveways and the safety record is good. As the highways get older, the traffic volume builds up, roadside businesses develop, more and more commercial driveways are cut, and the accident rate gradually increases."

(Continued)

GENERAL BENEFITS (Continued)

Access, Traffic Flow, And Accidents (Continued)

He presents the following findings of Cirillo, et. al., (2) on two-lane rural highways to support his statement:

Intersections Per Mile	Businesses Per Mile	Accidents Per 100-Million Vehicle-Miles
0.2	1	126
2.0	10	170
20.0	100	1,718

Solomon then concludes:

> "This tabulation demonstrates the importance of maintaining control of access when either two-lane or multi-lane highways are built on new locations. Increased numbers of either intersections or driveways along will also increase the accident rate. Intersections should be restricted to those essential for the highway, and the right of (direct) access from abutting businesses should be severely limited."

McGuirk (3) further established the fact that accidents of access drives increase as both through lane traffic volumes and driveway volumes increase. The problem has also been recognized in the following quote from the State Highway Access Code of Colorado (4):

> "The lack of adequate access management on the highway system and the proliferation of driveways and other access approaches is a major contributor to highway accidents and the greatest single factor behind the functional deterioration of highways in the state. As new access approaches are constructed and traffic signals erected, the speeds and capacity of the highway decrease, and congestion hazards to the traveling motorist increase."

(Continued)

GENERAL BENEFITS (Continued)

Access, Traffic Flow, And Accidents (Continued)

- **The Lack Of Adequate Access Management Results In A Proliferation Of Driveways**
- **Speed And Capacity Decrease**
- **Hazards To Motorists Increase**

Figures 1-1, 1-2, and 1-3, and Table 1-1 further illustrate the need for effective access management program and the benefits to be obtained.

(Continued)

GENERAL BENEFITS (Continued)

Access, Traffic Flow, And Accidents (Continued)

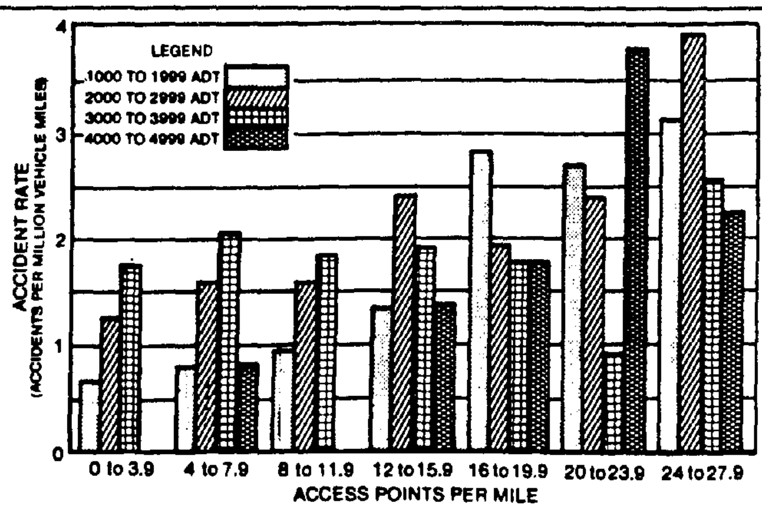


FIGURE 1-1: ACCIDENT RATES FOR ROAD SECTIONS WITH DIFFERENT TRAFFIC VOLUMES AND ACCESS POINT FREQUENCIES

Source: Reference (5), p. 4

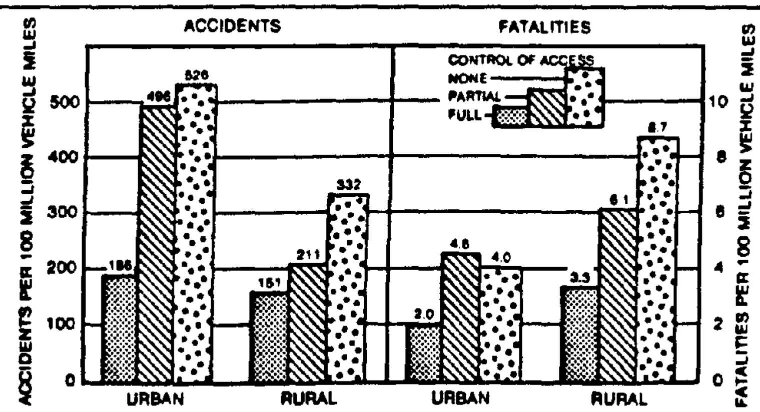


FIGURE 1-2: EFFECT OF CONTROL OF ACCESS ON ACCIDENTS AND FATALITIES IN URBAN AND RURAL AREAS

Source: Reference (5), p. 4

(Continued)

GENERAL BENEFITS (Continued)

Access, Traffic Flow, And Accidents (Continued)

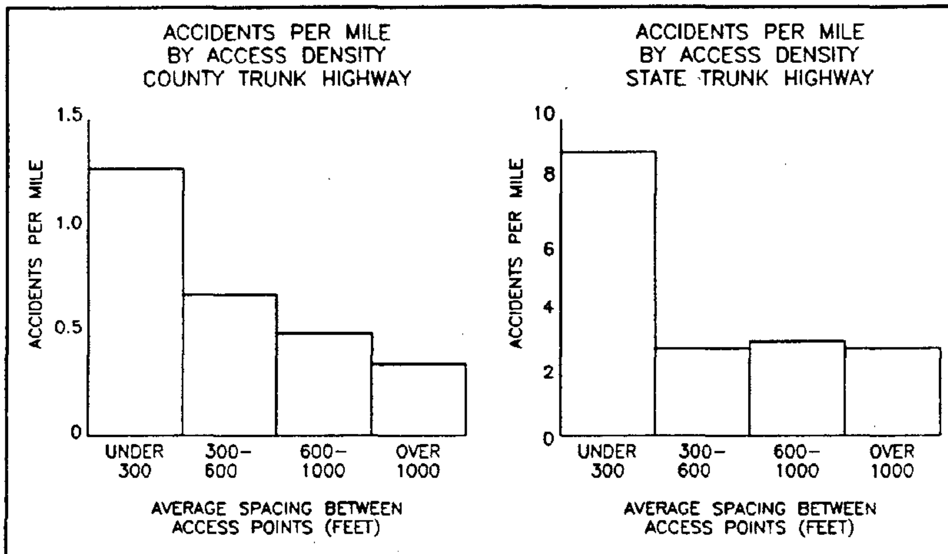


FIGURE 1-3: RELATIONSHIP BETWEEN ACCIDENTS PER MILE AND AVERAGE ACCESS SPACING

Source: Reference (6), pp. 3-4

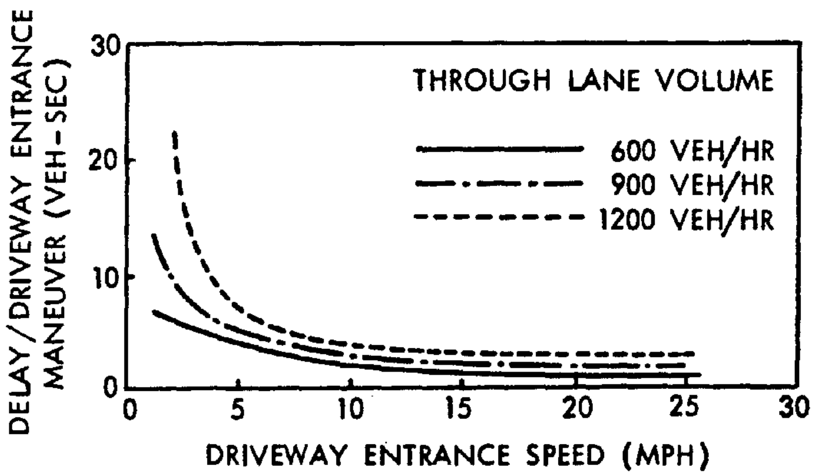
(Continued)

GENERAL BENEFITS (Continued)

Access, Traffic Flow, And Accidents (Continued)

TABLE 1-1: GENERAL BENEFITS OF ACCESS CONTROL MANAGEMENT TECHNIQUES

- Two-Way Left Turn Lanes: 35 percent reduction in total accidents (7, 8).
- Alternating Left Turn Lanes: 28 percent reduction in total accidents (9).
- Driveway Width Controls: 0.40 accidents reduced annually per driveway (10).
- Visual Cues For Driveways: Suspended red-yellow flashing beacon at a single commercial driveway -- 53 percent reduction in total accidents; advance warning sign and flashing beacon - 24 percent reduction in total accidents; and driveway illumination -- 42 percent reduction in total accidents (11).
- Left Turn Deceleration Lanes: 50 percent reduction in total accidents (12, 13).
- Driveway Accident Breakdown: Right turn enter -- 15 percent of total accidents; right turn exit -- 15 percent of total accidents; left turn enter -- 43 percent of total accidents; left turn exit -- 27 percent of total accidents (10).
- Delay Versus Driveway Entrance Speed: (14)



- One-Way Operations: 25 percent reduction in total accidents (15); 25 percent reduction in delay (16).
- Parking: 15 percent reduction in total accidents by preventing parking on the traveled way (16, 17).

Source: Reference (5) p. 12

(Continued)

GENERAL BENEFITS (Continued)

Access, Traffic Flow, And Accidents (Continued)

Breakdown Of Driveway Accidents

MANEUVER TYPE	COLLISION TYPE	PERCENT OF TOTAL DRIVEWAY ACCIDENTS
Left Ingress	Rear-End	26
Left Egress	Right-Angle	24
Left Ingress	Head-On Angle	15
Right Ingress	Rear-End	12
Right Egress	Right-Angle	7
Right Egress	All Other	8
Left Egress	All Other	3
Right Ingress	All Other	3
Left Ingress	All Other	2

(Continued)

GENERAL BENEFITS (Continued)

Access,
Traffic Flow,
And Accidents
(Continued)

Left Turn Accidents

MANEUVER TYPE	COLLISION TYPE	PERCENT OF TOTAL DRIVEWAY ACCIDENTS	
Ingress	Rear-End	26	
Ingress	Head-On Angle	15	
Ingress	All Other	2	
SUBTOTAL			43
Egress	Right-Angle	24	
Egress	All Other	3	
SUBTOTAL			27
TOTAL			70

(Continued)

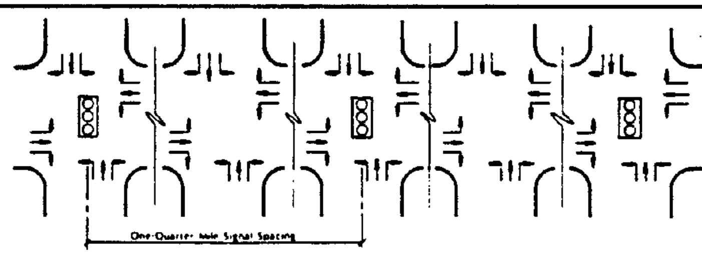
GENERAL BENEFITS (Continued)

Colorado Access Control Demonstration Project

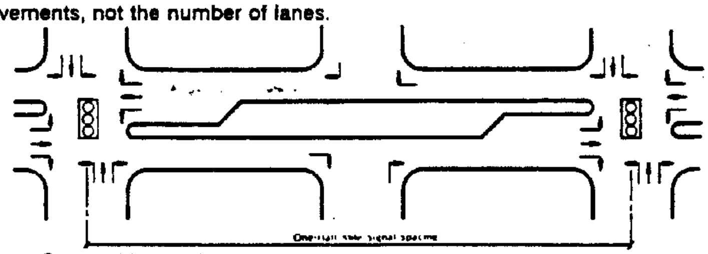
The Colorado Access Control Demonstration Project compared average travel speed, average daily traffic volume per lane, total accidents, rear-end accidents and "broadside" collisions for various roadways in the Denver Metropolitan Area (18, p. 33). Average travel speed and average daily traffic volume per lane were found to increase as the degree of access control increased. All three accident categories were found to have a marked decrease with an increase in access management.

Effect On Travel Hours And Delay

The Colorado Demonstration Project utilized TRANSYT 7F to evaluate the effect of access management on a five-mile segment of roadway. The two access conditions are illustrated in Figure 1-4. The analysis was performed for congested conditions (volume equal to 95% of capacity). The results are summarized in Table 1-2. The analysis shows that average travel speed with access control is increased by more than 50%. Total vehicle-hours of travel per hour decreased by over 40% and total delay decreased by nearly 60%.



A. "Uncontrolled Access Model": Quarter-mile signal spacing with all movements permitted at driveways located midway between signals. Arrows represent permitted movements, not the number of lanes.



B. Access Control Model: Half-mile signal spacing with right-turns only permitted at driveways located midway between signals. Arrows indicate the permitted movements, not the number of lanes.

FIGURE 1-4: SKETCHES ILLUSTRATING THE ACCESS CONDITIONS ANALYZED IN THE COLORADO ACCESS CONTROL DEMONSTRATION PROJECT

Source: Reference (18), pp. 23-24

(Continued)

GENERAL BENEFITS (Continued)

Fuel Savings

Studies by the Texas Transportation Institute (19) show that substantial fuel savings can be expected with half-mile signal spacings and right turns only (Figure 1-4-B) compared to quarter-mile signal spacings and allowing left and right turns (Figure 1-4-A). For example, considering the following:

Conditions

- Ten-mile section of urban arterial
- 700 vehicles per hour per lane in peak direction
- 55-45 directional split
- Two-hour morning and two-hour evening peak period
- Speed 13 mph without access control, 22 mph with access control

Fuel Savings

• Improvement in speed	240,000 gal/yr
• Reduction in delay	335,000 gal/yr
	575,000 gal/yr

TABLE 1-2: SUMMARY OF TRANSYT 7F MODEL RESULTS FOR A FIVE-MILE ROADWAY SEGMENT

	Travel Speed (mph)	Total Travel (vehicle-hours per hour)	Total Delay (vehicle-hours per hour)
Access Control	22	542	275
Uncontrolled Access	13	942	675
Percent Change: Access Control v. Uncontrolled	+54%	-42%	-59%

Source: Reference Adapted from (18)

SOCIAL, ECONOMIC, AND POLITICAL PROBLEMS

Social, Economic And Political Problems

- Uniformity May Not Be Maintained In The Interpretation, Application And Enforcement Of Control Measures.
- Lack Of Interjurisdictional Coordination Can Exist Between Different Levels Of Government.
- Political Pressure Will Be Exerted When Access Control Decisions Are Perceived To Affect Future Expansion, Land Values, Or Business Volumes.
- Most Access Management Policies Lack Comprehensive, Site-Specific Guidelines.

THE GENERAL PLAN

Importance Of The Comprehensive Plan To Access Management

The General Plan, or Comprehensive Plan, is a policy statement to guide the future physical development and redevelopment of the local governmental jurisdiction.

> **The GENERAL PLAN –**
> **A Policy Statement To Guide Future Physical Development**

It is important that the plan properly addresses transportation and land development issues, such as the following, in order to effectively provide policy guidance for the provision of access to major public streets.

Because of the complex and interrelated character of any urban community, the problems that exist today can seldom be solved individually or in isolation. Local government policies and practices influence the decisions of individual developers, affect the daily lives of all citizens, and give form to the community.

The comprehensive plan is the instrument by which local government establishes long-range general policies for guiding the physical growth and development of the community in a coordinated and unified manner. The comprehensive plan and its implementing procedures provide the only workable means for permitting the local government to fulfill all of its coordinating responsibilities relevant to physical development. In particular, coordination and cooperation among the many line departments of municipal government, such as public works, parks and recreation, library services, and fire and police protection, are of paramount importance. Other public and quasi-public agencies outside of municipal government, such as local school boards and utility companies, are all directly concerned with and affected by physical development. The comprehensive plan gives these agencies, and private developers, a context into which one can fit its own plans and programs. Coordination among the various public activities will be enhanced so that all should be working toward the same vision of the desirable future form of the city.

(Continued)

THE GENERAL PLAN (Continued)

Key Elements Of The General Urban Plan

The principal elements commonly included in an Urban Comprehensive Plan are:

- Introduction and Purpose
- Goals and Objectives
- Population
- Economic Base
- Transportation
- Land Use
- Housing
- Public Facilities (water, sewer, fire, etc.)
- Parks and Open Space

Access Policy Issues

Access Policy Issues To Be Addressed By The General Plan

- Functional Street Classification
- Uniform Signal Spacing
- Street Cross-Section
- Unsignalized Access Policy

ADMINISTRATIVE AND LEGAL CONSIDERATIONS

Access Policy Issues (Continued)

Compensatory Access Restrictions And Regulations

Abutter Entitled To Compensation If:

- . All Access To The Highway Network Is Totally Denied
- Access Permitted Is Insufficient For The "Highest And Best Use" Of Property
- Special Injury Is Incurred To One Specific Property Through Access Restrictions
- Highway Frontage Is Rebuilt As A Limited Access Facility And The Property Is Otherwise Landlocked
- Highway Improvements Damage Use Of Property Through Relocation Of Access Points

Non-Compensatory Access Restrictions And Regulations

Abutter Not Entitled To Compensation If:

- Access Is Circuitous, Or Regulated Reasonably
- Access Restrictions Are Sufficient For The "Highest And Best Use" Of Property
- No Special Injury Is Suffered
- New Limited Access Facility Is Constructed On New Right-Of-Way
- Highway Improvements Require Site Design Or Parking Area Changes Through Relocation Of Access Points

(Continued)

ADMINISTRATIVE AND LEGAL CONSIDERATIONS (Continued)

Access Policy Issues (Continued)

Elements Of A Comprehensive Program

- Legislation
- Technical Analysis Requirements
- Provisions For Enforcement
- Coordination

Legislation

- Establishes Authority And Purpose For Program
- Designates And Sets Up An Administering Authority
- Categorizes Highways Into Functional Classes
- Develops A Reasonable Process For Applying For Access To Highways
- Creates A Procedure For Uniformly Handling Variance Requests

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ADMINISTRATIVE AND LEGAL CONSIDERATIONS (Continued)

Access Policy Issues (Continued)

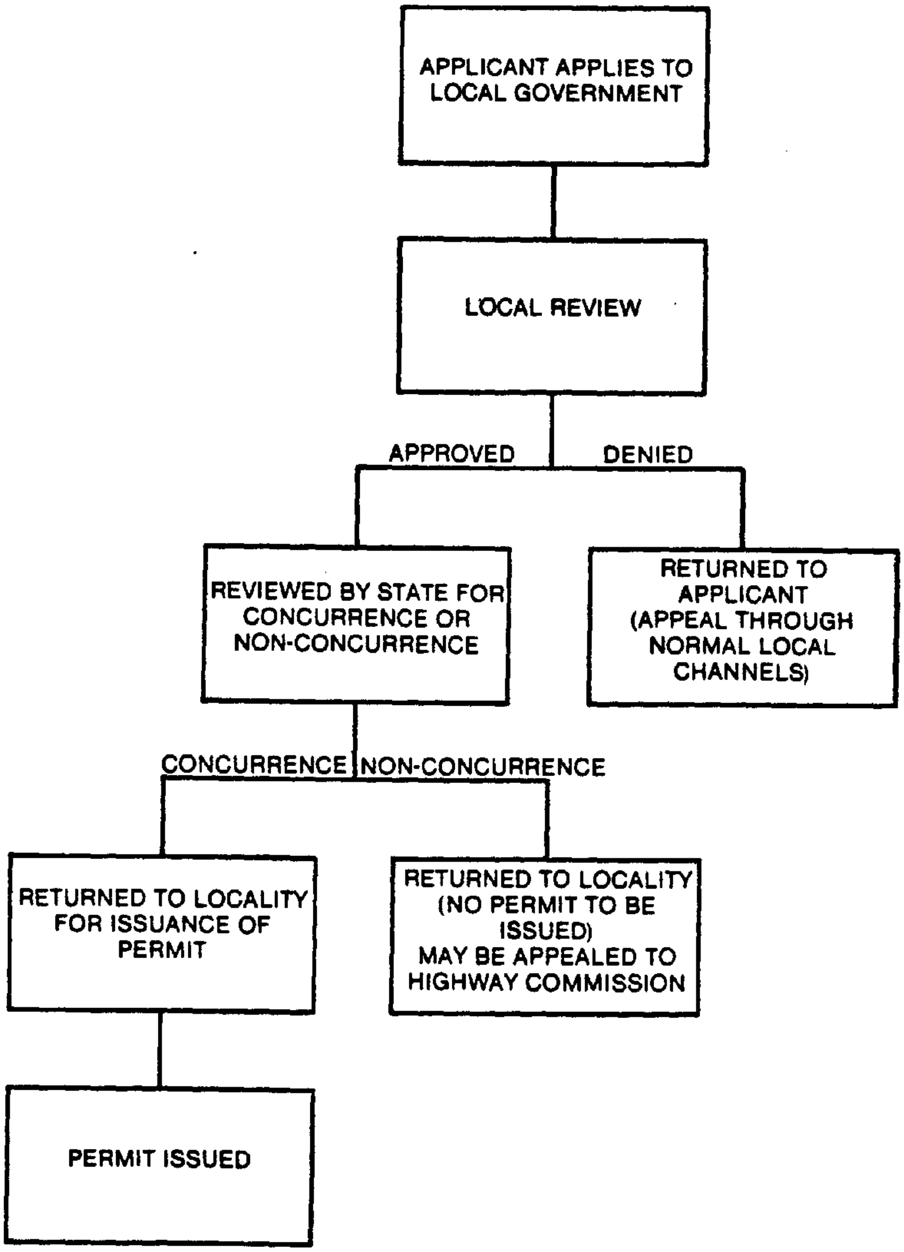

FIGURE 1-5: EXAMPLE OF PERMIT APPLICATION PROCESS

Source: Reference (5) p. 23

(Continued)

ADMINISTRATIVE AND LEGAL CONSIDERATIONS (Continued)

Access Policy Issues (Continued)

Technical Analysis

- Specific Design Guidelines
- Techniques For Assessing Traffic And Safety Impacts
- Procedures For Evaluating The Effectiveness Of Access Control Measures

Implementation

- Police Powers
- Eminent Domain

Coordination Among Agencies

Access Control Mechanisms

- Zoning Regulations
- Subdivision Approvals
- Site Plan Reviews
- Building Permits
- Occupancy Permits
- Driveway Permits

(Continued)

ADMINISTRATIVE AND LEGAL CONSIDERATIONS (Continued)

Access Policy Issues (Continued)

Zoning Regulations

- Establish Set-Backs
- Provide For Adequate Sight Distance
- Require Barriers Around Parking Areas
- Require All Maneuvering Of Off Public Right-Of-Way
- Control Adverse Intensive Use

Subdivision Approval

- Assure Proper Building Set-Backs
- Minimize Connections To Main Road
- Assure Street System Capacity
- Guarantee Adequate Frontage

DEFINITION OF TERMS

Access Control Dimensions	Various dimensions which are involved in the management of access to public streets and illustrated in Figure 1-6.

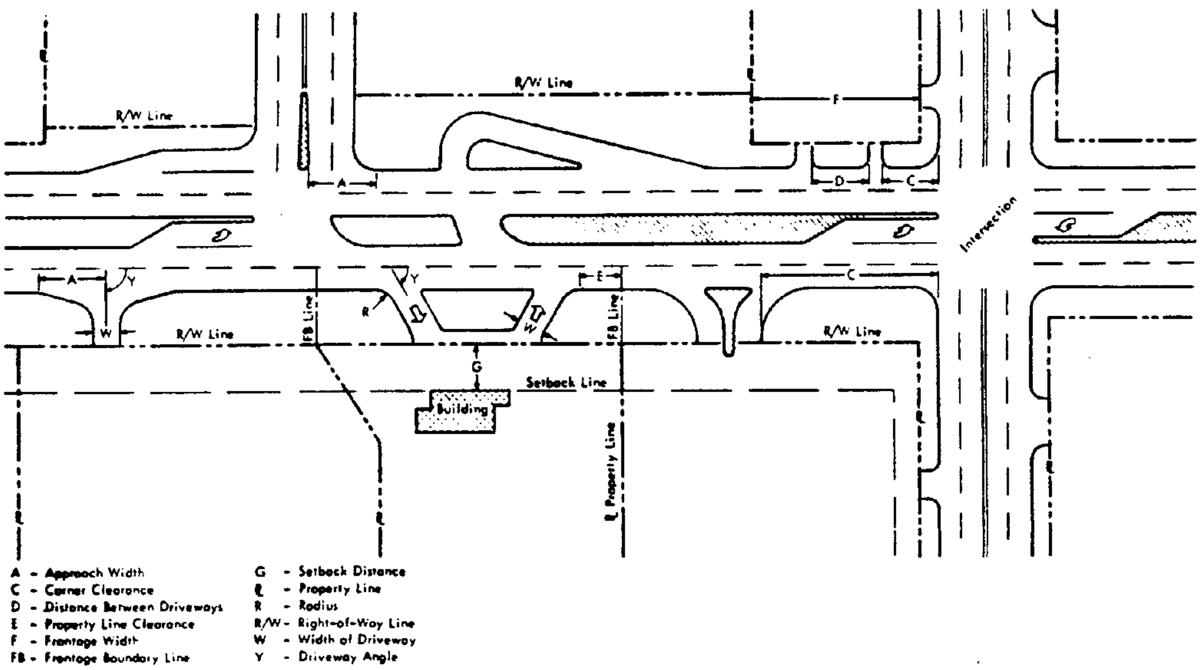

FIGURE 1-6: ILLUSTRATION OF DIMENSIONS USED IN ACCESS CONTROL

Source: Reference (20), p. 23

(Continued)

DEFINITION OF TERMS (Continued)

Access Management Terminology

Various terms used in access control management and defined as follows:

1. Acceleration Lane: A speed-change lane, including taper, for the purpose of enabling a vehicle entering a roadway to increase its speed to a rate of which it can safely merge with through traffic.

2. Access: The ability to enter or leave a public street or highway from an abutting private property or another public street.

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

4. Access, Full 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.

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 connection 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 Category: The degree to which access to a roadway is controlled according to a set of categories defining different level of access characteristics.

(Continued)

DEFINITION OF TERMS (Continued)

Access Management Terminology (Continued)

9. Access Control Plan: A roadway design plan which designates access locations and their designs for the purpose of bringing those portions of roadway included in the access control plan into conformance with their access category to the extent feasible.

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

11. ADT: The annual average two-way daily traffic volume. It represents the total annual traffic for the year, divided by 365.

12. Applicant: Owner of property or representative of owner applying for an access permit.

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

14. AWD: An average of weekday daily traffic volumes (five day week) in number of vehicles for a specific highway segment or access.

15. Bandwidth: The time in seconds or the percent of cycle between a pair of parallel speed lines which delineate a progressive movement on a time-space diagram. It is a quantitative measurement of the through traffic capacity of a signal progression system. A 10 percent bandwidth has very little traffic capacity, while a 40 percent bandwidth has good traffic capacity.

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

17. 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.

(Continued)

DEFINITION OF TERMS (Continued)

Access Management Terminology (Continued)

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

19. 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.

20. Conflict Point (Conflict Area): An area where intersecting traffic either merges, diverges, or crosses.

21. Control Of Access: The condition in which the right of owners or occupants of land abutting to a roadway is controlled by public authority.

22. Controlled-Access Highway: Every highway, street, or roadway in respect to which owners or occupants of abutting lands and other persons have no legal right of access to or from the same except at such points only and in such manner as may be determined by the public authority having jurisdiction over such highway, street, or roadway.

23. 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.

24. Deceleration Lane: A speed-change lane, including taper, for the purpose of enabling a vehicle to leave the through traffic lane at a speed equal to or slightly less than the speed of traffic in the through lane and to decelerate to a stop or to execute a slow speed turn.

25. 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.

26. Delay: The time consumed while traffic or a specified component of traffic is impeded in its movement by some element over which it has not control.

(Continued)

DEFINITION OF TERMS (Continued)

Access Management Terminology (Continued)

27. Design Hour Volume (DHV): A traffic vehicle volume determined for used in the geometric design of highways.

28. 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.

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

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

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

32. Driveway: The physical connection between a public street or highway and an abutting private tract of land.

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

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

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

36. 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.

(Continued)

DEFINITION OF TERMS (Continued)

Access Management Terminology (Continued)

37. 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.

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

39. 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.

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

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

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

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

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

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

46. 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.

(Continued)

DEFINITION OF TERMS (Continued)

Access Management Terminology (Continued)

47. 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.

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

49. Functional Classification: A classification system that defines a public roadway according to its purpose in providing movement or access.

50. Gradient (Grade): The rate or percent of change in slope, either ascending or descending from or along the highway. It is to be measured along the centerline of the roadway or access.

51. Guideline: A recommended value which reflects good engineering practice and which should be followed in most situations.

52. Highway: The entire width between the boundary lines of every way publicly maintained when any part thereof is open to the use of the public for purposes of vehicular travel.

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

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

55. Interchange: A facility that grade separates intersecting roadways and provides directional ramps for access movements between the roadways. The structure and the ramps are considered part of the interchange.

56. Lane: The portion of a roadway for the movement of a single line of vehicles and does not include the gutter or shoulder of the roadway.

(Continued)

DEFINITION OF TERMS (Continued)

Access Management Terminology (Continued)

57. 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.

58. Local Government: The board of county commissioners if the highway section is located in an unincorporated area of a county and the governing body of the municipality if the highway section is located within an incorporated municipality.

59. Local Road: A country road or city street for which the primary function is to provide access to adjacent properties.

61. Median: The physical portion of a highway separating the traveled ways for opposing traffic flows.

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

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

64. M.U.T.C.D.: The Manual on Uniform Traffic Control Devices.

65. 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.

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

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

(Continued)

DEFINITION OF TERMS (Continued)

Access Management Terminology (Continued)

68. 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.

69. 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.

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

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

72. Roadway: That portion of a highway improved, designed or ordinarily used for vehicular travel exclusive of the berm or shoulder. In the event a highway includes two or more separate roadways, "roadway" refers to any such roadway separately but not to all such roadways collectively.

73. 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.

74. 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.

75. Sight Distance: The distance visible to the driver of a passenger vehicle measured along the normal travel path of a roadway to a specified height above the roadway when the view is unobstructed to traffic.

(Continued)

DEFINITION OF TERMS (Continued)

Access Management Terminology (Continued)

76. Speed Change Lane: A separate lane for the purpose of enabling a vehicle entering or leaving a roadway to increase or decrease its speed to a rate at which it can more safely merge or diverge with through traffic. Acceleration and deceleration lanes are speed change lanes.

77. Stopping Sight Distance: The distance required by a driver of a vehicle, traveling at a given speed, to bring the vehicle to a stop after an object on the roadway becomes visible. It includes the distance traveled during driver perception and reaction times and the vehicle breaking distance.

78. Storage Length: Additional lane footage added to a deceleration lane to store the maximum number of vehicles likely to accumulate during a peak period so as not to interfere with the through travel lanes.

79. Time-Space Diagram: A chart on which the distance between signals and signal timing is plotted against time. The chart, when completed, indicates signal progression, bandwidth and speed of traffic.

80. 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.

81. 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.

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

83. Traffic Progression (Traffic Signal Progression): The progressive movement of traffic, at a planned rate of speed without stopping, through adjacent signalized locations within a traffic control system.

(Continued)

DEFINITION OF TERMS (Continued)

Access Management Terminology (Continued)

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

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

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

87. 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.

88. Warrant: A requirement based on a legal precedent, or officially adopted policy mandated for use within the jurisdiction of the adopting governmental unit.

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

90. 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.

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(Continued)

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CHAPTER 2

ACCESS MANAGEMENT POLICIES

CHAPTER 2 - ACCESS MANAGEMENT POLICIES

INTRODUCTION

Introduction

CHAPTER 2
ACCESS MANAGEMENT POLICIES

A growing awareness that excessive access results in the functional obsolescence of major roadways is creating increased interest in access design and management or the part of state and local government. This chapter includes examples of selected state and local programs.

STATE PROGRAMS

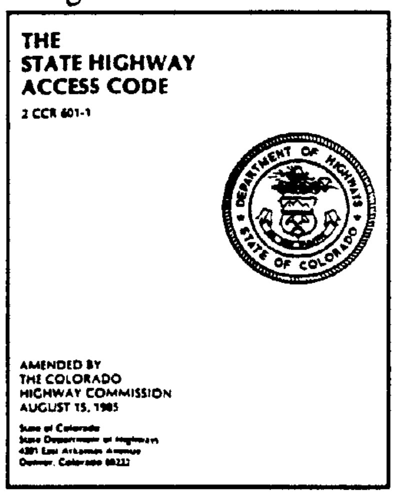
Introduction

The following are examples of state access control programs:

Examples Of State Programs
Colorado
Florida
New Jersey
New Mexico
Wisconsin

Colorado

The Colorado State Access Code represents the first comprehensive approach to access management.



THE
STATE HIGHWAY
ACCESS CODE
2 CCR 601-1

AMENDED BY
THE COLORADO
HIGHWAY COMMISSION
AUGUST 15, 1985

A copy of the code in its entirety is included herein as Appendix C. The success in implementing and administering this code is rooted in the fact that it has strong legislative support. Mr. Philip Demosthenes (*1*, p. 426), Access Program Administrator for the Colorado DOT explains the success of the program as follows:

(Continued)

STATE PROGRAMS (Continued)

Colorado (Continued)

"The promulgation of supporting legislation and regulation is an early and necessary step in improved access management. The regulating highway agency needs to have clear statutory backing to enforce the standards as well as to ensure that the agency can carry out the mandated program. The importance of functional maintenance to achieve and maintain a cost-effective and healthy transportation system and the reduction in capital expenditures by the protection of the existing arterial system, must be sold to the law makers. The exercise of these powers also must have a basis in fact. The public agency must document the necessity for the standards set and apply the standards in a uniform and equitable manner."

"A large part of access management is also internal agency policy decisions such as providing adequate budgets and staff for an access management program. The program must have good support from upper management and be placed within the agency where it can be effective."

The reader is directed to page iii of the Colorado code (see Appendix C) for a summary regarding its development and adoption.

Colorado established five levels of access (*1*, p. 425; *2* pp. 19-25) for application on the 9200 mile state highway system as identified below.

Category	Description
One	Interstate and other freeways
Two	Often a staged design for upgrade to category one. Control of private property by acquiring access is standard practice but at-grade intersections are allowed at 1 mile (rural) or 1/2 mile (urban) intervals.
Three	Urban and most rural arterials; about 75% of the state highway system. Direct private access is denied under most circumstances; deeded access rights are often acquired on primary highways. Signals are at 1/2 mile intervals.

(Continued)

STATE PROGRAMS (Continued)

Colorado (Continued)

Category	Description
Four	Facilities which are more urban in nature. Generally, limits direct access drives to one per parcel unless (1) access does not have potential for signalization, (2) left-turn would not create congestion or safety problems, and (3) alternative to the left-turn would cause operational and safety problems on the general system. Private access may be signalized if spacing requirements are met. Potential signalization requires progression at 35 mph, or the posted speed, with a band width of 30% desirable, 20% minimum, for cycle lengths of 90 to 120 seconds. Colorado does not consider Category Four to be a desirable design for major arterials, as it represents a 20 to 30% reduction in capacity compared to Category Three facilities (1, p. 426).
Five	Frontage and other service roads where access is the prime function.

Access to the 9200 mile Colorado State Highway system is regulated through a license system. About 550 access permits are issued per year (1, p. 426). The Access Program Administrator has summarized the permit policy as follows (1, p. 426):

(Continued)

STATE PROGRAMS (Continued)

Colorado (Continued)

"A permit is required for all access, both public streets and private driveways. When a permit is issued, access designs are required to be consistent with state regulations and the permittee is fully responsible for all construction costs. Colorado requires new access to meet desirable geometric dimensions not just minimums. Permits are issued for the intended use of the access. An access must be upgraded to current standards when a change in the use of the property increases access volume above twenty percent. Failure to construct, maintain or use the access consistent with the terms and conditions of the permit can lead to permit revocation. Additional regulatory controls also allow for the denial or closure of direct access when alternative access to a secondary highway is available. The Department, on its own initiative, can reconstruct or relocate an access when required by changes in roadway operations, design and safety..."

Figure 2-1 is a flow chart which identifies the basic process involved in the review and approval/denial of requests for direct access.

(Continued)

Colorado (Continued)

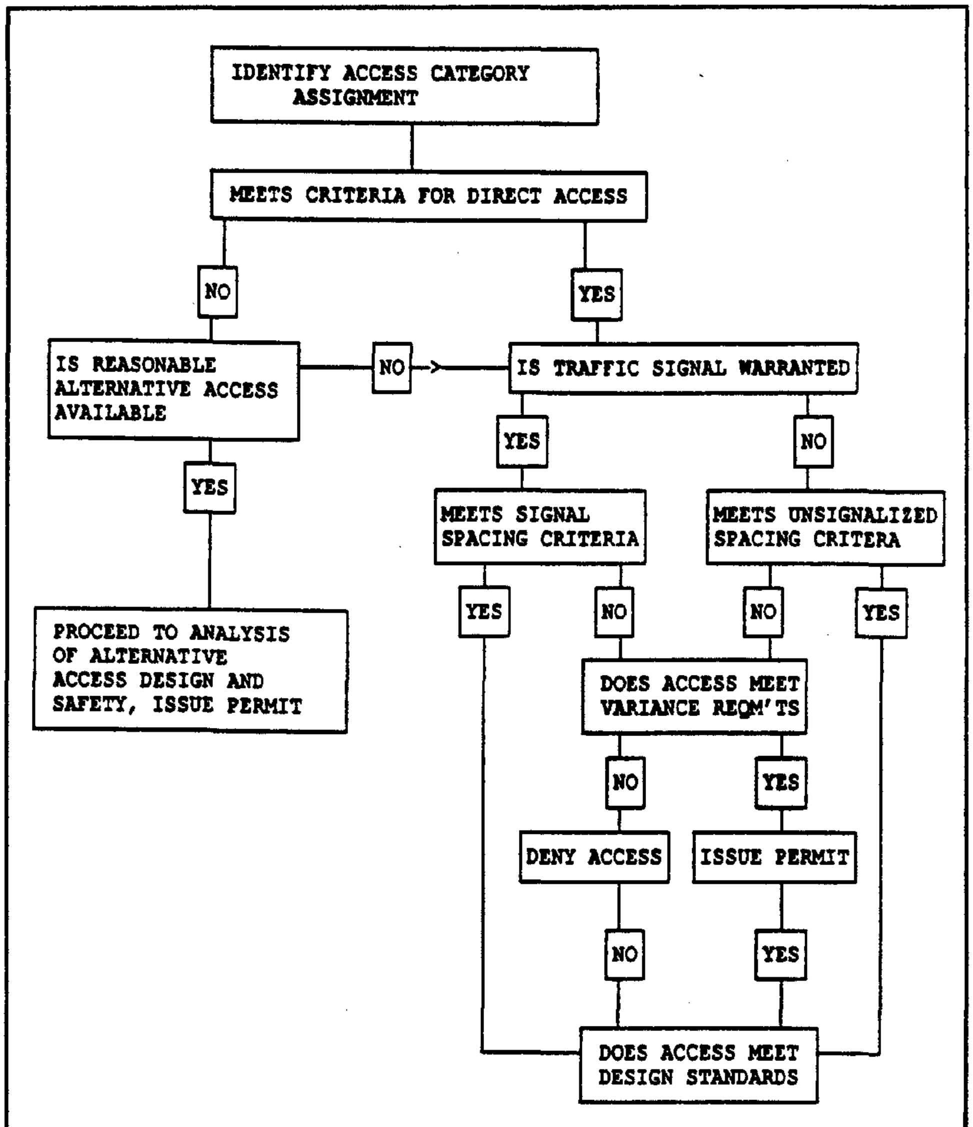


FIGURE 2-1: ACCESS DECISION FLOW CHART

Source: Reference (3)

Since its adoption many features of the Colorado Access code have been included in the access regulations of various state and local jurisdictions.

(Continued)

STATE PROGRAMS (Continued)

Florida

RULES OF THE DEPARTMENT OF TRANSPORTATION
CHAPTER 14-97
STATE HIGHWAY SYSTEM
ACCESS MANAGEMENT
CLASSIFICATION SYSTEM AND STANDARDS

The Florida DOT has adopted an access management classification system which utilizes seven levels of access controlled roadways (4). Access Class One is full control of access. As indicated in Table 2-1 interchange spacing is related to characteristics of the area in which the facility is located.

TABLE 2-1: FLORIDA DOT INTERCHANGE SPACING STANDARDS FOR ACCESS CLASS ONE (FREEWAY) FACILITIES

Access Class	Segment Location	Applicable Interchange Spacing Standard
1	AREA TYPE 1 CBD & CBD Fringe for Cities in Urbanized Areas	1 Mile
1	AREA TYPE 2 Existing Urbanized Areas Other Than Area Type 1	2 Miles
1	AREA TYPE 3 TTransitioning Urbanized Areas and Urban Areas Other Than Area Types 1 or 2	3 Miles
1	AREA TYPE 4 Rural Areas	6 Miles

Source: Reference (4), p. 9

(Continued)

STATE PROGRAMS (Continued)

Florida (Continued)

Standards for other controlled access roadways are given in Table 2-2.

TABLE 2-2: FLORIDA DOT STANDARDS FOR CONTROLLED ACCESS ROADWAYS OTHER THAN FREEWAYS

Access Class	Facility Design Features (Medial Treatment and Access Roads)	Minimum Connection Spacing (feet)	Minimum Median Opening Spacing		Minimum Signal Spacing (mile)
			Directional[1] (feet)	Full[2] (mile)	
2	Restrictive with Service Roads	1320/660[3]	1320	0.5	0.5
3	Restrictive	660/440[3]	1320	0.5	0.5
4	Non-Restrictive	660/440[3]	n/a	n/a	0.5
5	Restrictive	440/245[3]	660	0.5/0.25[3]	0.5/0.25[3]
6	Non-Restrictive	440/245[3]	n/a	n/a	0.25
7	Both	125	330	0.125	0.25

(1) Left turn ingress or left turn egress only.
(2) All movements, including crossing, possible.
(3) (Greater than 45 mph)/(Less than or equal to 45 mph)

Note:
- Section 14-97.003 and 14-97.004, FAC, contain supplementary and more detailed instructions for the use of these standards.
- These minimum spacings may not be adequate if auxiliary lanes and storage are required.
- Single properties with frontages exceeding the minimum spacing criteria may not receive permits for the maximum number of possible connections.

Source: Reference (4), p. 10

(Continued)

STATE PROGRAMS (Continued)

Florida (Continued)

Florida has also established the minimum corner clearance standards given in Table 2-3.

TABLE 2-3: FLORIDA STANDARDS FOR CORNER CLEARANCE AT INTERSECTIONS

With Restrictive Median		
Position	**Access Allowed**	**Minimum (feet)**
Approaching Intersection	Right In/Out	115
Approaching Intersection	Right In Only	75
Departing Intersection	Right In/Out	230 (125)*
Departing Intersection	Right Out Only	100
Without Restrictive Median		
Position	**Access Allowed**	**Minimum (feet)**
Approaching Intersection	Full Access	230 (125)*
Approaching Intersection	Right In Only**	100
Departing Intersection	Full Access	230 (125)*
Departing Intersection	Right Out Only**	100

* Access Class 7 and Interim "Special Case" at 35 mph or less, may use the measurements in parenthesis.

** Right In/Out, Right In Only, and Right Out Only connections on roads without restrictive medians shall, by design of the connection, effectively eliminate prohibited movements.

Source: Reference (4), p. 15

(Continued)

STATE PROGRAMS (Continued)

New Jersey

ACCESS AND SPACING STANDARDS FOR STATE HIGHWAYS

NEW JERSEY DEPARTMENT OF TRANSPORTATION

The New Jersey DOT (5) identified seven Levels of Access (LOA). As the following indicates, the LOA, defined by New Jersey DOT, is based on the nature of the access provided at private driveways.

LOA	Description
0	Freeway, full control of access.
I	Access via intersecting highway or street; direct access only if no alternative available.
II	Right-turns only at private access drive.
III	Driveway with provision for left-turn access from the state highway via a jughandle.
IV	Driveway with a provision for left-turn access from a state highway via a left-turn lane. Left-turns from the site may be allowed.
V	Driveway with provision of left-turn access (limited by spacing and safety considerations).
VI	Driveway access limited only by edge (corner) clearance and safety considerations. LOA VI is for roads having a primary function to provide local access.

(Continued)

STATE PROGRAMS (Continued)

New Jersey (Continued)	New Jersey DOT further proposed applying the levels of direct access to four classes of urban and five classes of rural highways. As shown in Table 2-4 each class of roadway is further subdivided by speed and cross-section. Thus, the functional (access) class of roadway is comparable to the roadway category used by Colorado and the LOA used by Florida. The level of access as used by New Jersey is more a description of the manner in which direct access is provided than the level of access per se.

(Continued)

STATE PROGRAMS (Continued)

New Jersey (Continued)

TABLE 2-4: MAXIMUM LEVEL OF ACCESS BY ACCESS CLASS AND HIGHWAY CHARACTERISTICS BASED ON DESIRABLE, YEAR 2010, SECTIONS

URBAN						
Access Class	Characteristics					
	High Speed[1] (>= 45 mph)			Low Speed[1] (< 45 mph)		
	Div.	Undiv. (multi-lane)	2-lane	Div.	Undiv. (multi-lane)	2-lane
Accessible Principal Arterials	II	IV	IV	III	IV	V
Minor Arterials	III/IV	IV	V	III/IV	IV	V
Collector Roads	IV	V	VI	IV	V	VI
Local Roads	VI	VI	VI	VI	VI	VI

RURAL						
Access Class	Characteristics					
	High Speed[1] (>= 50 mph)			Low Speed[1] (< 50 mph)		
	Div.	Undiv. (multi-lane)	2-lane	Div.	Undiv. (multi-lane)	2-lane
Accessible Principal Arterials	I	IV	IV	II	IV	V
Minor Arterials	II	IV	V	III/IV	IV	V
Major Arterials	III/IV	V	VI	IV	V	VI
Minor Collectors	IV	V	VI	IV	V	VI
Local Roads	VI	VI	VI	VI	VI	VI

Level of Access	Description
I	Access at intersection along public roadways only.
II	Right turn access driveway only.
III[2]	Driveway with provision for left turn access via jughandle (jughandle may be located at or in vicinity of access driveway).
IV[2]	Driveway with provision for left turn access via left turn lane.
V	Driveway with provision for left turn access (limited by spacing requirements & safety considerations).
VI	Driveway access limited only by edge clearance and safety considerations.

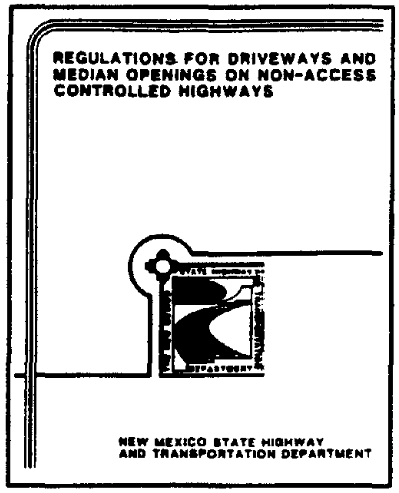
(1) Based on posted speed limit.
(2) Level of access will depend on design standards for the specific route involved.

Source: Adapted from Reference (5), p. 16

(Continued)

STATE PROGRAMS (Continued)

New Mexico


REGULATIONS FOR DRIVEWAYS AND MEDIAN OPENINGS ON NON-ACCESS CONTROLLED HIGHWAYS

NEW MEXICO STATE HIGHWAY AND TRANSPORTATION DEPARTMENT

The New Mexico State Highway Commission adopted regulations for driveway and median openings on non-access controlled highways in July 1989. The New Mexico regulations, in many respects, are similar to the Colorado Access Code. For example, sight distances, speed change lane lengths, taper rate, storage length, and requirements for acceleration and deceleration lanes are the same as Colorado.

The New Mexico regulations do not include a description of access categories. Nor does it contain standards for signalized intersection spacing or progression speeds and the width of the through progression band as a percentage of cycle length. Also, it does not address the classification of state highways by access category. Consequently it will undoubtedly be more difficult to administer than the Colorado or Florida regulations. The New Mexico regulations do include a designation of the vehicle type to be used for access design based upon the functional classification of the highway and the access drive (see Table 2-5).

(Continued)

STATE PROGRAMS (Continued)

New Mexico
(Continued)

TABLE 2-5: DESIGN TO BE USED FOR ACCESS DESIGN

Roadway Classification	Access Classification	Minimum Design Vehicle*
Rural Arterial	Private	SU
	Commercial	WB-50
	Public	WB-50
Rural Collector	Private	SU
	Commercial	WB-50
	Public	WB-50
Rural Local	Private	SU
	Commercial	SU
	Public	WB-50
Urban Arterial	Private	SU
	Commercial	SU
	Public	WB-50
Urban Collector	Private	P/SU
	Commercial	SU
	Public	WB-50
Urban Local	Private	P/SU
	Commercial	SU
	Public	SU

* P Passenger Vehicle
SU Single Unit Truck
WB-50 Tractor Semi-Trailer Combination

Source: Reference (6), p. 38

(Continued)

STATE PROGRAMS (Continued)

Wisconsin

PLANNED ACCESS:

PROTECTION FOR WISCONSIN'S HIGHWAYS

The Wisconsin DOT has a long history of involvement in access management(7). In 1949, the legislature gave the Wisconsin Highway Commission, now Wisconsin DOT, authority to designate as controlled-access highways up to 1500 miles of the rural state trunk highway system where the average ADT exceeds 2000 cars per day. After public hearings, these roads may be designated as controlled access highways and no private drive or public road intersection may be opened without Wisconsin DOT approval.

Wisconsin DOT also has authority to acquire, by negotiation or the power of eminent domain, and thus control individual access rights. The program of acquiring access rights includes the purchase of options on the access rights. As with any option-to-purchase contract Wisconsin DOT has the right of purchase, rather than permitting the access, should a property owner desire to develop the property. If the option is exercised, Wisconsin DOT pays the market value at the time of purchase. Wisconsin DOT also has the authority to review and approve subdivision plats where the proposed development will impact the state highway. Wisconsin DOT criteria for direct access are given in Table 2-6.

(Continued)

STATE PROGRAMS (Continued)

Wisconsin (Continued)

TABLE 2-6: GUIDELINES FOR ACCESS TYPE AND MINIMUM SPACING FOR SUBURBAN AREAS

Intersecting Highway	Major Route Under Study and Design Year ADT / Design Year ADT	Standard Arterial 20,000-30,000	Standard Arterial 10,000-20,000	Standard Arterial 3,500-10,000	Standard Arterial < 3,500	Minor Arterial 5,000-25,000	Minor Arterial < 5,000
Standard Arterial	20,000-30,000	1C					
	10,000-20,000	1C	2E				
	3,500-10,000	2E	2E	2E			
	< 3,500	2E	2E	2E	2E		
Minor Arterial	5,000-25,000	1C	2E	2E	2E	2E	
	< 5,000	2E	2E	2E	2E	2E	2G
High-Type Collector	> 2,500	2E	2E	2F	2F	2F	2G
	< 2,500	2E	2E	2F	2F	2F	2G
Low-Type Collector	> 2,500	2E	2E	2F	2F	2F	2G
	< 2,500	2E	2E	2F	2F	2F	2G
Local	> 2,500	2E	2E	2F	2F	2F	2G
	< 2,500	2E	2E	2F	2F	2F	2G
Private	All Volumes	2F	2G	2G	2G	2G	2G

Legend:

Minimum Access Spacing
- A: 5 miles
- B: 2 miles
- C: 1 mile
- D: 2,000 feet
- E: 1,000 feet
- F: 500 feet
- G: 300 feet

Access Type
- 0: No Access
- 1: Interchange
- 2: At-Grade

Source: Reference Adapted from (8)

LOCAL GOVERNMENT PROGRAMS

Examples Of Local Programs

Examples Of Local Government Access Control Programs

Lakewood, Colorado

Lee County, Florida

Waushara County, Wisconsin

Lakewood, Colorado

City of Lakewood

DEPARTMENT OF PUBLIC WORKS
Traffic Engineering Division

The City Council of Lakewood, Colorado adopted an ordinance on Transportation Engineering Design Standards in July 1985 (9). The Lakewood ordinance draws heavily upon the Colorado State Highway Access Code and the city administers the state code within its municipal limits. The categories of roadway by level access criteria and the requirements for acceleration and deceleration lanes are the same as the state highway code. Many of the other design standards are also the same. In some cases, the city design standards exceed those of the state code.

(Continued)

LOCAL GOVERNMENT PROGRAMS (Continued)

Lee County, Florida

LEE COUNTY, FLORIDA

Lee County, Florida has identified ten levels of access for facilities on which full control or partial control of access applies (*10*). This does not include facilities, local roads and streets, on which access control is not applied. As shown in Table 2-7 these are further subdivided based upon traffic speed which in effect gives 18 different groupings.

(Continued)

LOCAL GOVERNMENT PROGRAMS (Continued)

Lee County, Florida (Continued)

TABLE 2-7: ACCESS SPACING PROPOSED FOR LEE COUNTY, FLORIDA

Class Description	Geometry	Signal Spacing (mile)	Directional Median Break Spacing (feet)	Driveway Spacing (feet)
Limited Access Facilities				
I	Full Access Control	N/A	N/A	N/A
Controlled Access Facilities				
II	Median	1/2	1320(2) 660(3)	1320(2) 660(3)
III	Median	1/4	660(2) 330(3)	660(2)
IV	Median	1/2	1320(2) 660(3)	660(2) 330(3)
V	Median	1/4	660(2) 440(3)	440(2) 320(3)
VI	No Median(1)	1/2	N/A	330(2) 220(3)
VII	No Median(1)	1/4	N/A	220(2) 165(3)
VIII	No Median	1/2	N/A	660(2) 330(3)
IX	No Median	1/4	N/A	440(2) 220(3)
X	As Required	As Required	N/A	125

(1) Continuous center left turn lane.
(2) Speeds >50 mph.
(3) Speeds <50 mph.

Source: Reference Adapted from (*10*)

(Continued)

LOCAL GOVERNMENT PROGRAMS (Continued)

East Central Wisconsin Regional Planning Commission

The East Central Wisconsin Regional Planning Commission covers a 10 county region. In January 1980 the Commission prepared a report dealing with the technical and legal aspects of access control to assist the individual counties in developing and implementing access control within the rural and urban portions of the county trunk road system(*11*). The Commission provides technical assistance to the counties depending upon the activities and staffing of the individual county.

Waushara County is an example of an access control plan developed with the assistance of the East Central Wisconsin RPC (*12*).

Waushara County, Wisconsin

Waushara County
Access Control Plan

September 1986

The following is extracted from the Waushara County Access Control Regulations (*13*, pp. 43-47).

(Continued)

LOCAL GOVERNMENT PROGRAMS (Continued)

Waushara County, Wisconsin (Continued)

"In late spring, 1985, the Waushara County Board requested assistance from the East Central Wisconsin Regional Planning Commission to help develop a highway access control plan for the county. The request was initiated by members of the Waushara County Zoning Committee who had attended several meetings conducted by WisDOT District 4 on planned access. Interest in such planning had been expressed by various county board supervisors and local officials who recognized access-related problems in various parts of the county..."

"Because all of the problem corridors involved more than one jurisdiction, the Zoning Committee recommended a county-wide study as a first step in access planning. The Zoning Committee appointed an access planning committee to work with East Central and WisDOT District 4 in developing a plan. Included on the committee were three members of the Zoning Committee, the zoning administrator, the highway commissioner and the sheriff. The committee established two objectives:

(1) To develop a county-wide plan for managing access in the unincorporated areas of Waushara County.

(2) To identify potential problem corridors which local communities may wish to address with local access control plans.

The committee decided that the plan's primary intent was to manage access through land use planning and zoning rather than through highway design or markings. Through planning and zoning local governments have the ability to regulate access so that roadside development is efficiently served and the utility of adjacent or connecting roads is preserved."

(Continued)

Waushara County, Wisconsin (Continued)

The main provisions given below are excerpted verbatim:

ACCESS DRIVEWAYS

(1) Access Permits: Permits are required for all new access points created after the effective date of these amendments.

(a) Permit applications for access to Class A highways shall be made with the Wisconsin Department of Transportation, to Class B highways with the Waushara County Highway Department and to Class C highways with the Waushara County Zoning office. No separate access permit is needed for Class C highways if a land use permit has been issued.

(b) The agency which issues the permit application shall conduct inspections of the point of access to determine compliance with the ordinance provisions and shall maintain permanent records of data submitted, staff recommendations and permits issued.

(c) The authority to approve, conditionally approve or reject an application is delegated to the agency which issues the permit except if the proposed access does not conform to the access provisions of the zoning ordinance. Requests for nonconforming accesses shall be subject to review and approval by the Board of Adjustment prior to the issuing agency granting the permit.

(d) A copy of applications for conditional use permits, variance and zone changes related to access provisions shall be forwarded for review to the County Highway Department or the Wisconsin Department of Transportation 10 days prior to hearing on access to highways within their jurisdictions.

Copies of decisions on these matters shall be submitted to these departments within 10 days after they are granted or denied.

(Continued)

LOCAL GOVERNMENT PROGRAMS (Continued)

Waushara County, Wisconsin (Continued)

(2) Spacing Standards for Access Driveways: Access driveways to highways from abutting properties shall comply with the following requirements:

Class of Highway	Minimum Distance of Highway Frontage Between Centerline of Access Driveways	Minimum Distance Access Driveways May Be Located to Centerline of an Intersecting Highway
Class A Highways		
Principal Arterials	1000 feet	1000 feet
Minor Arterials	600 feet	600 feet
Collectors	300 feet	300 feet
Class B Highways		
Collectors	300 feet	300 feet
Local	75 feet	150 feet
Class C Highways	75 feet	150 feet

(a) New access should comply as closely as possible to the spacing standards where strict application of these standards would deny access to lots in existence prior to this amendment.

(b) Where the option exists, access shall be granted to a highway with a lower classification rather than one with a higher classification.

(3) Number and Width of Driveways Per Land Use: The maximum number and width of access driveways per land use to highways and service roads shall be as follows:

(Continued)

LOCAL GOVERNMENT PROGRAMS (Continued)

Waushara County, Wisconsin (Continued)

Type of Access Driveway	Maximum Number of Access Driveways	Maximum/Minimum Width
Commercial and Industrial Land Uses	2	35/24 feet
Residential Land Uses	1	35/16 feet
Agricultural Land Uses on Class A and B Highways	1 per parcel	35/24 feet
Agricultural Land Uses on Class C Highways	No Maximum Number	35/24 feet

Conversion of an access point from one type of use to another shall be treated the same as opening a new access point and must meet the conditions of these regulations.

(4) Design Standards: Driveways to Class A and Class B highways must comply with the design provisions of the access permit issued by the Wisconsin Department of Transportation or the County highway Department. Driveways to Class C highways must comply with inspection and culvert requirements of each town, provided they meet the following minimum standards:

-- Culverts, if needed, must be a minimum of 15 inches in diameter.

-- Driveway height must not exceed the level of the outside edge of the road shoulder.

-- No end or retaining walls shall be permitted on driveways.

-- The side slopes of the driveway shall equal or be flatter than the side slope of the main highway but should not be steeper than 2-1/2 to 1, unless otherwise designated on an individual basis.

(Continued)

LOCAL GOVERNMENT PROGRAMS (Continued)

Example Of A County Access Control Plan

ACCESS MANAGEMENT PLAN
WAUTOMA-SILVER LAKE HIGHWAY 21/73 CORRIDOR
JUNE, 1989
(REVISED)

A proposed access management plan for the Wautoma-Silver Lake Highway 21/73 corridor was completed in July, 1988. Opportunity to discuss the proposed plan was provided at several meetings scheduled by the Access Planning Committee and the Chamber of Commerce. Written responses were also requested.

Comments were evaluated by the Access Planning Committee and Chamber representatives and incorporated in the plan adopted in July, 1989. These revisions had minimal impact on the number of accesses proposed for closure. Among the revisions:

(1) All proposed frontage roads were deleted. It was felt the same ends could be achieved by closing or sharing individual access points rather than by constructing frontage roads to access existing businesses. Businesses were concerned about loss of parking and the high cost of frontage road construction.

(2) For several businesses with more than one access, the access originally suggested for closure was exchanged for another. In a few of these cases, shared accesses were proposed, or an access was moved to a different location.

(Continued)

LOCAL GOVERNMENT PROGRAMS (Continued)

Example Of A County Access Control Plan (Continued)

In the review process, comments were also received about the planning criteria and the implementation process. These were more fully explained in the revised plan. The section on implementation also has been updated to take into account activities which have occurred since completion of the original plan in July, 1988.

Average daily traffic volumes in 1985 ranged from just over 4,700 vpd to slightly over 11,000 vpd. At the highest volume location, average daily traffic projected to increase to 15,600 in the year 2001 and to 17,800 by the year 2011.

The 3.97 mile section of roadway passes through four local political jurisdictions. A summary of the existing and proposed access by jurisdiction is given in Table 2-8.

TABLE 2-8: SUMMARY OF MILEAGE AND DIRECT ACCESS BY LOCAL POLITICAL JURISDICTION

Jurisdiction	Number of Miles	Number of Existing Access Drives	Proposed Closures	Number of Remaining Access Drives
City of Wautoma	0.53	39	10	29
Town of Wautoma	0.59	32	12	20
Town of Dakota	1.16	58	26	32
Town of Marion	1.69	60	9	51
Total	3.97	189	57	132

Source: Reference (*13*), p. 4

(Continued)

LOCAL GOVERNMENT PROGRAMS (Continued)

Example Of A County Access Control Plan (Continued)

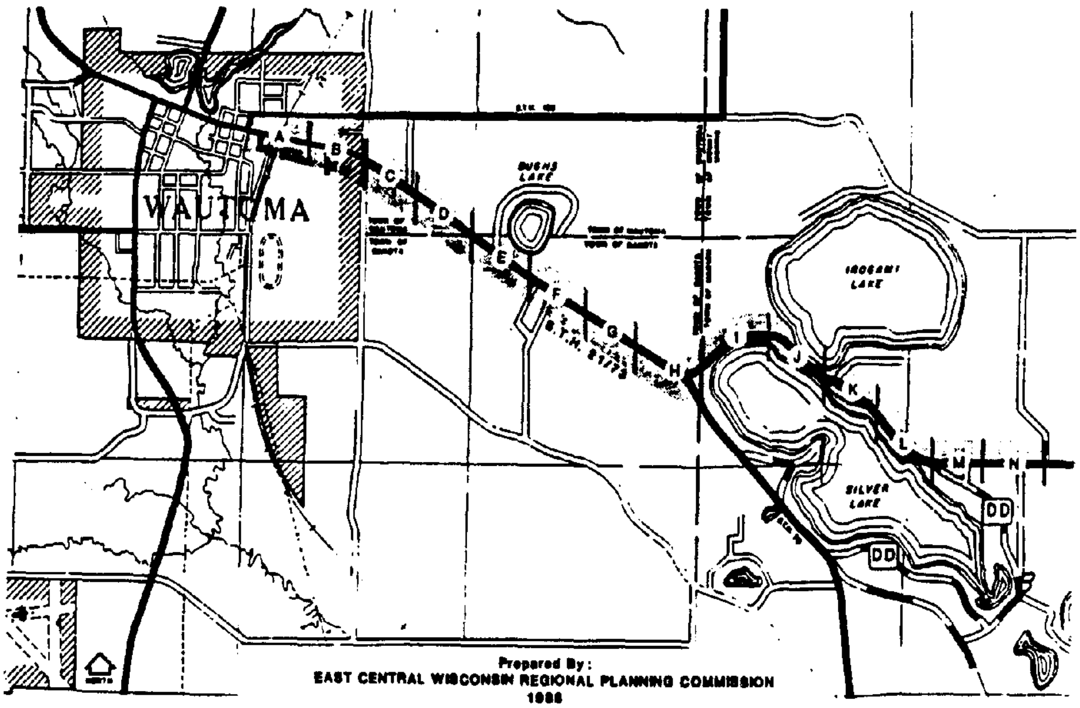


FIGURE 2-2: LOCATION MAP OF THE HIGHWAY 21/73 CORRIDOR

Source: Reference (13)

(Continued)

LOCAL GOVERNMENT PROGRAMS (Continued)

Example Of A
County Access
Control Plan
(Continued)

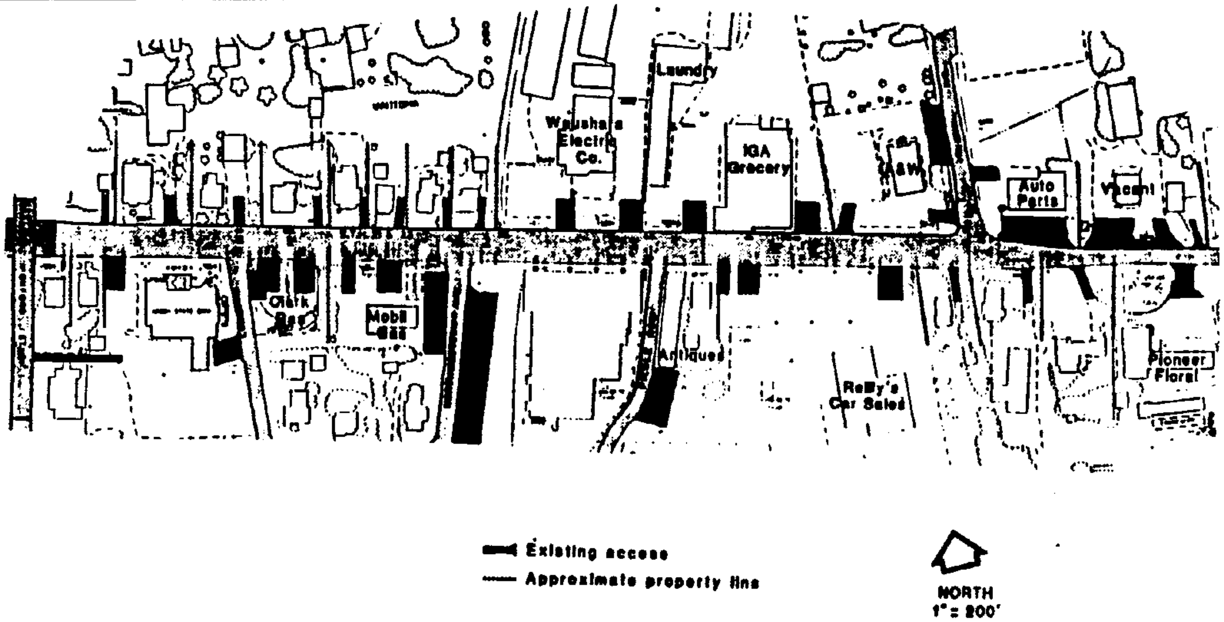


**FIGURE 2-3: EXISTING ACCESS SEGMENT "A"
CITY OF WAUTOMA**

Source: Reference (13), p. 8

(Continued)

LOCAL GOVERNMENT PROGRAMS (Continued)

Example Of A County Access Control Plan (Continued)

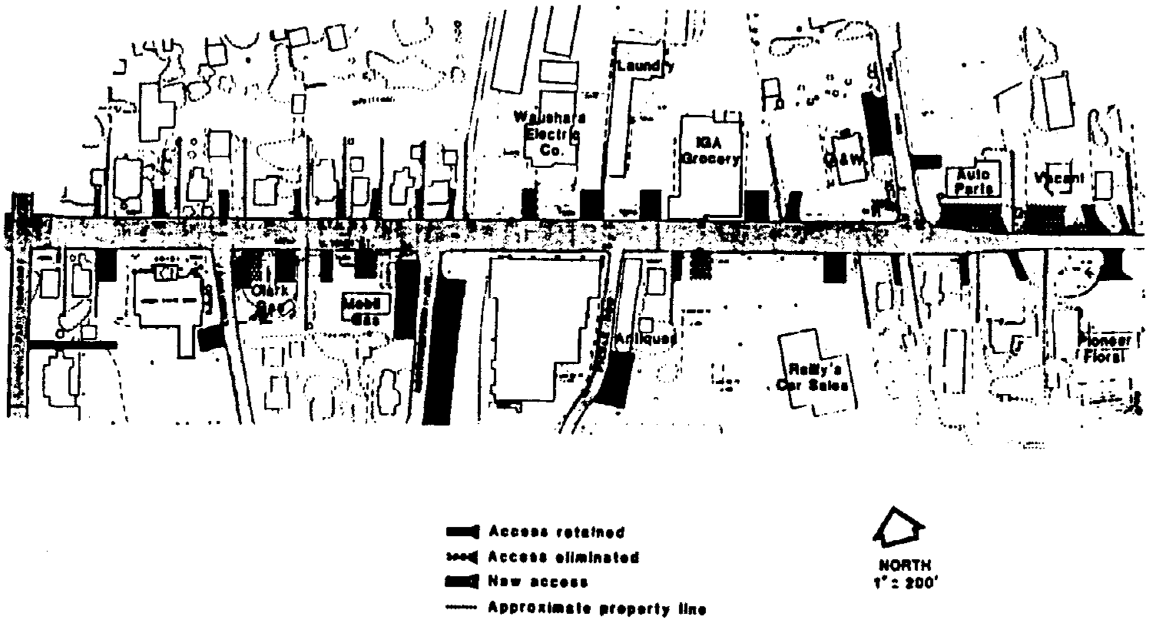


FIGURE 2-4: PROPOSED ACCESS SEGMENT "A" CITY OF WAUTOMA

Source: Reference (13), p. 9

(Continued)

LOCAL GOVERNMENT PROGRAMS (Continued)

Example Of A County Access Control Plan (Continued)

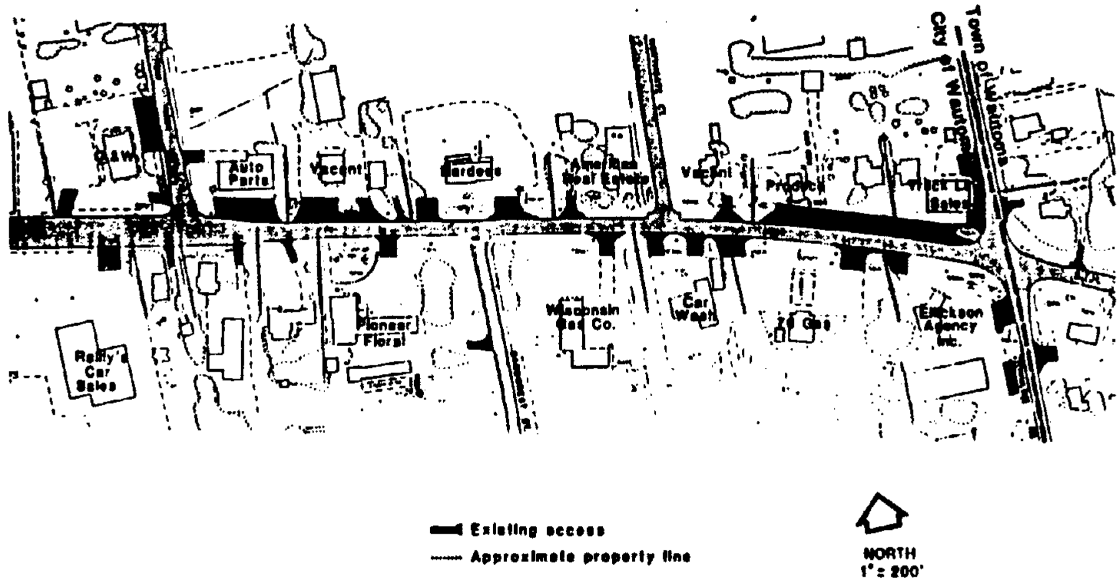


FIGURE 2-5: EXISTING ACCESS SEGMENT "B" CITY OF WAUTOMA

Source: Reference (13), p. 10

(Continued)

LOCAL GOVERNMENT PROGRAMS (Continued)

Example Of A County Access Control Plan (Continued)

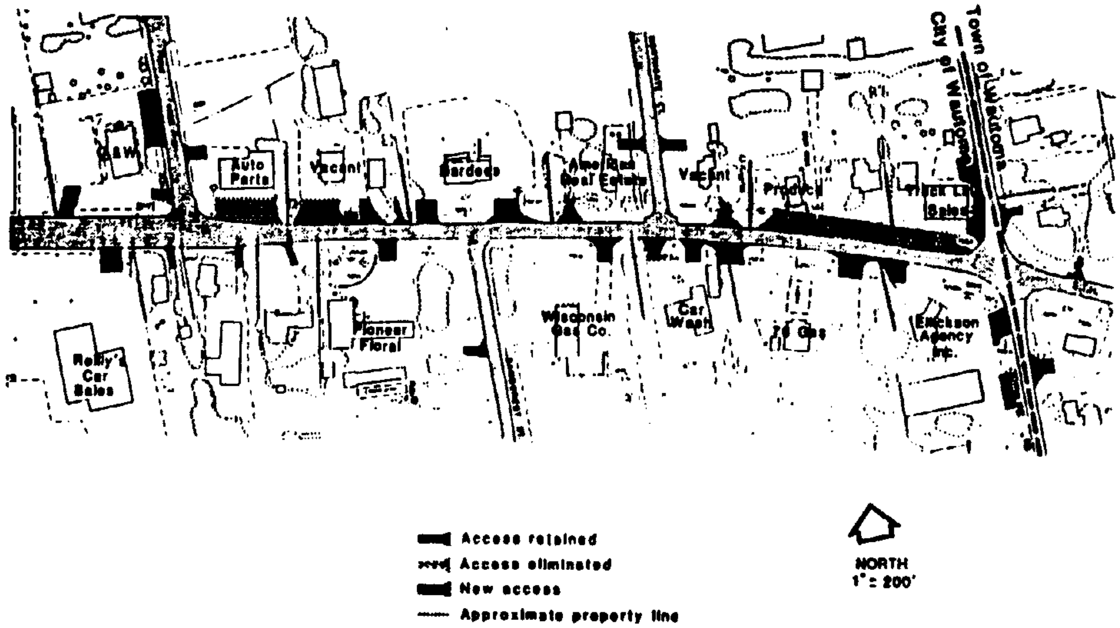


FIGURE 2-6: PROPOSED ACCESS SEGMENT "B" CITY OF WAUTOMA

Source: Reference (*13*), p. 11

(Continued)

LOCAL GOVERNMENT PROGRAMS (Continued)

Example Of A County Access Control Plan (Continued)

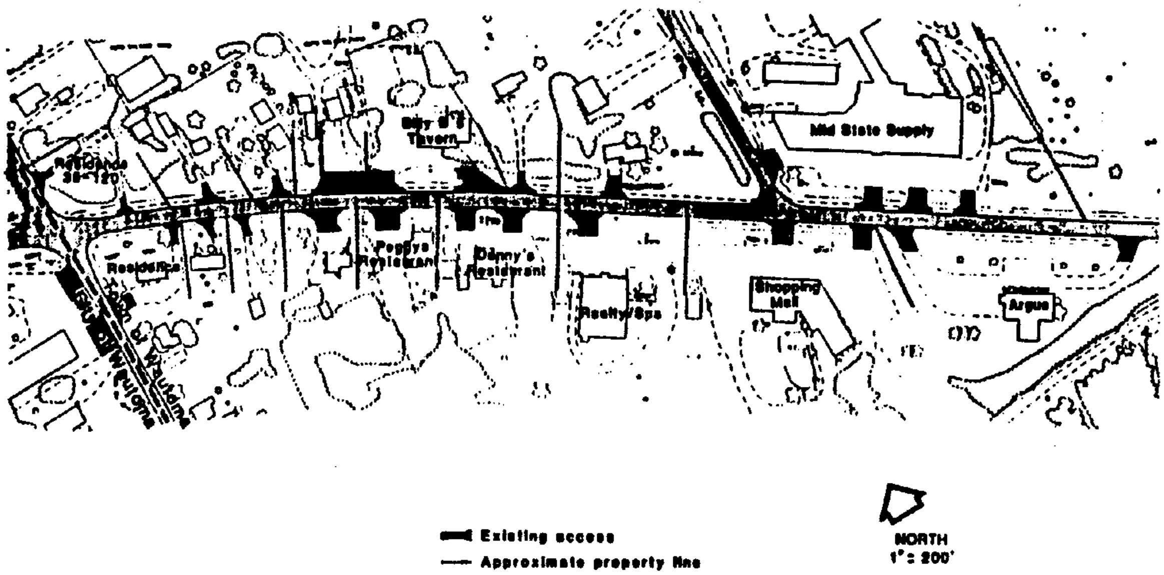


FIGURE 2-7: EXISTING ACCESS SEGMENT "C"
TOWN OF WAUTOMA

Source: Reference (*13*), p. 14

(Continued)

LOCAL GOVERNMENT PROGRAMS (Continued)

Example Of A County Access Control Plan (Continued)

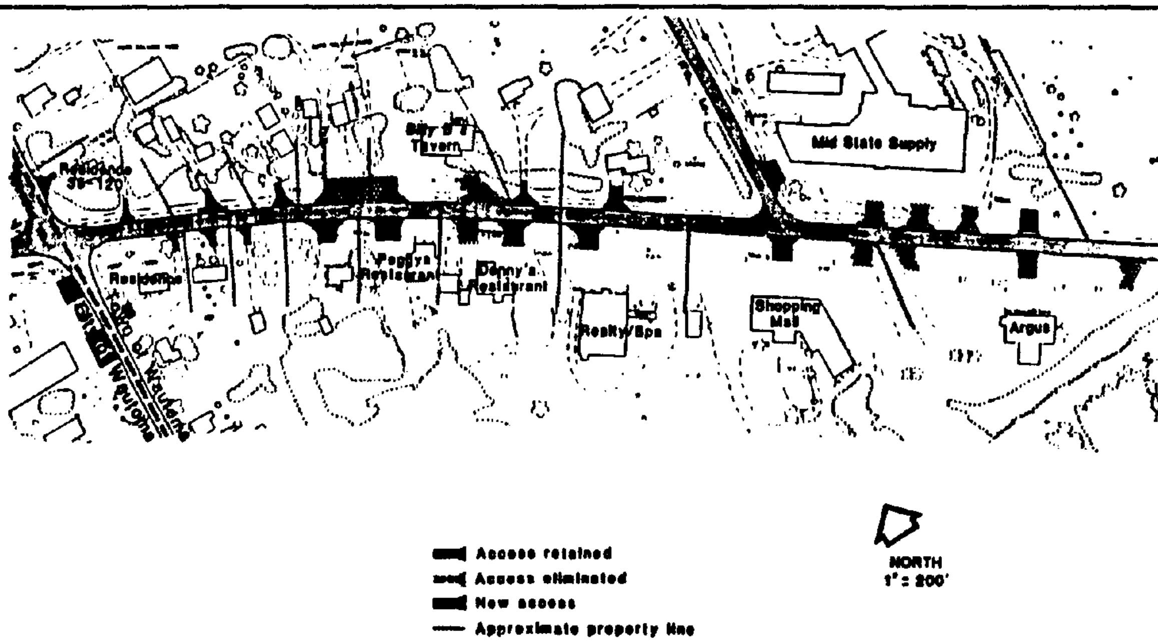


FIGURE 2-8: PROPOSED ACCESS SEGMENT "C" TOWN OF WAUTOMA

Source: Reference (13), p. 15

REFERENCES

1. Philip B. Demosthenes, "Access Management: Ten Successful Years in Colorado", Compendium of Technical Papers, Institute of Transportation Engineers, Milwaukee, Wisconsin, September 1991.

2. "The State Highway Access Code", State of Colorado Department of Highways, August 15, 1985.

3. Corresponsdence with Philip B. Demosthenes.

4. "Rules of the Department of Transportation Chapter 14-97", State Highway System Access Management Classification System and Standards, Florida Information Systems Planning Office, February 12, 1991.

5. "Access and Spacing Standards for State Highways", Summary Background Report Task 2, New Jersey Department of Transportation, February 9, 1990.

6. Regulations for Driveways and Median Openings on Non-Access Controlled Highways, New Mexico State Highway and Transportation Department.

7. Planned Access, Wisconsin Department of Transportation, 1988.

8. "Highways II. The Plan", Wisconsin State Highway Plan, Chapter V, State of Wisconsin.

9. Transportation Engineering Design Standards, Traffic Engineering Division Department of Public Works, Lakewood, Colorado, June 1985.

10. Correspondence with Lee County Traffic Engineer's Office, Lee County Florida.

11. Access Control, East Central Wisconsin Regional Planning Commission, January 1980.

12. Waushara County Access Control Plan, East Central Wisconsin Regional Planning Commission, September 1986.

13. Access Management Plan, Wautoma-Silver Lake Highway 21/73 Corridor, East Central Wisconsin Regional Planning Commission, June 1989.

APPENDIX 2-A

THE STATE HIGHWAY ACCESS CODE

2 CCR 601-1

AMENDED BY
THE COLORADO
HIGHWAY COMMISSION
AUGUST 15, 1985

State of Colorado
State Department of Highways
4201 East Arkansas Avenue
Denver, Colorado 80222

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STATEMENT OF BASIS AND PURPOSE REGARDING THE RULE AND REGULATION KNOWN AS THE STATE HIGHWAY ACCESS CODE BY THE COLORADO HIGHWAY COMMISSION

JULY 16, 1981

This code is based upon the authority granted in C.R.S. 1973, 43-2-147, as amended (hereafter "the act"). The act sets forth certain requirements before this code could be adopted as a rule and regulation. All these requirements have been met.

After the act was passed in 1979, a task force was established to draft the code. The task force consisted of members from a variety of disciplines, including engineers, Department of Highway personnel, representatives of the Colorado Municipal League and Colorado Counties Incorporated, representatives of counties, an attorney, and other people involved on a day-to-day basis with access approaches. Every municipality and county was provided with a draft proposed code and invited to provide comments and to attend a public meeting to discuss the draft. These meetings were held to comply with subsection 43-2-147(2) of the act.

On November 15, 1979 the code was submitted to the legislative council as required by subsection 43-2-147(2) of the act. The council, in turn, submitted the code to the legislative committees of reference of the second regular session of the 52nd General Assembly.

At a joint meeting of the House and Senate Transportation Committees held on March 13, 1980 the code was rejected and referred to the Interim Committee on Transportation for re-working during the summer. Pursuant to specific directions from the joint committees the Department of Highways held a series of public meetings throughout the state to collect public comments to assist in the summer legislative review. Prior to the meetings every unit of local government was provided the latest draft of the code and invited to make comments and attend one of several meetings held around the state.

After a series of hearings before the interim committee, in which amendments were made to the code, the code was resubmitted on January 7, 1981, to the committees of reference in the 1st regular session of the 53rd General Assembly. The committees decided to take no further action on the code, thus clearing the way for the Colorado Highway Commission to adopt the code as a rule and regulation.

The purpose of this rule and regulation (hereafter "rule") is to implement the act by providing specified uniform procedures and standards to guide the public, local governments, and the Department of Highways in the administration of permitting access approaches.

The major purpose of the procedural section of the rule is to ensure there is an orderly and uniform method for the administration of access permits. The purpose of the classification and design specification sections is to aid the department in determining if an access permit should be granted and to ensure the public's health, safety, and welfare is protected, smooth traffic flow is maintained, highway right-of-way drainage is maintained, the functional level of the highways is maintained, and the property owner's right of access to the general street system is protected.

The rule establishes design standards and criteria to be followed in applying for, granting or denying, building, using and maintaining access approaches, and sets forth the procedures to follow and standards to apply in reconstructing and relocating existing access approaches and in requesting a court to enjoin violations of the access code. The rule also defines the functional classifications into which all state highways shall be placed, and sets forth the procedure for the Highway Commission to follow in determining the functional classifications of state highways.

The design standards set forth in the rule are based upon national and state standards intended to ensure the safety of the motorist and pedestrian. The standards and specifications in the code are based in part upon the references in section 1.5 of the code and in part upon the engineering expertise and judgment of the engineers involved in drafting the code. The design standards and specifications are not intended to be inflexible, but rather are to be used as general guidelines that will apply in most situations. The national and state design standards are considered to represent the "state of the art" in the highway engineering. They are reference sources known and accepted in the highway design profession.

In brief, the rule implements the act and provides a reference for the public and the personnel of the State Department of Highways in applying for and administering, respectively, permits for access to state highways.

STATEMENT OF BASIS AND PURPOSE BY THE COLORADO HIGHWAY COMMISSION REGARDING AMENDMENTS TO THE RULE AND REGULATION KNOWN AS THE STATE HIGHWAY ACCESS CODE

JULY 15, 1982

The Department of Highways proposed amendments to the existing State Highway Access Code and after a public hearing at which the entire record was considered the Colorado Highway Commission adopted these amendments as rules and regulations.

The purposes of these amendments are to:

1) Clarify certain portions of the original rules by correcting grammar, spelling, and syntax errors and by adding definitions;

2) Set forth procedures to ensure the owner of the surface rights of property concurs in an application for access;

3) Ensure the permittee is required to sign an access permit when one is issued;

4) Set forth more precisely standards for accepting applications for access permits and explain how to handle incomplete applications;

5) Make clear the options available and time limits applicable to an applicant when a permit is denied;

6) Add a method by which local governments may obtain permission to construct an access approach that is not a driveway;

7) Remind public entities issuing access permits of their authority to establish reasonable fee schedules;

8) Set forth the duties of the Department regarding access when it undertakes a reconstruction project;

9) Streamline and clarify administrative procedures;

10) Ensure all traffic control devices installed in the construction of access approaches, meet the Department standards and specifications; and

11) Modify design standards and specifications regarding access applications and permits.

The basis for these amendments is the authority set forth in CRS 1973, 43-2-147, as amended. The need for the amendments is to fine-tune the access code in response to problems encountered in its first year of use.

STATEMENT OF BASIS, SPECIFIC STATUTORY AUTHORITY, AND PURPOSE REGARDING REVISIONS OF OCTOBER 18, 1984

On April 5, 1984 House Bill 1280 was signed into law by the Governor. This bill made certain amendments to section 43-2-147, C.R.S. also known as the highway access statute.

The specific statutory authority for the Commission to adopt the State Highway Access Code, 2 CCR 601-1 and amendments thereto as rule and regulation is found in section 43-2-147(4), C.R.S.

The rule amendments adopted by the Commission are only those necessary to bring the State Highway Access Code into compliance with 1984 House Bill 1280. This is the purpose of the Commission's action.

Amendments to the access code result in the following; (1) Removes one step in the administrative appeal process thereby allowing the plaintiff to proceed to judicial review following the decision of a hearing officer. (2) Makes a minor change that under certain circumstances limits the Department of Highways ability to take administrative action regarding changes in land use and driveway operations. (3) Further defines the allowance of variances and the possible result of failure to issue a variance.

STATEMENT OF BASIS, SPECIFIC STATUTORY AUTHORITY AND PURPOSE REGARDING REVISIONS OF AUGUST 15, 1985

After reviewing proposed amendments to the current State Highway Access Code from the State Department of Highways and other interested parties, and after a public hearing at which the entire record was considered, the Colorado Highway Commission adopted amendments as rule and regulation. Specific authority for this rule-making is vested in the Commission under section 43-2-147, C.R.S. (1984).

The purpose of the amendments are to:

1. Improve the grammar, sentence structure, and wording of the rules in order to improve clarity and reduce misinterpretations;
2. Provide nine new definitions for improved understanding;
3. Update recommended references;
4. Relocate and reorganize several paragraphs and procedural requirements, and provide some new subsection titles to make the code easier to read and use;
5. Remove the phrase "access approach" and substitute the term "access";
6. Make improved and greater use of the term "issuing authority" which includes the local issuing authority and the State Department of Highways;
7. Streamline and make more practical certain procedures;
8. Specify some of the access application attachments necessary for access review and allow the issuing authority not to accept incomplete applications;
9. Allow the issuing authority to record decisions with the county clerk and recorder;

10. Cancel extended permits for which construction has not been commenced within three years;
11. Require dedication of property to the Department of Highways when highway access improvements that must be maintained by the issuing authority are constructed on private property;
12. Provide for bonding for highway reconstruction;
13. Provide for permit phasing, delay in construction plans submitted and other items to reduce or delay certain permit and application requirements;
14. Provide for improved enforcement when permits are violated and allow the issuing authority to expend public funds to improve safety problems caused by permit violations and provides for reimbursement by the permittee;
15. Define when changes in property use as the result of changes in access operation require conformance with the code;
16. Emphasize the responsibility of local authorities to maintain conformance with the code where local roadways access the state highway;
17. Provide for the development and Commission approval of interchange management plans;
18. Provide that all overpasses, underpasses, structures, ramps, and highway sections between frontage roads and the main highway be access category 2;
19. Include signal system efficiency as another criteria for new traffic signal locations;
20. Improve and update several design and construction requirements for clarification, safety and in response to new nationally recommended standards;
21. Amend the auxiliary lane table criteria with new graphs based on theoretical conflict analysis;
22. Provide for bike paths at the request of local authorities;
23. Provide for the installation of traffic control devices; and
24. Provide for clear zone next to highways.

SECTION ONE
INTRODUCTION

1.1 Authority:

This code is promulgated pursuant to section 43-2-147(4), C.R.S. 1984, as amended which directs the Colorado Highway Commission to adopt a State Highway Access Code to implement the section on all state highways. The Commission shall determine the functional classification of all State highways. Section 43-2-147 authorizes the State Department of Highways and local governments to regulate vehicular access to or from any public highway under their respective jurisdiction from or to property adjoining a public highway.

1.2 Purpose:

1. It is the purpose of this code to provide the procedures and standards necessary to protect the public health, safety and welfare, to maintain smooth traffic flow, to maintain highway right-of-way drainage, and to protect the functional level of public highways while meeting state, regional, local, and private transportation needs and interests.

2. The lack of adequate access management of the highway system and the proliferation of driveway and other direct access to the state highway system is a major contributor to highway accidents and has been the greatest single factor behind the functional deterioration of highways in the state. As new accesses are constructed and traffic signals erected, the speed and capacity of the highway decrease, and congestion and hazards to the traveling motorist increase. As a result, significant amounts of tax dollars must be spent to widen highways, provide additional operation and safety measures, and construct new highways. The economic and social costs of widening major highways are becoming almost prohibitive.

3. This code addresses the design and location of driveways and other points of access to public highways under the jurisdiction of the Colorado Highway Commission. It is based upon the authority granted in the Act and considers existing and projected traffic volumes, the functional classification of public highways, adopted local transportation plans and needs, drainage requirements, the character of lands adjoining the highway, adopted local land use plans and zoning, the type and volume of traffic to use the access, other operational aspects of the access, the availability of vehicular access from local streets and local roads rather than a state highway, reasonable access by local streets and local roads, and the public health, welfare, and safety.

4. This section describes the authority, purposes and structure of the code, and defines those words that are technical or variable in their meanings and require definition for the purposes of this code. Section two describes the administrative procedures for implementing this code which shall be followed with due regard for the rights and privileges of all interested parties. Section three defines five categories of standards to ensure smooth traffic flow and to maintain the functional level of thepublic highways. Section three also shall be used to determine if an access should be allowed within the context of the highway's function in the transportation system and the assigned access category. Section four provides standards for the design and construction of all accesses. These standards are based upon criteria and specifications necessary to ensure the public health, welfare, and safety.

1.3 Implementation:

1. After the effective date of the access code, no person shall construct any access providing direct vehicular movement to or from any state highway from or to property adjoining a state highway without an access permit issued by the designated issuing authority, and the written approval of the State Department of Highways. Within those jurisdictions where the local authority has returned issuing authority to the Department, the Department has sole authority to issue state highway access permits.

2. Access permits shall be issued only in compliance with the code and may include terms and condition authorized by the access code. In no event shall an access be allowed or permitted, if it is detrimental to the public health, welfare, and safety.

3. Vehicular access to or from property adjoining a state highway shall be provided to the general street system, unless such access has been acquired by a public authority. Police, fire, ambulance, and other emergency stations shall have a right of direct access to state highways. Direct access from a subdivision to the highway shall be permitted only if the proposed access meets the purpose and requirements of this code. After the effective date of the Act, no person may submit an application for subdivision approval to a local authority unless the subdivision plan or plat provides that all lots and parcels created by the subdivision will have access to the state highway system only in conformance with this code (subdivision is defined in article 28, title 30, C.R.S.). The provisions of this code shall not be deemed to deny reasonable access to the general street system.

1.4 Definitions and Abbreviations

These definitions are provided and adopted to explain certain technical words, phrases and abbreviations found in this code.

1. "Acceleration lane" means a speed-change lane, including tapered areas, for the purpose of enabling a vehicle entering a roadway to increase its speed to a rate of which it can more safely merge with through traffic. Section 42-1-102(1), C.R.S.

2. "Access" means any driveway or other point of access such as a street, road or highway that connects to the general street system. Where two public roadways intersect, the secondary roadway shall be considered the access.

3. "Access category" means the degree to which access to a state highway is controlled according to the five categories described in section three.

4. "Access control plan" means a roadway design plan which designates access locations and their designs for the purpose of bringing those portions of roadway included in the access control plan into conformance with their access category to the extent feasible. It is further defined in section two.

5. "Act" means section 43-2-147, C.R.S. (1984 Supp. as amended)

6. "Administrative Procedure Act" means Article 4, Title 24, C.R.S. as amended.

7. "ADT" means the annual average two-way daily traffic volume. It represents the total annual traffic for the year, divided by 365.

8. "Applicant" means owner of property or representative of owner applying for an access permit.

9. "Appropriate local authority" means the board of county commissioners if the access is to be located in the unincorporated area of a county and the governing body of the municipality if the access is to be located within an incorporated municipality. Also referred to as the local authority.

10. "Average Peak Hour Volume" means only for the purposes of this code, the same as design hour volume (DHV).

11. "AWD" means an average of weekday daily traffic volumes (five day week) in number of vehicles for a specific highway segment or access.

12. "Bandwidth" means the time in seconds or the percent of cycle between a pair of parallel speed lines which delineate a progressive movement on a time-space diagram. It is a quantitative measurement of the through traffic capacity of a signal progression system. A 10 percent bandwidth has very little traffic capacity, while a 40 percent bandwidth has good traffic capacity.

13. "Code" means for the purposes of this code This State Highway Access Code.

14. "Commission" means the Colorado Highway Commission.

15. "Control of access" means the condition in which the right of owners or occupants of land abutting to a roadway is controlled by public authority.

16. "Controlled-access highway" means every highway, street, or roadway in respect to which owners or occupants of abutting lands and other persons have no legal right of access to or from the same except at such points only and in such manner as may be determined by the public authority having jurisdiction over such highway, street, or roadway. [section 42-1-102(13), C.R.S. as amended.]

17. "Date of Transmittal" means the date the department forwards to the applicants, by U.S. mail or personal service, a permit for signature or a letter of denial. This date marks the end of the review period pursuant to the Act, (5)(a).

18. "Deceleration lane" means a speed-change lane, including tapered areas, for the purpose of enabling a vehicle that is to make an exit turn from a roadway to slow to a safe turning speed after it has left the mainstream of faster-moving traffic.

19. "Department" means the State Department of Highways, State of Colorado.

20. "Design Hour Volume" also "DHV" means a traffic vehicle volume determined for use in the geometric design of highways. Also see section 4.3.

21. "Divided highway" means a highway with separated roadways for traffic in opposite directions, such separation being indicated by depressed dividing strips, raised curbings, traffic islands, or other physical separations, or indicated by standard pavement markings or other traffic control devices.

22. "Driveway" means an access that is not a public street, road, or highway.

23. "Functional classification" means a classification system that defines a public roadway according to its purposes in the local or statewide highway plans.

24. "General street system" means the interconnecting network of city streets, county roads, and state highways in an area.

25. "Grade separation" means a crossing of two roadways, or a roadway and a railroad at different levels.

26. "Gradient" or "grade" means the rate or percent of change in slope, either ascending or descending from or along the highway. It is to be measured along the centerline of the roadway or access.

27. "Highway" means the entire width between the boundary lines of every way publicly maintained when any part thereof is open to the use of the public for purposes of vehicular travel or the entire width of every way declared to be a public highway by any law of this state [Section 42-1-102(33) C.R.S. as amended]. It includes bridges, culverts, sluices, drains, ditches, waterways, embankments, walls, trees, shrubs and fences [section 43-1-203, C.R.S.]

28. "Interchange" means a facility that grade separates intersecting roadways and provides directional ramps for access movements between the roadways. The structure and the ramps are considered part of the interchange.

29. "Interchange management plan" means a plan similar in nature to an access control plan but limited to the immediate influence area of an interchange for the protection of its functional integrity.

30. "Issuing authority" means the government entity which issues access approach permits and includes the board of county commissioners, the governing body of a municipality, and the State Department of Highways [section 43-2-147(8)(e), C.R.S.].

31. "Lane" means the portion of a roadway for the movement of a single line of vehicles and does not include the gutter or shoulder of the roadway.

32. "Local government" means the board of county commissioners if the highway section is located in an unincorporated area of a county and the governing body of the municipality if the highway section is located within an incorporated municipality.

33. "Local road" means a county road, as provided in section 43-2-108 to 110, C.R.S. as amended.

34. "Local street" means a municipal street, as provided in Section 43-2-123 to 125, C.R.S. as amended.

35. "M.U.T.C.D." means the Manual on Uniform Traffic Control Devices and the Colorado supplement thereto referenced at subsection 1.5. Refer also to Section 42-4-501, C.R.S. as amended.

36. "Median" means that portion of a highway separating the opposing traffic flows.

37. "MPH" means a rate of speed measured in miles traveled per hour.

38. "Permit issue date" means the date when the authorized department official signs the permit after the permittee signs and pays any required fees.

39. "Permittee" means the individual(s) who is responsible for fulfilling all the terms and conditions of the permit.

40. "Potential for signalization" means an access that has the potential within the life of the permit to exceed 50 vehicles per hour for eight hours in an average day or has potential to meet any of the warrants for a traffic signal as defined by the M.U.T.C.D.

41. "Roadway" means that portion of a highway improved, designed or ordinarily used for vehicular travel exclusive of the berm or shoulder. In the event a highway includes two or more separate roadways, "roadway" refers to any such roadway separately but not to all such roadways collectively [section 42-1-102(67), C.R.S.].

42. "State highway" means a highway on the state highway system as defined in Section 43-2-101, C.R.S.43. "Sight distance" means the distance visible to the driver of a passenger vehicle measured along the normal travel path of a roadway to a specified height above the roadway when the view is unobstructed by traffic.

44. "Signal" or "signalization" means a traffic control signal or device.

45. "Signal progression" means the progressive movement of traffic, at a planned rate of speed without stopping, through adjacent signalized locations within a traffic control system.

46. "Speed change lane" means a separate lane for the purpose of enabling a vehicle entering or leaving a roadway to increase or decrease its speed to a rate at which it can more safely merge or diverge with through traffic. Acceleration and deceleration lanes are speed change lanes.

47. "Stopping sight distance" means the distance required by a driver of a vehicle, traveling at a given speed, to bring the vehicle to a stop after an object on the roadway becomes visible. It includes the distance traveled during driver perception and reaction times and the vehicle breaking distance.

48. "Storage lane" means additional lane footage added to a deceleration lane to store the maximum number of vehicles likely to accumulate during a peak period so as not to interfer with the through travel lanes.

49. "Time" for the purposes of this Code, all time periods allowed by these rules and the Act shall be computed in accordance with Rule 6(a), of the Rules of Civil Procedure, Volume 7A, Colorado Revised Statutes.

50. "Time-space diagram" means a chart on which the distance between signals and signal timing is plotted against time. The chart, when completed, indicates signal progression, bandwidth and speed of traffic.

51. "Traveled way" means that portion of roadway for the movement of vehicles, exclusive of shoulders and auxiliary lanes.

52. "Working day" means any day that the permittee can perform a normal day of work exclusive of delays which result from inclement weather, labor disputes and material shortages. It does not include weekends and legal holidays.

1.5 References

The standards and specifications contained in sections three and four of this code are based upon good engineering judgment of the following standard engineering references used by the State Department of Highways. These references are revised and amended from time to time. When appropriate, the Code will be amended to reflect changes in these references.

1. *A Policy on Geometric Design of Highways and Streets*, American Association of State Highway and Transportation Officials, Washington, D. C. 1984.

2. *Transportation and Traffic Engineering Handbook*, Institute of Transportation Engineers, Washington, D.C., 1982.

3. *Manual on Uniform Traffic Control Devices for Streets and Highways*, (M.U.T.C.D.), U.S. Department of Transportation and the Federal Highway Administration, Washington, D. C., as amended.

4. *The Colorado Supplement to the Manual on Uniform Traffic Control Devices for Streets and Highways*, State Department of Highways, as amended.

5. The current editions of the following manuals and standards of the State Department of Highways:

   a. *Roadway Design Manual*, as amended
   b. *Materials Manual*, as amended
   c. *Construction Manual*, as amended
   d. *Standard Specifications for Road and Bridge Construction*, as amended.
   e. *Colorado Standard Plans*, as amended.

6. *Evaluation of Techniques for the Control of Direct Access to Arterial Highways*, Report No. FHWA-RD-76-85, Federal Highway Administration, Washington, D. C. 1975.

7. *Trip Generation*, Third edition, Institute of Transportation Engineers, Washington, D.C. 1982. (525 School Street, S.W., Suite 410, Washington D.C. 20024, ATTN: Publications, Miss Lee, I.T.E. member $35.00, plus 10% postage, non-member $50.00 plus 10% postage).

SECTION TWO
ADMINISTRATION

2.1 Purpose

This section provides the administrative procedures and related information and standards for the implementation of the code. Any additional administrative procedures not defined herein or in the Act should comply with the "State Administrative Procedure Act", Article 4, Title 24, C.R.S., to the extent applicable.

2.2 Access Category Assignments

1. The Colorado Highway Commission shall assign to each highway section or segment of highway an access category from section three of this code based upon the present National Highway Functional Classification, consideration of existing and projected traffic volumes, the functional classification of public highways, adopted local transportation plans and needs, the character of lands adjoining the highway, adopted local land use plans and zoning, the availability of vehicular access from local streets and roads rather than a state highway, and reasonable access by city streets and county roads.

2. The process to determine the access category assignments shall include the following: (1) The Department shall prepare a draft access category assignment schedule consistent with subsection 2.2.1, and section three for each state highway. (2) The appropriate parts of the draft documents shall be sent to the appropriate local authorities and the metropolitan planning organizations for their review and comment (3) At the request of the appropriate local authority, or upon the Department's initiative public meetings may be held by the Department to discuss the proposed category assignments. (4) Based upon the comments received, the Department shall work toward resolving any differences. (5) The Department shall prepare a final draft which shall be published pursuant to section 24-4-103(3) C.R.S. (6) The final draft along with all written comments received shall be presented to the Commission for consideration and action. (7) Upon commission adoption of the access category assignment schedule, the Department shall complete any necessary procedures to make it effective. (8) The approved category assignment schedule shall be made available to the public, all issuing authorities and local governments.

3. The appropriate local authority or the Department may submit to the Commission requests for changes in the adopted access category schedule for sections of state highway within their jurisdiction. All requests shall include an explanation for the requested change consistent with the purposes of the Act and the standards of this code. The Department shall review and provide a recommendation to the Commission on each request. The appropriate local authority shall be notified of requested changes by the Department at least 60 days prior to Commission action. The appropriate local authority will be provided with a copy of all pertinent documents 30 days prior to Commission action. A meeting between the local authority and the Department shall be held prior to Commission action if the local authority so requests. The Commission shall act upon pending category change requests no less than once each six calendar months, and more often as necessary. All reasonable local authority requests that are in compliance, with the purposes of this code and the standards outlined in Subsection 2.2.1, shall receive a favorable recommendation from the Department.

2.3 Obtaining a Permit

1. The Act provides to each appropriate local authority the authority to issue driveway permits to state highways within its jurisdiction. Each permit must receive the written approval of the Department to be valid. The local authority may request that the Department administer or assist in the administration of driveway permits if it does not desire to administer driveway permits.

2. Persons wishing to apply for direct access to a state highway should contract their appropriate local authority or a Department of Highway's office in their region to determine who is responsible for processing permit applications. Regional offices are located in Alamosa, Aurora, Craig, Denver, Durango, Grand Junction, Greeley, and Pueblo. Requests must be submitted on standard access permit application forms obtainable from the issuing authority. The issuing authority or Department may require any of the following items or others, when relevant to the evaluation of an access application or construction of an access: A) Highway and driveway plan and profile. B) Complete drainage plan of the site showing impact to the highway right-of-way. C) Map and letters detailing utility locations before and after development in and along the highway. D) A subdivision zoning or development plan. E) Property map indicating other access and abutting public roads and streets, and F) Proposed access design.

3. Upon written request to the Department by the appropriate local authority, the Department shall administer or assist in the administration of driveway permits to the state highway system in that jurisdiction. This authorization may be changed by the local authority at any time by written notification to the Department. Changes in authorization shall take effect upon receipt of the written notice by the Department. If the local authority requests that the Department process the access permit application and requires local authority approval prior to final action, this shall constitute Department assistance, not administration, and the local authority shall remain the issuing authority.

2.4 Application for an Access Permit to the State Highway When the Appropriate Local Authority is the Issuing Authority

1. The applicant shall submit the completed access permit application (Department Form No. 137) and any required attachments to the appropriate local authority. If the applicant is other than the surface rights owner of the property to be served, then the applicant must include written evidence of concurrence in the application by the surface rights owner. The issuing authority may require from the applicant information needed to evaluate the impacts of the proposed access on the general street system regarding the regulatory purposes of the Act. The issuing authority may refuse to accept the application when necessary and relevant information is missing from the application or when there is no written evidence that the owner(s) of the property surface rights concurs in the application. The applicant shall be notified of what is missing from the application. The local issuing authority shall date and initial or stamp the original copy with the date of acceptance. A 45 day review begins with the acceptance of the application. A copy of the application form shall be mailed or delivered by the issuing authority to the appropriate local office of the Department within ten days of application acceptance.

2. Upon acceptance of the permit application and any required attachments, the issuing authority shall use this code, the Act and any other applicable state statutes for evaluating and action on the application. The issuing authority should work cooperatively with the applicant in attempting to resolve all difficulties prior to taking final action on the application. It is

recommended that the issuing authority consult with the Department to help avoid differences that might arise during Department review. The issuing authority shall complete its review and take final action to approve or deny the request within 45 days. After 45 days from the date of application acceptance, if the Department has not received notice from the issuing authority of their final action on the permit application, the Department shall notify the issuing authority and take final action on the application within 20 days as required by the Act.

3. If an applicant wishes to seek a variance from the standards of the code, a request must be submitted as an attachment to the permit application form. Department Form No. 112 may be used. Subsection 2.8 should be reviewed for further information.

4. The access permit completed by the issuing authority shall conform to all sections of this code. Variance procedures, subsection 2.8, may be used where the design standards of this code are not entirely applicable given proposed access site specific conditions and local considerations. If the issuing authority does not approve the permit application, it shall 1) provide the applicant with a copy of the permit application marked "denied" along with copies of any attachments and a written explanation of the decision, and 2) provide the Department with a copy of the denied application and the written explanation. The Department shall not reverse the denial decision by the issuing authority. Any appeal by the applicant of local action shall be to the local issuing authority and shall be consistent with the appeal procedures of that issuing authority. The Department shall be notified of appeals made of local issuing authority actions on state highway access permits and applications.

5. If the issuing authority approves the application and access, a permit shall be prepared. The issuing authority shall sign and transmit the permit with all attachments and pertinent information to the appropriate district engineer of the Department or designated representative. If the Department fails to act within 20 days from receipt of the transmitted materials, the permit shall be deemed approved and an appropriate permit issued in accordance with the design and construction standards of the code. Transmittal of the permit application, unsigned by the issuing authority, for the purpose of obtaining the Department's comments prior to local approval, does not constitute the initiation of the 20 day review period.

6. If the permit is approved by the local issuing authority, the Department shall review the permit for compliance with this code, the Act and other state statutes which may be applicable. If necessary, the Department shall discuss the permit application with the applicant and the issuing authority. Before denying a permit, the Department shall discuss the reasons for the denial with the applicant and the issuing authority so long as time remains within the review period. The Department may request a meeting with the issuing authority and the applicant.

7. If the Department denies the permit, the Department shall provide copies of the permit and attachments marked 'denied' to the applicant along with a written explanation for the decision, and shall provide the issuing authority with a copy of the denied permit and the written explanation. Appeals of Department action may be made pursuant to subsection 2.7.

8. If the Department approves the permit, the permit shall be transmitted to the applicant for signature. This transmittal constitutes action on the permit as required by subsection 5(a) of the Act. It is the responsibility of the applicant to obtain the signature of the permittee. The permittee noted on the permit will normally be the surface rights owner. The permittee shall sign the permit if the terms and conditions are acceptable and return the entire permit with any required permit fee to the Department at the address noted. If the Department has not received the signed copy and fee payment, if any, from the applicant within 60 days of the date

of transmittal, the permit may be deemed unacceptable to the permittee and therefore denied. After receiving the signed permit and fee payment, if any, the Department shall mark the permit paid, assign a permit number to the permit, sign the permit, and return a copy to the applicant. The Department shall provide a copy of the completed permit and any collected fees to the issuing authority. If the permittee does not agree to all the terms and conditions of the permit, the permit shall be deemed denied.

9. The issue date of the permit is the date the Department representative signs the permit which is after the permittee has signed the permit and paid any required fees.

10. The permitted access shall be completed in accordance with the terms and conditions of the permit prior to being used. In accepting the permit, the permittee agrees to all terms and conditions of the permit. Should the applicant or permittee choose to appeal a denied application, or the terms and conditions of a permit, the appeal must be filed within 60 days of the date of transmittal of the notice of denial or transmittal of the permit for signature. Any appeal of actions or permit terms or conditions of the local issuing authority shall be to the local issuing authority consistent with its appeal procedures.

11. Final action on a permit application by the issuing authority or the Department is not considered action on a previously issued legal permit unless so stated as terms and conditions of a newly accepted permit.

2.5 Application for an Access Permit to the State Highway when the State Department of Highways is the Issuing Authority.

1. The applicant shall submit the completed access permit application (Department Form No. 137) and any required attachments to the appropriate district engineer of the Department or his designated representatives. If the applicant is other than the surface rights owner of the property to be served, then the applicant must include written evidence of concurrence in the application by the surface rights owner. The Department may require from the applicant any information needed to evaluate the impacts of the proposed access on the general street system in regards to the regulatory purposes of the Act. The Department may refuse to accept the application when necessary and relevant information is missing from the application, or when there is no written evidence that the owner of the property surface rights concur in the application. The applicant shall be notified as to what is missing from the application. A 45 day review begins with the acceptance of the application.

2. Upon acceptance of the application materials, the Department shall use this code, and the Act any other applicable state statutes for evaluating and acting on the application. The Department should work cooperatively with the applicant and attempt to resolve all difficulties prior to taking final action on the application. If the Department fails to act within 45 days upon acceptance of an application for an access permit, such application shall be deemed approved and the Department shall prepare and issue an appropriate access permit without delay in accordance with the design and construction standards of the code. Transmittal of a completed permit for the permittee's signature or transmittal of the denied application constitutes action as required by the Act.

3. Requests for variance from the standards of this code may be submitted to the Department by the applicant or initiated by the Department and shall be considered an attachment to the application. The request and review of the variance shall be consistent with subsection 2.8 and include specific written and documented reasons for the request.

4. A completed access permit shall conform to all sections of this code. Variance procedures, subsection 2.8 may be used where the design standards of this code are not entirely applicable given proposed access site specific conditions and local considerations. Before denying an access application, the Department shall discuss the reasons for the denial with the applicant so long as time remains within the review period. The Department may request a meeting with the applicant, which may include the local government, and attempt to resolve the reasons for the denial.

5. If the Department denies an application, the Department shall provide the applicant a copy of the application marked "denied" along with any attachments and a written explanation for the decision.

6. If the Department approves an application, a permit shall be prepared and transmitted to the applicant for signature. This transmittal constitutes action upon the permit as required by subsection 5(a) of the Act. It is the responsibility of the applicant to obtain the signature of the permittee. The permittee noted on the permit will normally be the surface rights owner. The permittee shall sign the permit if the terms and conditions are acceptable and return the entire permit with the required permit fee payment to the Department at the address noted within 60 days from the date of transmittal by the Department. After receiving a signed permit and any required fee payment, the Department shall mark the permit paid, assign a permit number to the permit, sign the permit, and return a copy to the applicant. The Department shall provide a copy of the permit to the appropriate local authority if so requested. If the permittee does not agree to all the terms and conditions of the permit, the permit shall be deemed denied.

7. The issue date of the permit is the date the Department representative signs the permit which is after the permittee has signed the permit and paid any required fees.

8. The permitted access shall be completed in accordance with the terms and conditions of the permit prior to being used. In accepting the permit the permittee agrees to all terms and conditions of the permit. Should the permittee or applicant choose to appeal a denied application, or the terms and conditions of a permit, the appeal must be filed within 60 days of the date of transmittal of the notice of denial or transmittal of the permit for his signature according to subsection 2.7.

9. Final action on a permit application by the issuing authority is not considered action on a previously issued and legal permit unless so stated as a term and condition of a new accepted permit.

2.6 Access Requests By Local Authorities

1. Requests by appropriate local authorities for new access or for the reconstruction of existing access to the state highway shall be administered by the Department as discussed under subsection 2.5 or by written agreement between the Department and the local authority. The local authority shall be considered the applicant. The Department shall work cooperatively with local authority realizing that the access will serve multiple property owners. Access to subdivisions and other developments shall be considered private access and applied for pursuant to subsections 2.4 or 2.5 until the access is constructed and accepted as a local public roadway.

2.7 Appeals

1. Should the permittee or applicant object to a permit application denied by the Department or object to any of the terms or conditions of the permit placed therein by the Department, an appeal must be filed with the Colorado Highway Commission within 60 days of transmittal of notice of denial or transmittal of the permit for signature. The decision by the Commission or by a hearing officer shall be considered final agency action and subject to judicial review pursuant to the provisions of section 24-4-106, C.R.S. (1982)

2. The permittee or applicant wishing to appeal to the Commission shall file the request for the hearing in writing and submit it to the Colorado Highway Commission, 4201 East Arkansas Avenue, Denver, Colorado 80222. The request shall include reasons for the appeal and may include recommendations by the permittee or applicant that would be acceptable to him.

3. The Department may consider any objections and requested revisions at the request of the applicant or permittee. If agreement is reached, the Department, with the approval of the local issuing authority (if applicable), may revise the permit accordingly, or issue a new permit, or require the applicant to submit a new application for reconsideration. Changes in the original application, proposed design or access use will normally require submittal of a new application.

4. Regardless of any communications, meetings, or negotiations with the Department regarding revisions and objections to the permit or a denial, if the permittee or applicant wishes to appeal the Department's decision to the Commission, the appeal must be brought to the Commission within 60 days of transmittal of notice of denial or transmittal of the permit.

5. Any appeal by the applicant or permittee of action by the local issuing authority when it is the appropriate local authority (under subsection 2.4), shall be filed with the local authority and be consistent with the appeal procedures of the local authority.

6. If the final action or denial is not further appealed, the Department or local authority may record the decision with the County Clerk and Recorder.

2.8 Variance Procedures

1. If an applicant wishes to seek a variance from the standards of this code, a request must be submitted as an attachment to a permit application form. Department Form No. 112 should be used. The request for variance shall include specific and documented reasons. The request and supporting documents should be submitted at the time of permit application.

2. The applicant may supplement the application with a variance request if the issuing authority determines that sufficient time remains in the mandatory review period to consider the variance. In the public interest, the issuing authority may supplement a permit application with a variance.

3. The issuing authority shall consider the variance request along with the permit application. If the variance and remainder of the application is acceptable, a permit shall be approved and the approved variance included in the application file. In consideration of the variance request, the issuing authority shall determine if, (a) there is exceptional and undue hardship on the applicant, and (b) a variance would not be detrimental to the public health, welfare and safety, and (c) a variance is reasonably necessary for the convenience and welfare of the public. Valid consideration shall also be given to the land use plans, policies, and local traffic circulation operations of the local jurisdiction.

4. The issuing authority shall grant a variance from the state highway access code if such variance would be consistent with paragraph (a) of subsection (1) of the Act and if such variance is reasonably necessary for the convenience, safety, and welfare of the public. If failure to grant a variance would deny reasonable access to the general street system, such denial may be subject to the provisions of section 43-1-208, C.R.S. (1984), and section 15 of article II of the state constitution.

5. If the variance request is denied, the issuing authority shall continue to process the permit application and issue a permit if it can be approved without a variance. If failure to grant a variance or the permit denies reasonable access to the general street system, such denial may be subject to section 43-1-208, C.R.S. on requirements of eminent domain and section 15, article II of the state constitution on compensation.

6. The recommendations and actions of the Department regarding the variance shall be in writing with pertinent information attached and shall be included as part of the permit application record. The Department may include in its action any special terms and conditions that shall be imposed on the permit if approved.

2.9 Construction of Access

1. The permit shall be deemed expired and null and void if the access is not under construction within one year of the permit issue date or before the expiration of any authorized extension. When the permittee is unable to commence construction within one year after the permit issue date, he may request a one year extension from the issuing authority. No more than two extensions may be granted. If the access is not under construction within three years from date of issue the permit will be considered void. Any request for an extension must be in writing and submitted to the issuing authority before the permit expires. Denial of an extension may occur only when the issuing authority ascertains and documents that unforeseen and significant changes in highway traffic operations, proposed access operation, or statutes and rules that were not considered in the issuing of the permit have occurred. The issuing authority shall obtain the concurrence of the Department, prior to the approval of an extension, and shall notify the Department of all denied extensions within ten days. Any person wishing to reestablish an access permit that has expired may begin again with the application procedures.

2. The expected dates of construction and use of the access shall be included on the application form. The permittee shall have the individual or the office specified on the permit notified of the pending construction at least 48 hours prior to any construction in state highway right-of-way. The access shall be completed in an expeditious and safe manner and shall be finished within 45 days from initiation of construction within the highway right-of-way. A construction time extension not to exceed 30 working days may be requested from the individual or office specified on the permit.

3. The issuing authority or the Department shall inspect the access during construction and upon completion of the access to ensure that all terms and conditions of the permit are met. All highway access improvements including pavement, curbs, gutters, sidewalks, drainage structures, ditches, and auxiliarylanes, shall be on public right-of-way. Property required for highway access improvements shall be dedicated without cost to the Department.

4. The construction of the access and its appurtenances as required by the terms and conditions of the permit shall be completed at the expense of the permittee except as provided in subsection 2.10. The permittee may arrange for this work to be done by qualified contractors.

Work shall be accomplished under Department or local authority inspection and shall meet all Department specifications. The Department or local authority may bill the permittee for direct costs and labor provided by the Department for the installation and relocation of all traffic control devices within public right-of-way directly related to the use of the permitted access. Where construction requires the reconstruction of the existing main lanes of the highway, the Department may require the contractor or permittee to post a bond to ensure completion of the work.

5. Where it is necessary to evaluate the construction details of a proposed access in order to take final action on a permit application, the application shall provide construction drawing of sufficient detail. All construction drawings shall be completed to the detail necessary to ensure that the construction of the access will be in compliance with the permit terms, and conditions, including materials specifications. Detailed drawings may be submitted after the approval of the permit and prior to access construction when the level of detail is not necessary for conditional permit approval but is necessary to ensure construction compliance.

6. A conditional permit shall be issued if any construction plans or other specified items are allowed to be completed after the issuance of the permit. When completed, these items must receive the approval of the issuing authority and the Department prior to proceeding with any construction within the highway right-of-way. If for any reason, the issuing authority or Department and the permittee cannot resolve disagreements regarding the approval of the final plans or other conditional requirements, the permit shall be deemed denied and the permittee given 60 days to file an appeal pursuant to subsection 2.7.

7. It is the responsibility of the permittee to complete the construction of the access according to the terms and conditions of the permit. If the permittee wishes to use the access prior to completion, arrangements must be approved by the issuing authority and Department and included on the permit. The Department or issuing authority may order a halt to any unauthorized use pursuant to statutory and regulatory powers. Reconstruction or improvement to the access may be required when the permittee has failed to meet required specifications of design or materials. If any construction element fails within two years due to improper construction or material specifications, the permittee is responsible for all repairs.

8. When closure of the access is a hardship on access users and the Department or issuing authority has been unsuccessful in obtaining compliance with the permit by the permittee, and an immediate safety hazard exists with the continued use of the access, the Department or issuing authority may complete the necessary modifications with public funds. The permittee shall reimburse the public expenditure. The Department or issuing authority shall require reimbursement of these public funds by the permittee, his agents, heirs, successors-in-interests and assigns, by available statutory authority.

9. Upon request the phasing of the installation of access design requirements may be allowed if the use of the access at any time does not exceed the constructed design and the Department or local authority is provided monetary or legal guarantees that access permit terms and conditions will be met prior to any use of the access exceeding the existing design of the access. The following items may be used in this regard: bonding, irrevocable letter of credit, certificates of deposit, inclusion in zoning ordinance, inclusion in subdivision plats or land use permit requirements, inclusion in the deeds to the properties involved and any other techniques as approved and accepted by the Department. All such arrangements shall be included as terms and conditions of the permit. The local authority or Department may record notices in the county records of such agreements to inform future property owners of potential liabilities and responsibilities.

10. Adequate advance warning is required at all times during access construction, in conformance with the Manual on Uniform Traffic Control Devices for Streets and Highways. This may include the use of signs, flashers, barricades and flaggers. This is also required by section 42-4-501, C.R.S. as amended. The issuing authority, the Department and their duly appointed agents and employees shall be held harmless against any action for personal injury or property damage sustained by reason of the exercise of the permit.

11. The hours of work on or immediately adjacent to the highway may be restricted due to peak hour traffic demands and other pertinent roadway operating restrictions.

12. A copy of the permit shall be available for review at the construction site. If necessary, minor changes and additions shall be ordered by the Department or local authority field inspector to meet unanticipated site conditions.

13. The permit may require the contractor to notify the individual or office specified on the permit at any specified phases in construction to allow the field inspector to inspect various aspects of construction such as concrete forms, subbase, and base course compaction.

2.10 Use of Access

1. Where in the course of highway reconstruction by the Department it is necessary to reconstruct, relocate, or bring into conformance with this code an existing access, the Department shall initiate the appropriate procedures and agreements. Where the local authority retains issuing authority, the Department may request temporary administrative authority to issue access permits for any access within a designated highway project segment, or the issuing authority will be requested to concur in each access permit prior to permit approval by the Department. Access permits issued within the project limits shall be constructed within two years from the date of issue. Extensions may be approved. Construction procedures and timing will be consistent with any project contract requirements. Procedures for these actions shall be consistent with the provisions of the State Administrative Procedure Act and, when necessary, the standard procedures of eminent domain.

2. It is the responsibility of the property owner to ensure that the use of the access to the property is not in violation of the code, permit terms and conditions or the Act. The terms and conditions of the permit are binding upon all assigns, successors-in-interest and heirs.

3. When there are changes in property use which result in changes in the type of access operation, and the access is not in conformance with the code, the reconstruction, relocation, or conformance of the access to the code may be required when any one of the following access change criteria occur or will occur as a result of changes in property use.

   A. The use of the access increases in actual or proposed vehicular volume by 20 percent.

   B. A particular directional characteristic (such as left turns) increases by 20 percent.

   C. The change in the use of the property or modifications to the property causes the flow of vehicles entering the property to be restricted or to queue or hesitate on the highway creating a highway hazard.

   D. The use of the access by vehicles exceeding 30,000 pounds gross vehicle weight increases by 20 percent or by 10 vehicles per day.

E. If a parcel of land with direct highway access has been in a state of non-use for more than four years, recommencement of access use shall be considered a change in use. If the use of the access exceeds the design limitations of the access or is non-conforming with the present code, a new permit may be required.

Change in property use may include but is not limited to; structural modifications, remodeling, change in type of business, expansion in existing business, change in zoning, change in property division creating new parcels. It does not include modifications in advertising, landscaping, general maintenance or aesthetics that do not affect internal or external traffic flow or safety.

4. Vehicular use and operation of public accesses (county roads and municipal streets) to the state highway is the responsibility of the appropriate local authority. The local authority should maintain access conformance with the code to the extent feasible and practicable within statutory and public funding limitations. The local authority may fund any necessary improvements by requiring contributions from the primary users of the access or as off-site subdivision improvements necessary for the public safety pursuant to section 30-28-133 and 133.1, C.R.S. and section 31-23-201 to 227, C.R.S., or other available public funds.

5. The Department may, when necessary for the improved safety and operation of the roadway, rebuild, modify, remove, or redesign the highway including any auxiliary lane.

6. Any driveway, whether constructed before, on, or after June 30, 1979, may be required by the Department with written concurrence of the appropriate local authority to be reconstructed or relocated to conform to the access code, either at the property owner's expense if the reconstruction or relocation is necessitated by a change in the use of the property which results in a change in the type of driveway operation; or at the expense of the Department if the reconstruction or relocation is necessitated by changes in road or traffic conditions. The necessity for the relocation or reconstruction shall be determined by reference to the standards set forth in the code.

7. Action pursuant to this code by the local authority or Department against an existing legal access either to revoke, suspend, limit, reconstruct, relocate or modify the access shall be accomplished pursuant to the Administrative Procedure Act if by Department action, and the administrative and ordinance procedures of the local authority if action is by the local authority.

2.11 Illegal Access to the Highway

1. The Department may install barriers across or remove any access which provides direct access to a state highway which is constructed without an access permit after the effective date of the code. The property owner shall be sent written notice of the Department's action within ten days. When practical, the Department will notify the property owner and or illegal access user of pending action. Any person who drives a vehicle onto or from any State Highway except at permitted access locations commits a class three traffic offense pursuant to section 42-4-910, C.R.S., as amended.

2. When a permitted driveway or any access is constructed or used in violation of this code, permit terms and conditions, or the Act, either the issuing authority or the Department or both may obtain a court order enjoining violation of the access code, permit terms and conditions, or the Act. Such access permits may be revoked by the issuing authority if, at any time, the permitted access and its use fail to meet the requirements of the Act, the access code, or the terms and conditions of the permit.

2.12 Access Control Plans

1. Either the Department or the appropriate local authority may, at its discretion, develop an access control plan for a designated portion of state highway.

2. An access control plan provides the appropriate local authority and the Department with a comprehensive roadway access design plan for a designated portion of state highway for the purpose of bringing that portion of highway into conformance with its access category to the extent feasible given existing conditions. The access control plan shall indicate existing and future access locations and all roadway access design elements, including traffic signals, that are to be modified and reconstructed, relocated, removed, added, or remain. All traffic control devices or modifications shall meet the requirements of the M.U.T.C.D. as required by state and federal statutes. The plan shall specify the assigned access category of the roadway and to the extent practical conform to all standards and specifications in section four of this code. At least one advertized public meeting shall be held during the development phase of the plan. All property owners of record abutting the state highway within the plan limits shall be notified by the Department or the appropriate local authority.

3. The plan must receive the approval of both the Department and the appropriate local authority to become effective. This approval shall be in the form of a formal written agreement signed by the local authority and the Chief Engineer of the Department. After an access control plan is in effect, modifications to the plan must receive the approval of the local authority and the Department. Where an access control plan is in effect, all action taken in regard to access shall be in conformance with the plan and this code unless both the Department and the local authority approve a variance under subsection 2.8 of this code.

2.13 Conformance of Subdivisions

After June 21, 1979, no person or persons may submit an application for the subdivision of property abutting a state highway to a local authority unless the subdivision plan or plat provides that all lots and parcels created by the subdivision will have access to the state highway system in conformance with this code. Direct access from the subdivision to the highway shall be permitted only if the access approach meets the requirements of this code. Depending upon the assigned access category, direct highway access may not be permitted to individual lots or parcels created by a subdivision.

2.14 Improvements to a Lawful Access

The property owner or his authorized representative served by a lawful access may make physical improvements to an access with the permission of the issuing authority and the Department. The applicant shall make the request on standard permit application forms and may specify that the request is for improvements according to this subsection. Processing shall be the same as discussed under 2.4 or 2.5 except the Department and local issuing authority may only take action on the request for improvement. Denial of the application for improvements does not constitute revoking the existing access authorization.

2.15 Permit Fees and Processing Forms

1. The issuing authority shall establish a reasonable schedule of fees for access permits issued pursuant to this code. The fees shall not exceed the costs of the administration of access permits. Local governments which are issuing authorities shall inform the Department of their fee schedules, if any.

2. The Department shall provide at reasonable cost to the issuing authority all official Department forms necessary for processing access applications, including the permit form and any other forms necessary to ensure consistent record keeping and legal and administrative action on the part of all those charged, in whole or in part, with the administration of this code.

2.16 Interchange Management Plans

1. An interchange management plan is a simplified roadway and right-of-way design plan for both intersecting highways, that includes the location of all access, public and private; traffic patterns, signal systems, signing and striping; the purchase of access rights where necessary; and any other controls that will ensure the continued protection of the functional integrity of the interchange as the interchange area develops.
2. A plan is required for any new interchange approval. The interchange and the management plan must receive the approval of the Commission unless such authority is delegated to the Chief Engineer of the Department.
3. Plan development procedures shall follow the requirements of subsection 2.12, Access Control Plans, where they apply. The design of the plan will be developed using good traffic operation planning and roadway design standards. No more specific design guidelines are given due to the high degree of variability in interchange design, topography, existing land use and transportation needs.

SECTION THREE
ACCESS CATEGORY STANDARDS

3.1 Purpose

This section provides a five level access control classification system. The levels are called categories. The number, spacing, type, and location of access and traffic signals often have a direct and significant effect on the capacity, speed, and safety of the highway. The design standards within each category are appropriate to ensure that the highway will continue to function at the level (category) assigned. Each state highway segment is assigned a category as provided in subsection 2.2 of this code. Access permits issued after August 31, 1981 shall meet the design standards of section three in accordance with this code, or as amended by an approved variance.

3.2 Use of This Section

The existing design of the highway is not required to meet the design standards of the assigned category at the time it is assigned. All new access permitting decisions shall be made pursuant to the code. This provides a mechanism for improving a highway to its functional purpose and integrity. The development of an access control plan is recommended as a comprehensive method of improving existing conditions and is the most effective way to deal with site specific conditions.

3.3 Deeded Access Rights

Along some sections of federal-aid state highway, access rights have been obtained and recorded by deed often at the time of highway construction. Where access is controlled by deed there is no right of direct access through the deeded section except at those locations, if any, and in such a manner as described by the deed and this code. The property owner so affected may inquire about changes or purchase of any deeded access rights. Access permits shall not be issued across sections of deeded access except as provided by the deed. The obtaining of access rights by deed is not regulated under this code.

3.4 Category One

Functional Characteristics

1. These highways have the capacity for high speed and high volume traffic movements over long distances in an efficient and safe manner, including interstate, interregional, intercity, and in larger urban areas, intracity travel. Federal aid interstate highways are typical of this category.

Design Standards

2. All opposing traffic movements shall be separated by physical constraints such as grade separations and median separators. Access, consisting of directional ramps, shall be suitably spaced and designed to provide the minimum differential between the speed of the through traffic stream and the speed of the merging or diverging vehicles. Location and design of access shall be determined on an individual basis by the Department in accordance with its authority under section 43-3-101 to 107, C.R.S. as amended, and federal regulations governing federal-aid highway design and construction. Each access allowed to a category one highway must receive the approval of the Commission pursuant to section 43-1-105, C.R.S. Access to interstate highways must also comply with federal regulations and receive Federal Highway Administration approval.

3.5 Category Two

Functional Characteristics

1. These highways have the capacity for efficient and safe high speed and high volume traffic movements, providing for interstate, interregional, and intercity, travel needs and some intracity travel needs. Service to abutting land is subordinate to providing service to major traffic movements. The function of category two is similar to category one. Category two is sometimes an early stage of development of a category one where category one design elements will be incorporated at a future date as priorities and funds allow. It is the highest category that permits at-grade intersections.

Design Standards

2. It is the intent that the design of category two highways be generally capable of achieving a posted speed limit of 55 MPH. Typical spacing of intersecting streets, roads and highways shall be planned on intervals of one mile and normally based upon section lines where appropriate. One-half mile spacing should be permitted only when no reasonable alternative access exists.

3. Unless otherwise specifically noted, a category two shall be assumed for all overpasses, underpasses, structures, ramps, and roadway sections between frontage roads and the main highway.

4. Private direct access shall not be permitted except when the property in question has no other reasonable access to the general street system. The following standards shall be applied when direct access must be provided.

   a. The access shall continue until such time that some other reasonable access to a lower functional category street or highway is available and permitted. The access permit should specify under what circumstances the change will be required, and if known, the future access location and the date the change will be made. At no time shall the property be denied reasonable access to the general street system pursuant to this code.

   b. All private direct access permitted under subsection 3.5.4, above shall be for right turns only unless: (1) the access approach does not have the potential for signalization, and (2) out of direction movement exceeds two miles, and (3) a left turn movement can be designed that meets all safety requirements.

   c. No additional access shall be provided upon the splitting or dividing of existing parcels or contiguous parcels under the same ownership or control. All access to the newly created properties shall be provided internally from the existing access or a new access determined by the permit application or subdivision procedures and be consistent with the requirements of this code.

5. All access provided shall be done so with the understanding that if the highway is reconstructed to a category one, alternative access may be provided by a frontage road or other means.

6. Opposing roadway traffic movements shall be separated by physical constraints such as grade separation or a median separator of sufficient design to physically prevent illegal movements.

7. Junctions with heavy intersecting traffic volumes should have either grade separations or interchanges.

8. Traffic signals should be programmed to allow 45 MPH speeds and a desirable bandwidth of at least 50 percent. Signals at intersections with major cross streets should be programmed to optimize traffic on both streets equally. The efficiency of the signal system should be analyzed including volume/capacity and level of service calculations.

3.6 Category Three

Functional Characteristics

1. These highways have the capacity for medium to high speeds or medium to high volume traffic movements over medium and long distances in an efficient and safe manner, providing for inter regional, intercity, and intracity travel needs. Direct access service to abutting land is subordinate to providing service to traffic movement.

Design Standards

2. It is the intent that the design of all category three highways be capable of achieving a posted speed limit of 45 MPH in urban signalized segments and preferably 55 MPH in undeveloped areas. The posted speed limit shall be used to meet the requirements of this code unless an approved access control plan to improve the highway requires that a higher speed limit be used.

3. Private direct access to the state highway system shall be permitted only when the property in question has no other reasonable access to the general street system or if the local authority and Department determine and agree that denial of direct access to the state highway and alternative direct access to another roadway would cause unacceptable traffic operation and safety problems to the overall traffic flow of the general street system. When direct access must be provided, the following shall be considered.

   a. Such access shall continue until such time that some other reasonable access to a lower function category street or highway is available and permitted. The access permit should specify under what circumstances the change will be required, and if known, the future access location and the date the change will be made. At no time shall the property be denied reasonable access to the general street system pursuant to this code. Subdivisions should be designed to provide for alternative access at a future date.

   b. No more than one access shall be provided to an individual parcel or to contiguous parcels under the same ownership unless it can be shown that: (1) additional access would be significantly beneficial to the safety and operation of the highway, or (2) allowing only one access would be in conflict with local safety regulations.

   c. An access shall be limited to right turns only unless, (1) the access does not have the potential for signalization, (2) a left turn would not create unreasonable congestion or safety problems and lower the level of service and, (3) in the determination of the issuing authority, alternatives to the left turn would cause unacceptable traffic operation and safety problems on the general street system.

   d. Private access which has the potential for signalization may be permitted left turn movements if, (1) it meets the signalization spacing requirements for intersecting public streets, roads and highways, as per subsection 3.6.5 below, and (2) it does not interfere with the location, planning, and operation of the general street system and access to nearby properties.

4. Since intersecting streets, roads and highways may in time warrant signalization, it is required that all intersecting streets, roads and highways, that allow left turns meet the signal spacing criteria under subsection 3.6.5. Those that do not meet these requirements shall be limited to right turns only unless they meet the requirements of subsection 3.6.3.

5. Spacing and Signalization

   a. For those rural highway sections where existing traffic signals are infrequent and where significant development is not expected in the foreseeable future, spacing of all intersecting public streets, roads, highways and other major accesses shall be on one-half mile intervals, plus or minus approximately 200 feet, and based upon section lines where feasible. Where topography makes one-half mile intervals inappropriate, location of any public access shall be determined by topography, property ownerships, property lines and physical design constraints. The final location should serve as many properties and interests as possible to reduce the need for direct private access to the state highway.

   b. In urban areas and developing areas where higher volumes are present or growth that will require signalization is expected in the foreseeable future, it is imperative that the location of any public access be planned carefully to ensure good signal progression. A spacing of one-half mile for all accesses should be maintained. This spacing is usually desirable to achieve good speed, capacity, and optimum signal progression.

   c. However, to provide flexibility for existing conditions and ensure optimum two-way signal progression, an approved traffic engineering analysis shall be made to properly locate any proposed access that may require signalization. The analysis shall consider any access that is existing and possible future signal locations for at least one mile in each direction as well as all potential roadway and signal system improvements. A progression analysis shall be completed which shall use a cycle length approved by the Department of between 90 and 120 seconds and a travel speed of 45 MPH unless the existing posted speed limit is less. A desirable bandwidth of 40 percent for the highway shall be used where existing conditions allow. In order to reduce the proliferation of delays to the motorist, a minimum of 30 percent bandwidth shall be used where the existing optimum bandwidth is below 30 percent. Where the other intersections or accesses have no signals presently but are expected to have signals in the future, a minimum 40 percent cycle split for the access shall be assumed. The green time allowed for the cross street shall in no case be less than the time which is required to accommodate pedestrian movement across the highway. The efficiency of the signal system should also be analyzed, including volume/capacity and level of service calculations.

   d. Any access which would reduce the optimum bandwidth if a traffic signal were installed shall be limited to right turns unless it meets other requirements of this section.

   e. When an existing access meets the warrants for a traffic signal as defined in the M.U.T.C.D., and the location does not meet the requirements of subsection 3.6.5, a median separator should be installed or the access designed to direct vehicles into right turns only. These design solutions may not be practicable or feasible where there are physical constraints such as curbs, sidewalks, structures, and lack of rights-of-way. Piecemeal median separators are usually not desirable and can pose other safety and highway operation difficulties. The access may be required to be reconstructed, or relocated, to conform to the access code to ensure that the purposes of this code and the Act are met.

f. Traffic signals and their installation are regulated by the *Manual on Uniform Traffic Control Devices* and the Colorado Supplement under Subsection 42-4-501., C.R.S., as amended.

3.7 Category Four

Functional Characteristics

1. These highways have the capacity for moderate travel speeds and moderate traffic volumes for medium and short travel distances providing for intercity, intracity and intercommunity travel needs. There is a reasonable balance between direct access and mobility needs within this category.

Design Standards

2. It is the intent that the design of all category four highways be capable of achieving a posted speed limit of 35 MPH. The posted speed limit shall be used to meet the requirements of this code unless an approved access control plan to improve the highway requires that a higher speed limit be used.

3. Private Direct Access

   a. No more than one access shall be provided to an individual parcel or to contiguous parcels under the same ownership unless it can be shown that, (1) additional access would not be detrimental to the safety and operation of the highway and are necessary for the safety and efficient use of the property, or (2) allowing only one access would be in conflict with local safety regulations, and the additional access would not be detrimental to public health, safety and welfare.

   b. An access shall be limited to right turns only unless (1) the access does not have the potential for signalization, (2) a left turn would not create unreasonable congestion or safety problems and lower the level of service, and (3) in the determination of the issuing authority alternatives to the left turn would cause unacceptable traffic operation and safety problems on the general street system.

   c. Private access which has the potential for signalization may be permitted left turn movements if, (1) it meets the signalization spacing requirements for intersecting public streets, roads and highways, as per subsection 3.7.5 and, (2) it does not interfere with the location planning and operation of the general street system and access to nearby properties.

4. Since intersecting streets, roads and highways may in time warrant signalization, it is required that all intersecting streets, roads and highways that allow left turns meet the signal spacing criteria under subsection 3.7.5. Those that do not meet these requirements shall be limited to right turns only unless they meet the requirements of subsection 3.7.3b.

5. Spacing and Signalization

   a. For those rural highway sections where existing traffic signals are infrequent and where significant development is not expected in the foreseeable future, spacing of all major intersecting public streets, roads, highways and other major accesses should be on one-half mile intervals plus or minus approximately 200 feet and based upon section lines where feasible. Where topography makes one-half mile intervals inappropriate, location of any public access shall be determined by topography, property ownerships, property lines and physical design constraints. Minor access that has the potential for signalization should be located to meet the requirements of paragraph 5b that follows. Where the criteria stated in paragraph b are impracticable, a quarter mile interval shall be used. The final location should serve as many properties and interests as possible to reduce the need for more public streets and direct access to the state highway.

b. In urban areas and developing areas where higher volumes are present or growth that will require signalization is expected in the foreseeable future it is imperative that the location of any public access be planned carefully to ensure good signal progression. Where at all feasible, major access spacing shall be at either one mile or one-half mile interval spacing. This spacing allows the greatest flexibility for locating minor signalized access between major access while maintaining good traffic signal progression and highway capacity. Additional minor access that requires traffic signals may be permitted where they will not restrict the signal progression bandwidth established by the major accesses that bracket the proposed access. While this category allows more signals per mile than category three, it is still desirable to keep signals to a minimum as signals usually reduce highway capacity and safety.

c. To provide flexibility for existing conditions and to ensure optimum two way signal progression, an approved traffic engineering analysis shall be made to precisely locate any proposed access that may require signalization. The analysis shall consider any accesses that are existing or possible future signal locations for at least one mile in each direction as well as all potential roadway and signal system improvements. A progression analysis shall be completed which uses a cycle length of between 90 and 120 seconds and a travel speed of 35 MPH or the posted speed if it differs. A desirable bandwidth of 30 percent shall be used where existing conditions allow. In order to reduce the proliferation of delays to the motorist, a minimum of 20 percent bandwidth shall be used where the existing optimum bandwidth is below 20 percent and there is little or no chance to improve the bandwidth. Where other accesses have no signals presently but are expected to have signals, a maximum of 50 percent cross street cycle split shall be assumed. The green time allowed for the cross street shall in no case be less than the time which is required to accommodate pedestrian movement across the main highway. The efficiency of the signal system should also be analyzed, including volume/capacity and level of service calculations.

d. Any access which would reduce the optimum bandwidth if a traffic signal were installed shall be limited to right turns unless it meets other requirements of this code.

e. When an existing access meets the warrants for a traffic signal as defined in the *M.U.T.C.D.* and the location does not meet the requirements of subsection 3.7.5, a median separator should be installed or the access designed to direct vehicles into right turns only. These design solutions may not be practical or feasible where there are physical constraints such as curbs, sidewalks, structures, and lack of rights-of-way. Piecemeal median separators are usually not desirable and can pose other safety and highway operation difficulties. The access may be required to be reconstructed or relocated to conform to the access code to ensure that the purposes of this code and the Act are met.

3.8 Category Five

Functional Characteristics

1. Category five shall be assigned only to roadways that are designated as frontage or service roads where there is no intended purpose of providing for long distance or high volume traffic movements. At the request of the local authority, the Commission may change any frontage or service road to category three or four. Access needs take priority over through traffic movements without compromising the public health, welfare, or safety. Providing reasonable and safe access to abutting property is the primary purpose of this access category.

Design Standards

2. One direct access will be provided to each individual parcel or to contiguous parcels under the same ownership or control.
3. Additional access may be permitted to a parcel when (a) there will not be any significant safety or operational problems and (b) the spacing meets the access spacing requirements of the code, subsection 4.9.2 and (c) additional access would not knowingly cause a hardship to an adjacent property.
4. All turning movements including left turns shall be allowed provided adequate safety and design standards are met.
5. The existing posted speed limit shall be used in any access permit and design decisions.
6. Minimum spacing between signals shall be that which is necessary for the safe operation and proper design of adjacent accesses. Preference in traffic signal timing and operation shall be given to highways and cross streets of a higher access category or function.

SECTION FOUR
DESIGN STANDARDS AND SPECIFICATIONS

4.1 Purpose

The Department has developed the following design and construction standards and specifications to protect the public health, safety, and welfare; maintain smooth traffic flow; maintain highway right-of-way drainage; and to protect the functional level of public highways.

4.2 Use of Section Four

1. When an application for access to a state highway meets the necessary criteria of section three of this code, section four shall be used to precisely locate, design and construct the access within the limitations set forth in section three. When a local government is the issuing authority and it has established by ordinance or resolution more stringent design standards than required in this section, the local standards shall govern when required by the local government.

2. If an access meets section three criteria and is unable to comply with section four criteria, the access permit should be denied unless a variance is authorized pursuant to section two of this code.

4.3 Reference and Data Sources

1. The most recent edition of the references in subsection 1.5 may be used when determining the design standards to be applied to a variance under subsection 2.8.

2. *Trip Generation*, Third edition, The Institute of Transportation Engineers 1982, shall be used as a reference in estimating DHV or Average Peak Hour values of an access where required by this code.

3. For the purposes of this section the DHV for the access location may be considered synonymous with the term "average peak hour volume" often used for traffic analysis. However, DHV calculations are preferred and shall be used when available.

4. Speed, as used in this section refers to the posted legal speed limit at the access location at the time of permit approval. A higher design speed shall be used if the section of highway is presently being redesigned or reconstructed to a higher speed or an approved access control plan requires a higher speed.

5. The design of roadway improvements cannot be properly evaluated based solely upon average total daily traffic figures. Average peak hour traffic operations shall be taken into account by using an estimated design hour volume.

6. The DHV or average peak hour traffic volume estimates for any access shall be based upon the anticipated total build out of the development to be served and the twentieth year prediction for highway volumes. In the case of a public access, a reasonable prediction of the twentieth year access volume shall be made based upon predicted growth, zoning and any comprehensive plan. Estimates shall be based upon average weekday traffic at locations where weekday employment predominates.

7. Unless other acceptable analysis is completed that proves otherwise or the access design or site has operational limitations, all average daily directional splits shall be equally allocated in each direction for each access. For example, a full movement access shall be considered to have 50 percent of entering vehicles making a left turn and 50 percent making a right turn on an average day.

8. The applicant shall submit an estimate of the volume and type of traffic to use the access. The issuing authority shall assist any applicant requesting traffic estimates for the purpose of obtaining an access permit. To determine the DHV of the proposed access in lieu of a traffic study prepared by a registered professional engineer, or in the evaluation of such a traffic study, the issuing authority shall refer to the *Trip Generation* manual referenced in subsection 1.5, as well as site conditions and other information that may apply. In determining the traffic generation the average peak hour factor in the Institute of Transportation Engineers *Trip Generation* manual may be used.

9. When the access will exceed a DHV of 50 vehicles per hour, it is recommended that the applicant complete a traffic analysis.

10. The DHV of any state highway may be obtained from the latest copy of the *Colorado Traffic Volume Study For State Highways* by contacting the local district office of the Department.

4.4 Access Width

1. Access width for any rural type access without curbs shall be measured exclusive of the radii or flares. Access with a street style curb return entrance and driveways with curb cuts, shall be measured behind the flared section.

2. Sixteen to 24 feet of width shall be used for any two-way access when the single unit vehicle volume does not exceed five DHV except as noted in subsection 4.4.3.

3. Twenty-five to 35 feet of width shall be used for any two-way access when any one or more of the following apply to the access.

   a. Vehicle volume of the access exceeds five DHV.

   b. Multi-unit vehicles are intended to use the access.

   c. Single unit vehicles in excess of 30 feet in length will use the access.

   d. Special equipment using the access exceeds 16 feet in width.

4. One-way access shall have a width of 16 feet to 24 feet. If two, one-way accesses are adjacent to each other, they shall be divided by a physical median of at least four feet but no more than 25 feet wide.

5. When a public street, road, highway or any access intended to become a public roadway intersects with a state highway, the design criteria of the local government and the Department shall be used to select an appropriate access width subject to the approval of the Department. We recommend that no two-way public roadway access in excess of 10 D.H.V. should be less than 36 feet in width at the intersection.

4.5 Access Radii

1. No access except a curb cut shall have an equivalent turning radius of less than 20 feet except as allowed in subsection 4.5.6.

2. A 50 foot equivalent turning radius should be used for an access when multi-unit vehicles or single unit vehicles exceeding 30 feet in length are intended to use the access on a daily basis.

3. The access equivalent turning radii shall accommodate the turning radius of the largest vehicle using the access on a daily basis.

4. If the frequency of multi-unit vehicles or single unit vehicles over 30 feet in length is such that two of these vehicles, one entering and one exiting, use the access at the same time, radii should be adequate to accommodate both vehicles with no turning conflicts.

5. The issuing authority shall determine if a curb cut or radius curb returns are required in accordance with existing or planned conditions.

6. When a public street, road, or highway or any access intended to become a public roadway intersects with a state highway, the design criteria of the local government and the Department shall be used to select an appropriate radii, corner and intersection design, subject to the approval of the Department.

7. Where large numbers of multi-unit vehicles will use the access, the access width or radius may be increased as determined by the issuing authority, if necessary to ensure safe turning movements without encroachment onto opposing traffic lanes.

8. Where there are numerous accesses such as along an established city street, it may be desirable to reduce the radii in order to improve visual and physical separation of accesses. Where feasible or required by the code, access should be combined or closed to reduce the frequency and increase the spacing.

9. Where a private access will have high traffic volumes, the access may be designed with curb returns and at a width and design as determined by the issuing authority to adequately provide for the level of activity.

10. To minimize pedestrian conflict and total access width at the roadway edge, it is generally recommend not to construct a radius that is any larger than required by subsection 4.5.

11. Where access channelization islands are installed, a 70 foot radius is recommended for the channel lane.

4.6 Access Surfacing

1. The access shall be surfaced upon completion of earthwork construction and prior to being used. A delay in installation of hot bituminous pavement due to seasonal restrictions may be allowed provided adequate temporary gravel surfacing is substituted.

2. The surfacing of the access shall extend at least from the highway traveled way to the right-of-way line.

3. Surfacing material shall be specified according to the Department's standard design specifications and the conditions and future use of the access and the highway. Gravel will be permitted for individual residential access or field entrances where conditions allow, and where curbs are not required.

4. Surfacing improvements shall not be allowed on the highway right-of-way between access unless a concrete curb or other physical separator such as a drainage ditch is constructed and maintained to limit access movements to permitted locations.

5. Surfacing material is defined as gravel, concrete, or bituminous pavement.

4.7 Speed Change Lanes

Speed change lanes, also called auxiliary lanes, are very helpful in maintaining the safety, flow and operation of the highway and access. They are required according to the subsections that follow.

4.7.1 General Criteria for Speed Change Lanes

a. The graphs in subsection 4.7 are based upon trucks exceeding 30,000 pounds gross vehicle weight (G.V.W.) being less than seven percent of the DHV. If the access will have a larger percentage of vehicles exceeding 30,000 pounds G.V.W., the access DHV values in the graphs may be reduced by one-half to require median speed change lanes in the interest of public safety.

b. Where higher left turning volumes, safety, or traffic operations necessitates, a double left turn design may be required.

c. If the design of the access is within two different speed zones, the criteria for the higher speed zone will apply.

d. When public safety so requires due to site specific conditions, such as sight distance, a turn lane may be required even though the criteria in subsection 4.7 are not met.

e. Where there are three or more through lanes in the direction of travel, the Department will normally drop the requirement for right turn acceleration and deceleration lanes. However, each case shall be reviewed independently and a decision made based upon site specific conditions. Generally, the lanes will be required only for high volume access or when a specific geometric safety problem exists.

f. When calculating the highway single lane DHV, it will be assumed that all lanes have equal volumes.

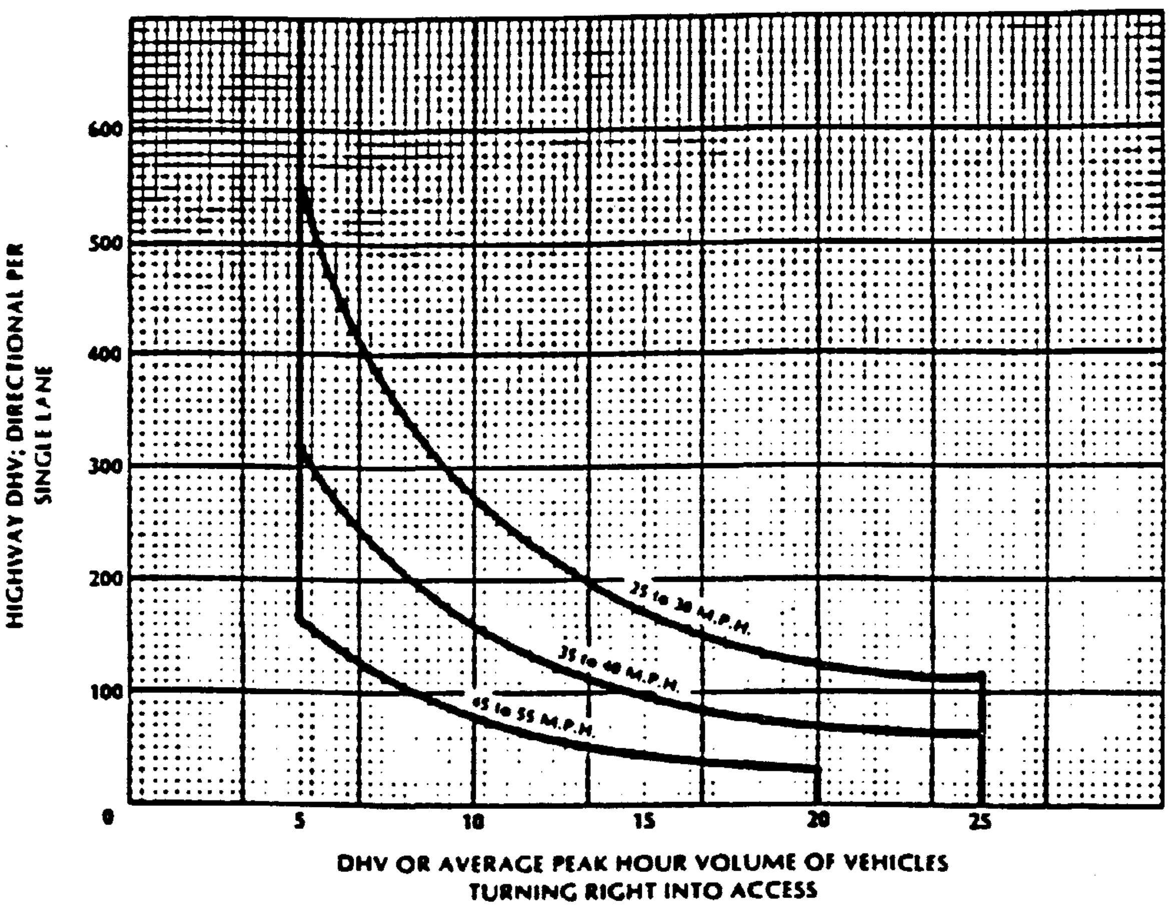
4.7.2 Deceleration Lanes for Right Turning Vehicles

a. A speed change lane for right turning deceleration movements is required for any access according to graph 4.7.2 when the DHV values of the highway single lane and the DHV of right turns intersect at a point on or above the curve for the posted speed.

b. Where the DHV of the right turn into the access is less than five DHV and the outside lane volume exceeds 250 DHV on 45 to 55 MPH highway, or 450 DHV on a 35 to 40 MPH highway, or 600 DHV on a 25 to 30 MPH highway, then a right turn lane may be required due to high traffic volumes or other unique site specific safety considerations.

c. When the access volume meets or exceeds 25 DHV with a highway posted speed of 25 to 40 MPH or 20 DHV above 40 MPH, a right turn deceleration lane is required.

GRAPH 4.7.2



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4.7.3 Acceleration Lane for Right Turning Vehicles

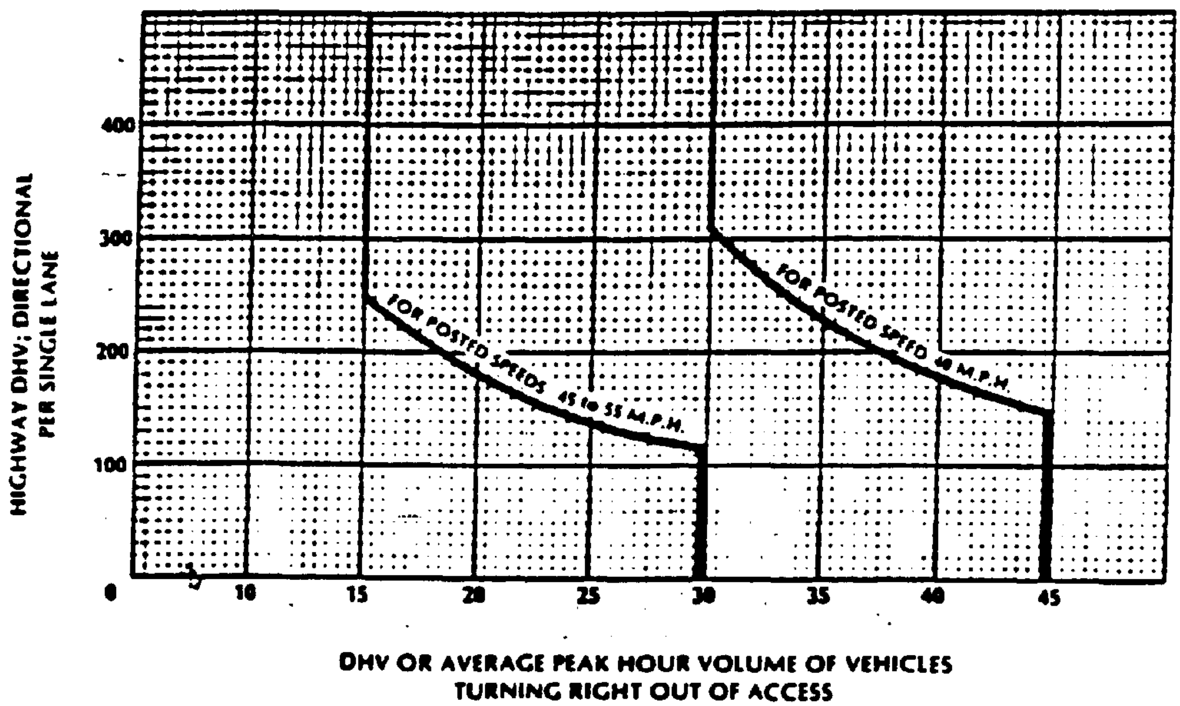
a. A speed change lane for right turning acceleration movements is required for any access according to graph 4.7.3 when the DHV values of the highway single lane and the DHV of right turns intersect at a point on or above the curve for the posted speed.

b. A right turn acceleration lane may be required for any access where a high traffic volume on the highway and lack of gaps in traffic make use of an acceleration lane necessary for vehicles to enter the highway traffic flow through the use of merging techniques.

c. A right turn acceleration lane is not normally required when the posted speed is less than 40 MPH. However, an acceleration lane may be required where necessary for public safety and traffic operations based upon site specific conditions.

d. Where the DHV of the right-turn movement out of the access is less than 15 DHV for speeds of 45 MPH and above, or less than 30 DHV for a speed of 40 MPH, no acceleration lane is required unless specifically necessary due to safety considerations.

GRAPH 4.7.3



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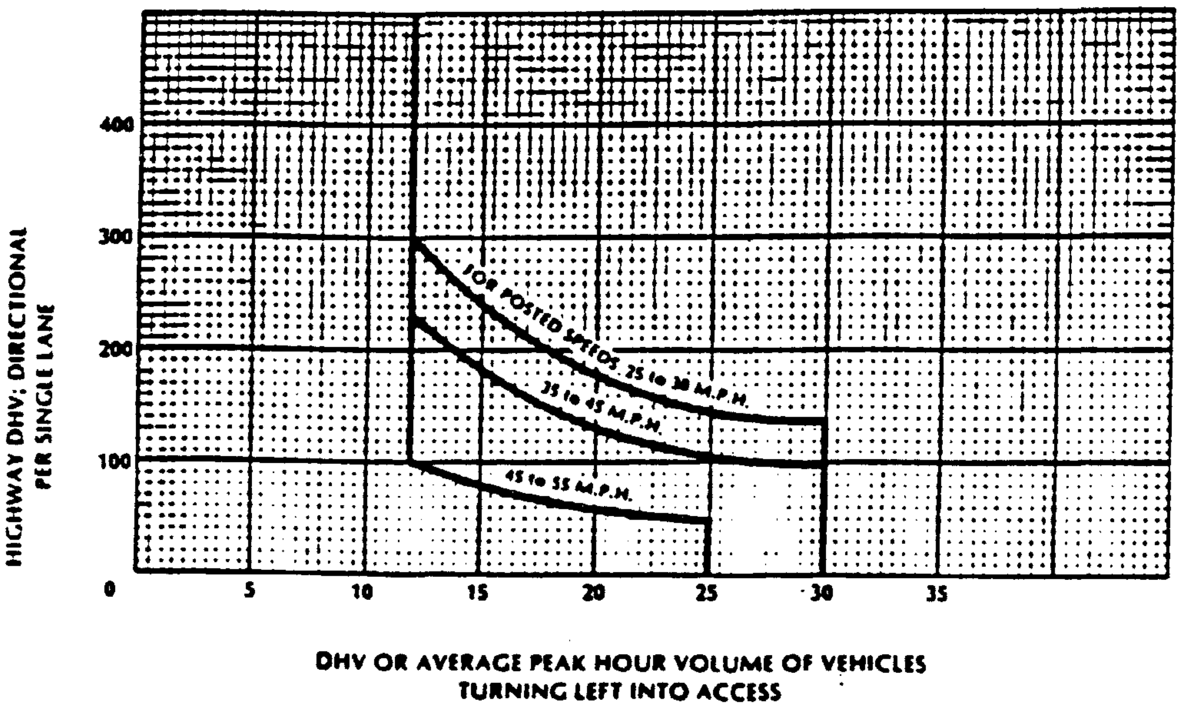
4.7.4 Deceleration Lanes for Left Turning Vehicles

a. A speed change lane for left turning movements, is required for any access according to graph 4.7.4 when the DHV values of the highway single lane and the DHV of left turns intersect at a point on or above the curve for the posted speed.

b. Where the DHV of the left turn into the access is less than 12 DHV and the inside lane volume exceeds 250 DHV on 45 to 55 MPH highways or 400 DHV on 25 to 40 MPH highways, a left turn lane may be required due to the high traffic volumes or other unique site specific safety considerations.

c. When the access volume meets or exceeds 30 DHV for 25 to 40 MPH highways, or 25 DHV on 45 to 55 MPH highways, a left turn deceleration lane is required.

GRAPH 4.7.4



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4.7.5 Acceleration Lanes for Left Turning Vehicles

a. The need for and use of a left turn acceleration lane is site specific. Factors such as highway speed, access volume, nearby access, existing highway auxiliary lanes, traffic control devices, available stopping sight distance and other topographic and highway design factors are influential. A left turn acceleration lane may be required if the values of graph 4.7.3 are met, and the issuing authority determines that the lane would be a benefit to highway safety and operation.

b. Left turn acceleration lanes are not required where: 1) when the posted speed is below 40 MPH unless required for public safety by the Department's District Traffic and Safety Engineer, or 2) the intersection is signalized, or 3) the acceleration lane would interfere with left turn ingress movements to any other access.

4.8 Construction of Speed Change Lanes

1. When speed change lanes are required, they shall be constructed in accordance with this subsection and other applicable parts of section four.

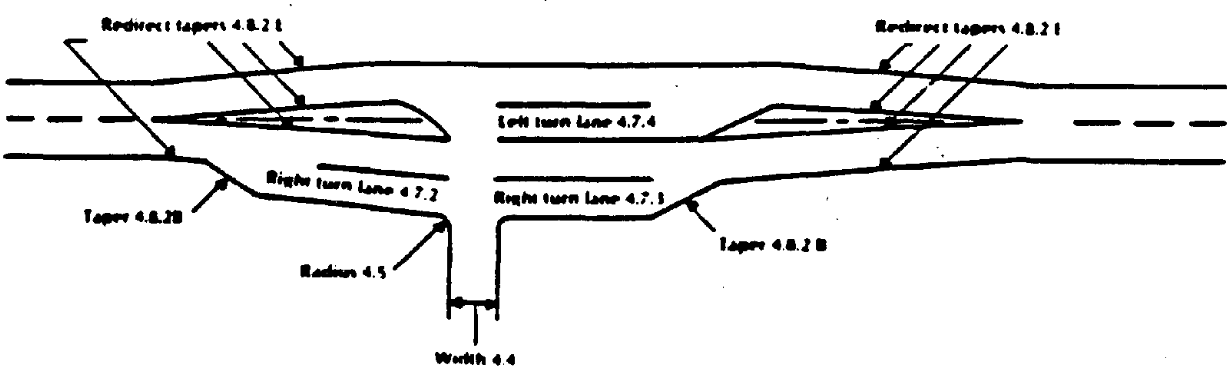
2. Where two accesses have speed change lanes that overlap, or are in close proximity but do not overlap, a continuous lane shall be established between the accesses to improve roadway consistency, safety, and to maintain edge continunity.

3. Speed change lanes shall normally be 12 feet wide exclusive of gutter pan or shoulder. If existing thru travel lanes are less than 12 feet wide or if local government standards recommend, a lesser width may be used provided a minimum of 10 feet of width is attained. Speed change lanes should be a minimum of 11 feet on highways with a posted speed above 40 MPH, and where there is a high percentage of large trucks use.

4. Where no curb and gutter is required, a paved shoulder shall be provided that matches the existing shoulder width along the highway or is a minimum of four feet in width, whichever is greater.

Figure 4.8

Information Guide to Some Auxiliary Lane Elements:



4.8.1 Lane Length

a. Table 4.8.1 shall be used along with other criteria of 4.8 in determining speed change lane lengths as required by the following tables and text. The lengths are in feet. The length of the tapers are a product of the full lane width and the ratio. "Stop Condition" means the vehicle comes to a complete stop or very slow speed prior to making the turn into the access or is in a stop mode before exiting the access onto the highway. For deceleration lanes, a 15 MPH turn shall normally be assumed for a curb return design only if the radius is 40 feet or greater. A stop condition shall be assumed for a curb cut. For an acceleration lane, a stop condition shall be assumed.

b.

TABLE 4.8.1

Posted Speed	Stop Condition		15 MPH turn		ratio for straight taper for A & D	Minimum "D" taper Ratio
	A	D	A	D		
20		160		100	7.5:1	7.5:1
25	100	200	90	150	7.5:1	7.5:1
30	190	235	190	185	10:1	8:1
35	270	275	240	235	12.5:1	10:1
40	380	315	320	295	15:1	11.5:1
45	550	375	480	350	15:1	13:1
50	760	435	700	405	20:1	15:1
55	960	485	910	450	22.5:1	18.5:1

c. The lengths under "A" are for acceleration according to the posted speed limit. The lengths under "D" are for deceleration according to the posted speed limit. All lengths are given in feet.

d. The lengths in table 4.8.1 are for generally flat grades of less than 3 percent slope. For all grades of 3 percent or greater, multiplication factors contained in the tables under 4.8.5 shall be used.

e. The length of the speed change lane shall be the sum of the appropriate length from table 4.8.1 adjusted, if applicable, by subsection 4.8.5 grade, plus the taper design from 4.8.2, plus any storage requirements under 4.8.4, for any access where: (1) turning movement DHV exceeds by twice the access turning movement values in the graphs in subsection 4.7 which require speed change lanes, or (2) the number of vehicles in excess of 30,000 pounds gross vehicle weight using the access exceeds 25 percent of the appropriate DHV values in the graphs in 4.7 or (3) the access is on an access category two highway.

f. Physical or legal constraints may necessitate eliminating all or part of the deceleration length and providing only the taper and storage lengths. This minimum design criterion shall be used only on highways posted at 40 MPH or less when the requirements of 4.8.1b, and e are not feasible, and (1) the access category is four or five, or (2) the highway has in that section four or more intersections per mile per side, and there is driver expectancy of speed changes, turning movements and weaving movements along that section of highway.

4.8.2 Taper Design

A. Minimum tapers apply only to deceleration lanes where it is not physically feasible to use the normal taper.

B. The length of a taper is calculated by multiplying the width of the speed change lane by the ratio value associated with the posted speed in table 4.8.1. A 25 MPH zone and a 12 foot wide speed change lane at a 7.5:1 ratio, requires a 90 foot taper.

C. The length of the required taper shall be considered a part of the appropriate speed change length given in table 4.8.1 for any access not included under 4.8.1e. The applicant that qualifies for this shorter length may choose to design to the specification of paragraph 4.8.1e if the Department approves.

D. If a straight line taper is used, the ratios in the right columns of Table 4.8.1 are to be used. The value given is the ratio of taper length to speed change lane width. Partial tangent tapers, symmetrical reverse curve tapers, or asymmetrical reverse curve tapers may be used, provided a radius of at least 150 feet is used in curve calculations.

E. Where it is necessary to establish a left turn median island, tapers required for redirecting main travel lanes shall be according to the following table.

TABLE 4.8.2E

Posted speed in MPH	30 or less	35	40	45	50	55 and above
Straight taper ratio	20:1	25:1	30:1	40:1	45:1	50:1

4.8.3 Median Design

a. A median area is necessary in order to construct a left turn speed change lane when such a lane is required according to subsection 4.7.

b. Where a median does not exist or where a painted median is less than 14 feet in width, the roadway shall be widened in order to provide a painted median of at least 14 feet, preferably 16 feet in width. Where there is a median of 14 feet or greater in width, the existing width may be used. Where the existing median is of raised design any new median construction shall also be of raised design unless otherwise instructed by the Department. The median area shall be 18 feet in width for a raised median. Minimum raised median shall be four feet in width across the top exclusive of any gutter. These design features will not be required where physical constraints, curbs, sidewalks, structures, and lack of available right-of-way restricts installation.

c. When it is necessary to widen a highway for a median and public right-of-way is made available, the highway should be widened equally on both sides in order to maintain the existing highway centerline alignment.

4.8.4 Storage Length

a. Additional storage length is required to accommodate turning vehicles according to the following table where vehicle turning movements for a left turn deceleration lane are 30 DHV or greater. A right turn deceleration lane shall provide for vehicle storage length when there is a controlled stop condition. Storage for right turns may be one-half the length required by table 4.8.4.

TABLE 4.8.4

Turning vehicles per hour	30	60	100	200	300
Required Lane length in feet	25	50	100	175	250

b. For every 15 DHV of trucks larger than a single unit, the length of the average truck plus 10 feet shall be added to the storage length required by this table.

4.8.5 Grade Adjustment

Speed change lanes including tapers require adjustments in length according to the following conditions. Speed change lanes shall use the following multiplication factors in determining speed change length for all highways with grades of 3 percent or greater. Grade is the ratio of the change in elevation to the length of slope. Multiply the lengths required in subsections 4.8.1 and 4.8.2 by the appropriate factors given below.

A. For Deceleration Lanes

TABLE 4.8.5a

For all posted speeds	3 to 4.9% upgrade	3 to 4.9% downgrade
	0.9	1.2
	5 to 7% upgrade	**5 to 7% downgrade**
	0.8	1.35

B. For Acceleration Lanes

TABLE 4.8.5b

Posted Speed, MPH	3 to 4.9% upgrade	3 to 4.9% downgrade
25 to 45	1.3	.7
50	1.4	.65
55	1.5	.65
60	1.5	.6
Posted Speed, MPH	**5 to 7% upgrade**	**5 to 7% downgrade**
25 to 45	1.5	.6
50	1.8	.55
55	2.0	.55
60	2.3	.5

4.9 Sight Distance

1. Permits shall not be issued that include any design element or allow any turning movements where the sight distance is not adequate to allow the safe movement of any motorist using or passing the access.

2. The following table shall be used to determine the required horizontal and vertical sight distance necessary as measured from the vehicle traveling on the highway to the access.

TABLE 4.9.2

Posted speed, MPH	30	35	40	45	50	55
Required sight distance in feet	200	250	325	400	475	550

   a. This table is based on wet pavement conditions and the average vehicle maintaining the posted speed limit. These lengths shall be adjusted for any grade of three percent or greater using the tables in 4.8.5.

   b. For calculating this sight distance, a height of 3.5 feet shall be used for the driver's eyes and a height of 4.25 feet shall be used for a vehicle assumed to be on the centerline of the access five feet back from the edge of the traveled way. The driver's eye shall be assumed to be at the centerline of the inside lane (inside with respect to the curve) for measurement purposes.

3. In addition to the sight distance necessary for vehicles traveling on the highway to see vehicles or objects in the traveled way, it is also necessary to provide the entering vehicle adequate sight distance in order to enter or cross the highway. The following table shall be used to establish the minimum sight distance necessary for the entering vehicle.

TABLE 4.9.3

*Vehicle expected to enter or cross highway	Sight distance in feet for each 10 MPH of posted speed limit along highway		
	2 lane	4 lane	6 lane
Passenger car	100	120	130
Single Unit Truck	130	150	170
Multi-unit Trucks	170	200	210

   *a. The vehicle shall be the largest vehicle normally intended to use the access in excess of an average of one per day.

   b. Sight distance shall be measured at a height of 3.5 feet from the entering driver to a height of 4.25 feet for the oncoming vehicle.

   c. The entering driver's eyes shall be assumed to be 10 feet back from the edge of the traveled way.

   d. If there is no median or if the median is too narrow to safely store a left turning or crossing vehicle (a 20 foot minimum for passenger cars), both directions shall be considered from the access location.

e. If the median can safely store the turning or crossing vehicle, then sight distance shall consider a two stop condition. The vehicle will stop once at the outside edge of the outside lane and again within the median. Each one-way highway direction shall be considered separately.

4. After sight distance requirements are met and an access permit issued, a sign structure or parked vehicle shall not be permitted where it will obstruct the required sight distance.

4.10 Other Design Elements

1. For all curb cuts, the vertical curve from the traveled way into the access shall be the flattest curve that can be obtained. To prevent center or overhang drag, with some allowance for load and bounce, crest vertical curves should not exceed a four inch hump in a 10-foot chord and sag vertical curves should not exceed a four inch depression in 10-foot chord. For any access that is not a curb cut, including streets and private access using curb returns, the first 20 feet beyond the closest highway lane, including speed change lanes or the distance to the side drain, whichever is greater, shall slope down and away from the highway at a two percent grade to ensure proper drainage control. Exceptions may be made where steep topography such as a mountain makes this requirement very difficult to fulfill. The approved design must protect the highway from drainage flows. Valley gutters and cross-pans are not recommended.

2. Within the right-of-way, maximum grades shall be limited to ten percent for low volume residential access. All other accesses shall be limited to a maximum of eight percent grade. Lesser grades may be required for drainage control purposes.

3. The horizontal axis of an access to the highway shall be at a right angle to the centerline of the highway and extend a minimum of 40 feet beyond the traveled way. An angle between 90 and 60 degrees may be acceptable only if significant physical constraints require a skew angle less than 90 degrees and is approved based upon site specific conditions.

4. Access specifications shall ensure that the access is designed and constructed in a manner that will encourage proper use by the motorist. Access for one-way operation shall be approved only when design conditions ensure one-way operation.

5. An access that has a gate across it shall be designed so that the longest vehicle using it can completely clear the traveled way when the gate is closed.

6. The access shall be designed to facilitate the movement of vehicles off the highway to prevent the queuing of vehicles on the traveled way. An access shall not be approved for parking areas that require backing maneuvers within state highway rights-of-way. All off-street parking areas must include on-site maneuvering areas and aisles to permit user vehicles to enter and exit the site in forward drive without hesitation.

7. Fill slopes and cut slopes shall be constructed either to (a) current Department minimum standards, or (b) to the slope of the existing highway near the access, whichever is safer. It is desirable that all side slopes have a slope of 6:1 for 12 feet. A minimum of 4:1 for six feet, then not steeper than 3:1 unless physically restricted. Tighter slopes may be permitted when necessary.

8. Access design shall provide for the safe movement of all highway right-of-way users, including but not limited to pedestrians, bicyclists, and the handicapped. Sidewalks may be required where appropriate or when requested by local authority. Bikepaths may be included in the access permit upon request by the local authority.

9. In the event it becomes necessary to remove any right-of-way fence, the posts on either side of the entrance shall be securely braced with an approved end post before the fence is cut to prevent any slacking of the remaining fence. All posts and wire removed are Department property and shall be turned over to a representative of the Department.

10. Where necessary to remove, relocate, or repair a traffic control device or public or private utilities for the construction of a permitted access, the relocation or removal shall be accomplished by the permittee without cost to the Department or issuing authority, and at the direction of the Department or utility company. Any damage to the state highway or other public right-of-way beyond that which is allowed in the permit shall be repaired immediately.

11. Further details of access construction and design, including pavement thickness and specifications, curb design and specifications, roadway fill design and compaction, and other specific details, shall be provided by the Department.

12. Installation of any traffic control device necessary for the safe and proper operation and control of the access may be required pursuant to the M.U.T.C.D. Where the access may warrant signalization in the future, phasing of the installation may be required. All traffic control devices within the highway or other public right-of-way or access that serve the general public shall conform to the M.U.T.C.D.

13. An access that crosses or otherwise affects pedestrian, bicycle, or handicapped facilities, shall have the necessary modifications to ensure the safe crossing of the access and the safe use of the facility by pedestrians, bicyclists and the handicapped.

14. Each access should be separated by a distance equal to the stopping sight distance values in table 4.9.2. This allows the motorist reaction time and stopping distance between adjacent access. When speed change lanes are present, it is desirable that the lanes do not overlap.

15. When an access permit requires the widening or reconstruction of the roadway, the design of horizontal and vertical curves, superelevations, transitions, and other specifications, shall be no less than those necessary to meet the minimum posted speed of the highway or the constructed design speed of the existing highway, whichever is greater.

16. Physical separation and delineation along a property frontage such as curb and gutter or fencing, may be required where necessary to ensure that access will be limited to permitted locations.

17. A clear zone is a relatively clear and flat area beyond the edge of the roadway and is important for the recovery of errant vehicles. Roadway hazards in the clear zone such as fixed objects or steep embankments, may need to be removed, reconstructed or shielded by a proper barrier. In urban areas with speeds of 40 MPH or less and vertical curbs, a clear zone of at least 1.5 feet minimum should be provided. Where there is no curb in urban and rural areas and the speed is 40 MPH or less, a ten foot clear zone should be provided. At speeds of 45 MPH or greater, a 20 to 30 foot clear zone is recommended. Within the highway right-of-way, every attempt will be made to adhere to the clear zone requirements.

4.11 Drainage

1. Each access shall be constructed in a manner that shall not cause water to enter onto the roadway, and shall not interfere with the drainage system on the right-of-way.

2. The permittee shall provide, at his own expense, drainage structures for his access which will become an integral part of the existing drainage system. The type, design, and condition of these structures must meet the approval of the Department in unincorporated areas. Structures and design must be approved by the municipality and the Department in incorporated areas.

3. Drainage structures shall not restrict the existing drainage system nor any adopted municipal drainage plan. Drainage pipe shall be a minimum of 18 equivalent inches in diameter. Where hydrological studies have been completed, the drainage shall be designed to handle at least the 2½ year storm, for an underground system and a five year storm for side drains but not less than the existing drainage system. On larger systems and developments, the effects of a 100 year flood event should be assessed.

4. The highway drainage system is for the protection of the state highway right-of-way. It is not designed or intended to serve the drainage requirements of abutting properties beyond that which has historically flowed to the state right-of-way. Drainage to the state highway right-of-way shall not exceed the undeveloped historical flow. The use of controlled flow detention ponds shall be considered to control this flow from developed properties. When curb and gutter is required, the drainage ditch should be eliminated by installing a storm sewer system. The Department shall determine the appropriate drainage controls necessary to meet existing or projected site specific conditions.

4.12 Maintenance

The permittee, his heirs, successors-in-interest, and assigns, of the property serviced by the access shall be responsible for meeting the terms and conditions of the permit and the removal or clearance of snow or ice upon the access even though deposited on the access in the course of Department snow removal operations. The Department shall maintain in unincorporated areas the highway drainage system, including those culverts under the access which are part of that system within the right-of-way.

STATE OF COLORADO

HIGHWAY ACCESS LAW

SECTION 43-2-147
COLORADO REVISED STATUTES
Updated to June 1985

43-2-147. **Access to public highways.** (1) (a) The state department of highways and local governments are authorized to regulate vehicular access to or from any public highway under their respective jurisdiction from or to property adjoining a public highway in order to protect the public health, safety, and welfare, to maintain smooth traffic flow, to maintain highway right-of-way drainage, and to protect the functional level of public highways. In furtherance of these purposes, all state highways are hereby declared to be controlled-access highways, as defined in section 42-1-102 (13), C.R.S.

(b) Vehicular access to or from property adjoining a state highway shall be provided to the general street system, unless such access has been acquired by a public authority. Police, fire, ambulance, and other emergency stations shall have a right of direct access to state highways. After June 21, 1979, no person may submit an application for subdivision approval to a local authority unless the subdivision plan or plat provides that all lots and parcels created by the subdivision will have access to the state highway system in conformance with the state highway access code.

(c) The provisions of this section shall not be deemed to deny reasonable access to the general street system.

(2) After consultation with units of local government, the commission, on or before November 15, 1979, shall submit a state highway access code to the legislative council. The legislative council may appoint a committee to review the code and it shall transmit the code and any findings thereon to the senate committee on transportation and the house of representatives committee on transportation and energy at the beginning of the 1980 session of the general assembly.

(3) In reviewing the state highway access code, the legislative committees of reference may approve, approve with modifications, or reject the code. Failure of either or both committees to act on or before March 15, 1980, shall be deemed approval thereof. Should, however, either or both committees specifically reject the code, the committee shall make necessary changes in the access code and resubmit it to the committee of reference at the next regular session of the general assembly.

(4) The commission shall adopt a state highway access code, by rule and regulation, for the implementation of this section, on or after March 16, 1980. The access code shall address the design and location of driveways and other points of access to public highways. The access code shall be consistent with the authority granted in this section and shall be based upon consideration of existing and projected traffic volumes, the functional classification of public highways, adopted local transportation plans and needs, drainage requirements, the character of lands adjoining the highway, adopted local land use plans and zoning, the type and volume of traffic to use the driveway, other operational aspects of the driveway, the availability of vehicular access from local streets and roads rather than a state highway, and reasonable access by city streets and county roads.

(5) (a) After the effective date of the access code, no person shall construct any driveway providing vehicular access to or from any state highway from or to property adjoining a state highway without an access permit issued by the appropriate local authority with the written approval of the state department of highways. If the local authority fails to act within forty-five days after an access permit has been requested, such permit shall be deemed issued subject to written approval of the state department of highways. If the state department of highways does not act upon an access permit within twenty days after notice by the local authority, or within twenty days after local authorities should have acted, whichever is the lesser, such permit shall be deemed approved. Upon written request by a local authority, the state department of highways shall administer or assist in the administration of access permits in that jurisdiction. If the state department of highways undertakes to administer access permits in a jurisdiction, it shall act upon requested access permits within forty-five days of request. If the state department of highways fails to act within forty-five days upon a requested access permit, such permit shall be deemed approved. Access permits shall be issued only in compliance with the access code and may include terms and conditions authorized by the access code.

(b) The issuing authority shall establish a reasonable schedule of fees for access permits issued pursuant to the access code and this section, which fees shall not exceed the costs of administration of access permits.

(c) When a permitted driveway is constructed or utilized in violation of the access code, permit terms and conditions, or this section, either the issuing authority or the state department of highways or both may obtain a court order enjoining violation of the access code, permit terms and conditions, or this section. Such access permits may be revoked by the issuing authority if, at any time, the permitted driveway and its use fail to meet the requirements of this section, the access code, or the terms and conditions of the permit. The state department of highways may install barriers across or remove any driveway providing direct access to a state highway which is constructed without an access permit.

(6) (a) The provisions of this section shall not apply to driveways in existence on June 30, 1979, unless specifically stated otherwise. Driveways constructed between July 1, 1979, and the effective date of the access code shall comply with the driveway code adopted by the state department of highways pursuant to statutory authority prior to July 1, 1979.

(b) Any driveway, whether constructed before, on, or after June 30, 1979, may be required by the state department of highways with written concurrence of the appropriate local authority to be reconstructed or relocated to conform to the access code, either at the property owner's expense if the reconstruction or relocation is necessitated by a change in the use of the property which results in a change in the type of driveway operation or at the expense of the state department of highways if the reconstruction or relocation is necessitated by changes in road or traffic conditions. The necessity for the relocation or reconstruction shall be determined by reference to the standards set forth in the access code.

(c) Any party who has received an adverse decision by the state highway department may request and shall receive a hearing before the state highway commission or before a hearing officer, at the discretion of the state highway commission. Such hearing shall be conducted in accordance with the provisions of article 4 of title 24, C.R.S. Decisions by the state highway commission or by a hearing officer shall be considered final agency action.

(d) Reconstruction or relocation of a driveway shall be administered in the same manner as the revocation of a license under the "State Administrative Procedure Act".

(7) The boards of county commissioners may, by resolution, and other local authorities may, in the manner prescribed in article 16 of title 31, C.R.S., adopt by reference the state highway access code, in whole or in part, or may adopt separate provisions, for application to local roads and streets that are not a part of the state highway system.

(7.5) The issuing authority shall grant a variance from the state highway access code if such variance would not be inconsistent with paragraph (a) of subsection (1) of this section and if such variance is reasonably necessary for the convenience, safety, and welfare of the public. If failure to grant a variance would deny reasonable access to the general street system, such denial may be subject to the provisions of section 43-1-208 and section 15 of article II of the state constitution.

(8) As used in this section, unless the context otherwise requires:

(a) "Access control plan" means a roadway design plan which designates preferred access locations and their designs for the purpose of bringing those portions of roadway included in the access control plan into conformance with their functional classification to the extent feasible.

(b) "Appropriate local authority" means the board of county commissioners if the driveway is to be located in the unincorporated area of the county and the governing body of the municipality if the driveway is to be located within an incorporated municipality.

(c) "Functional classification" means a classification system that defines a public roadway according to its purposes in the local or statewide highway plans. The commission shall determine the functional classification of all state highways. The functional classification of county roads and city streets shall be determined by the appropriate local authority.

(d) "General street system" means the interconnecting network of city streets, county roads, and state highways in an area.

(e) "Issuing authority" means the entity which issues access permits and includes the board of county commissioners, the governing body of a municipality, and the state department of highways.

(f) "Local road" means a county road, as provided in sections 43-2-108 and 43-2-109, and "local street" means a municipal street, as provided in sections 43-2-123 and 43-2-124.

APPENDIX 2-B

RULES OF THE DEPARTMENT OF TRANSPORTATION
CHAPTER 14-97
STATE HIGHWAY SYSTEM ACCESS MANAGEMENT CLASSIFICATION SYSTEM AND STANDARDS

SYSTEMS PLANNING OFFICE
605 SUWANNEE STREET, MS 19
TALLAHASSE, FL 32399-0450
DECEMBER, 1990

ADOPTED FEBRUARY 12, 1991

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RULES OF THE DEPARTMENT OF TRANSPORTATION

CHAPTER 14-97

STATE HIGHWAY SYSTEM ACCESS MANAGEMENT CLASSIFICATION SYSTEM AND STANDARDS

14-97.001 Purpose. This rule chapter adopts an access classification system and standards to implement the State Highway System Access Management Act of 1988 for the regulation and control of vehicular ingress to, and egress from, the State Highway System. The implementation of the classification system and standards is intended to protect public safety and general welfare, provide for the mobility of people and goods, and preserve the functional integrity of the State Highway System. All segments of the State Highway System shall be assigned an access classification and standard. The standards shall be the basis for connection permitting and the planning and development of Department construction projects.
Specific Authority 334.044(2), 335.188 FS.
Law Implemented 334.044(10)(a), 335.188 FS.
History-New

14-97.002 Definitions. For the purposes of this rule chapter the following definitions shall apply unless the context clearly indicates otherwise:

(1) "Area Type" means one of four specific land categories reflecting certain land use and intensity characteristics used in specifying the interchange spacing standards for limited access facilities.

(2) "Central Business District (CBD)" means that portion of a municipality in which the dominant existing and projected land use, as documented in the current adopted Local Government Comprehensive Plan, is for intense business and commercial activity. This district is generally characterized by large numbers of pedestrians, on-street parking, and on-street truck loading. For the purpose of this rule this term is only applicable for access classification 1 (limited access facilities) within Urbanized Areas.

(3) "Central Business District (CBD) Fringe" means the portion of a municipality immediately outside the Central Business District. This area predominantly exhibits a wide range of business activity with some concentrated residential areas. The area generally exhibits less pedestrian traffic and lower parking turnover than in the Central Business District, however, large parking areas serving the Central Business District might be present. For the purposes of this rule chapter this term is only applicable for Urbanized Areas.

(4) "Central Business District (CBD) and CBD Fringe (Area Type 1)" means the area contained within a boundary designated as CBD and CBD fringe area type in the adopted MPO Long Range Transportation Plan. For the purpose of this rule chapter this term is only applicable for access classification 1, limited access facilities for Urbanized Areas.

(5) "Collector-Distributor System" means a fully access controlled roadway, generally parallel to, and part of, but typically physically separated from the through or mainline lanes of the limited access facility and serving areas adjacent to the limited access facility.

(6) "Connection" means a driveway, street, turnout, or other means of providing for the right of access to or from controlled access facilities on the State Highway System. For the purpose of this rule chapter two one-way connections to a property may constitute a

single connection.

(7) "Controlled Access Facility" means a transportation facility to which access is regulated through the use of a permitting process by the governmental entity having jurisdiction over the facility. Owners or occupants of abutting lands and other persons have a right of access to and from such facility at such points only and in such a manner as may be determined by the permitting authority(ies).

(8) "Corner Clearance" means the distance from an intersection of a public or private road to the nearest connection along a controlled access facility. This distance is measured from the closest edge of pavement of the intersecting road to the closest edge of pavement of the connection measured along the traveled way (through lanes). The projected future edge of pavement of the intersecting road should be used where available in an adopted five year transportation plan. The future edge of the through lane can be used for this measurement when an auxilliary lane will be built.

(9) "Corridor Access Management Plan" means a plan defining site specific access management features for a particular roadway segment, developed in coordination with the appropriate local government(s) and adopted by the Department in cooperation with the appropriate local government(s).

(10) "Department" means the Florida Department of Transportation.

(11) "Directional Median Opening" means an opening in a restrictive median which provides for U-turn only, and/or left-turn in movements. Directional median openings for two opposing left or "U-turn" movements along one segment of road are considered one directional median opening.

(12) "Existing Urbanized Areas other than CBD and CBD Fringe (Area Type 2)" means the area between the CBD and CBD Fringe area boundary and the existing Urban Area Boundary for Urbanized Areas as defined by the US Bureau of Census. For the purpose of this rule chapter, this term is only applicable for access classification 1, limited access facilities.

(13) "Federal Highway Administration Urban Area Boundary" means the boundary developed by an MPO or local government, concurred in by the Department and approved by FHWA which is the basis for the designation of the Federal-Aid Highway System. This boundary is an adjustment to the urban boundary as defined by the US Bureau of Census taking into consideration changes in land use densities subsequent to the last official census for a particular area.

(14) "FHWA" means Federal Highway Administration.

(15) "Full Median Opening" means an opening in a restrictive median designed to allow all turning movements to take place from both the state highway and the adjacent connection.

(16) "Intersection" as used in this rule chapter, means an at-grade connection or crossing of a local road or another state highway with a state highway.

(17) "Limited Access Facility" means a street or highway especially designed for through traffic and over, from, or to which owners or occupants of abutting land or other persons have no right or easement of access, light, air, or view by reason of the fact that their property abuts such limited access facility or for any other reason. The right of access may have been donated by the property owner or purchased by the Department.

(18) "Metropolitan Planning Organization (MPO)" is as defined in Section 339.175(1), Florida Statutes.

(19) "Minimum Connection Spacing" means the minimum allowable distance between conforming connections, measured from the closest edge of pavement of the first connection to the closest edge of pavement of the second connection along the edge of the traveled way.

(20) "Minimum Median Opening Spacing" means the minimum allowable spacing between openings in a restrictive median to allow for crossing the opposing traffic lanes to access property or for crossing the median to travel in the opposite direction (U-turn). The minimum spacing or distance is measured from centerline to centerline of the openings along the traveled way.

(21) "Minimum Signal Spacing" means the minimum spacing or distance in miles between adjacent traffic signals on a controlled access facility measured from centerline to centerline of the signalized intersections along the traveled way.

(22) "MPO" means the Metropolitan Planning Organization.

(23) "Non-Restrictive Median" means a median or painted centerline which does not provide a physical barrier between center traffic turning lanes or traffic lanes traveling in opposite directions. This includes highways with continuous center turn lanes and undivided highways.

(24) "Permitting Authority" means the Department or any county or municipality or transportation or expressway authority authorized to regulate access to the State Highway System.

(25) "Reasonable Access" means the minimum number of connections, direct or indirect, necessary to provide safe ingress and egress to the State Highway System based on the Access Management Classification, projected connection and roadway traffic volumes, and the type and intensity of the land use. The applicant shall be allowed to submit any site specific information which the applicant deems to be pertinent to the Permitting Authority's review of the connection permit application.

(26) "Restrictive Median" means the portion of a divided highway or divided driveway physically separating vehicular traffic traveling in opposite directions. Restrictive medians include physical barriers that prohibit movement of traffic across the median such as a concrete barrier, a raised concrete curb and/or island, and a grassed or a swaled median.

(27) "Rural Areas (Area Type 4)" means the area between the outer boundary of Area Type 3 and the next Area Type 3 outer boundary. For the purpose of this rule chapter, this term is only applicable for limited access classification 1 facilities.

(28) "Service Road" means a public or private street or road, auxiliary to and normally located parallel to a controlled access facility, which has as its purpose the maintenance of local road continuity and provision of access to parcels adjacent to the controlled

access facility.

(29) "Significant Change" means a change in the use of the property, including land, structures or facilities, or an expansion of the size of the structures or facilities causing an increase in the trip generation of the property, based on the 4th Edition of the Institute of Transportation Engineers "Trip Generation Manual", exceeding 25% more trip generation (either peak hour or daily) and exceeding 100 vehicles per day more than the existing use. Where such additional traffic is projected, the property owner is required to contact the permitting authority to determine if a new permit application and modifications to existing connections will be required. If the permitting authority determines that the increased traffic generated by the property does not require modifications to the existing permitted connections, a new permit application shall not be required.

(30) "State Highway System (SHS)" means the network of limited access and controlled access highways that have been functionally classified and which are under the jurisdiction of the State of Florida as defined in Florida Statutes.

(31) "Transitioning Urbanized Area" means the area between the existing Urbanized Area Boundary and the future projected Urbanized Area Boundary anticipated within the next 20 years as established by the MPO and the Department. For non-urbanized areas this boundary will be established by the appropriate local government and the Department. These developing transitional areas will include those areas with existing population between 5,000 and 49,999. For the purpose of this rule chapter, this term is only applicable for access classification 1 limited access facilities.

(32) "Traveled Way" means the portion of roadway for the movement of vehicles, exclusive of shoulders and auxiliary lanes.

(33) "Urban Area" means an area defined by the US Bureau of Census having a population of at least 5,000 at specific urban densities.

(34) "Urbanized Area" means an area defined by the US Bureau of Census, having a population of at least 50,000 at specific urban densities. Such designated areas are required by Federal and State

law to have a formal transportation planning process administered by an MPO. The US Bureau of Census urbanized area boundary can be modified, subject to FHWA regulations for the purpose of the transportation planning process.
Specific Authority 334.044(2), 335.188 FS.
Law Implemented 334.044(10)(a), 335.188 FS.
History-New.

14-97.003 Access Management Classification System and Standards.

(1) The Classification System and Standards. This section provides a seven classification access management system to be used for all roads on the State Highway System. Single Category I connections, as defined in Rule Chapter 14-96, with expected peak hour two-way traffic of five vehicles or less may be exempt from the connection spacing requirements of this rule where the proposed connection can be shown, as part of the application process, as not creating a safety or operational hazard. The Department will, to the greatest extent possible, encourage joint use driveways and work with local governments to ensure individual residential driveways on State Highways are kept to a minimum. This exemption also means that these minor connections will not be considered in measuring the distance to other connections for their compliance with the spacing standards in this rule chapter. The classification system and standards for each access class are shown on Figures 1 and 2.

FIGURE 1

ACCESS CLASSIFICATION AND STANDARDS
LIMITED ACCESS FACILITIES
INTERCHANGES

Access Class	Segment Location	Applicable Interchange Spacing Standard
1	**AREA TYPE 1** CBD & CBD FRINGE FOR CITIES IN URBANIZED AREAS	1 MILE
1	**AREA TYPE 2** EXISTING URBANIZED AREAS OTHER THAN AREA TYPE 1	2 MILES
1	**AREA TYPE 3** TRANSITIONING URBANIZED AREAS AND URBAN AREAS OTHER THAN AREA TYPE 1 OR 2.	3 MILES
1	**AREA TYPE 4** RURAL AREAS	6 MILES

FIGURE 2

CONTROLLED ACCESS FACILITIES

ACCESS CLASS	FACILITY DESIGN FEATURES (MEDIAN TREATMENT AND ACCESS ROADS)	MINIMUM CONNECTION SPACING (FEET)	MINIMUM MEDIAN OPENING SPACING DIRECTIONAL (FEET)	MINIMUM MEDIAN OPENING SPACING FULL (MILE)	MINIMUM SIGNAL SPACING (MILE)
2	Restrictive with Service Roads	1320/660	1320'	0.5	0.5
3	Restrictive	660/440	1320'	0.5	0.5
4	Non-Restrictive	660/440	N/A	N/A	0.5
5	Restrictive	440/245	660'	0.5/0.25	0.5/0.25
6	Non-Restrictive	440/245	N/A	N/A	0.25
7	Both	125	330'	0.125	0.25

(Greater than 45 MPH/ Less than or = 45 MPH)

NOTE:
* Section 14-97.003 and 14-97.004, FAC, contain supplementary and more detailed instrictions for the use of these standards.
* These minimum spacings may not be adequate if auxiliary lanes and storage are required.
* Single properties with frontages exceeding the minimum spacing criteria may not receive permits for the maximum number of possible connections.

Interim standards as contained in Rule 14-97.004(1) shall be effective for all segments of the State Highway System until superseded by an adopted classification of the highway segment into one of the six controlled access classifications in this rule chapter. Permit applications received after adoption of this rule chapter but before the classification of a highway segment is adopted, shall be reviewed for consistency with the interim standards.

(a) Connection permit applications on controlled access facilities of the State Highway System received after that particular segment of highway has been formally classified according to this rule chapter, shall be reviewed subject to the requirements of this rule chapter pursuant to the permit application process of Rule Chapter 14-96.

(b) For the purpose of the interim standards and for the assignment of an access classification to a segment of highway by the Department pursuant to Rule 14-97.004, permitted connections and those unpermitted connections exempted pursuant to Section 335.187(1), Florida Statutes, and existing median openings, and signals are not required to meet the interim standards or the standards of the assigned classification. Such features will generally be allowed to remain in place. These features shall be brought into reasonable conformance with the standards of the assigned classification or the interim standards where new connection permits are granted for significant changes in property use, or as changes to the roadway design allow. Applicants issued permits based on the interim standards as set forth in Rule 14-97.004 shall not have to reapply for a new permit after formal classification of the roadway segment unless significant change pursuant to Rule Chapter 14-96 and Rule 14-97.002 has occurred.

(c) A property that cannot be permitted access consistent with the interim standards as set forth in Rule 14-97.004 or connection spacing standards of the classification assigned to that particular segment of highway and which has no reasonable access to the State Highway System, either directly or indirectly, as determined pursuant to the connection permit process, as defined in Rule Chapter 14-96, shall be issued a conforming permit by the Department or permitting authority for a single connection pursuant to Rule Chapter 14-96. If Additional connections are requested and approved they shall be considered non-conforming and shall contain restrictions pursuant to Rule Chapter 14-96.

(d) Access class standards represent minimums for each access class. A more detailed, segment specific classification may be enacted by the Department in cooperation with the appropriate local government entities through the adoption of individual Corridor Access Management Plans pursuant to Rule 14-97.004 (5).

(e) The minimum connection and median opening spacings specified in this rule may not be adequate in some cases. Greater distances between connections and median openings may be required by the Permitting Authority to provide sufficient site-specific traffic operations and safety requirements. In such instances, the Permitting Authority shall document, as part of the response to an application submitted pursuant to Rule Chapter 14-96, a justification based on traffic engineering principles as to why such greater distances are required.

(f) When a full median opening or non-restrictive median is reconstructed by the Department to allow for opposing left or U-turns only, these openings shall be considered as one opening.

(g) Adjacent properties under the same ownership shall not be considered as separate properties for the purpose of the standards associated with the access class of the highway segment but shall be deemed to be one parcel. Applicants requesting connections for one or more adjacent properties under the same ownership may, however, as a part of the permit application process, request that the properties be considered individually for connection permitting purposes. Such requests shall be included as part of the permit application and shall provide specific analyses and justification of potential safety and operational hazards, associated with the compatibility of the volume, type or characteristics of the traffic using the connection. Such properties and single ownership properties with frontage exceeding the minimum standards of the assigned access class may not be permitted, pursuant to the permit application process in Rule Chapter 14-96, the maximum number of connections, median openings, or signals possible based on the spacing standards. The total number of connections permitted will be the minimum number necessary to provide reasonable access. Lease hold interests existing prior to the effective date of this rule chapter or a bonafide contract for sale shall be considered as separate ownership from the parent tract for the purpose of this rule chapter.

(h) The speed criteria referred to in Figure 2, Controlled Access Facilities, and in the interim standards means the speed limit posted for the highway segment at the time of the highway access classification designation.

(i) Corner clearances for connections shall meet or exceed the minimum connection spacing requirements for the interim standards or for access classifications 2 through 7 where the roadway segment has been assigned a classification. However, a single connection may be placed closer to the intersection for the circumstances set forth in Rule Sections 14-97.003 (1)(i) 1., 2., and 3., and pursuant to the permit application process of Rule Chapter 14-96.

1. If, due to property size, corner clearance standards of this Rule Chapter cannot be met, and where joint access which meets or exceeds the applicable minimum corner clearance standards cannot be obtained with a neighboring property or in the determination of the permitting authority, is not feasible based on conflicting land use or conflicting traffic volumes/characteristics, then the following minimum corner clearance measurements can be used to permit connections. Such properties, for the purpose of this rule chapter will be

called "isolated corner properties"

2. In cases where connections are permitted under the criteria of the following minimum corner measurements, the permit will contain the following additional conditions:

a. There will be no more than one connection per state road frontage.

b. When joint or alternate access which meets or exceeds the applicable minimum corner clearance becomes available, the permittee will close the permitted connection, unless the permittee shows that such closure is not feasible because of conflicting land use or conflicting traffic volumes/characteristics or existing structures which preclude a change in the existing connection.

3. The minimum corner clearance measurements for these isolated corner properties set forth in 1. above, shall be used for isolated corner properties, as defined in this section, classes 3 through 7, inclusive, defined in Rule 14-97.003(2) and the interim standards defined in Rule 14-97.004(1).

4. Corner Clearances for "isolated corners properties" are as follows:

Corner Clearance at Intersections
With Restrictive Median

Position	Access Allowed	Minimum (Feet)
Approaching intersection	Right In/Out	115
Approaching intersection	Right In Only	75
Departing intersection	Right In/Out	230 (125)*
Departing intersection	Right Out Only	100

Without Restrictive Median

Position	Access Allowed	Minimum (Feet)
Approaching intersection	Full Access	230 (125)*
Approaching intersection	Right In Only**	100
Departing intersection	Full Access	230 (125)*
Departing intersection	Right Out Only**	100

* Access Class 7 and Interim "Special Case" at 35 MPH or less, may use the measurements in parenthesis.

** Right In/Out, Right In Only, and Right Out Only connections on roads without restrictive medians shall, by design of the connection, effectively eliminate unpermitted movements.

(j) Connections and median openings on a controlled access facility located up to 1/4 mile from an interchange area or up to the first intersection with an arterial road, whichever distance is less, shall be regulated to protect the safety and operational efficiency of the limited access facility and the interchange area. The 1/4 mile distance shall be measured from the end of the taper of the ramp furthest from the interchange.

1. The distance to the first connection shall be at least 660 feet where the posted speed limit is greater than 45 MPH or 440 feet where the posted speed limit is 45 MPH or less. This distance will be measured from the end of the taper for that particular quadrant of the interchange on the controlled access facility. A single connection per property not meeting this connection spacing standard shall be provided, pursuant to the connection permit process as defined in Rule Chapter 14-96, if no reasonable access to the property exists and if permitting authority review of the connection permit application provided by the applicant determines that the connection does not create a safety, operational or weaving hazard pursuant to Rule 14-96.007. In such cases, applications for more than a single connection shall be examined as non-conforming connections pursuant to Rule 14-96.009.

2. The minimum distance to the first median opening shall be at least 1320 feet as measured from the end of the taper of the egress ramp.

3. Connections and median openings meeting spacing standards still may not be permitted in the location requested in the permit application pursuant to Rule 14-96.007 and the criteria in Rule 14-96.007 when the Department determines, based on traffic engineering principles, that the engineering and traffic information provided in the permit application shows that the safety or operation of the interchange or the limited access highway would be adversely affected.

(k) Traffic signals meeting signal warrants which are proposed at intervals closer than the standard for the access class for the highway segment shall be considered by the Permitting Authority but shall only be approved where the need for such signals is clearly demonstrated for the safety and operation of the highway based on Permitting Authority review of the traffic and signal information provided by the applicant in the connection permit application pursuant to Rule Chapter 14-96.

(2) **Access Class Description and Standards.** The access classification system and standards are shown in Figures 1 and 2.

(a) **Access Class 1, Limited Access Highways.** These highways do not provide direct property connections. Highways in this class provide for efficient and safe high speed and high volume traffic movements, serving interstate, interregional, and intercity, and, to a lesser degree, intracity travel needs. Federal-Aid Interstate highways and Florida's Turnpike are typical of this Class. The interchange spacing standards, based on the Area Type the highway is passing through, are for the through lanes or main line of the facility. Interchanges with limited access collector distributor systems do not have to meet these standards, however such connections shall be approved by the Department and FHWA utilizing the Interchange Justification Report Process. In addition to meeting the spacing standards, new interchanges to the Interstate Highway System shall be to other public roads only and warranted based on an engineering analysis of the operation and safety of the system. An Interchange Justification Report pursuant to Section III, Title 23 USC, must be prepared by the applicant and approved by the Department and FHWA prior to any new connections to the Interstate Highway System being constructed.

1. New interchange requests must be consistent, to the maximum extent feasible, with adopted local government comprehensive plans and MPO transportation plans.

2. For proposed new interchanges on the Interstate Highway System, the applicant must update a Department and FHWA approved master plan (if applicable) if the interchange is not part of the plan or if the Department determines that a major change in the land use or traffic has occurred since approval of the master plan. After approval of the master plan update by the Department and FHWA, the applicant must prepare an Interchange Justification Report for concurrence by the Department and approval by FHWA

prior to the new interchange being approved.

3. Based on an engineering study, prepared by the applicant, documenting why existing interchanges cannot be utilized, why alternative transportation system improvements are not economically, environmentally or socially acceptable and an analysis of the impact of the proposed new interchange on the safety and operation of adjacent interchanges and the limited access facility. Interchanges not meeting the spacing standards can be considered, however, such interchanges will only be approved by the Department and the Federal Highway Administration if the need for the interchange is clearly demonstrated, alternative transportation system improvements are determined not to be feasible, the use of existing interchanges including improvements to arterial roads leading to the interchange and necessary interchange improvements are shown as not feasible and the addition of the interchange does not cause an operational or safety problem on the limited access facility.

(b) **Access Classes 2 through 7, General Description.** The Access Management Classifications for controlled access highways (Classes 2 through 7) are arranged from the most restrictive (Class 2) to the least restrictive (Class 7). Generally the highways serving areas without existing extensive development or properties without subdivided frontages will be classified at the top of the range (Classes 2, 3, and 4). Those roadways serving areas with existing moderate to extensive development or subdivided properties will generally be classified in the lower classes of the range (Classes 5, 6, and 7). The standards for each class are further defined where the posted speed limit is greater than 45 MPH or where the posted speed limit is 45 MPH or less.

1. **Access Class 2.** These are highly controlled access facilities distinguished by the ability to serve high speed and high volume traffic over long distances in a safe and efficient manner. These highways are distinguished by a

system of existing or planned service roads. This access class is distinguished by a highly controlled limited number of connections, median openings, and infrequent traffic signals. Segments of the State Highway System having this classification usually have the access restrictions supported by local ordinances and agreements with the Department.

2. **Access Class 3.** These facilities are controlled access facilities where direct access to abutting land will be controlled to maximize the operation of the through traffic movement. This class will be used where existing land use and roadway sections have not completely built out to the maximum land use or roadway capacity or where the probability of significant land use change in the near future is high. These highways will be distinguished by existing or planned restrictive medians and maximum distance between traffic signals and driveway connections. Local land use planning, zoning and subdivision regulations should be such to support the restrictive spacings of this designation.

3. **Access Class 4.** These facilities are controlled access highways where direct access to abutting land will be controlled to maximize the operation of the through movement. This class will be used where existing land use and roadway sections have not completely built out to the maximum land use or roadway capacity or where the probability of significant land use change in the near future is high. These highways will be distinguished by existing or planned non-restrictive median treatments.

4. **Access Class 5.** This class will be used where existing land use and roadway sections have been built out to a greater extent than those roadway segments classified as Access Classes 3 and 4 and where the probability of major land use change is not as high as those roadway segments classified Access Classes 3 and 4. These highways will be distinguished by existing or

planned restrictive medians.

5. **Access Class 6.** This class will be used where existing land use and roadway sections have been built out to a greater extent than those roadway segments classified as Access Classes 3 and 4 and where the probability of major land use change is not as high as those roadway segments classified Access Classes 3 and 4. These highways will be distinguished by existing or planned non-restrictive medians or centers.

6. **Access Class 7.** This class shall only be used in urbanized areas where existing land use and roadway sections are built out to the maximum feasible intensity and where significant land use or roadway widening will be limited. This class shall be assigned only to roadway segments where there is little intended purpose of providing for high speed travel. Access needs, though generally high in those roadway segments, will not compromise the public health, welfare, or safety. Exceptions to standards in this access class will be considered if the applicant's design changes substantially reduce the number of connections compared to existing conditions. These highways can have either restrictive or non-restrictive medians.
Specific Authority 334.044(2), 335.188 FS.
Law Implemented 334.044(10)(a), 335.188 FS.
History-New

14-97.004 Application of Access Management Classification System and Standards.

(1) **Interim standards to be applied to the State Highway System prior to classification.** If a roadway segment has not been classified according to this rule the following standards shall be used to carry out the provisions of Section 335.18, Florida Statutes, The State Highway System Access Management Act. These standards shall be used by The Department for the review of all connection permit applications received after adoption of this rule chapter until the highway is classified in accordance with this rule chapter. After a highway has been classified pursuant to this rule chapter, the standards associated with the access classification shall supersede these interim standards for the classified roadway segment.

INTERIM STANDARDS

Posted Speed	Minimum Connection Spacing	Minimum Median Opening (Full)	Minimum Median Opening (Directional)	Minimum Signal Spacing
(MPH)	(Feet)	(Miles)	(Feet)	(Miles)
35 or less Special Case	125	0.125	330	0.25
35 or less	245	0.25	660	0.25
36 - 45	440	0.25	660	0.25
Over 45	660	0.50	1320	0.25

(a) The 35 MPH or less (special case) standards shall be used only where current connection development averages at least 50 connections per mile on the side of the highway for which the connection is requested, based on actual count of connections 1/4 mile in each direction (total 1/2 mile) from the proposed connection.

(b) The implementation of the interim standards shall be consistent with the provisions of Rule 14-97.003(1).

(2) **Coordination with Local Government Comprehensive Planning and land development Regulation.** Local land use planning and regulation decisions must be considered in the access management classification process. Such decisions can impact on the Department's ability to meet the access standards assigned to a particular segment of highway. Effective access management must not only involve access permitting, but should also be coordinated with local government land use planning, development and subdivision regulation activities. The application of the access management classification system and standards and the assignment of an access classification to all segments of the State Highway System shall be the responsibility of the Department. The

Department shall provide adequate notice of proposed classification and shall coordinate with and consider the comments and concerns of the affected local governments before assigning a final classification to a roadway segment. The Department shall hold public hearing(s) as set out in 14.97.004 (4) below to seek input into the assigned classifications prior to the final classification assignment. After the public hearing, local governments shall receive notification of the access classifications assigned to each segment of the State Highway System and shall be asked to coordinate land use planning and land development regulation activities with the classification. The access classification shall also apply to local governments or expressway authorities issuing connection permits pursuant to the dual permitting provisions, in Rule 14-96.013, FAC, and the delegation of permit authority provisions of Rule 14-96.014, FAC.

(3) **Access Management Class Assignment to Highway Segments.** The process to be followed in applying the classification system and standards and assigning a classification to all segments of the State Highway System is as follows:

(a) **Defining Segments.** The determination of the length and termini of segments shall be the responsibility of the Department working in cooperation with the appropriate local governmental entities.

1. The length and termini of segments of limited access facilities shall be defined by Area Type boundaries by the Department and the Metropolitan Planning Organization for urbanized areas and by the Department and appropriate local governments in urban areas with population between 5,000 and 50,000. Physical characteristics and boundaries will be used rather than imaginary lines.

2. Segments of controlled access facilities shall be defined by the Department in cooperation with local governments. The length and termini of segments shall take into consideration the mobility and access needs of the driving public, the access needs of the existing and proposed land use abutting the segment, and the existing

and desired mobility characteristics of the roadway. The number of classification changes occurring along a particular highway shall be minimized to provide highway system continuity, uniformity, and integrity to the maximum extent feasible. The segments shall not necessarily be confined by local jurisdictional boundaries.

(b) **Assignment of an Access Classification to All State Highway System Segments.**

1. All limited access facilities shall be assigned to Access Management Class 1. Interchange spacing standards for that segment shall be based on the adopted Area Type of the particular highway segment's location.

2. All controlled access facilities on the State Highway System shall be assigned to one of the Access Management Classes 2 through 7. The assignment of a classification to a specific segment of the State Highway System shall be the responsibility of the Department. The designation shall be made in cooperation with the appropriate governmental entities. This classification decision shall take into consideration the potential for the desired access management classification and standards to be achieved based on existing land use, probability for land use change, adopted future roadway improvements and on the ultimate cross section of the roadway identified in adopted plans. The assignment of a classification shall specifically take into consideration the following factors:

a. The current and potential functional classification of the road;

b. Existing and projected future traffic volumes;

c. Existing and projected state, local and Metropolitan Planning Organization transportation plans and needs (including a consideration of new or improved parallel facilities);

d. Drainage requirements;

e. The character of the lands adjoining the highway (existing and projected);

f. Local land use plans, zoning and land development regulations as set forth in adopted comprehensive plans;

g. The type and volume of traffic requiring access;

h. Other operational aspects of access, including corridor accident history;

i. The availability of reasonable access to a state highway by way of county roads or city streets as an alternative to a connection to the state highway;

j. The cumulative effect of existing and projected connections on the State Highway System's ability to provide for the safe and efficient movement of people and goods within the state.

(4) **The Department shall make an initial access management classification assignment to all segments of the State Highway System.** The Department shall coordinate this initial assignment with affected local governments and, to the greatest extent possible, incorporate local government recommendations on the assigned classification and standards. The Department shall advertise all public hearings in a newspaper of general circulation in the affected area at least 10 days prior to the scheduled public hearing. Prior to the assignment of a final classification, the Department shall hold at least one public hearing in each urbanized area and at least one public hearing for the remaining counties in each district to solicit public input. After the public input has been received, the Department shall, in cooperation with the local government finalize any changes to the initial access classification. The Department shall

provide notice of its classification in a newspaper of general circulation for the affected area and shall notify all appropriate local governments in writing of this classification determination. All documentation used in determining the classification will be available to the public.

(5) **Corridor Access Management Plans** may be developed and adopted by the Department in cooperation with the appropriate local governments for specific segments of the State Highway System based on analysis of special circumstances for the particular segment location and adjacent land use. These plans shall be based on an engineering analysis by the Department and will allow for more site specific classifications. Prior to the adoption of such plans, the Department shall notify the local governmental entities and abutting property owners and shall hold a public hearing. After consideration of public input, the Department shall, in cooperation with the affected local government finalize the plan. Upon adoption of the plan, the Department shall notify affected local government(s). These plans shall specify the highway, termini, and the specific standards for connections, medians, intersections, and signals, that shall apply.

(6) **Interchange and Connection Review Process.**

(a) Applications for new interchanges on limited access facilities shall be examined for consistency with the spacing standards based on the Area Type the segment is located in. The applicant shall prepare an engineering analysis including consideration of Transportation Systems Management techniques and documenting why existing interchanges cannot be used, including consideration of arterial road and interchange improvements, an analysis of the operation and safety of the interchange with respect to adjacent interchanges and the operation of the mainline and a systems analysis of the impact of the additional traffic generated by the development using the interchange on the operation of the limited access facility. For additional interchanges on the Interstate Highway System, the interchange must be to a public road only and the applicant must update the adopted master plan (if applicable) and prepare an Interchange Justification Report for review and concurrence by the Department and approval by FHWA. For

Turnpike or bond funded facilities, additional economic analysis to determine bond feasibility shall also be developed by the applicant. The Department has the responsibility to approve or deny new interchanges on the turnpike or other state (non-interstate) limited access facilities.

(b) Permit Applications for new or modified connections to controlled access facilities must follow Rule Chapter 14-96, FAC.
Specific Authority 334.044(2) FS.
Law Implemented 334.044(10)(a), 335.188 FS.
History-New

14-97.005 Review and Modification of Classifications.

(1) The Department shall review the access management classifications for specific segments of the State Highway System when a major change in any of the factors noted in Rule 14-97.004(3) have occurred. Prior to the initiation of any change in classification for a roadway segment(s), the Department shall notify in writing the appropriate local government(s) and owners or occupants of abutting properties. After publishing its intent to reclassify a roadway segment(s) in a newspaper of general circulation in the affected area, the Department shall to hold a public hearing on the change(s) in classification in the affected county. The Department shall coordinate with, and shall take into consideration, any comments or concerns of the local government and those comments received during the public hearing during the analysis of the classification modification(s). The Department shall notify the affected local government(s) in writing of the final determination on the reclassification action(s).

(2) A written request may be made to the appropriate District Secretary, that the Department review the access classification of any specific segment(s) of the State Highway System at any time. Such written request shall include specific justification why the change of roadway segment classification is sought, and shall indicate the desired roadway segment classification and specific justification therefor based on the standards and criteria contained in Rules 14-97.003(2) and 14-97.004(3). The Department shall consider such requests, coordinating with the appropriate governmental entity(ies), and shall deny the request or publish notice of the Department's intent to reclassify the roadway segment(s) and shall follow the public hearing requirements in 14.97.005(1) above.

(3) MPO or local government initiated changes in boundaries of Area Types which affect interchange spacing standards shall become effective when the Department concurs in such changes and notifies the MPO or local government in writing.
Specific Authority 334.044(2) FS.
Law Implemented 334.044(10)(a), 335.188 FS.
History-New

INDEX

CHAPTER 3

ACCESS DESIGN PRINCIPLES

INTRODUCTION

AASHTO Policy

CHAPTER 3

ACCESS DESIGN PRINCIPLES

The adoption of the 1984 edition of **A Policy on the Design of Geometric Highways and Streets** (the AASHTO Green Book) represents a significant change in design philosophy with functional design replacing volume based design.

AASHTO Green Book

- Failure to Accommodate Each Trip Stage by Suitable Design is a Prominent Cause of Highway Obsolescence
- Driveways are At-Grade Intersections

The Green Book includes the following statements which have significant implications relative to access design.

"The failure to recognize and accommodate by suitable design each of the different trip stages of the movement hierarchy is a prominent cause of highway obsolescence. Conflicts and congestion occur at interfaces between public highways and private traffic-generating facilities when the functional transitions are inadequate. Examples are commercial driveways that lead directly from a relatively high-speed arterial into a parking aisle without intermediate provisions for transition deceleration and arterial distribution . . . " (*1* p. 2; *2* p. 2)

"Driveways are, in effect, at-grade intersections and should be designed consistent with the intended use. The number of accidents is disproportionately higher at driveways than at other intersections; thus their design and location merit special consideration." (*1* p. 841)

(Continued)

AASHTO Policy (Continued)

This suggests that the design of urban arterial streets is essentially a matter of designing a hierarchy of intersections which are connected by relatively short segments of tangents and curves; both horizontal and vertical. Thus the logic of functional design suggests that the urban arterial street design process should begin with those intersections which are the most important and then, in turn, consider those which are successively lower in the functional hierarchy.

Access Related Issues
• Hierarchy of Intersections • Functional Boundary of Intersections • Signal Spacing • Location and Design of Unsignalized Intersections

Major issues relative to access control relating to urban arterial intersection design include the following:

- Recognition that there is a hierarchy of trip stages and the establishment of a functional hierarchy of intersections, including private access drives.
- Determination of the functional boundary of intersections so that an intersection of lower functional classification is not located within the functional boundary of an intersection of higher classification.
- Spacing of signalized intersections (private access as well as public streets) so that efficient traffic movement can be achieved on the arterial streets in both peak and off-peak periods.

(Continued)

INTRODUCTION (Continued)

AASHTO Policy (Continued)

- Establishment of a comparability between the intersections of two public streets and intersections resulting from the connection of private access drives to public streets.
- Design and locate intersections (private drives as well as public streets) so that left-turning and/or right-turning vehicles do not cause serious interference with through traffic.
- Design medians and median openings to provide access control at unsignalized intersections -- public as well as private.
- Insure that the location and the geometries of all intersections, including private access drives, are visible to the drivers and that adequate sight distances are provided.

FUNCTIONAL DESIGN

Basic Concepts

Functional Design is Based on a Hierarchy of Movement

- Termination
- Access
- Collection / Distribution
- Primary Movement

- Transitions

The AASHTO Green Book recognizes that a functionally designed circulation system provides for distinct travel stages (*1* pp. 1-3; *2* pp. 1-3). It also indicates that, according to functional design concepts, each stage should be handled by a separate facility and that "... the failure to recognize and accommodate by suitable design each of the different stages of the movement hierarchy is a prominent cause of highway obsolescence."(*1* p. 3; *2* p. 2) The AASHTO policy also indicates that the same principles of design should be applied to access drives and the comparable intersections of public streets.

Hierarchy Of Movement

A typical trip on an urban street system can be described as occurring in identifiable steps or stages illustrated in Figure 3-1. These stages can be sorted into a definite hierarchy with respect to how the competing functions of movement and access are satisfied. At the low end of the hierarchy are highway facilities that provide good access to adjoining residences and businesses but provide poor opportunity for movement due to the conflicts caused by vehicles entering and exiting the roadway. Vehicles entering or exiting a roadway typically perform the ingress or egress maneuver at a very low speed, momentarily blocking through traffic and impeding the movement of traffic on the roadway. The high end of the hierarchy is represented by facilities that provide good movement by restricting and controlling access to the roadway, thereby reducing conflicts that slow the flow of through traffic.

(Continued)

FUNCTIONAL DESIGN (Continued)

Hierarchy Of Movement (Continued)

A transition occurs each time the vehicle passes from one roadway to another and should be accommodate by a facility specifically designed to handle the movement. Even the area of transition between a private driveway and a local street is considered to be an intersection and should be treated accordingly (1, 2). Many urban circulation systems utilize the entire range of facilities in the order presented here, but it is not always necessary or desirable that they do so. In some instances it may be beneficial to use fewer types of facilities by short-cutting the chain or not using the complete chain.

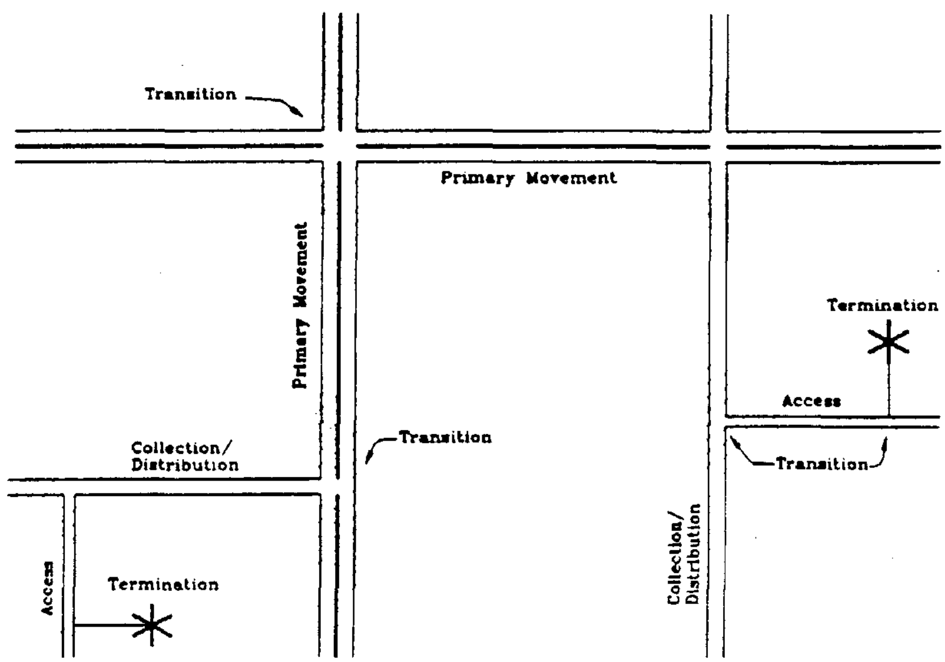


FIGURE 3-1: TRIP STAGES

Source: Adapted from References (1, 2)

Highway Specialization

Highway specialization simply means using each individual street facility to perform the desired function of access or movement. This is accomplished by classifying highways with respect to the amount of access or movement they are to provide and then identifying and utilizing the most effective facility to perform that function.

(Continued)

FUNCTIONAL DESIGN (Continued)

Functional Classes

Functional classification groups highways by the character of the service they provide (*1*, *2*). The functional system of classification divides streets into three basic classes identified as arterials, collectors, and locals as illustrated in Figure 3-2.

The function of an arterial is to provide movement of traffic. Access to an arterial is controlled to reduce interferences and allow movement. Collector streets supply a mix of the functions of movement and access and therefor accomplish neither well. The predominate purpose of local streets is to provide good access, which is accomplished by having numerous access points that cause interferences with through traffic and result in seriously curtailed movement.

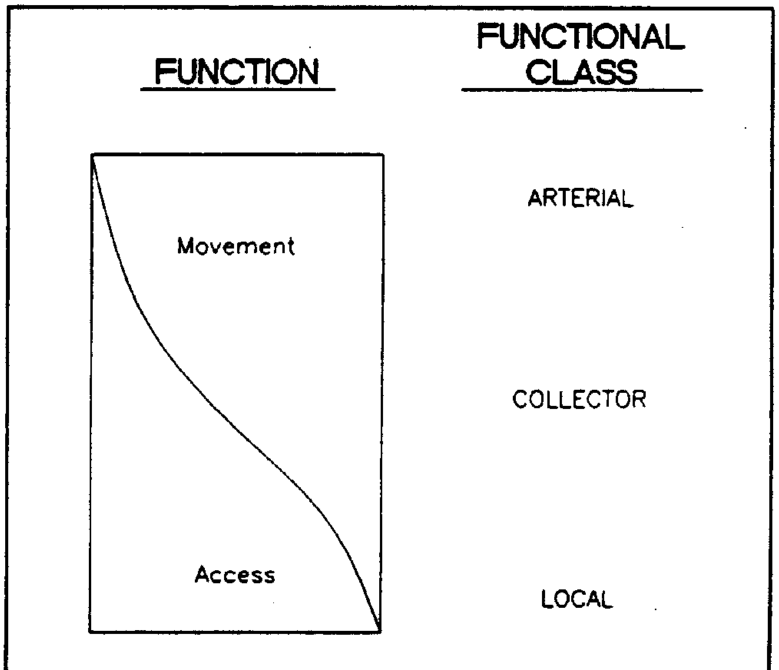


FIGURE 3-2: BASIC FUNCTIONAL CLASSES

Source: Adapted from References (*1*, *2*)

(Continued)

FUNCTIONAL DESIGN (Continued)

Functional Classes (Continued)

The functional classes represent a continuum of facilities that range from unrestricted access (no through traffic) to complete access control (no local traffic). As illustrated in Figure 3-3, each functional class can be divided into design classes. These design classes can, in turn, be further divided into a number of typical cross-sectional designs.

FUNCTIONAL CLASS	DESIGN CLASS
	Freeway
Arterial	Major Arterial
	Minor Arterial
Collector	Major Collector
	Minor Collector
Local	Local

FIGURE 3-3: HIERARCHY OF ROADWAYS IN A FUNCTIONALLY DESIGNED SYSTEM

Source: Reference (3)

Relationship Between Functional Classes

Each class combines the functions of access and movement and distributes or collects traffic for the adjacent class. As shown in Figure 3-4, facilities of a particular class should only interconnect with, or have transitions between, facilities of the same or adjacent class. Transitions connect locals to other locals or collectors only. Collectors connect to both locals (the class adjacent below) and arterials (the class adjacent above). Arterial facilities should connect only to collectors. Under no circumstances should transitions be provided to connect a local to any type of arterial facility.

(Continued)

FUNCTIONAL DESIGN (Continued)

Relationship Between Functional Classes (Continued)

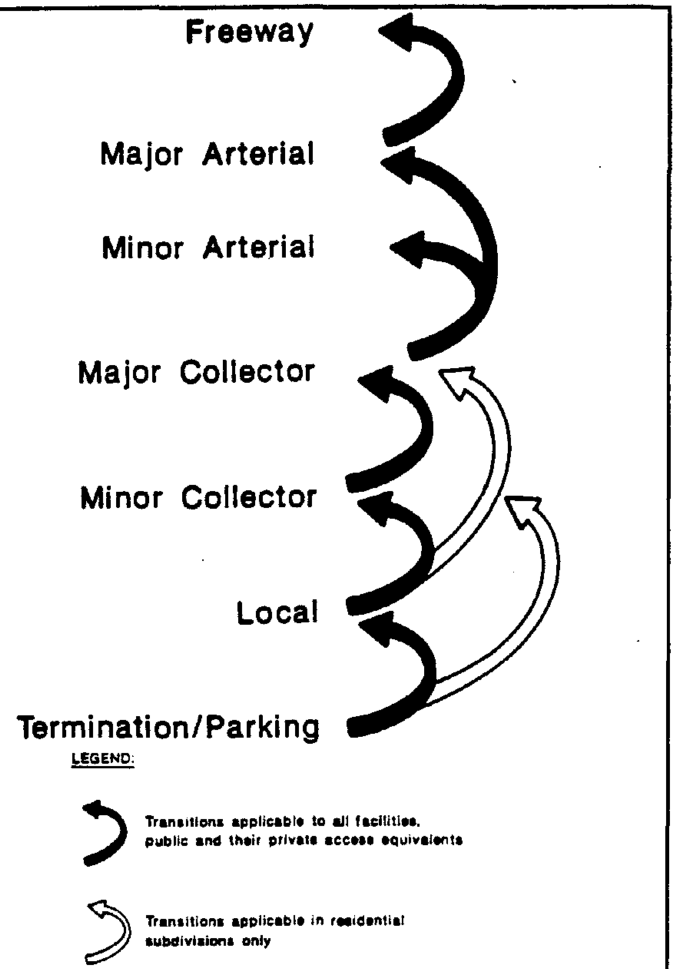


FIGURE 3-4: FUNCTIONAL HIERARCHY OF INTERSECTIONS

Source: Reference (3)

Two or more typical designs might be developed for each depending upon the conditions commonly encountered by an agency. For example, the intersection of a major arterial and a major collector where the collector serves a residential development will experience different traffic conditions than an intersection of the same major arterial and a major collector servicing retail, office or industrial development.

(Continued)

Relationship Between Functional Classes (Continued)

Consequently, there should be at least two different typical designs for major arterial-major collector intersections. Moreover, there is an increasing awareness that some major arterials are of urban regional significance while other major arterials are of significance to a portion of a large urban region. Thus, there should be at least five typical major arterial-major arterial intersections, in order of decreasing hierarchical importance these are: (1) 6-lane regional to 6-lane regional, (2) 6-lane regional to 6-lane sub-regional, (3) 6-lane regional to 4-lane sub-regional, (4) 6-lane sub-regional to 4-lane sub-regional, and (5) 4-lane sub-regional to 4-lane sub-regional.

Driveways Are Intersections

The fact that driveways create intersections with the public street system is recognized by AASHTO (*1* p. 841; *2* p. 888). While not clearly stated, the recognition of transition as a separate trip stage combined with the concept of functional classification (the degree to which a given facility is to accommodate movement-access) implies the following:

- There is a hierarchy in the provision of transitions between facilities intended to accommodate different degrees of access-v-movement.
- There is (or should be) a hierarchy in the design of intersections.

As shown in Figure 3-4, transition from/to a facility of lower functional design should be limited to a facility of the next higher design. That is: a local street should intersect with a minor collector, or in some cases a major collector in carefully designed residential subdivisions. Majors only should intersect with an arterial and only major at-grade arterials should interconnect with freeway type facilities. Private access drives (the termination facilities) serving individual dwelling should intersect with local streets and minor residential collectors only. This concept of design is well recognized in the design of modern limited access subdivisions and municipal ordinances commonly prohibit private residential driveways and local streets from intersecting with arterials. However, this principal is not as well recognized in the provision of access between major streets and adjacent nonresidential development.

(Continued)

FUNCTIONAL DESIGN (Continued)

Driveways Are Intersections (Continued)

While implied by functional design principles, there is very little literature which addresses the hierarchy of intersections of public streets and their private access or on-site circulation equivalents. A suggested generalized hierarchy is shown in Table 3-1.

TABLE 3-1: GENERALIZED HIERARCHY OF INTERSECTIONS

HIGH ↑	Freeway Main Lanes - Ramp
	Major Arterial - Freeway Ramp
	Major Arterial - Major Arterial
	Major Arterial - Minor Arterial
	Major Arterial - Major Collector
	Minor Arterial - Major Collector
	Major Collector - Major Collector
	Minor Collector - Local
↓ LOW	Local - Residential Drive/Parking Place

Source: Reference (3)

OPERATIONAL CONTROLS

Introduction

Basic vehicle and driver characteristics which influence operational controls include the following.

Operational Controls

- Design Vehicle Dimensions
- Vehicle Turning Path and Speed
- Vehicle Deceleration Rate
- Vehicle Acceleration Rate
- Speed Differential Between Vehicles
- Driver Perception-Reaction Time

Design Vehicles

The physical characteristics of vehicles and the proportion of different sized vehicles in the traffic stream are important and positive controls in the design of access management techniques. It is therefore necessary to examine all vehicle types and establish a representative-sized vehicle that needs to be accommodated. Two general classes of vehicles are typically used -- the passenger vehicle and trucks. In the design of any access management techniques, the largest design vehicle likely to be encountered with considerable frequency must be taken into account to determine the design of the critical elements.

Operational Controls

Type	Symbol
• Passenger Car	P
• Single Unit Truck	SU
• Single Unit Bus	BUS
• Semitrailer Combination	
– Intermediate	WB-40
– Large	WB-50
– Full Trailer	WB-60

(Continued)

OPERATIONAL CONTROLS

Design Vehicles (Continued)

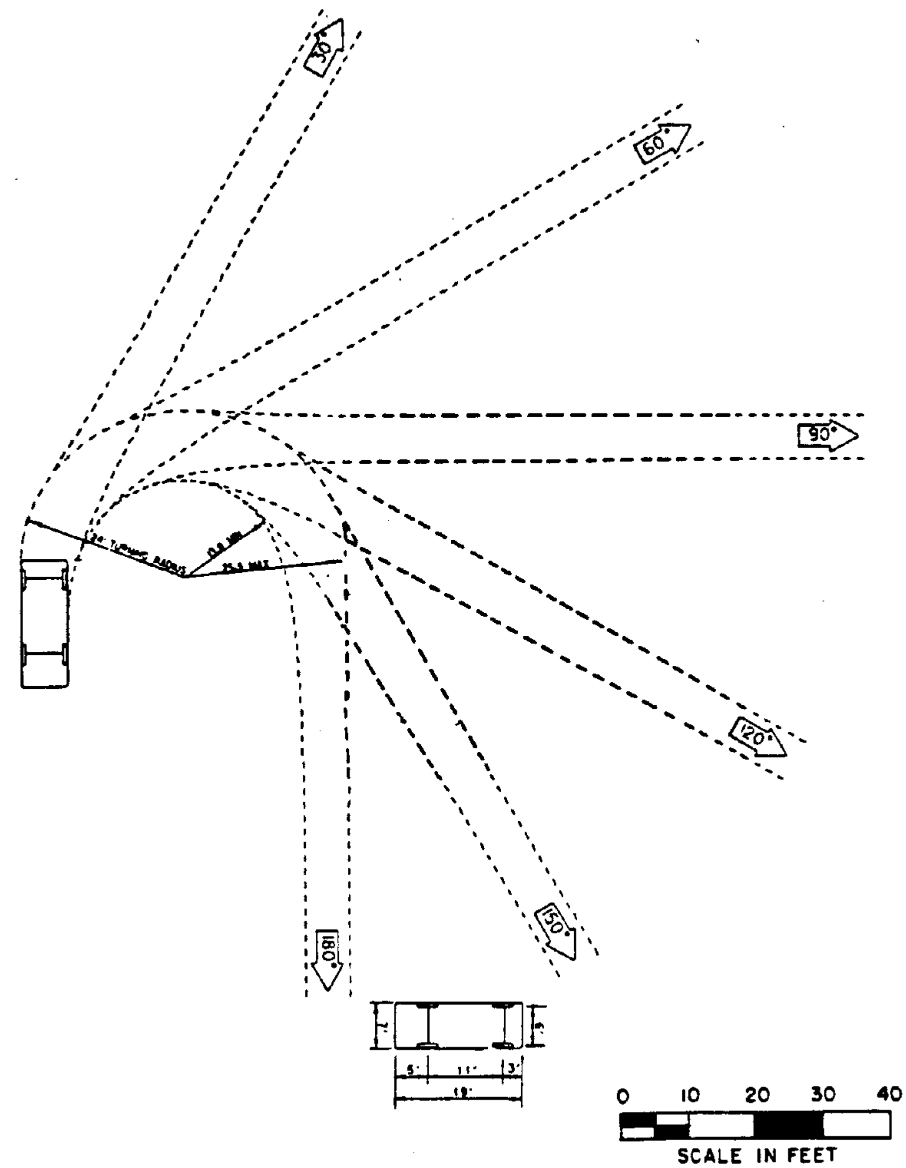


FIGURE 3-5: TURNING PATH FOR P DESIGN VEHICLES

Source: Reference (*1*), Figure II-1, p. 24

(Continued)

OPERATIONAL CONTROLS

Design Vehicles (Continued)

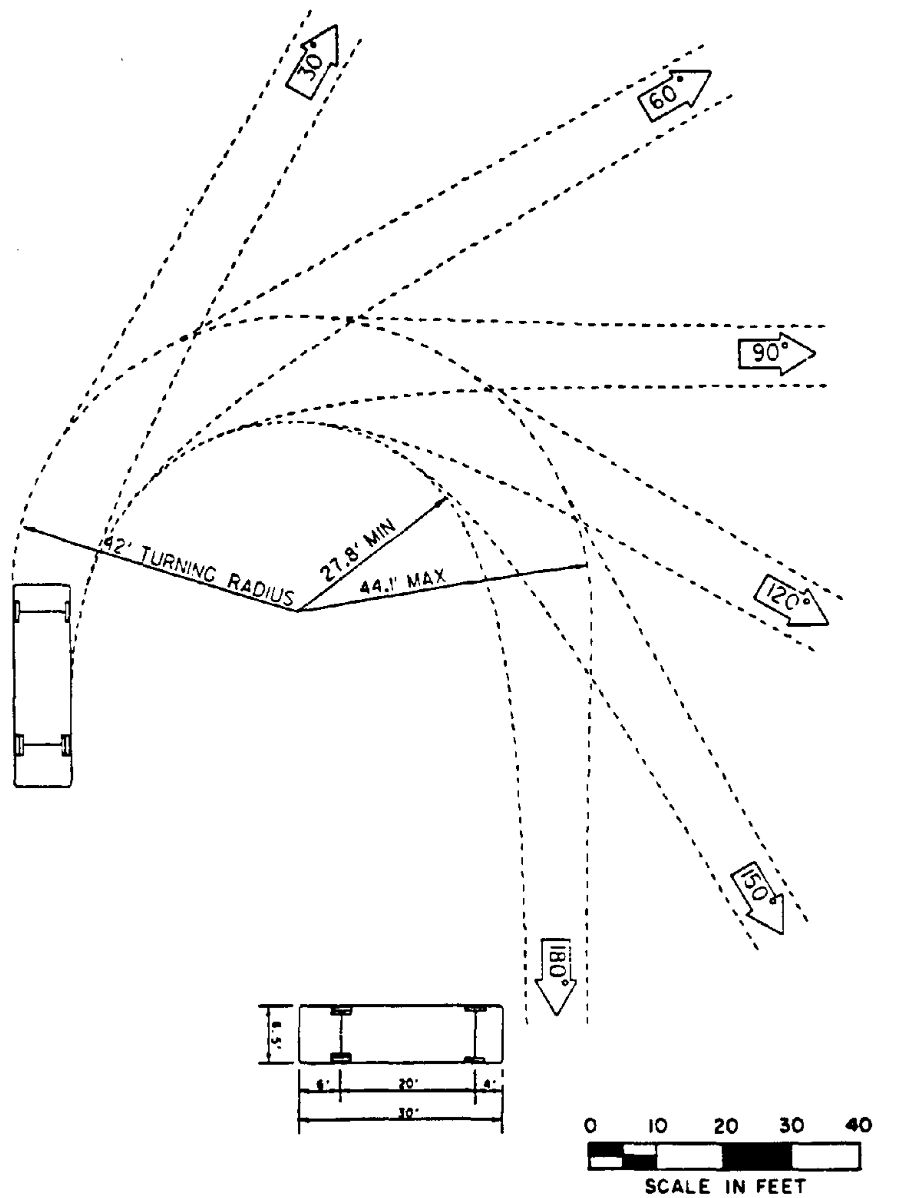


FIGURE 3-6: TURNING PATH FOR SU DESIGN VEHICLES

Source: Reference (*1*), Figure II-2, p. 25

(Continued)

OPERATIONAL CONTROLS

Design Vehicles (Continued)

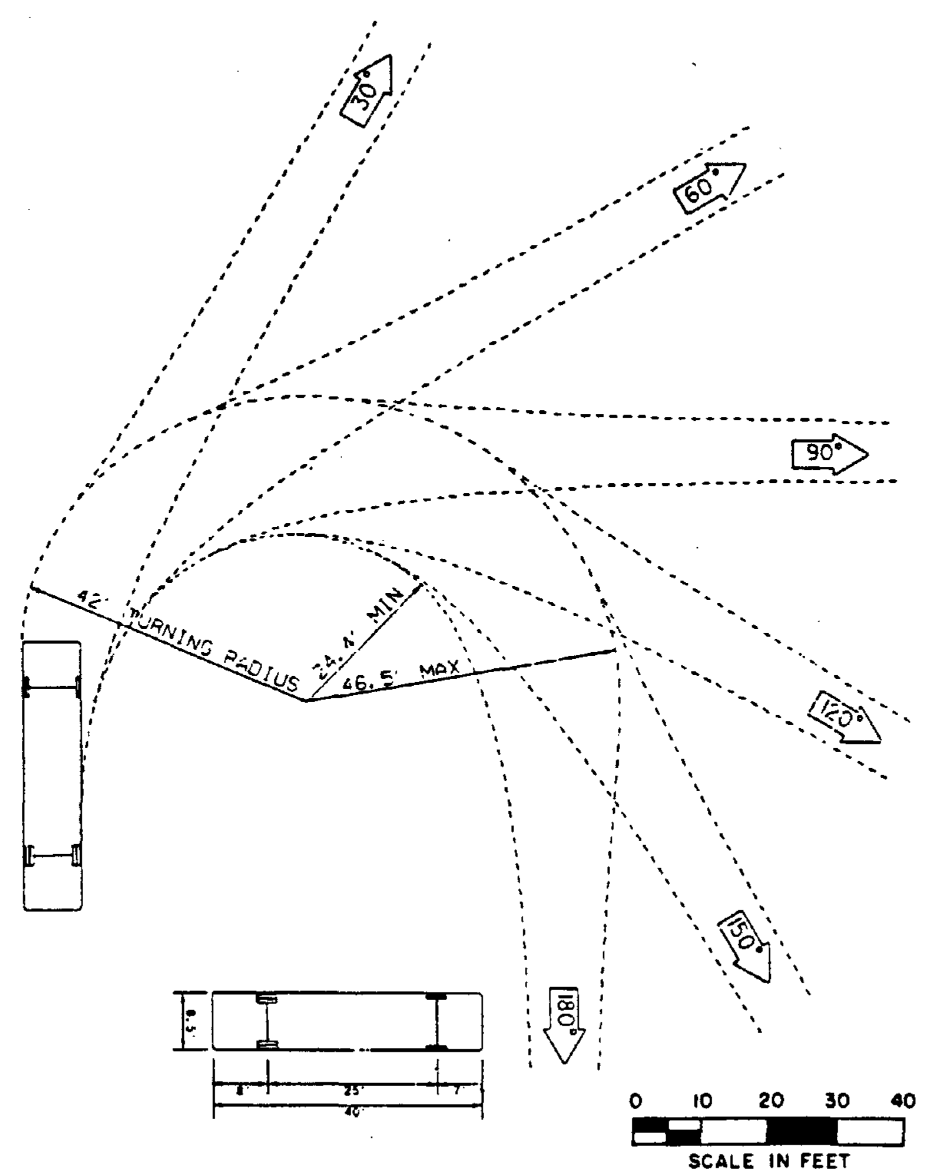


FIGURE 3-7: TURNING PATH FOR BUS DESIGN VEHICLES

Source: Reference (*1*), Figure II-3, p. 26

(Continued)

OPERATIONAL CONTROLS

Design Vehicles (Continued)

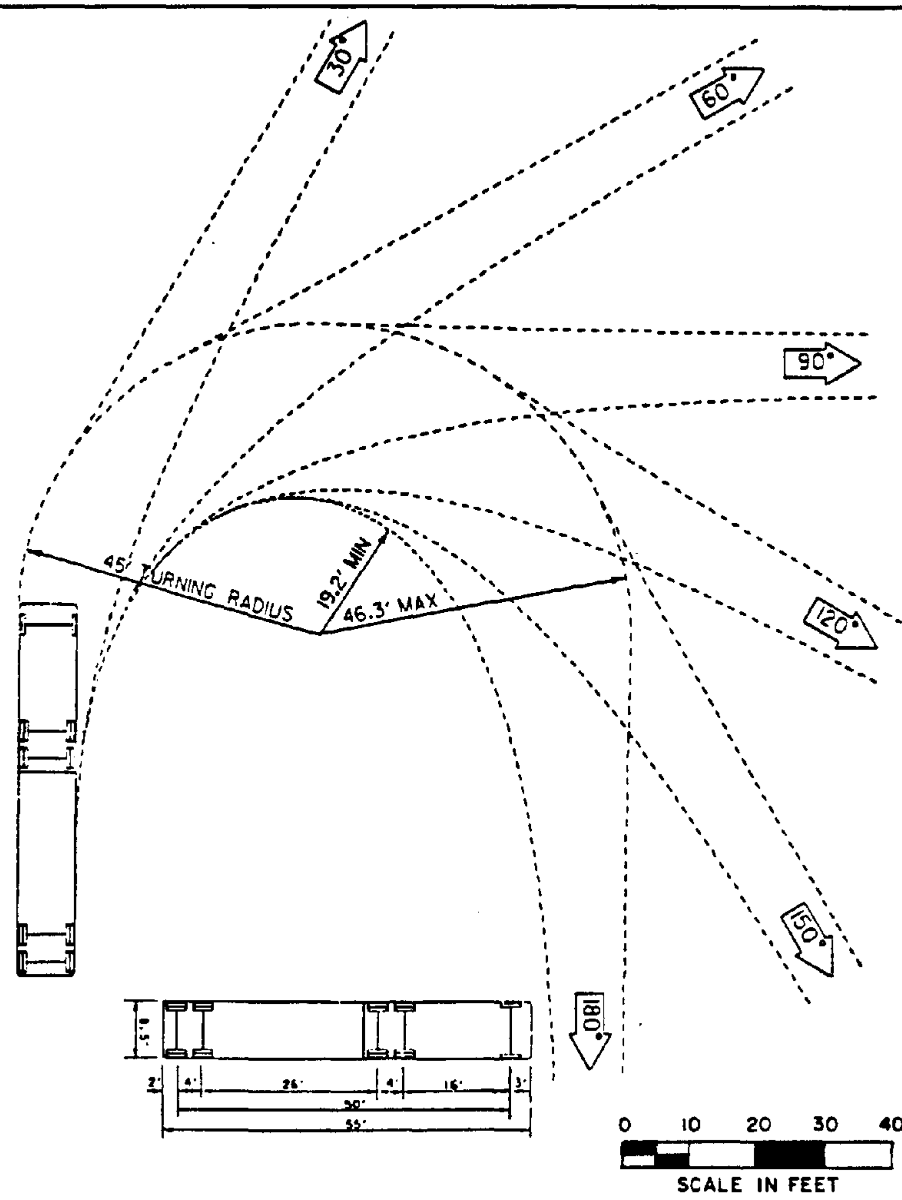


FIGURE 3-8: TURNING PATH FOR WB-50 DESIGN VEHICLES

Source: Reference (1), Figure II-6, p. 30

SIGNALIZED INTERSECTION SPACING

Introduction

Signalized Intersection Spacing

- **Essential to Movement Function**
- **Parameters**
  - **Speed**
  - **Cycle Length**
  - **Signal Spacing**
  - **Efficiency of Progression**

Major arterials are intended to provide a high degree of mobility and serve the longer trips. Since movement, not access, is their principal function, access management is essential in order to preserve capacity and safety. This principle was recognized in the 1984 edition of **A Policy on the Geometric Design of Highways and Streets** (the AASHTO Green Book). Further, the adoption of functional design, in lieu of volume based design, represented a major change in the philosophy of planning and design of street and highway systems.

Many commercial lessees and businesses demand that the developer obtain access commitments that include signals and direct assess driveways as a specific part of a pre-lease agreement. The developer then presses the public agencies for approval. The transportation agency must be able to act by its standards and regulations in order to provide a safe and efficient highway.

Controlling Parameters

The variables involved in the planning design and operation of signalized arterial streets are:

- speed
- cycle length
- signal spacing
- efficiency of progression

(Continued)

SIGNALIZED INTERSECTION SPACING (Continued)

Controlling Parameters (Continued)

Major arterials in developed urban areas experience very high travel demand during the morning and after work peak periods. Hence, capacity is always an issue once the property in the vicinity of the major street becomes fully urbanized. It has long been recognized that maximum flow rates are achieved when traffic is moving at a uniform speed of about 35 mph (56 kph) to 40 mph (64 kph). It might also be noted that fuel consumption and emissions are also minimum under these conditions. During off-peak conditions a major arterial should operate of speeds of between 45 and 55 mph (72 to 88 kph). Thus, a signal timing plan must be able to provide efficient traffic flow at different speeds. The signal timing plan must also be able to operate efficiently within a range of cycle lengths. During off-peak conditions, a cycle of about 60 seconds is commonly employed. Longer cycle lengths are used during the high volume peak periods in order to minimize the "lost time" which occurs each time the signal indication is changed. This includes the delay between the beginning of the green indication and when the first vehicle enters the intersection as well as headways between successive vehicles as the queue begins to move and before the minimum headway is achieved.

The only other variable is the efficiency of traffic progression (progression band width divided by cycle length). The higher the efficiency -- the higher the capacity. Moreover, at high efficiencies, fewer vehicles are required to come to a stop. Deceleration noise is reduced, thus vehicle emissions, fuel consumption and delay are minimized. Since capacity will always be an issue on a major urban arterial once urban development has occurred, the signal spacing must be such that very high progression efficiencies can be obtained. New Jersey, for example, specifies that a minimum acceptable through band width of 50% on those facilities functionally classified as principal arterials (4 p. 1068).

The optimum combinations of speed and cycle length for 1/2-mile (0.805 km), 1/3 mile (0.536 km) and 1/4-mile (0.402 km) spacings were determined by varying speeds from 15 mph (24 kph) to 60 mph (97 kph) in 5 mph (8 kph) intervals. The PASSER II-87 program maximized the progression band width and provided the optimum cycle length and phasing. The results of the numerous PASSER runs are presented in Figure 3-9.

(Continued)

SIGNALIZED INTERSECTION SPACING (Continued)

Controlling Parameters (Continued)

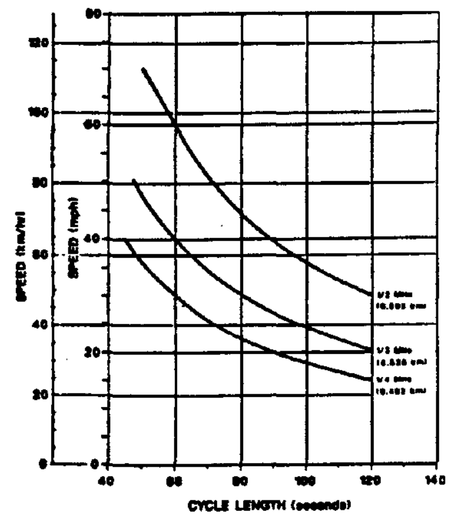


FIGURE 3-9: OPTIMUM SIGNAL SPACING AS A FUNCTION OF SPEED AND CYCLE LENGTH

Source: Reference (5), Figure 1

TABLE 3-2: OPTIMUM SIGNALIZED INTERSECTION SPACINGS IN FEET NEEDED TO ACHIEVE EFFICIENT TRAFFIC PROGRESSION AT VARIOUS SPEEDS AND CYCLE LENGTHS

Cycle Length (sec)	Speed (mph)						
	25	30	35	40	45	50	55
	Distance in Feet						
60	1,100	1,320	1,540	1,760	1,980	2,200	2,430
70	1,280	1,540	1,800	2,050	2,310	2,500	2,820
80	1,470	1,760	2,050	2,350	2,640	2,930	3,220
90	1,630	1,980	2,310	2,640	2,970	3,300	3,630
120	2,200	2,640	3,080	3,520	3,960	4,400	4,840
150*	2,750	3,300	3,850	4,400	4,950	5,500	6,050

* Represents maximum cycle length for actuated signal if all phases are fully used. One-half mile (2,640 ft.) spacing applies where optimum spacing exceeds one-half mile.

(Continued)

SIGNALIZED INTERSECTION SPACING (Continued)

Controlling Parameters (Continued)

Progression at reasonable speeds can be achieved at short signal spacings such as at 1/4 mile (0.402 km) only so long as the traffic volumes are very low and short cycles (60 seconds or less) can be used. Inspection of Figure 3-10 reveals that a 60 second cycle will result in a progression speed of about 30 mph (48 kph).

However, as arterial and cross street traffic volumes increase, longer cycle lengths must be used in order to increase capacity by minimizing lost time. As a result, cycle lengths of 90 to 120 seconds are commonly used on major urban arterials during peak periods in developed urban areas. A 90 second cycle and a 1/4 mile (0.402 km) spacing the progression speed is only 20 mph (32 kph), with a 120 second cycle it drops to less than 15 mph (24 kph).

Experience has shown that high traffic volumes and capacity problems will result on major arterials when the area is fully urbanized. Therefore, the future cycle length must be considered in selecting a signalized intersection spacing pattern which will provide efficient progression at speeds which will yield maximum flow rates. As shown by the shaded area in Figure 3-10, a 1/2 mile (0.805 km) spacing will enable traffic flow at speeds of between 35 mph (56 kph) and 40 mph (64 kph) with the use of cycles which are 90 seconds to slightly more than 100 seconds. Figure 3-10 also illustrates that a 1/2-mile (0.805 km) spacing is needed to provide efficient progression at 30 mph (48 kph) with a 120 second cycle commonly used in developed urban areas during peak hours. At slower speeds the increase in headway will result in a serious reduction in flow rate.

A 1/2 mile (0.805 km) spacing also enables the implementation of timing plans which will result in appropriate off-peak progression speeds at cycle lengths which are appropriate for use with off-peak traffic volumes. A 65 second cycle will provide progression at a speed of 55 mph (88 kph) whereas an 80 second cycle provides progression speed of 45 mph (72 kph).

(Continued)

SIGNALIZED INTERSECTION SPACING (Continued)

Controlling Parameters (Continued)

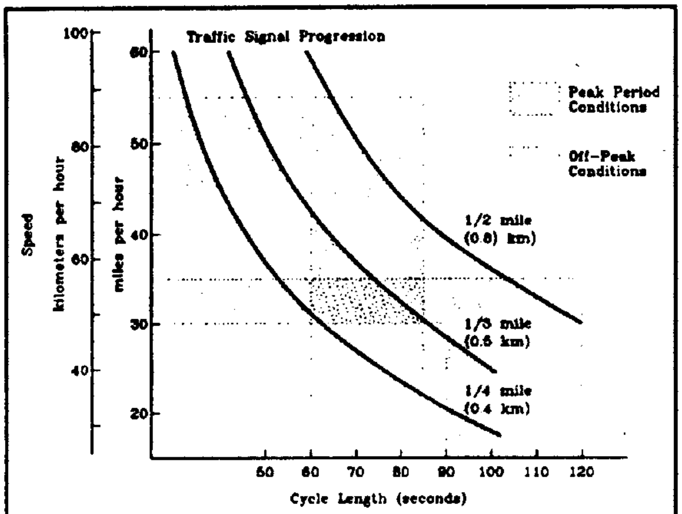


FIGURE 3-10: RELATIONSHIP BETWEEN PROGRESSION SPEED, CYCLE LENGTH, AND SIGNAL SPACING

Source: Adapted from Reference (6), Figure 4-13, p. 97

Cycles shorter than 65 seconds result in progression speeds which are too fast whereas cycles longer than 80 seconds produce progression at speeds which are too slow for off-peak arterial service.

For example, as shown in Figure 3-11, if a 60-second cycle length is chosen for the off-peak period on an arterial with signalized intersection spacing of 1/2 mile (0.805 km), the speed necessary to provide progression is approximately 58 mph (93 kph). This speed is unacceptable on an urban arterial. Thus, the cycle length must be lengthened to provide for slower speeds. Also, if a speed of 50 mph (80 kph) is desired, the appropriate cycle length is approximately 70 seconds.

(Continued)

SIGNALIZED INTERSECTION SPACING (Continued)

Controlling Parameters (Continued)

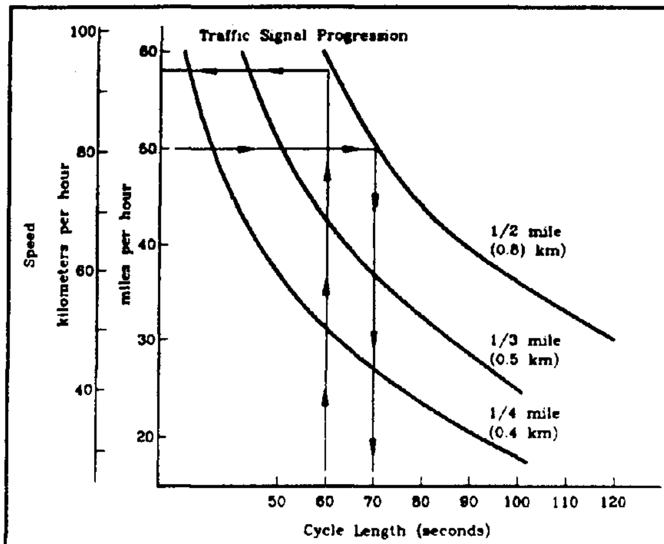


FIGURE 3-11: SELECTION OF PEAK PERIOD CYCLE LENGTH ONCE A UNIFORM SIGNALIZED INTERSECTION SPACING HAS BEEN ESTABLISHED

Source: Reference (3)

Selection Of A Signal Spacing Interval

Major urban arterials will experience high traffic demand during peak periods. Thus, it is suggested that a uniform signalized intersection interval be selected to provide maximum potential capacity when the area is fully developed. This involves the selection of a signal spacing which will accommodate traffic speeds of at least 30 to 35 mph (48 to 56 kph) using the longest cycle length which may be anticipated.

When a shorter cycle length will produce an unacceptably high progression speed given the selected long, uniform signal spacing progression may be achieved by increasing the percentage of the cycle devoted to the major roadway's green time. The corresponding reduction in green for the intersecting minor street will increase the delay to left turning and crossing traffic; right turning traffic will not be materially affected with right-turn-on-red. For example, if the uniform signal spacing is 1/2 mile (0.805 km) and a 60 second cycle is to be used with a desired 50 mph (80 kph) speed, 50% of the cycle will be devoted to the major arterial green and less than 50% to the minor cross-street approach.

FUNCTIONAL INTERSECTION AREA

Functional Boundary

AASHTO specifically states that: "Driveways should not be situated within the functional boundary of at-grade intersections. This boundary would include the longitudinal limits of auxiliary lanes." (*1* p. 841, *2* p. 888). While AASHTO does not present guidelines as to the size of the functional area of an intersection, logic indicates that it must be much larger than the physical area (see Figure 3-12).

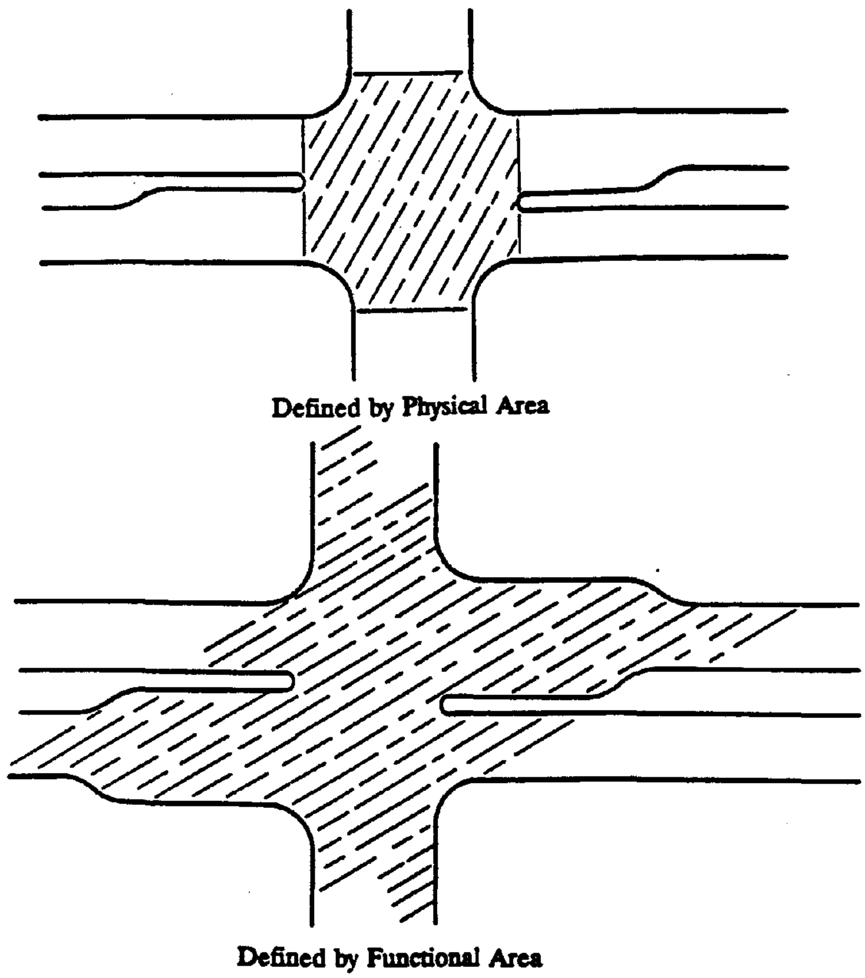


FIGURE 3-12: BOUNDARY OF INTERSECTION

Source: Reference (*6*), Figure 4-16, p. 100

(Continued)

FUNCTIONAL INTERSECTION AREA (Continued)

Functional Boundary (Continued)

Logic also suggests that the functional area should be comprised of the maneuver distance plus any required storage length. The minimum maneuver distance, assumes that the driver is in the proper lane and only needs to move laterally into a right turn bay (as illustrated), or a left turn bay.

As indicated in Figure 3-13, the physical length of a turn bay excludes the distance traveled during the perception-reaction time. The maneuver elements required to move laterally from a through lane to a turn bay are illustrated in Figure 3-14. Parameters which must be evaluated in the determination of maneuver distance include the following:

d_1: The perception-reaction time required by the driver. For motorists who frequently use the street this may be as little as one second or less. However, strangers may not be in the proper lane to execute the desired maneuver and may require several seconds.

d_2: Braking while moving laterally is a more complex maneuver than braking alone -- perhaps one-half the deceleration rate utilized in d_3. Lateral movement under urban conditions is commonly assumed to be 4 feet per second (1.2 metres per second) and 3 feet per second (0.9 metres per second) for rural conditions. At low deceleration rates the driver will have shifted laterally so that a following vehicle can pass without encroaching on the adjacent lane before a 10 mph (16 kph) speed differential occurs. At deceleration rates over about 4 fps^2 (1.2 mps^2) the speed differential will exceed 10 mph (16 kph) before the turning vehicle "clears" the through traffic lane.

d_3: Deceleration after moving laterally into the turn bay should be at a rate which will be used by most drivers. Studies (7, 8) have found that most drivers (85%) will utilized a deceleration rate of 6 fps^2 (1.8 mps^2) or more; only about 50% can be expected to accept a rate of 9 fps^2 (2.7 mps^2) or greater.

d_4: Length required to store all turning vehicles.

(Continued)

FUNCTIONAL INTERSECTION AREA (Continued)

Functional Boundary (Continued)

The calculated distances are given in Table 3-3 are the sum of d_2 and d_3 as defined in Figure 3-14. In calculating these deceleration distances, full deceleration rates of 6 fps^2 (1.8 mps^2) and 9 fps^2 (2.7 mps^2) were used. As shown in Figure 3-15, a 6 fps^2 (1.8 mps^2) deceleration is accepted by 85% of drivers. This value is used for the "desirable condition" since it will be used , or exceeded, by most drivers. Only 50% of drivers accept an acceleration of 9 fps^2 (2.7 mps^2) and is used as a "limiting" or upper limit for design. Maneuvering from the through land to an exiting lane while decelerating is a more demanding driving task decelerating only. Therefore one-half of the average full deceleration rate is used in calculating distance d_2.

It is to be noted that the difference in the maneuver distance required for peak and off-peak speeds will provide some storage. For example, using the desirable values, an off-peak speed of 55 mph (90 kph), and a 30 mph (50 kph) peak speed, a storage of about 450 feet (135 metres) is "built in". At 25 feet (7.7 metres) per vehicle, measured front bumper-to-front bumper, a queue of about 18 cars can be accommodated. This will generally be sufficient to provide the necessary right turn storage on arterial approaches at the intersections with minor arterials and major collectors. At high volume intersections, the functional limits are commonly controlled by peak-period conditions since peak period maneuver distance plus storage is longer than the maneuver distance plus storage needed in the off-peak. Consequently, the functional boundaries will be greater than the distances shown in Table 3-3 or developed from similar analyses.

(Continued)

FUNCTIONAL INTERSECTION AREA (Continued)

Functional Boundary (Continued)

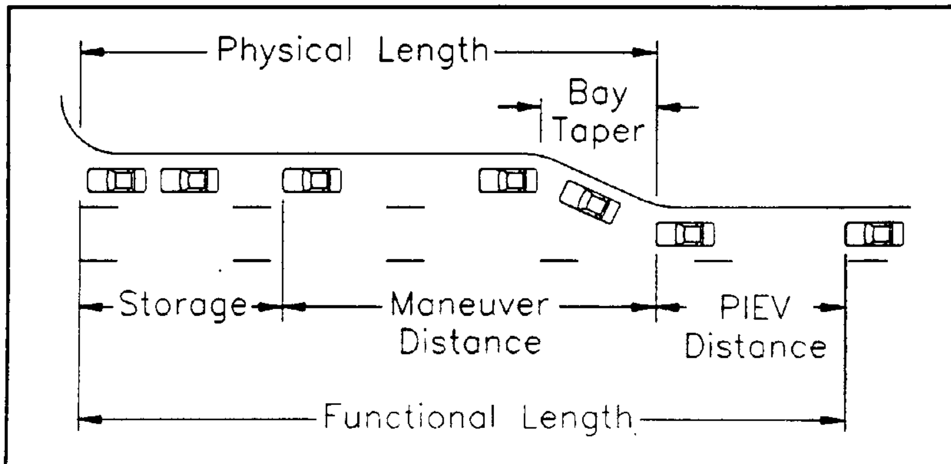


FIGURE 3-13: ELEMENTS OF THE FUNCTIONAL AREA OF AN INTERSECTION

Source: Reference (3), Figure 6, p. 23

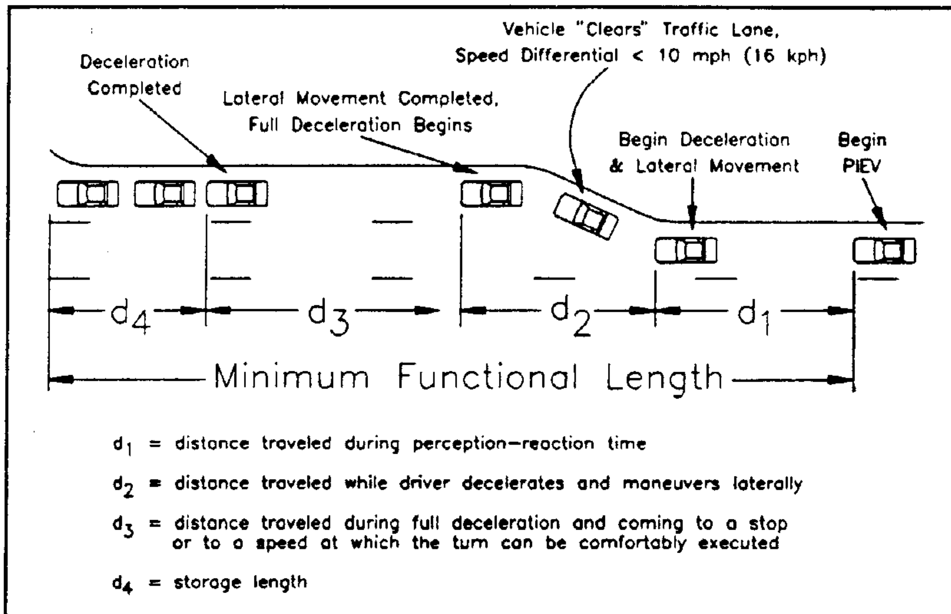


FIGURE 3-14: DETERMINANTS OF THE INTERSECTION MANEUVER DISTANCE

Source: Reference (3), Figure 7, p. 24

(Continued)

FUNCTIONAL INTERSECTION AREA (Continued)

Functional Boundary (Continued)

Table 3-3 presents maneuver distances and total distances (maneuver plus PIEV distance) for the selected conditions indicated with the table. These distances represent the minimum functional length of an approach to an intersection as they exclude storage.

TABLE 3-3: CALCULATED UPSTREAM MANEUVER DISTANCES

	Minimum Maneuver Distance[1] in Feet (Metres)			
	Desirable Conditions[2]		Limiting Conditions[3]	
Speed mph (kph)[4]	Deceleration[5]	Total[6]	Deceleration	Total[6]
30 (50)	225 (70)	325 (100)	170 (50)	215 (65)
35 (55)	295 (90)	425 (130)	220 (65)	270 (80)
40 (65)	375 (115)	525 (160)	275 (85)	335 (700)
45 (70)	465 (140)	630 (190)	340 (105)	405 (125)
50 (80)	565 (170)	750 (230)	410 (125)	480 (145)
55 (90)	675 (205)	875 (265)	485 (150)	565 (170)
60 (95)	785 (240)	1005 (305)	565 (170)	655 (200)

Source: Calculations by author.

(1) All values rounded to nearest 5 feet (5 metres).
(2) 2.5 second perception-reaction time; 3.5 fps^2 (1.1 mps^2) average deceleration while moving laterally into turn bay and an average 6 fps^2 (1.8 mps^2) deceleration thereafter; 10 mph (16 kph) speed differential.
(3) 1.0 second perception-reaction time; 4.5 fps^2 (1.4 mps^2) deceleration while moving laterally into turn bay and an average 9.0 fps^2 (2.7 mps^2) deceleration thereafter; 10 mph (16 kph) speed differential.
(4) Nearest 5 kph for design.
(5) Distance to decelerate from speed to a stop while maneuvering laterally into a left or right-turn bay.
(6) Deceleration distance plus distance traveled in perception-reaction time.

Source: Adapted from Reference (3), Table 3, p. 35

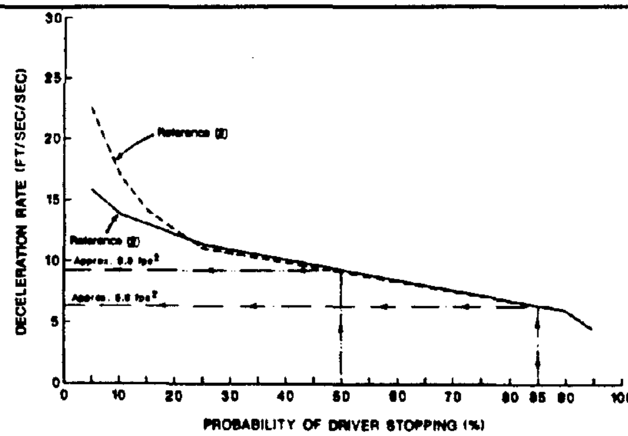


FIGURE 3-15: OBSERVED DECELERATION RATES

Source: Adapted from References (8, 9)

(Continued)

FUNCTIONAL INTERSECTION AREA (Continued)

Rear End Accidents

As shown in Figure 3-16, the chance of being involved in an accident is minimal when successive vehicles are traveling at the same speed. Whereas about 65% of the cars involved in rear-end accidents were traveling at a difference in speed of over 10 mph (16 kph), only approximately 35% of the other cars (not involved in rear-end accidents) were traveling at speeds which differed by more than 10 mph (16 kph).

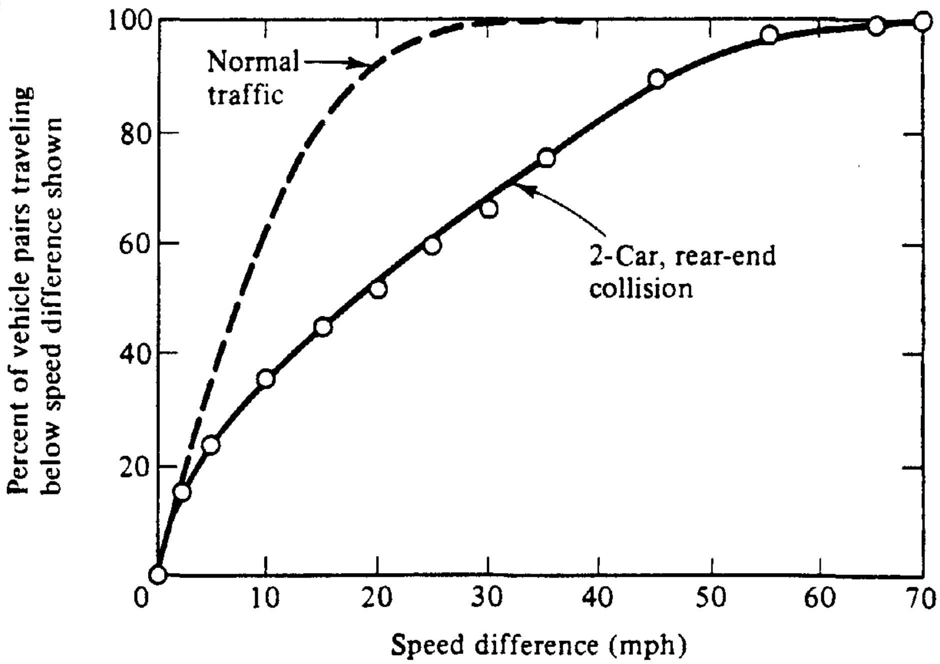


FIGURE 3-16: INCIDENCE OF REAR-END ACCIDENTS AS A FUNCTION OF SPEED DIFFERENTIAL

Source: Reference (<u>10</u>)

(Continued)

FUNCTIONAL INTERSECTION AREA (Continued)

Accident Rates

Figure 3-17 clearly shows that the accident involvement rate increases substantially when a vehicle travels much faster or slower than the average speed of traffic.

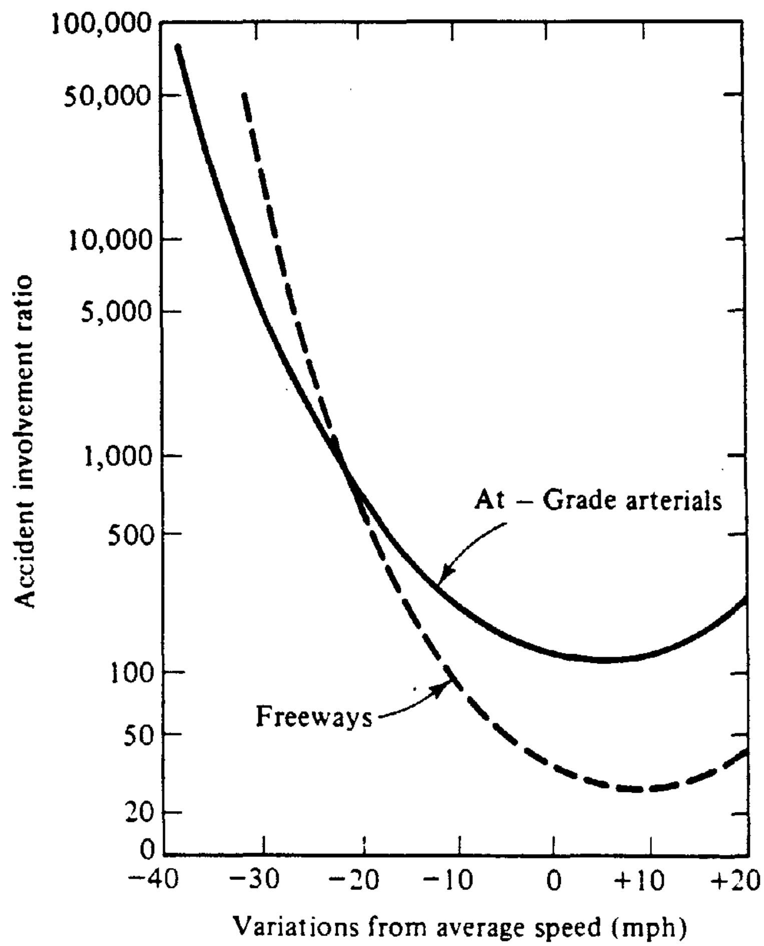


FIGURE 3-17: ACCIDENT RATES AS A FUNCTION OF SPEED DIFFERENTIAL

Source: Reference (10)

(Continued)

FUNCTIONAL INTERSECTION AREA (Continued)

Relative Accident Rates

The relative rates in Table 3-4 may be expected to be much more transferable. In this form, the data indicates that a vehicle traveling on an at-grade arterial at a speed 35 mph (56 kph) slower than the speed of the normal traffic stream is 180 times (20,000/110) more likely to be involved in an accident than a vehicle traveling at the same speed as the other vehicles in the traffic stream. A vehicle traveling 15 mph (24 kph) slower than the traffic stream has 90 times (20,000/220) the chance of being involved in an accident as a vehicle traveling 10 mph (16 kph) slower. While the relative ranges may be in considerable error for any specific section of street of freeway, they clearly show the increased accident potential. Thus, designs which produce small speed differentials of less than 10 or 15 mph (16 to 24 kph) should be major criteria for the functional design of arterials.

TABLE 3-4: RELATIVE ACCIDENT-INVOLVEMENT RATES

Facility	Speed Differential (mph)				
	0	-10	-20	-30	-35
At-Grade Arterials:					
Accident Rate	110	220	720	5,000	20,000
Ratio, 0-mph differential	1	2	6.5	45	180
10-mph differential		1	3.3	23	90
Freeways:					
Accident Rate	30	100	600	2,000	
Ratio, 0-mph differential	1	3.3	20	67	
10-mph differential		1	6	20	

NOTE: 10 mph = 16 kph

Source: Reference (6), Table 4-5, p. 106

(Continued)

Speed Entering Driveway

The speed of a vehicle making a turn at an intersection is very slow from all reasonable combinations of throat width and curb return radii as illustrated in Figure 3-18. The forward speeds of the vehicle (as measured by fifth wheel) are between 6 and 13 mph (10 and 21 kph); however, the speed vector parallel to the through traffic lanes is only 1.5 to 2.5 mph (2.4 to 4.0 kph).

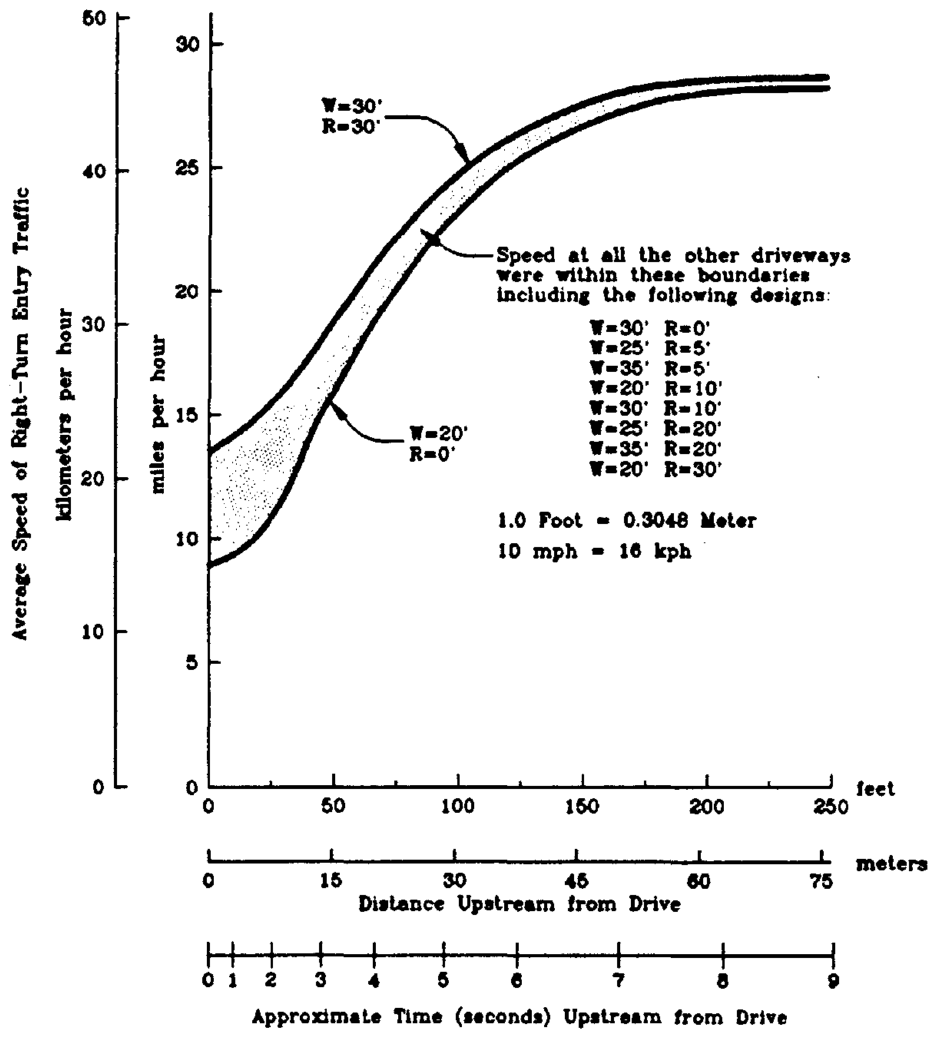


FIGURE 3-18: SPEED PROFILE OF DRIVEWAY TRAFFIC

Source: Reference (6), Figure 5-29, p. 150

(Continued)

FUNCTIONAL INTERSECTION AREA (Continued)

Speed Differential	A speed differential of 10 mph (16 kph) or more occurs at least 250 feet (76.2 metres) and at least 9 seconds upstream from the driveway for off-peak arterial street speeds of 40 to 45 mph (64 to 72 kph). The fact that excessive speed differentials are created a considerable distance upstream from the point at which the driveway maneuver is made probably results in an under-reporting of driveway related accidents on accident reports. It also shows that turn lanes are needed in order to achieve acceptable speed differentials between driveway traffic and through vehicles on arterial streets.
Taper	Use of taper on the upstream side of the driveway does not significantly influence the speed of the vehicle making the driveway maneuver. However, the taper results in a reduction in exposure time (the time which the turning vehicle is blocking the through traffic lane).
Design Implications	Accident expectancy is known to increase exponentially as the difference in speed between vehicles in a traffic stream increases. Moreover, all reasonable combinations of driveway curb return radii and throat width have been found to produce a speed differential which is essentially equal to the speed of traffic in the through lanes. Thus, it must be concluded that auxiliary left turn and right turn lanes (bays) are needed at all intersections on major roadways.

STOPPING SIGHT DISTANCE

Stopping Sight Distance

The stopping sight distance considered safe under various assumptions of physical conditions and driver behavior is directly related to vehicle speeds and to the resulting distances traveled during perception and reaction time and braking.

Stopping Distance

For stopping sight distance, AASHTO assumes a 2.5 second perception-reaction time (*1*, p. 119) and an average coefficient of friction which varies with speed. The equation used by AASHTO for the stopping distance is:

$$d = 1.47\,Vt + \frac{V^2}{30f}$$

Where:
- d = stopping distance in feet;
- V = the approach sped in miles per hour;
- t = the perception-reaction time; and,
- f = the coefficient of friction between tires and pavement.

The selection of design values for the coefficient of friction are based on wet surface skid tests and represent the lower levels of coefficients of friction that may be expected to be physically available -- not necessarily values which the vehicle operator will encounter.

The design values imply that deceleration rates of about 9.7 fps^2 to about 12.9 fps^2 will be utilized by most drivers. Objects will slide off the seat at 11 fps^2. While data is limited on deceleration rates which vehicle operators are willing to use under different conditions, generally acceptable rates would seem to be less than 9 fps^2. Experience suggests that deceleration rates greater than 6 to 7 fps^2 are objectionable to many individuals.

Table 3-5 gives the AASHTO stopping sight distances.

(Continued)

STOPPING SIGHT DISTANCE (Continued)

Stopping Distance (Continued)

TABLE 3-5: MINIMUM STOPPING SIGHT DISTANCES

Design Speed (mph)	Assumed Coefficient Of Friction	Rounded For Design (feet)	Implied Average Deceleration Rate (fps^2)
15	0.40	75	12.9
20	0.40	125	12.9
25	0.38	150	12.2
30	0.35	200	11.3
35	0.34	250	10.9
40	0.32	325	10.3
45	0.31	400	9.9
50	0.30	475	9.7
55	0.30	550	9.7
60	0.29	650	9.3
65	0.29	725	9.3
70	0.28	850	9.0

Source: Adapted from Reference (1), Table III-1, page 120

Truck Requirements

The AASHTO minimum stopping sight distances directly reflect passenger car operation. Trucks, especially the larger and heavier units, require longer stopping distances and longer sight distances than passenger vehicles do. However, the truck operator is usually able to see roadway features and other vehicles at longer distances because of a higher eye height.

(Continued)

STOPPING SIGHT DISTANCE (Continued)

Adjustments For Grades

On down-grades, the sight distance must be increased to account for the increased stopping distance due to the effect of gravity. Adjustments are given in Table 3-6. On up-grades, the stopping distance is shortened and the sight distance may be reduced slightly.

It should be observed that the adjustments for up-grades are negligible for operating speeds of less than 60 mph. Therefore, reductions in stopping distance are not made in urban design. This practice compensates to some extent for the high deceleration rates assumed by AASHTO.

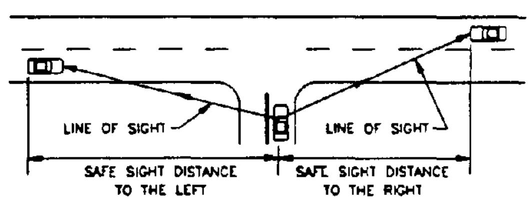
TABLE 3-6: EFFECT OF GRADE ON STOPPING SIGHT DISTANCE

Design Speed (mph)	Increase for Downgrades Correction in Stopping Distance (ft)			Assumed Speed for Condition (mph)	Decrease for Upgrades Correction in Stopping Distance (ft)		
	3%	6%	9%		3%	6%	9%
30	10	20	30	28	—	10	20
40	20	40	70	36	10	20	30
50	30	70	—	44	20	30	—
60	50	110	—	52	30	50	—
65	60	130	—	55	30	60	—
70	70	160	—	58	40	70	—

Source: Reference (*1*), Table III-2, p. 125

INTERSECTION SIGHT DISTANCE

Introduction



Intersection Sight Distance

The operator of a vehicle on a major roadway approaching an at-grade intersection with another roadway (including driveways) should have an unobstructed view of the entire intersection and sufficient distance to the intersecting highway to permit control of the vehicle to avoid collisions.

The driver of a vehicle on a minor roadway at the intersection with a major roadway must be able to see an on-coming vehicle in sufficient time to safely execute the maneuver to enter, or cross the major roadway. Ideally, the driver should have an unobstructed view of the pavement surface within the required intersection sight distance. As a minimum, the driver should be able to see the headlights of an on-coming vehicle on the major roadway. Thus, a common practice is to assume a 2.0 foot height. This will provide a moving "target" of such a size that a driver attempting to enter, or cross, the major roadway can evaluate if the gap is of sufficient size to safely make the intended maneuver.

Sight Triangle

Unobstructed sight distance must be provided on all approaches at an intersection. Any object within the sight triangle high enough above the elevation of the adjacent roadway to constitute a sight obstruction should be removed or lowered. Such objects include: buildings, signs, cut slopes, hedges, trees, bushes, and tall crops. This also requires the elimination of parking within the sight triangle.

After a vehicle has stopped at an intersection, the driver must have sufficient sight distance to make a safe departure through the intersection area. The intersection design should provide adequate sight distance for any of the various vehicular maneuvers required upon departure from the stopped position.

(Continued)

INTERSECTION SIGHT DISTANCE (Continued)

Types Of Control

The required sight distance is different for each of the four types of controls that apply to at-grade intersections. These four conditions are:

1. No Control - When there is no traffic control device at an intersection, desirable practice is to provide sufficient sight distance so that a driver may observe a vehicle on another approach in time to bring his or her vehicle to a stop before entering the intersection.

2. YIELD Control - When vehicles on the minor intersecting roadway must yield to vehicles on the major intersecting roadway the sight distance criteria for no control should be provided.

3. STOP Control - (1) Two-way where traffic on the minor roadway must stop prior to entering the major roadway and (2) Four-way where traffic on all four approaches to the intersection must stop. The driver of the stopped vehicle must have sufficient sight distance for a safety departure from the stopped position.

4. Signal Control - Sight distances at signal controlled intersections should be the same as that provided for stop control. The reasons for providing such sight distances include: (1) violations of the signal, (2) right turn on red, (3) signal malfunction, and (4) flashing red-yellow mode.

(Continued)

INTERSECTION SIGHT DISTANCE (Continued)

No Control

When there is no control at the intersection, both drivers must have adequate sight distance to permit them to see a vehicle approaching on the cross roadway and bring their vehicle to a stop. The dimensions associated with no control are illustrated in Figure 3-19. The distances d_a and d_b are the stopping distances. Again, it should be realized that the AASHTO design criteria reflect the coefficients of friction that encompass the pavement surfaces and likely field conditions that might be encountered. They are not based upon deceleration rates (and hence utilized coefficients of friction) which drivers find acceptable.

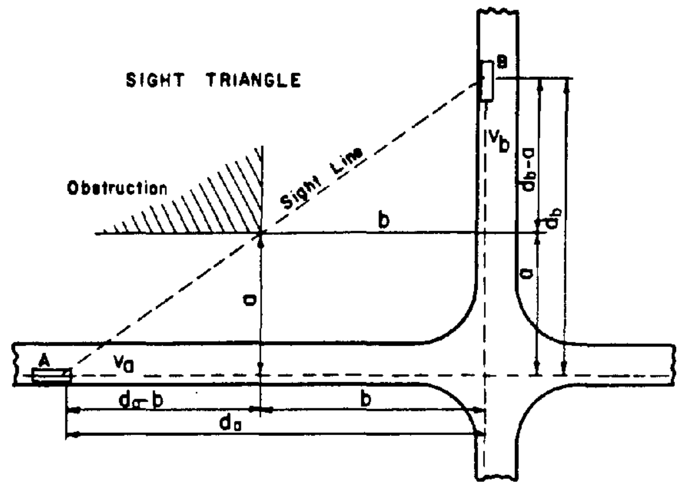


FIGURE 3-19: MINIMUM SIGHT TRIANGLE AT INTERSECTION FOR NO CONTROL

Source: Reference (1), Figure IX-32, p. 741

Basic Requirement For Controlled Intersections

A basic requirement for all controlled intersections is that drivers must be able to see the control device far enough in advance to perform the action it indicates. When the traffic control device cannot be seen soon enough, advance warning signs are needed.

(Continued)

INTERSECTION SIGHT DISTANCE (Continued)

YIELD Control

Posting a YIELD sign requires the driver on that approach to reduce speed and be prepared to stop if a vehicle is approaching from the left or right. Reference is made to Figure 3-19 for No Control.

The required line of sight is established by the stopping distance for the vehicle on the YIELD approach and the distance traveled, at the design speed, by a vehicle on the through street. A reduced approach speed of 15 mph is commonly used for the YIELD approach for urban conditions and 20 to 25 mph for rural conditions.

STOP Control

Where traffic on the minor road of an intersection is controlled by STOP signs, the driver of the vehicle on the minor road must have sufficient sight distance for a safe departure from the stopped position. The three basic maneuvers which can occur at a typical intersections are as follows:

Intersection Sight Distance Cases

- Case A - Crossing
- Case B - Left Turn
- Case C - Right Turn

For Case A, the vehicle must travel across the intersecting roadway by clearing traffic approaching from both the left and the right of the crossing vehicle. Case B requires a left turn onto the roadway by first clearing traffic approaching from the left and then entering the through lane without being overtaken by vehicles approaching from the right. Case C involves a right turn onto the roadway without being overtaken by vehicles approaching from the left.

The assumed conditions and AASHTO sight distances curves for the crossing maneuver, Case A, are given in Figure 3-20. The conditions for the left turn, Case B, are illustrated in Figure 3-21 and Figure 3-22; the right turn, Case C, conditions are shown in Figure 3-23. The AASHTO sight distance curves are reproduced in Figure 3-24.

(Continued)

INTERSECTION SIGHT DISTANCE (Continued)

1990 AASHTO Crossing Sight Distances

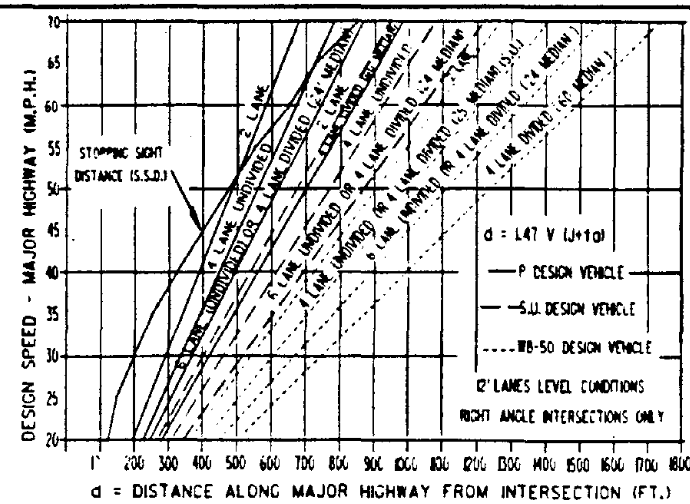


FIGURE 3-20: AASHTO DEPARTURE SIGHT DISTANCE REQUIRED FOR CROSSING A MAJOR ROADWAY FROM A TWO-WAY STOP

Source: Reference (*1*), Figure IX-39, p. 761

Left Turn Maneuver

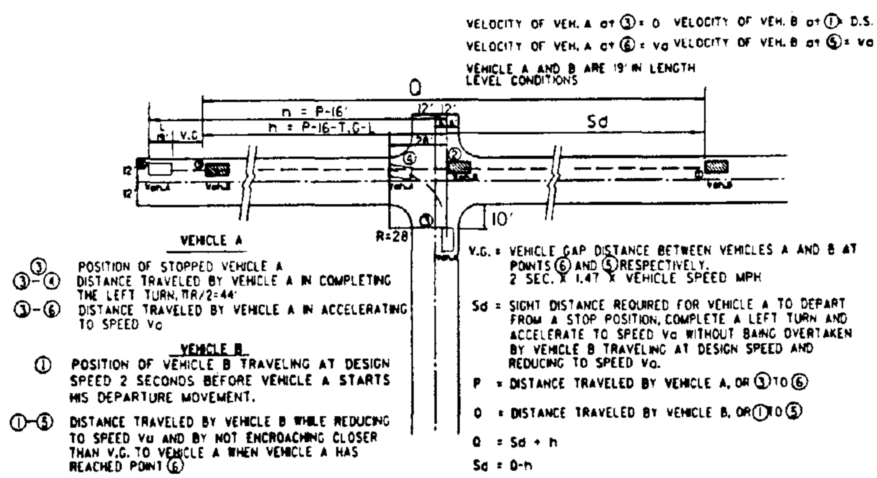


FIGURE 3-21: AASHTO CONDITIONS FOR STOPPED VEHICLE TURNING LEFT ONTO A TWO-LANE MAJOR HIGHWAY

Source: Reference (*1*), Figure IX-36, p. 756

(Continued)

INTERSECTION SIGHT DISTANCE (Continued)

Left Turn To Divided Roadway

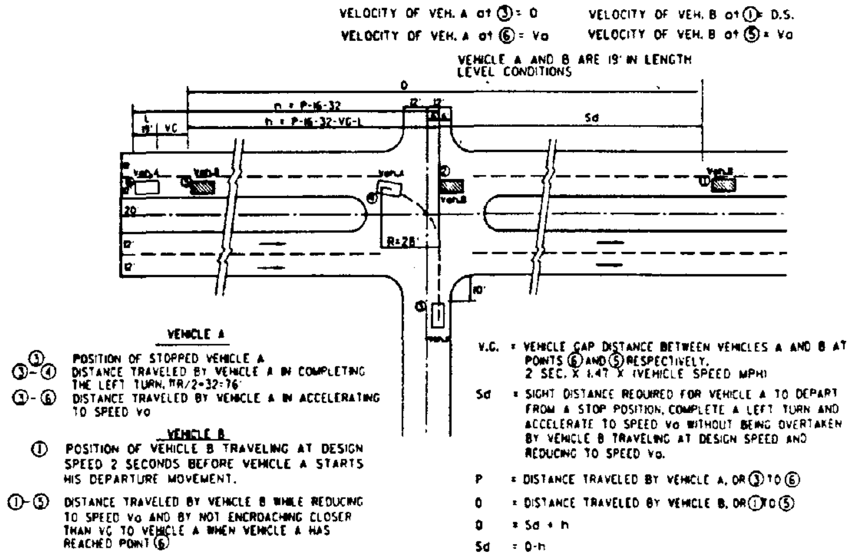


FIGURE 3-22: AASHTO CONDITIONS FOR STOPPED VEHICLE TURNING LEFT ONTO A FOUR-LANE MAJOR HIGHWAY

Source: Reference (*1*), Figure IX-37, p. 757

Right Turn Maneuver

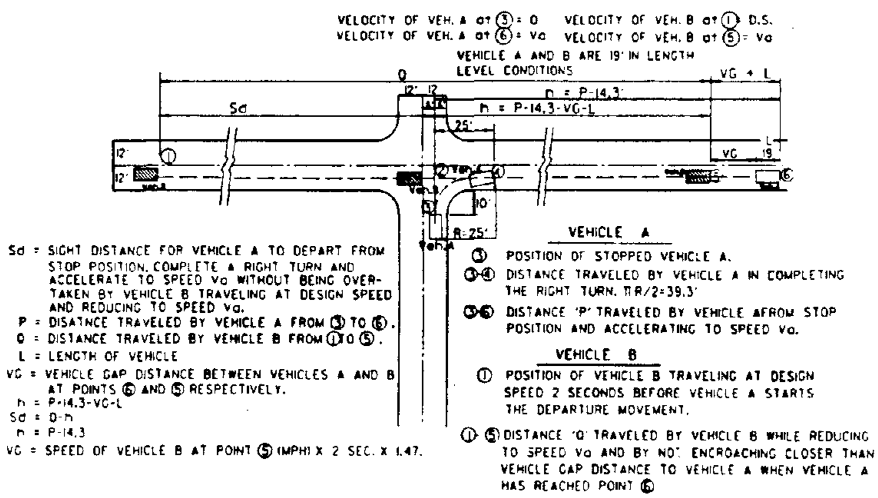


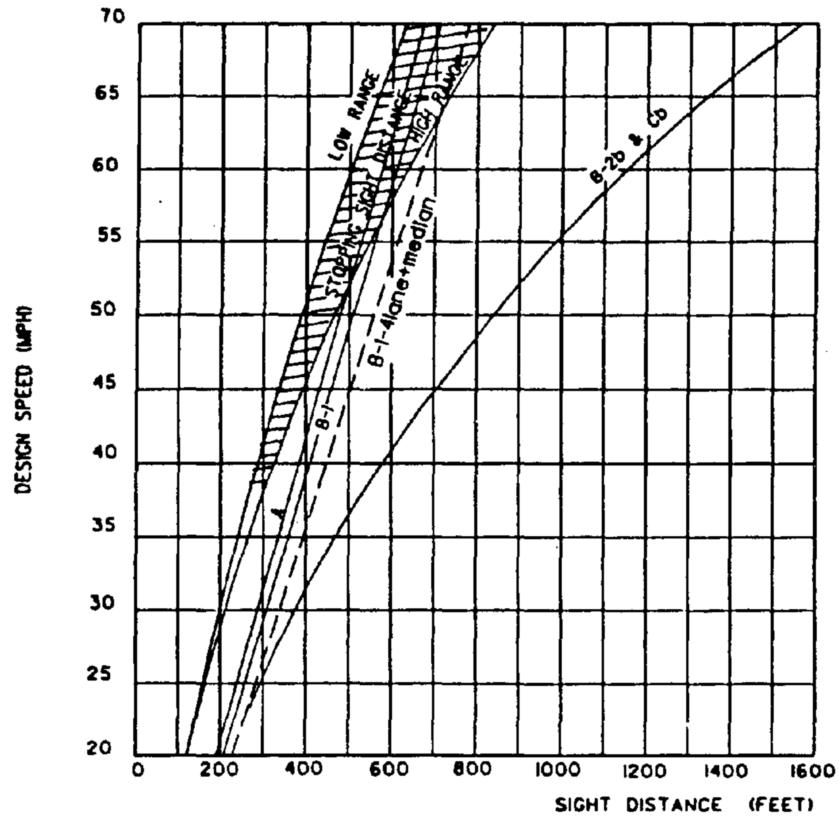
FIGURE 3-23: AASHTO CONDITIONS FOR STOPPED VEHICLE TURNING RIGHT ONTO A MAJOR HIGHWAY

Source: Reference (*1*), Figure IX-38, p. 759

(Continued)

INTERSECTION SIGHT DISTANCE (Continued)

1990 AASHTO
Sight Distance
Curves



A- SIGHT DISTANCE FOR P VEHICLE CROSSING 2-LANE HIGHWAY FROM STOP. (SEE DIAGRAM)

B-1- SIGHT DISTANCE FOR P VEHICLE TURNING LEFT INTO 2-LANE HIGHWAY ACCROSS P VEHICLE APPROACHING FROM LEFT. (SEE DIAGRAM)

B-1-4Lane+median SIGHT DISTANCE FOR P VEHICLE TURNING LEFT INTO 4-LANE HIGHWAY ACCROSS P VEHICLE APPROACHING FROM LEFT. (SEE DIAGRAM)

B-2b- SIGHT DISTANCE FOR P VEHICLE TO TURN LEFT INTO 2-LANE HIGHWAY AND ATTAIN 85% OF DESIGN SPEED WITHOUT BEING OVERTAKEN BY A VEHICLE APPROACHING FROM THE RIGHT REDUCING SPEED FROM DESIGN SPEED TO 85% OF DESIGN SPEED. (SEE DIAGRAM)

Cb- SIGHT DISTANCE FOR P VEHICLE TO TURN RIGHT INTO 2-LANE HIGHWAY AND ATTAIN 85% OF DESIGN SPEED WITHOUT BEING OVERTAKEN BY A VEHICLE APPROACHING FROM THE LEFT AND REDUCING FROM DESIGN SPEED TO 85% OF DESIGN SPEED.

FIGURE 3-24: DEPARTURE SIGHT APPROACHES REQUIRED FOR LEFT AND RIGHT TURNS ONTO A MAJOR ROADWAY FROM A TWO-WAY STOP

Source: Reference (1), Figure IX-40, p. 762

(Continued)

INTERSECTION SIGHT DISTANCE (Continued)

1984 Conditions

Sight distances for left turns and right turns are given for a 2-lane roadway only.

A PIEV time of 2.0 seconds is stated as being adequate for left turns, right turns, and crossing maneuvers. However, logic and experience clearly indicate that the need for a driver making a left turn or crossing maneuver to look left and right requires more time than only looking left as required for the right turn maneuver.

Two sight distance curves are provided. One is for a left turning or right turning vehicle to attain the traffic speed without being overtaken by the approaching through vehicle and assumes no reduction in speed by the through vehicle traveling at design speed. The other curve assumes that the stopped vehicle makes the turn and accelerates to the average running speed of the major roadway without being overtaken by the approaching through vehicle and assumes a reduction in speed to the average running speed by the through vehicle. This requires that through traffic on the major roadway would need to decelerate in order to avoid a collision with a vehicle entering the roadway. Fifty mph traffic would need to decelerate to 44 mph; 40 mph traffic would need to slow to 36 mph.

For conditions other than 2-lane, undivided roadways, the required sight distances must be calculated using the assumed vehicle-driver characteristics and the geometry of the intersection. It should be noted that the 1984 sight distance curves can not be reproduced using the assumptions stated in the 1984 edition of the Green Book.

For divided highways with medians where the median is wider than the length of the design vehicle plus front and rear clearance, use of the 1984 edition assumes that the maneuvers can be performed as two operations. The stopped vehicle must first have adequate sight distance to depart from a stopped position and cross traffic approaching from the left. The crossing vehicle may then stop in the median prior to performing the second operation. The second move requires the necessary sight distance for vehicles to depart from the median, to turn left into the cross road, and to accelerate without being overtaken by vehicles approaching from the right.

(Continued)

INTERSECTION SIGHT DISTANCE (Continued)

1990 Conditions

As in the 1984 edition of the Green Book, a PIEV time of 2.0 seconds is stated as being adequate for left turn, right turn, and crossing maneuvers. All the curves are for passenger cars.

Curve B-2b & Cb shown in Figure 3-24 assumes that the stopped vehicle makes the turn and accelerates to 85% of the speed of traffic on the major roadway. This requires that on-coming traffic on the major roadway decrease speed by 15%.

Using the information that was provided, and making some reasonable assumptions for the missing information, Fitzpatrick and Mason (12) reported that they could reproduce the curves within 8 percent of the values shown by the curves in Figure 3-24.

Left Turn Maneuver

The 1990 edition of the Green Book includes the following three conditions which were not included in the 1984 edition.

Curve B-1 is the sight distance required for a passenger car to turn left across a vehicle approaching from the left with no vehicle approaching from the right.

Curve B-1-4 (4-lane + median) is the sight distance required for the stopped passenger vehicle to turn left onto a 4-lane highway across a vehicle approaching from the left.

Curve B-2b is the sight distance required for the stopped passenger vehicle to make the left turn and accelerate to 85% of the speed of traffic on the major roadway.

Comparison Of Intersection Sight Distances

Table 3-7 compares the 1984 and 1990 AASHTO sight distances for left and right turns with those calculated using a 2.0 second perception-reaction time for right turns and 3.5 seconds for left turns. Acceleration rates were derived from the speed distance curves shown in Figure 3-25.

(Continued)

Comparison Of Intersection Sight Distances

TABLE 3-7: COMPARISON OF SIGHT DISTANCES FOR LEFT AND RIGHT TURNS BY P-VEHICLE

Design Speed (mph)	1984 AASHTO Left & Right Turns		1990 AASHTO Left & Right Turns	Calculated[(1)(2)] No Speed Reduction	
	Zero Reduction	Running Speed		Left Turn	Right Turn
20	250	250	230	175	150
25	325	325	300	275	225
30	450	410	375	375	325
35	580	530	460	475	400
40	750	670	575	625	525
45	940	840	700	800	700
50	1,180	1,040	850	1,025	900
55	1,440	1,240	1,000	1,250	1,150
60	1,750	1,470	1,150	1,560	1,425

(1) 3.5 second perception-reaction time for left turn and 2.0 seconds for right turn. All values rounded to 25 foot increment for design.

(2) Acceleration Rates:

Speed (mph)	Acceleration (ft/sec^2)
20	5.7
30	4.9
40	4.3
50	3.6
60	3.1

Source: Adapted from Reference (*11*), Chapter 4

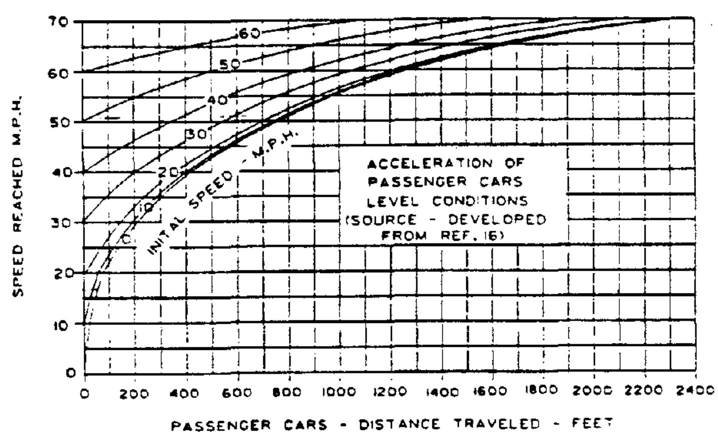


FIGURE 3-25: ACCELERATION OF PASSENGER CARS

Source: Reference (*1*), Figure IX-34, p. 749

(Continued)

INTERSECTION SIGHT DISTANCE (Continued)

Comparison Of Intersection Sight Distances (Continued)

The intersection sight distances given in the 1984 edition of AASHTO's Green Book are unrealistically long at speeds above about 40 mph. This is probably due to a use of very low (and outdated) acceleration rates. However, it should be noted that the curves given in the 1984 edition cannot be reproduced using the conditions stated therein.

The intersection sight distances contained in the 1990 edition are substantially less than those in the 1984 edition -- presumably due to the use of more appropriate acceleration rates. However, the assumption as to the use of the same perception-reaction time for both left and right turns meets serious question.

The assumption that a turning vehicle attains a speed of 85% of the traffic stream might also be questionable on high volume, high speed urban arterials for the following two reasons. (1) Drivers in the through traffic lanes will have limited opportunity to change lanes even under moderate volumes. And (2) forcing vehicles in the through traffic lanes to decelerate 15% will produce a speed differential "shock wave" in the traffic lane.

Additionally, it is to be noted that the intersection sight distances given in the 1990 edition cannot be duplicated using the assumptions given in this edition of the Green Book. The calculated intersection sight distances for left and right turns are based upon acceleration rates which are believed to represent the current vehicle-driver capability. These acceleration rates are also implied by the acceleration-distance-speed curves contained in the 1990 edition of the Green Book. However, it is not known if they represent vehicle-driver performance by nearly all drivers, about half the drivers, or only a few drivers.

Comparison and evaluation of the sight distances given in Table 3-7 suggests that the 1990 AASHTO values are inappropriately low for major urban arterials -- and especially for the left turn maneuver. These may be appropriate minimums for low volume facilities where a "forced" deceleration in the through traffic lane does not create a speed differential problem.

(Continued)

INTERSECTION SIGHT DISTANCE (Continued)

Comparison Of Intersection Sight Distances (Continued)

The 2.0 second perception-reaction time assumed by AASHTO is generally considered to be inadequate for the crossing maneuver. Table 3-8 gives a comparison of the 1984 and 1990 AASHTO crossing sight distances for a P-vehicle crossing a 2-lane roadway with calculated distances for the conditions indicated in the footnotes to the table.

Inspection of Table 3-8 indicates that sight distances in the 1984 and 1990 editions of the Green Book are slightly less than the 1984 values. Comparison with the calculated distances, and evaluation of the conditions used in calculating these distances, suggests that the 1990 AASHTO crossing sight distances are unrealistically low -- especially for multi-lane roadways and for the higher speed and volumes encountered on major urban arterials.

(Continued)

INTERSECTION SIGHT DISTANCE (Continued)

Comparison Of Crossing Maneuver Sight Distances (Continued)

TABLE 3-8: COMPARISON OF SIGHT DISTANCES FOR A P-VEHICLE CROSSING A TWO-LANE ROADWAY

Speed (mph)	Crossing Sight Distance (feet)		
	1984 AASHTO	1990 AASHTO	Calculated(1) (2) 2-lane(3)
20	200	195	250
25	250	240	300
30	300	290	375
35	350	340	425
40	400	390	475
45	450	440	550
50	500	480	600
55	550	525	675
60	600	570	725

(1) 3.5 second perception-reaction time

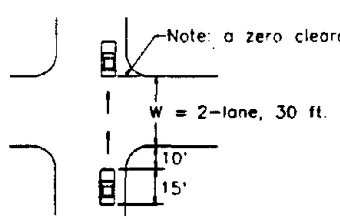
acceleration rate:

speed (mph)	acceleration (ft/sec^2)
0-20	5.7
20-30	4.9
30-40	4.3
40-50	3.6
50-60	3.1

(2) all distances rounded to 25 feet

(3) 30 ft back-of-curb to back-of-curb; 8.2 second crossing time

Conditions:



Source: Adapted from Reference (*11*), Chapter 4

(Continued)

INTERSECTION SIGHT DISTANCE (Continued)

Gap Acceptance Criteria

It has been suggested that drivers have difficulty in evaluating movement at distances greater than 800 feet or detail beyond 1,400 feet. This suggests that perception-reaction times should be increased as speed increases -- especially on high speed, high volume urban arterials. It also suggests that some speed differential will very likely be introduced into the through traffic lanes by a turning vehicle entering a high speed arterial.

A recent study by Fitzpatrick, Mason, and Harwood (13) proposed the use of gap acceptance to determine stopping sight distance for intersection design. A gap acceptance intersection sight distance procedure is based on the gaps in traffic which a driver will safely accept during actual intersection operations.

Gap Acceptance Design

Generally speaking, intersections currently operate with slight distances less than those calculated and for practical reasons design procedures should reflect actual field operations. This can be accomplished by explicitly considering gaps in the major traffic that are accepted by minor road drivers. Gap acceptance involves the evaluation of available gaps in opposing traffic streams and the decision to carry out a specific maneuver within a particular gap. At a STOP controlled intersection, drivers observe the gaps in the traffic streams and then join or cross the major road traffic stream within the length of the selected gap. Gap acceptance data is then used to determine the required sight distance at an intersection.

Sight distance values for both left and right turning vehicles listed in Table 3-9 were calculated based on design speed and gap acceptance lengths of 7.0, 8.25, and 10.5 seconds for passenger cars and 8.5, 10.0, and 15.0 seconds for trucks (13). These sight distances are the distance traveled by approaching traffic traveling at the speed indicated.

(Continued)

INTERSECTION SIGHT DISTANCE (Continued)

Gap Acceptance Design (Continued)

TABLE 3-9: CALCULATED SIGHT DISTANCES REQUIRED BY DRIVERS ACCEPTING GAPS OF A GIVEN SIZE

Speed (mph)	Passenger Car Sight Distances (ft)			Truck Sight Distances (ft)		
	Gap Accepted (sec)			Gap Accepted (sec)		
	7.0	8.25	10.5	8.5	10.0	15.0
20	206	243	309	250	294	441
25	257	303	386	312	368	551
30	309	364	463	375	441	662
35	360	424	540	437	515	772
40	412	485	617	500	588	882
45	463	546	695	562	662	992
50	515	606	772	625	735	1,103
55	566	667	849	687	809	1,213
60	617	728	926	750	882	1,323
65	669	788	1,003	812	956	1,433
70	720	849	1,080	875	1,029	1,544

Source: Reference (13), Table 8

Passenger Car Gap Acceptance

For passenger cars, a 7.0 second gap is supported by AASHTO Green Book 1984 and 1990 edition discussions on local roads as well as findings from the field study conducted by Fitzpatrick, Mason, and Harwood (13). AASHTO states that a "minimum" of 7 seconds should be available to the driver of a passenger vehicle crossing the through lanes" on a local road or street and that the resulting "sight distance should be sufficient to permit a vehicle on the minor leg of the intersection to cross the travel way without requiring the approaching through-traffic to slow down" (1).

Fifty percent of passenger car drivers were found to accept a gap of less than 7.0 seconds for both left and right turns. A gap of 8.25 seconds was accepted by 85% of passenger car drivers turning right or left at moderate to high volume intersections. A 10.5 second gap was accepted by 85% of the drivers at an intersection where the accepted gaps were influenced by low volume and the intersection's geometry (13).

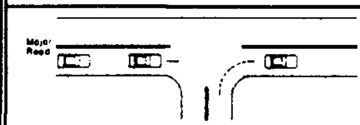
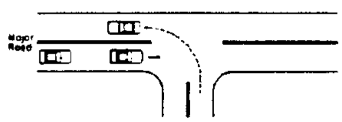
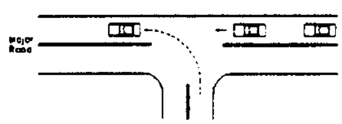
(Continued)

INTERSECTION SIGHT DISTANCE (Continued)

Passenger Car Deceleration

The field studies show that passenger car drivers will enter a roadway by accepting a gap which is too short for them to accelerate to the speed of traffic before being overtaken by the on-coming vehicle(s). Table 3-10 summarizes the deceleration rates used by drivers forced to reduce speed by a driver entering the major roadway.

TABLE 3-10: AVERAGE DECELERATION RATES USED BY DRIVERS FORCED TO REDUCE SPEED BY A VEHICLE ENTERING THE TRAFFIC STREAM

Major Road Vehicle Reacting to		Deceleration Rate (fps^2)		Speed Reduction (mph)	
		50th Percentile	85th Percentile	50th Percentile	85th Percentile
	Truck	5.39	8.60	21.2	38.1
	P	3.85	5.51	12.3	16.2
	P	3.01	4.51	15.3	20.1
	P	2.18	3.47	8.3	13.1

Source: Adapted from (13)

(Continued)

INTERSECTION SIGHT DISTANCE (Continued)

Comparison Of Passenger Car Results To 1990 AASHTO

Table 3-11 compares the average intersection sight distances (ISD) from the field studies (13) with the 1990 AASHTO distances. This indicates that drivers are willing to accept situations involving sight distances which are from 19 to 31 percent less than those from curve B-2b and Cb in the 1990 AASHTO Green Book.

The deceleration distance-time values assume a constant 3.85 fps^2 over the range of speeds.

TABLE 3-11: COMPARISON OF AVERAGE SIGHT DISTANCES USED BY DRIVERS ENTERING A TRAFFIC STREAM AND 1990 AASHTO DISTANCES

Speed V_s (mph)	Speed Reduction (mph)	Reduced Speed V_{rs} (mph)	Acceleration		Deceleration		ISD[1] Field Results FPC (ft)	1990 AASHTO ISD B-2b&Cb (ft)	Percent Difference
			Time t_t (sec)	Distance P (ft)	Distance D_{dec} (ft)	Time t_{dec} (sec)			
20	5	15	3.87	59	49	1.91	166	240	31
25	5	20	6.01	112	83	1.91	225	300	25
30	5	25	8.05	179	77	1.91	298	370	19
35	10	25	8.05	179	168	3.82	349	470	26
40	11	29	9.69	244	213	4.20	430	570	24
45	11	34	11.73	339	244	4.20	531	710	25
50	13	37	12.95	403	317	4.96	624	850	27
55	14	41	14.59	496	377	5.34	736	980	25
60	16	44	**	**				1,150	
65	16	49	**	**				1,350	
70	20	50	**	**				1,550	

(1) Intersection Sight Distance (ISD) and Field study Passenger Car (FPC)

Source: Reference (13), Table 9

Truck Gap Acceptance

About fifty percent of left and right turning 5-axle trucks at a high volume intersection accepted a gap of 8.5 seconds. A 10 second gap was accepted by 85% of 5-axle truck drivers at high volume locations. A 15 second gap was accepted by 85% of 5-axle truck drivers at low volume intersection (13).

(Continued)

INTERSECTION SIGHT DISTANCE (Continued)

Comparison Of Truck Results

At high speeds, truck characteristics used to calculate sight distance resulted in values greater than those at which drivers can normally detect motion. The 1990 AASHTO Constant Speed procedure produces a sight distance of 3,200 feet for a 50 mph major road design speed; the Reduced Speed procedure (through traffic is forced to reduce speed by 15%) resulted in a sight distance of 2,500 feet for the same design speed (*13*). Operation experience at intersections indicates that sight distances of such magnitude are rarely necessary for safe and efficient operation.

Truck results from the field observations (*13*) presented in Table 3-12 were between 55 and 73 percent less than the values using the Green Book truck characteristics. Comparison of Tables 3-9 and 3-12 shows that the field sight distance results were close to the values required by a driver accepting a 10.0 second gap for speeds less than 55 mph and were greater than the stopping sight distance values. The 15.0 second gap procedures produces significantly longer sight distances than the results from the field observations.

TABLE 3-12: COMPARISON OF AASHTO SIGHT DISTANCES AND FIELD STUDIES FOR TRUCKS

Speed V_s (mph)	Speed Reduction (mph)	Reduced Speed V_{rs} (mph)	Acceleration		Deceleration		ISD(1) Field Results (ft)	1990 AASHTO ISD B-2b&Cb (ft)	Percent Difference
			Time t_r (sec)	Distance P (ft)	Distance D_{dec} (ft)	Time t_{dec} (sec)			
20	5	15	10.61	125	35	1.36	299	670	55
25	10	15	10.61	125	80	2.72	343	903	62
30	10	20	14.41	223	100	2.72	457	1,179	61
35	15	20	14.41	223	165	4.09	512	1,213	58
40	15	25	18.21	349	195	4.09	654	1,549	58
45	20	25	18.21	349	280	5.45	718	1,971	64
50	25	25	18.21	349	376	6.81	792	2,516	69
55	30	25	18.21	349	481	8.17	877	3,232	73
60	35	25	18.21	349	596	9.54	971	**	
65	35	30	22.01	502	686	9.54	1,141	**	
70	40	30	22.01	502	801	10.90	1,248	**	

(1) Intersection Sight Distance (ISD)

Source: Reference (*13*), Table 10

(Continued)

INTERSECTION SIGHT DISTANCE (Continued)

Skewed Intersections

Skewed intersections and negative grades require that sight distances be increased. The actual sight distance must be calculated given the geometry of the individual intersection.

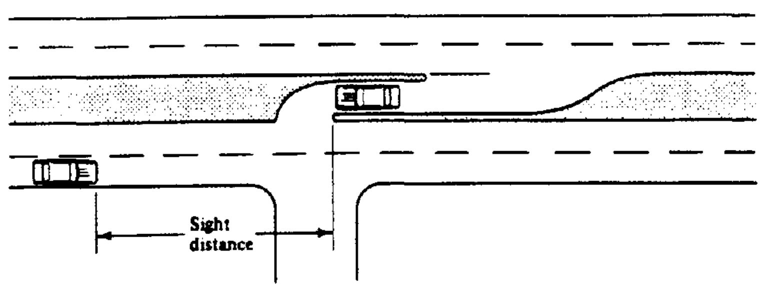
Left Turn From Major Roadway

Where left turns are permitted from the major roadway, sight distance must be sufficient to allow the driver of the left turning vehicle to judge whether or not a gap in the opposing traffic stream is sufficient to safely make the turn.

The required sight distances for the P-vehicle to complete a left turn from a major roadway are given in Table 3-13.

TABLE 3-13: MINIMUM SIGHT DISTANCE FOR PASSENGER CAR TO TURN LEFT FROM A MAJOR ROADWAY TO AN INTERSECTING MINOR STREET OR ACCESS DRIVE

Operating Speed (mph)	Safe Sight Distance (feet)		
	2-lane	4-lane	6-lane
20	240	260	280
30	360	390	420
40	470	520	560
60	590	650	700



Source: Reference (<u>14</u>)

(Continued)

INTERSECTION SIGHT DISTANCE (Continued)

Design Issues

Issues which must be resolved in the design of access include the following:

Intersection Sight Distance Issues

- PIEV Time Required for Left & Right Turns
- Speed Reduction Required by Through Traffic
- Gap Acceptance by Driver Entering Roadway
- Trucks
- Ability to Evaluate Traffic at a Distance

UNSIGNALIZED ACCESS SPACING

Marginal Access

Unsignalized Access Spacing
• Marginal
• Medial

Various conditions may be considered in the determination of unsignalized access. These include the conflict overlap and maximization of egress capacity in addition to stopping sight distance, intersection sight distance, and the maneuver distance previously covered in this chapter.

Considerations Of Unsignalized Access Spacing
• Stopping Sight Distance
• Intersection Sight Distance
• Maneuver Distance
• Right Turn Conflict Overlap
• Maximize Egress Capacity

Stopping sight distance must be maintained in all situations, including driveways, so as to allow a driver in the through lane to bring a vehicle to a safe stop in the event a vehicle enters the through lane from an access drive. Intersection sight distance allows a vehicle to enter the roadway without requiring undue deceleration of vehicles in the through traffic lanes. Intersection sight distances which require no reduction in speed or a reduction of no more than 10 mph, are substantial and may constitute the most severe limitation on minimum access spacing.

(Continued)

UNSIGNALIZED ACCESS SPACING (Continued)

Right Turn Conflict Overlap

Minimizing the number of access points which the driver must monitor simplifies the driving task. A single conflict between a through vehicle and an egress vehicle is created where the driver of the through vehicle must be alert for a right-turning vehicle entering the roadway from one driveway at a time as illustrated in Figure 3-26-A. Through vehicles must decelerate to avoid a collision if a vehicle enters the roadway from a driveway. As illustrated in Figure 3-26-B, the driver must monitor two access locations at a time while performing the other driving tasks.

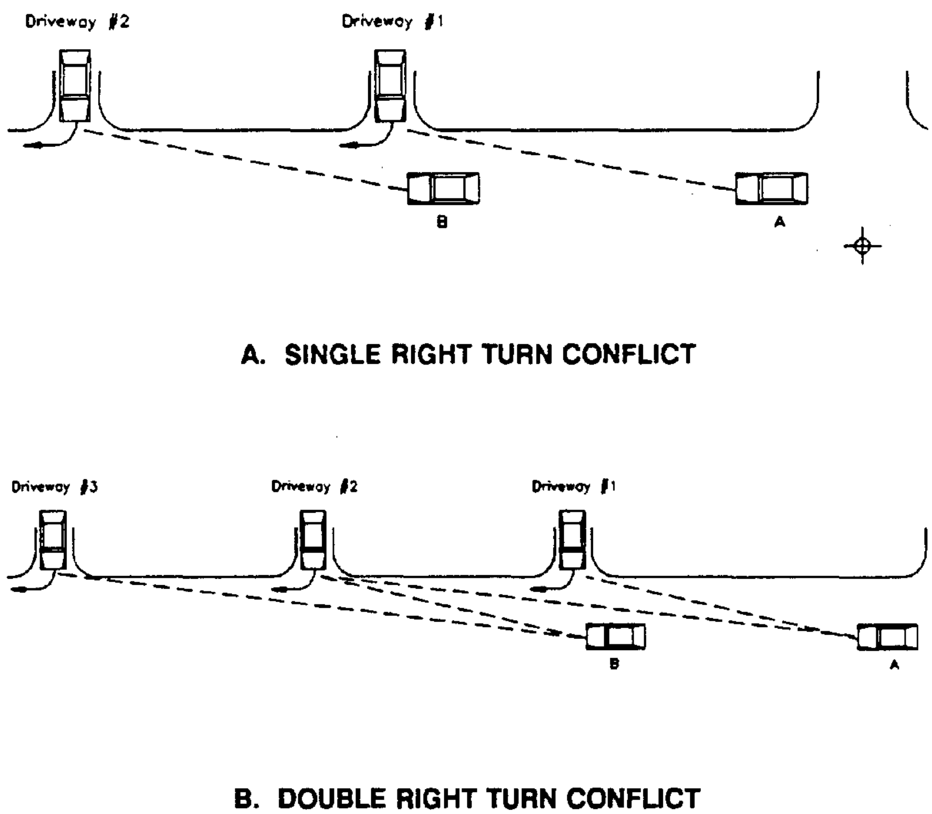


FIGURE 3-26: SCHEMATIC ILLUSTRATION OF THE RIGHT TURN CONFLICT OVERLAP

(Continued)

UNSIGNALIZED ACCESS SPACING (Continued)

Right Turn Conflict Overlap (Continued)

Minimum distances required to avoid the conflict overlap are given in Table 3-14. As noted in the footnotes, a speed differential substantially in excess of 10 mph will be created. Thus the conflict overlap criteria results in considerably shorter distances than the criteria of a 10 mph speed differential between a turning vehicle and through traffic.

TABLE 3-14: MINIMUM DISTANCE TO REDUCE COLLISION POTENTIAL DUE TO RIGHT TURN CONFLICT OVERLAP

	Minimum Spacing (feet)[a]			
	Stover and Koepke (center-to-center of drive)[b]			Glennon (center-to-center assuming 30' drive)[f]
Speed (mph)	Preferable[c]	Limiting[d]	Glennon (17)[e]	
30	185	100	125	155
35	245	160	150	180
40	300	210	185	215
45	350	300	230	260

a) Spacing allows drivers in the through traffic stream to consider one access drive at a time. It requires that a through vehicle decelerate in order to avoid a collision when a vehicle enters the through traffic lane.

b) Measured center-to-center of access drives.

c) A vehicle entering the traffic stream from a driveway completes the 90-degree right turn and accelerates from a stop at 2.0 fps^2. The vehicle in the outside through traffic lane does not change and decelerates at 6.0 fps^2 after a 2.0 second perception-reaction time. No clearance is provided between the through vehicle and the vehicle entering from the driveway. The implied speed differentials between the driveway vehicle and the through traffic stream are:

Arterial speed (mph)	30	35	40	45
Speed differential (mph)	20	24	28	32

d) The driveway vehicle Completes the 90-degree right turn and accelerates at an average of 3.1 fps^2. The through vehicle decelerates at an average of 6.0 fps^2 after a one second perception-reaction time. No clearance is provided between the vehicles. The implied speed differentials are:

Arterial speed (mph)	30	35	40	45
Speed differential (mph)	14	19	24	29

The lower speed differentials for the "limiting" case result from the higher assumed acceleration rate of the driveway vehicle.

e) Measured near curb to near curb. Assumes: 8.5 fps^2 deceleration by the through vehicle; driveway vehicle accelerates at an average of 2.1 fps^2 to a 30 mph speed and an average of 1.7 fps^2 for all higher speeds. Perception-reaction time is not specified but is presumable about 1 second.

f) Adjusted to reflect distance center-to-center of driveways assuming a 30 foot driveway width.

Source: Reference (6), p. 109

(Continued)

UNSIGNALIZED ACCESS SPACING (Continued)

Right Turn Conflict Overlap (Continued)

The difference in the acceleration and deceleration conditions assumed by the two authors should be noted when comparing the different distances. It should be noted that subsequent to this work by the two authors 6.0 fps^2 was found to be acceptable to about 85% of drivers whereas 8.5 fps^2 is acceptable to slightly more than 50% of drivers (see Figure 3-15). It should also be noted that one author (Glennon) used near curb-to-near curb for defining spacing whereas the other (Stover) used center-to-center of the access drives. The adjustment to Glennon's values, assigning a typical driveway width of 30 feet facilitates a comparison of the spacing values.

If the right-turn conflict is to be limited to one driveway at a time and the speed of traffic on the through traffic lanes is not required to reduce speed more than some accepted amount (such as a speed reduction of 0 mph, 10 mph, or 15% below design speed), the minimum driveway spacing is the intersection sight distance. Thus, it should be realized that the minimum spacings in Table 3-14 represent a condition in which the access spacing has a significant impact on the through traffic. The potential magnitude of this impact is suggested by the speed differential that may be precipitated in the traffic stream.

The distances given in Table 3-14 can be used to determine minimum spacings requiring the driver to monitor multiple driveways by simply dividing the distance by the number of drives to be monitored simultaneously. For example, using 350 feet for 45 mph, a separation of 175 feet will require drivers in the through traffic to monitor two driveways simultaneously.

Egress Capacity

Major and Buckley (*18*) reported that driveways spaced at distances greater than 1.5 times the distance required to accelerate from zero to the speed of through traffic will reduce delay to vehicles entering the traffic stream and will improve the traffic absorption characteristics of the traffic stream. Spacings based on acceleration distances for passenger cars on level grades are given in Table 3-15.

(Continued)

UNSIGNALIZED ACCESS SPACING (Continued)

Egress Capacity (Continued)

TABLE 3-15: MINIMUM ACCESS SPACING TO PROVIDE MAXIMUM EGRESS CAPACITY

Speed (mph)	Spacing (feet)[1]
20	120
25	190
30	320
35	450
40	620
45	860
50	1,125
55	1,500
60	1,875

(1) 1.5 times the distance required for a passenger car on level terrain to accelerate from zero to through traffic speed based on acceleration information from NCHRP Report 270 as contained in the 1990 AASHTO Green Book, Reference (*1*), Figure IX-34, p. 749.

A desirable peak period speeds (about 35 mph), the minimum spacing is 450 feet. This suggests that more than five right-turn in and right-turn out driveways between signals at 1/2-mile spacings will result in a reduction in the number of vehicles that can enter the through roadway from adjacent properties and will actually be detrimental to the businesses located on the arterial.

Comparison Of Spacing For Different Criteria

The minimum unsignalized access spacing according to the various criteria are compared in Table 3-16. Inspection of this table reveals the following:

(1) The safe stopping sight distance results in approximately the same distances as the criteria of a speed differential of 20 mph or less between a turning vehicle and through traffic.

(2) Driveway spacings which will maximize the capacity for vehicles to enter a traffic stream from a driveway are much longer than that for a 10 mph speed differential for speeds over 30 mph.

Additionally they are (criteria 4) very similar to the spacings required to eliminate the right-turn overlap conflict if the through traffic is required to reduce speed by 15% (criteria 3c).

(Continued)

UNSIGNALIZED ACCESS SPACING (Continued)

Comparison Of Spacing For Different Criteria (Continued)

TABLE 3-16: COMPARISON OF UNSIGNALIZED ACCESS SPACING IN FEET BY SPEED FOR VARIOUS CRITERIA

Criteria	Posted Speed (mph)								
	20	25	30	35	40	45	50	55	60
1. Safe Stopping Sight Distance(1)	125	150	200	250	325	400	475	550	650
2. Turning Traffic To Leave Through Lane With A Speed Differential Of:									
a) ≤ 10 mph					490	590	700	820	950
b) ≤ 15 mph				390	390	490	590	700	820
c) ≤ 20 mph			320	320	320	390	490	590	700
3. Minimize Right Turn Conflict Overlap									
a) Stover(3)			100	160	210	300			
b) Glennon(4)			155	180	215	260			
c) Reduce Speed by 15%	300	375	460	575	700	850	1,000	1,150	1,250
4. Maximum Egress Capacity(6)	120	190	320	450	620	860	1,125	1,500	1,875

(1) Table 3-5
(2) Table 3-3
(3) Table 3-14, Stover; center-to-center of driveways
(4) Table 3-14, Glennon; adjusted to center-to-center of driveways assuming 30 foot driveway
(5) Assumes typical urban practice of design speed is 5 mph higher than ultimate posted speed and, AASHTO curves B-2b and Cb condition that through traffic must reduce speed from design speed to 85% of design speed.
(6) Table 3-15

CHANNELIZATION

Introduction

Channelization is the separation or regulation of conflicting traffic movements into definite paths of travel by means of islands or pavement markings to facilitate the safe and orderly movement of both vehicles and pedestrians. Proper channelization increases capacity, improves safety, provides maximum convenience, and instills driver confidence. Improper channelization has the opposite effect and may be worse than none at all. Over-channelization should be avoided as it can create confusion and worsen operations.

Design of channelization usually involves the following significant controls: the type of design vehicles, the cross sections on the cross streets, the volumes in relation to capacity that are expected through the intersection, the number of pedestrians, the speed of vehicles, the location of any required bus stops, the type of traffic control, and location of traffic control devices. In addition, the physical controls such as right-of-way and terrain have an effect on the extent of channelization that is economically feasible.

Channelization Principles

The following principles should be followed in the design of channelization. The extent to which they are applied will depend upon features of the overall design.

1. Motorists should not be confronted with more than one decision at a time.

2. Unnatural paths, such as reverse curvature, or a left-turn maneuver requiring an initial turn to the right, should be considered only under special situations.

3. Areas of vehicle conflicts should be reduced as much as possible. However, merging and weaving areas should be as long as conditions permit. Channelization should be used to keep vehicles within well-defined paths that minimize the area of conflict.

4. Traffic streams that cross without merging and weaving should intersect at or near right angles.

(Continued)

CHANNELIZATION (Continued)

Channelization Principles (Continued)

5. Angle of intersection between merging streams of traffic should be small.

6. Points of crossing or conflict should be well separated from other such points in the total plan.

7. Refuge areas for turning vehicles should be provided clear of through traffic.

8. Prohibited turns should be blocked wherever possible.

9. Location of essential control devices should be established as part of the design of a channelized intersection.

10. Channelization may be desirable to separate the various traffic movements where multiple-phase signals are used.

Islands

An island is a defined area between traffic lanes for control of vehicle movements or for pedestrian refuge. Within an intersection, a median or an outer separation is considered an island.

Islands generally are either elongated or triangular in shape, and are situated in areas normally unused as vehicle paths, the dimensions depending upon the particular intersection layout. Islands should be located and designed to offer little hazard to motor vehicles, be relatively inexpensive to build and maintain, and occupy a minimum of roadway space but yet be commanding enough that motorists will not drive over them deliberately. Island details are dependent upon particular conditions and should be designed to conform to the general principles which follow.

Channelizing islands should be placed so that the proper course of travel is immediately obvious, easy to follow, and of unquestionable continuity. When designing an island, attention should be given the fact that the driver's eye view is different from a plan view.

(Continued)

CHANNELIZATION (Continued)

Islands (Continued)

Particular care must be taken where the channelization on or beyond a crest vertical curve, however slight, or where there is substantial horizontal curvature on the approach to or through the channelized area. Islands should allow for traffic streams in the same general direction to converge at small angles and align crossing movements to nearly right angles. The outline of islands should be gently flowing curved lines or straight lines nearly parallel to the line of travel. Where islands separate turning traffic from through traffic, the radii of curbed portions should equal or exceed the minimum for the turning speeds expected. Drivers should not be confronted suddenly with and unusable area in the normal vehicle path. Islands first approached by traffic should be indicated by a gradually widening marking or a conspicuously roughened strip that directs traffic to one side in a path easily traversed at the expected normal speeds.

Islands should be sufficiently large to command attention. The smallest island that normally should be considered is one that has an area of at least 75 square feet and preferably 100 square feet. Accordingly, triangular islands should not be less than about 12 feet, and preferably 15 feet, on the side after rounding of corners. Elongated or divisional islands should be not less than 4 feet wide and 25 feet long, and preferably at least 10 feet wide and 75 feet long.

Islands should be highly visible at all times. Mountable curbs should be used in all applications. Where drainage is not involved, curb 4 inches or less in height should be used.

The approach end of an island should be conspicuous to approaching drivers and should be definitely clear of vehicle paths, physically and visually, so that drivers will not veer from the island. A raised delineator (nonrigid) may be desirable on the approach end, particularly if the island is so narrow that it could be straddled by vehicles. The offset from the travel lane to the approach nose should be normally about 2 feet. For median islands, the face of curb at the approach island nose should be offset at least 2 feet, and preferably 4 feet, from the normal (median) edge of pavement. The median island should then be gradually widened to its full width. For other islands, the total nose offset should be 4 to 6 feet from the normal edge of through pavement, and 2 to 3 feet from the pavement edge of a turning roadway.

(Continued)

CHANNELIZATION (Continued)

Islands (Continued)	Where a shoulder is carried through the intersection, the island should be placed at the outside of the shoulder. However, where speeds are high and the island is preceded by a deceleration lane or a gradually widening auxiliary pavement, it may be desirable to offset the nose of large islands 2 to 4 feet outside the edge of the shoulder. In heavily developed areas, an offset as small as 1 foot may be appropriate where the approach nose of the island is offset and tapered, particularly where pedestrian traffic is a factor.

EFFECT OF TURN LANES ON INTERSECTION CAPACITY

Introduction

Urban street capacity is controlled by the capacity at critical intersections. The capacity, in turn, is a function of the conflicting lane volumes. The capacity increase can be analyzed by either (1) using constant approach volumes and calculating the critical volume or (2) by using a constant critical volume and calculating the total volume through the intersection. The first is more applicable to traffic impact analysis whereas the second is more applicable to street design, including redesign of existing facilities. The constant approach volume method is illustrated below using an application of dual left turn lanes. The constant critical volume approach is illustrated using right turn lanes.

Left Turn Lanes

The approach volumes are held constant in the following three figures. The critical volume with a single left turn lane on each of the four approaches results in a critical volume of 1,000 vph as illustrated in Figure 3-27-1.

The provision of dual left turns for the critical left turns reduces the sum of critical volumes to 1,500 vph as shown in Figure 3-27-2. It should also be noted that critical left turns are now the northbound and eastbound movements, whereas the southbound and westbound left turns were critical with single left turn lanes (Figure 3-27-1).

As shown in Figure 3-27-3, The provision of dual left turns on all four approaches reduces the sum of critical volumes to 1,400 vph.

Impact Of Left Turns On Through Lane Capacity

Inspection of the following figures shows that in order to accommodate increased left turn volume, the capacity of the through lanes must be reduces, (e.g. increase in the percentage of the cycle length devoted to left turns can be achieved only by decreasing the percentage of the cycle devoted to through traffic). Hence it is often necessary to provide dual left turn lanes even when left turn volumes are relatively moderate so that more time can be given to the green indication for the through traffic lanes. Consequently, dual left turn lanes may be desirable on the lower volume approaches simply so that an increased percentage of the cycle can be devoted to the higher volume approaches. Until volumes justify the use of both lanes on each approach, the outside lane should be striped to indicate that it should not be used.

(Continued)

EFFECT OF TURN LANES ON INTERSECTION CAPACITY (Continued)

Effect Of Left Turn Lanes

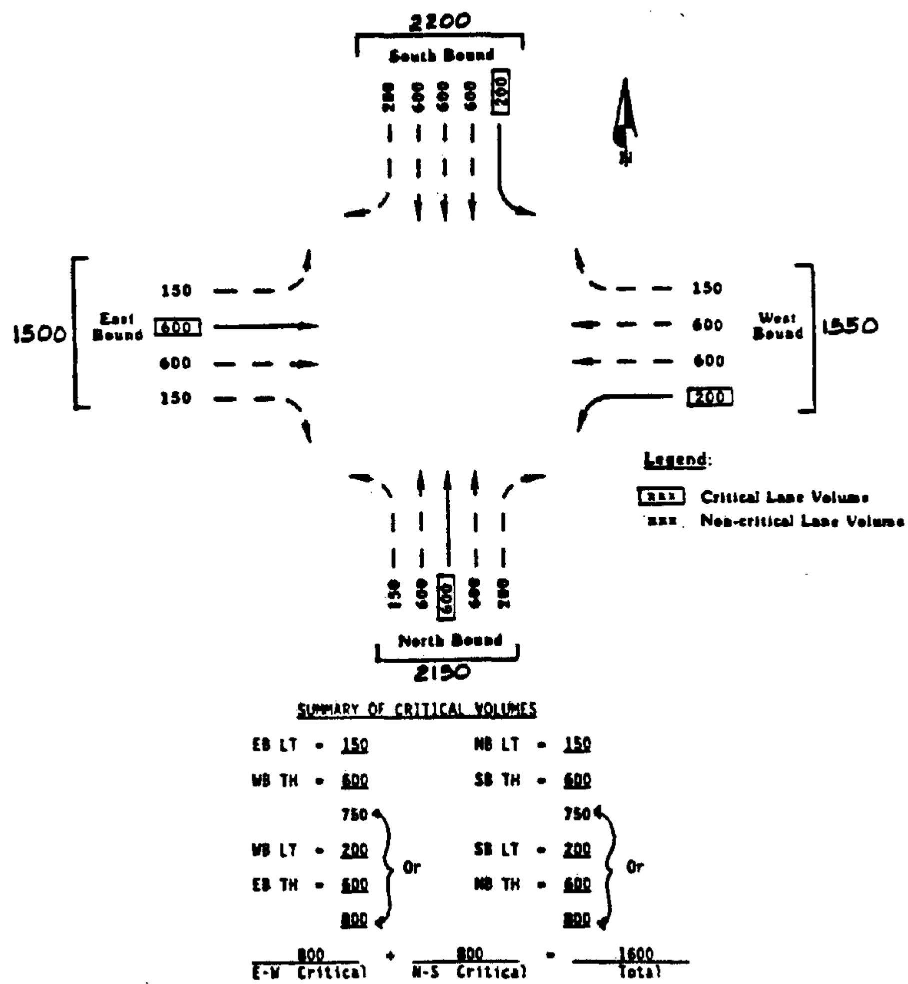


FIGURE 3-27-1: CRITICAL VOLUME WITH SINGLE LEFT TURN LANES

Source: Reference (*11*), Chapter 4

(Continued)

EFFECT OF TURN LANES ON INTERSECTION CAPACITY (Continued)

Effect Of Left Turn Lanes (Continued)

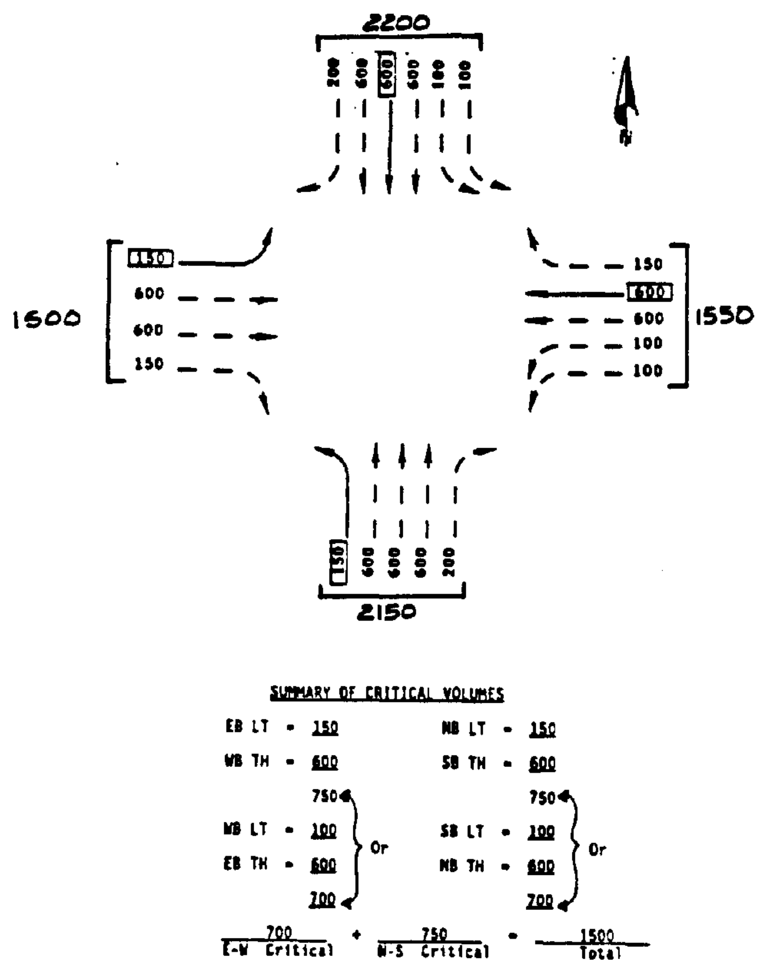


FIGURE 3-27-2: CRITICAL VOLUME WITH DUAL LEFT TURNS ON HIGH VOLUME APPROACHES

Source: Reference (*11*), Chapter 4

(Continued)

EFFECT OF TURN LANES ON INTERSECTION CAPACITY (Continued)

Effect Of Left Turn Lanes (Continued)

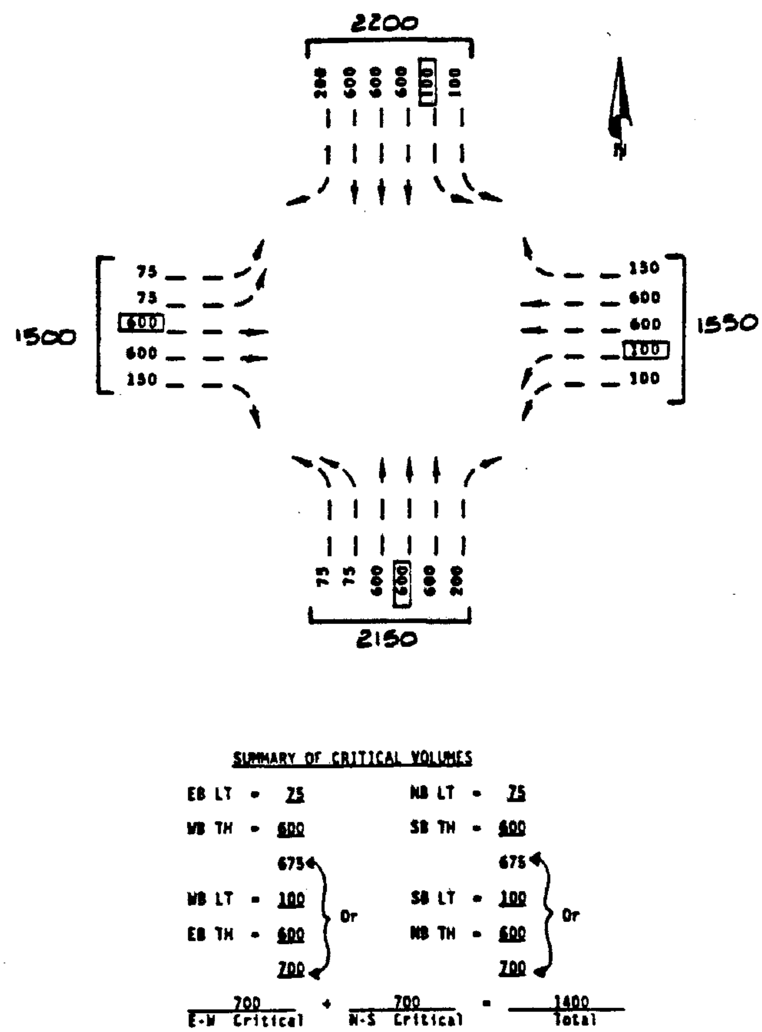


FIGURE 3-27-3: CRITICAL VOLUMES WITH DUAL LEFT TURNS ON ALL APPROACHES

Source: Reference (*11*), Chapter 4

(Continued)

EFFECT OF TURN LANES ON INTERSECTION CAPACITY (Continued)

Effect Of Right Turn Lanes

Turn bays are the only method of limiting the speed differential between right turning vehicles and through traffic. Right turn bays also have a significant effect on intersection capacity.

Figure 3-28-1 illustrates the capacity of a selected intersection without right turn bays. The sum of critical volumes is 1,400 vph which indicates that the intersection is at capacity. The total volume through the intersection is 6,750 vph.

With right turn lanes on all approaches, the sum of critical volumes is 1,400 vph (the same as above). However, as shown in Figure 3-28-2, the total volume through the intersection is 7,450 vph -- approximately a 10% increase in capacity at the same level-of-service. As a general rule, the provision of right turn lanes at an arterial intersection will increase the intersection capacity by at least one percent for each one percent of the intersection volume that consists of right turns. In as much as capacity is (or will be) an issue at major intersections, right turn bays should always be provided as part of original design for capacity as well as safety considerations. On existing arterials, the addition of right turn bays should be a high priority for the same reasons.

(Continued)

EFFECT OF TURN LANES ON INTERSECTION CAPACITY (Continued)

Effect Of Right Turn Lanes (Continued)

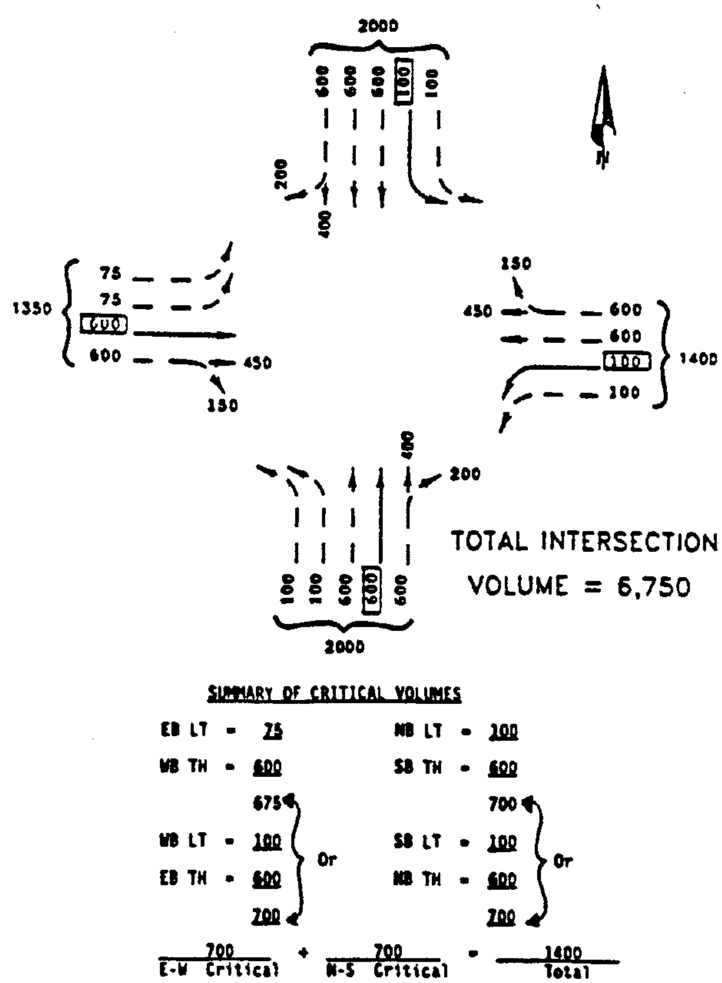


FIGURE 3-28-1: TOTAL INTERSECTION WITHOUT RIGHT TURN LANES

Source: Reference (*11*), Chapter 4

(Continued)

EFFECT OF TURN LANES ON INTERSECTION CAPACITY (Continued)

Effect Of Right Turn Lanes (Continued)

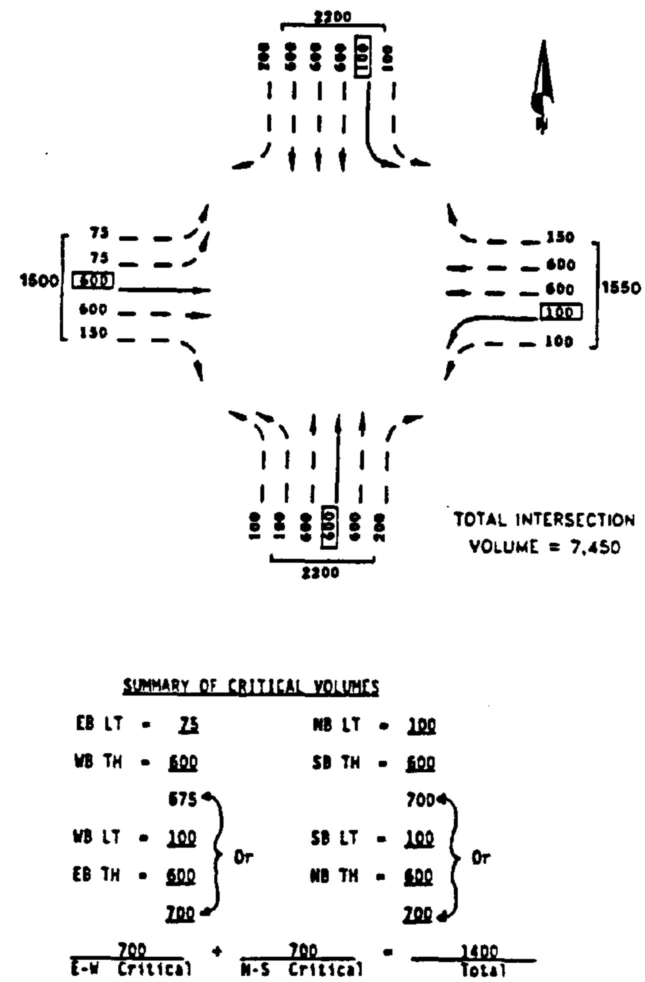


FIGURE 3-28-2: TOTAL INTERSECTION VOLUME WITH RIGHT TURN LANES ON ALL APPROACHES

Source: Reference (*11*), Chapter 4

ACCESS CONTROL BENEFITS

Introduction

Access Control Benefits

- Improve Traffic Flow
  - Increase Average Speed
  - Decrease Vehicle-Hours of Delay
  - Decrease Stopped Delay
  - Decrease Fuel Consumption
  - Decrease Vehicular Emissions
- Reduce Traffic Accidents
- Preserve Capacity

The objective of access management is to improve traffic flow and safety. The cost-effectiveness of access control as compared to roadway widening or the construction of new facilities as a method of receiving capacity and mobility is another measure.

Effect On Traffic Flow

As part of the Colorado Access Control Demonstration Project (15), TRANSYT 7F was used to evaluate traffic flow for two different signal spacings and unsignalized access conditions. One consisted of 1/2 mile signalized intersection spacings with right turns only at the midpoint between signals (at the 1/4 mile interval). The other was for 1/4 mile signalized intersection spacings with all movements (left, right, and crossing) permitted at 1/8 mile points between the signalized intersections. The results are given in Table 3-17.

TABLE 3-17: SUMMARY OF SIGNAL PROGRESSION RESULTS

	Travel Speed (mph)	Total Travel Veh-Hr/Hr	Total Delay Veh-Hr/Hr
Unrestricted Segment	12.82	942.40	675.02
Access Controlled Segment	22.30	542.47	274.76
% Change Controlled-v-Uncontrolled	+74%	-42%	-59%

Source: Reference (15), p.31

(Continued)

ACCESS CONTROL BENEFITS (Continued)

Effect On Capacity	The Colorado study also concluded that a 4-lane divided highway with access control (1/2 mile spacing and right turns only at the 1/4 mile locations) would have the same capacity as a 6-lane divided highway with frequent access (1/4 mile spacing and full movement access at the 1/8 mile points). The cost of the 6-lane highway was estimated to be 34% higher.

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CHAPTER 4

ACCESS MANAGEMENT TECHNIQUES

CHAPTER 4 - ACCESS MANAGEMENT TECHNIQUES

INTRODUCTION

Traffic Conflicts

CHAPTER 4

ACCESS MANAGEMENT TECHNIQUES

Following adoption of a comprehensive policy, the next step in the development of an access control program is the identification of effective control measures which will enhance the safe and efficient movement of traffic. These measures include all traffic operations actions which serve to minimize the frequency and severity of traffic conflicts associated with driveways.

A traffic conflict point occurs where the paths of two traffic movements intersect. As illustrated in Figure 4-1, these maneuvers in order of increasing severity of conflict are diverge, merge, weave, and cross. In each case drivers of one or more vehicles may need to take appropriate action in order to avoid a collision. Crossing conflicts are the most serious because of the potential for high speed head-on, or nearly head-on, and right-angle collisions. Hence, these conflict points are often referred to as "major conflict points."

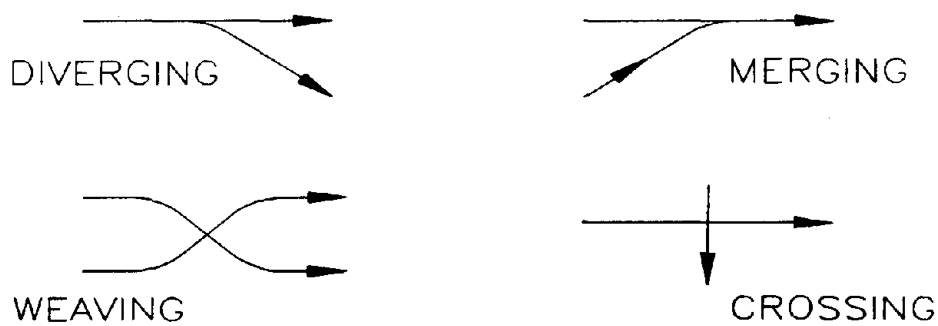


FIGURE 4-1: INTERSECTION VEHICULAR MANEUVERS INVOLVING CONFLICT

(Continued)

INTRODUCTION (Continued)

Traffic Conflicts (Continued)

Diverge and merge conflict are potentially less severe and are often referred to as "minor conflict points." Diverge conflicts occur when a driver executes a left-turn or right-turn maneuver. This often requires significant corrective action by drivers of following vehicles - especially on high speed and/or high volume roadways. Merge conflicts occur where a vehicle makes a left or right-turn and enters a through traffic stream. The burden for avoiding a collision primarily rests with the driver of the vehicle executing the turn maneuver. However, drivers in the through traffic stream are often required to take action to avoid a collision when the driver of the merging vehicle accepts a gap which is too short to accelerate to the speed of through traffic before being overtaken by on-coming vehicles.

In some cases, the conflict point covers a substantial area; as for example, when a driver executes a left-turn from a through traffic lane and a queue of vehicles forms while the left-turning driver waits for an acceptable gap in the opposing traffic stream. Defining the location and minimizing the area of such conflicts will contribute to traffic safety by reducing driver uncertainty.

The area and complexity of the crossing conflicting points are also affected by the roadway cross-section. For example, on a 2-lane roadway, each of the conflict points with the traffic stream approaching from the left and the right is only one lane wide. With a 4-lane cross-section, each conflict points is 2 lanes wide.

An example of potential conflict points at a typical four-way intersection is shown in Figure 4-2.

(Continued)

INTRODUCTION (Continued)

Traffic Conflicts (Continued)

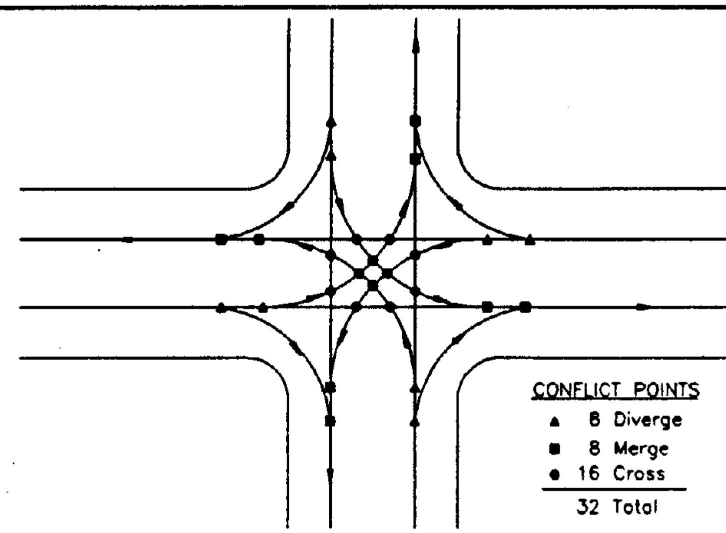


FIGURE 4-2: CONFLICT POINTS AT A TYPICAL FOUR-WAY INTERSECTION

As shown in Figure 4-3, a 3-way intersection has 9 conflict points, of which only 3 are crossing conflicts. Moreover, traffic on the "stem" of the intersection "naturally yields" to other traffic. Three-way intersections, therefore, experience fewer accidents than 4-way intersections.

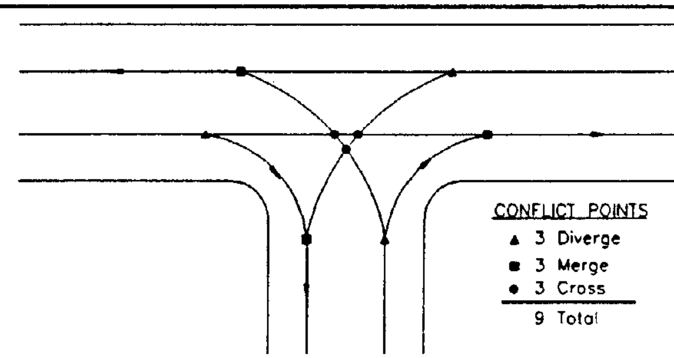


FIGURE 4-3: CONFLICT POINTS AT A TYPICAL THREE-WAY INTERSECTION

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES

Introduction

CATEGORIES OF TREATMENT FOR IMPROVING TRAFFIC FLOW

A. Limit Number of Conflict Points.

B. Separate Conflict Points.

C. Limit Deceleration.

D. Remove Turning Vehicles from Through Lanes.

The several techniques of access management that might be considered for implementation on existing roadways can be grouped into four general categories. These are as follows:

Category	Type Of Technique
A	Limit the number of 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.
B	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.
C	Reduce deceleration requirements: These techniques reduce the severity of conflicts by increasing driveway turning speeds, by decreasing through highway speeds, or by increasing driveway perception time.

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

Introduction (Continued)	D	Remove turning vehicles from the through lanes: These techniques directly reduce both the frequency and severity of conflicts by providing separate paths and storage areas for turning vehicles.

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY A: Limit The Number Of Conflict Points

Introduction

CATEGORIES OF TREATMENT FOR IMPROVING TRAFFIC FLOW

A. Limit Number of Conflict Points.

B. Separate Conflict Points.

C. Limit Deceleration.

D. Remove Turning Vehicles from Through Lanes.

The number of conflict points at 4-way and 3-way intersections are shown in Figure 4-2 and 4-3 respectively. Major conflict points are defined as those where movement paths cross. Minor conflict points occur where paths diverge on merge.

As shown in Figure 4-2, there are 16 major and 16 minor conflict points at a 4-way intersection. Whereas there are only 3 major conflict points at a 3-way intersection. This, plus the fact that traffic on the "stem" of the 3-way intersection "naturally yields" to other traffic, results in accident rates being much lower at 3-way intersections.

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY A: Limit The Number Of Conflict Points (Continued)

A-1: Install Median Barrier With No Left Turns At The Median Opening

A-1: Description

The physical median barrier is a route design technique for controlling access on arterial highways. The barrier, which can be the concrete safety shape median barrier (often referred to as a New Jersey Barrier) or a curbed nontraversable median. This eliminates direct left turns at all driveways and U-turns along the highway. Indirect left turns to driveways are accommodated by right-hand ramps (jughandle) and crossovers or by cloverleaf loops at cross streets.

The technique eliminates the conflict points at all driveways except at the median opening. At a 4-way intersection on a 4-lane roadway the number of conflict points are reduced from 32 (including 24 major conflicts) to only 15, of which 8 are major conflict points.

More important, the barrier totally eliminates the more hazardous crossing conflict points at all driveways. The frequency of rear-end conflicts on the through lanes is expected to decrease as a result of the elimination of direct left turns; on the other hand, the frequency of right-turn conflicts at minor driveways will probably increase proportionally to the number of indirect left turns. Some tradeoff is realized by the creation of additional basic conflict points at indirect left-turn locations.

A-1: Application

This application may be effective along highway sections where mid-block accident experience involving left-turning vehicles is excessive. In general, it may be cost effective on multi-lane arterial roadways with speeds over 40 mph, ADT's greater than 10,000, and where peak hour left-turn movements equal or exceed 150 vph per one-mile or where development levels exceeds 30 driveways per mile.

A-1: Design

Figures A-1-1 and A-1-2 indicate alternative ways of accommodating left-turns where technique A-1 is used. Critical elements to consider are ramp radius, width, and length to accommodate left-turning vehicles as per the volume, speeds, and types of vehicles expected.

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY A: Limit The Number Of Conflict Points (Continued)

A-1:
Design
(Continued)

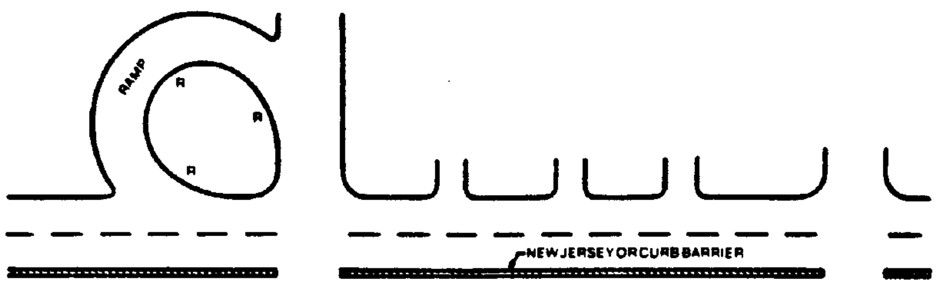


FIGURE A-1-1: MEDIAN BARRIER WITH INDIRECT LEFT TURN RAMP (CLOVERLEAF LOOP)

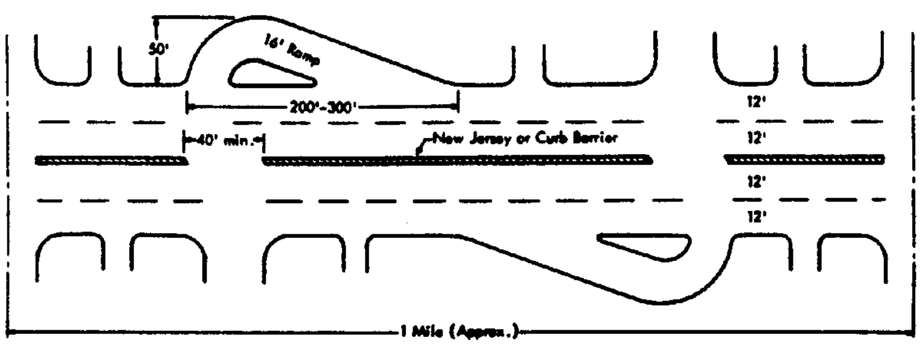


FIGURE A-1-2: MEDIAN BARRIER WITH INDIRECT LEFT TURN RAMPS (JUG-HANDLE)

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY A: Limit The Number Of Conflict Points (Continued)

A-2: Install Raised Median Divider With Left Turn Deceleration Lane

A-2: Description

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

This technique completely eliminates the hazardous crossing conflict points at driveways where right-turns in and out only are permitted. This reduces the conflicts to only two diverge/merge conflicts from 11 which existed on a 4-lane roadway.

For intersections and major driveways where left-turns are permitted, the frequency and severity of conflicts associated with left-turn vehicles are reduced by allowing deceleration and shadowing of these vehicles in left-turn lanes.

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

A-2: Application

A non-traversable median with left-turn bays at all signalized intersections should be included in the design of major arterials in new locations and included in the major reconstruction of existing major arterials.

On existing multi-lane roadways, this technique may be cost effective where speeds exceed 30 mph, ADT's exceed 10,000, and levels of development exceed 30 driveways per mile or peak hour left-turn volumes exceed 150 vph per one-mile section. It should be particularly effective where there is a high accident experience involving left-turn ingress vehicles.

(Continued)

CATEGORY A: Limit The Number Of Conflict Points (Continued)

A-2: Design

The length of the turn bay will be controlled by the sum of the maneuver distance plus storage length required in the peak period or the off-peak - which ever is longer. Inadequate length presents a safety problem if excessive deceleration must take place in the through traffic lane and a high speed differential is created between the turning vehicles and traffic in the through lane. The safety problem is especially severe if the left-turn queue spills into the through traffic lane.

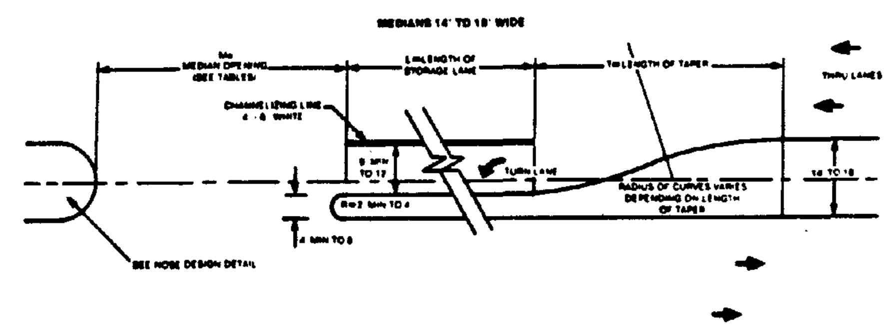


FIGURE A-2-1: SINGLE LEFT TURN LANE

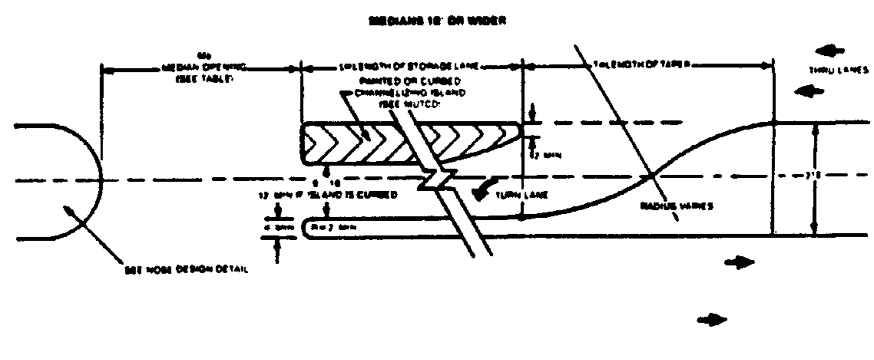


FIGURE A-2-2: DUAL LEFT TURN STRIPED FOR SINGLE LANE OPERATION

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY A: Limit The Number Of Conflict Points (Continued)

A-3: Install One-Way Operations On The Highway

A-3: Description	Converting an urban street to one-way operation eliminates the conflict between the left-turning vehicles and opposing traffic at all access drives and intersections. The number of conflicts at T-intersections and drives at the right-hand side of the street are reduced from 9 to 2 as right-turn in and right-turn out only are permitted. At the left-side of the roadway, conflicts are reduced from 9, on a 2-lane street and 11 on a 4-lane street, to 3 (the left-turn ingress diverge, left-turn egress merge and the crossing conflict between the left-turn ingress and egress maneuvers). Capacity is increased where an odd number of lanes can be utilized. One-way streets also lend themselves to significantly improved signal progression with a resulting increase in progression speed, reduced delay, and increased capacity. Negative considerations include increased circuity of travel (indirect or around-the-block maneuvers and impact on residential property between and along the streets which constitute the one-way pair.
A-3: Application	A two-way street can be converted to one-way operation where there is an existing parallel street. The technique is applicable on 2-way roadways experiencing high accident rates and the right-of-way is insufficient for implementing other remedial techniques. It may be cost effective as a safety measure where speeds exceed 30 mph and they are at least 30 commercial driveways per mile, or the turn maneuvers over a one-mile section is equal to 30% of the hourly volume on the section.

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY A: Limit The Number Of Conflict Points (Continued)

A-4: Install Traffic Signal At High Volume Driveway

A-4: Description	If properly designed, installed, and maintained, traffic signals tend to reduce right-angle collisions vehicular-pedestrian collisions, and opposing left-turn collisions. However, rear-end collisions commonly increase. Delay to the driveway traffic will be decreased; however, total delay at the intersection will be increased if the signal interferes with progression. Moreover, if the signal system has poor progression, the resulting queues can block upstream assess drives. Also, improperly located signals will increase total traffic delays through the system, cause a deterioration in the speed, and efficiency of progression, and seriously increase fuel consumption and vehicular emissions.
A-4: Application	A driveway should be considered for signalization only if installation of the signal does not interfere with traffic progression on the major arterial, or will not interfere when the major street system reaches capacity conditions when the area becomes fully urbanized. This normally means that signalization be limited to driveways which meet the uniform signalized intersection spacing which will provide maximum progression efficiency at speeds of 30 to 35 mph at the longest cycle length which is expected to be utilized in the peak periods when the area becomes fully urbanized. When the high volume access drive does not conform to the selected long, uniform spacing criteria, consideration of signalization should be based upon a traffic engineering study which demonstrates that the signal will not interfere with efficient traffic progression for peak and off-peak conditions. Different criteria for progression may be applied to different functional classes of roadways. The following are suggested.

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY A: Limit The Number Of Conflict Points (Continued)

A-4:
Application
(Continued)

Functional Class	Category	Period	Minimum Progression	
			Speed (mph)	Efficiency[1] (%)
Major Arterial	A	peak	≥30	45
		off-peak	≥45	40
Major Arterial	B	peak	≥30	40
		off-peak	≥	35
Minor Arterial	C	peak	≥30	35
		off-peak	≥40	30

(1) Green phase for major street divided by cycle length.

A-4:
Design

All traffic signal installations must conform to the Manual on Uniform Traffic Control Devices (MUTCD). Installation of any signal serving an access drive, or other intersection, should not be made until the applicable volume or accident warrants are met.

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY A: Limit The Number Of Conflict Points (Continued)

A-5: Channelize Median Opening To Prevent Left Turn Ingress Or Left Turn Egress

A-5: Description

This technique provides positive access control on major roadways through the design of median openings so as to allow designated movements only and the prohibition of all other movements. The crossing movement is prohibited in all cases. The number and type of conflicts which are eliminated at the intersection (access drive) at which the median opening is provided depends upon which of the 5 variations of this technique is used. The conflicts at all other drives are reduced to 2 which are the diverge and merge conflicts associated with the right-turn ingress and egress respectively. The 5 variations of this technique are:

Case 1: Left-turn egress from one direction only, Figure A-5-1. This design reduces the number of conflicts from 24 to 6 where access drives on opposite sides of the roadway are directly across from each other and the most dangerous crossing conflicts reduced from 16 to 1. At an existing 3-way intersection, the total conflicts are reduced from 9 to 4; the crossing conflicts are reduced from 3 to 1. Most importantly, the left-turning vehicle is removed from the through traffic lane. This greatly reduces the likelihood of rear-end collisions. Also, capacity is increased and delay to through traffic is decreased.

Case 2: Left-turn egress from one approach only, Figure A-5-2. The number of conflicts are reduced from 24 to 6 when installed at an existing 4-way intersection (or where driveways are opposite each other); and the serious crossing conflicts are reduced from 16 to 1. With proper design, the left-turn egress driver is able to cross the traffic stream approaching from the left and then wait in the median while selecting a suitable gap in the traffic stream approaching from the right. This significantly increases egress capacity, as well as safety, especially when the access drive is located where the traffic platoon approaching from the left arrives as the platoon from the right passes, or visa-versa.

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY A: Limit The Number Of Conflict Points (Continued)

A-5: Description (Continued)

Case 3: **Left-turn ingress from both directions, Figure A-5-3.** The total number of conflict points is reduced from 24 to 9; the number of major conflicts (those involving crossing maneuver) is reduced from 16 to only 2. Moreover, the left-turn ingress vehicles can leave the traffic stream while creating a minimum speed differential between the turning vehicles and through traffic. This greatly reduces the chances of a rear-end collisions; it also decreases delay to through traffic.

Case 4: **Left-turn ingress from one direction and left-turn egress from one approach, Figure A-5-4.** While this design reduces the total number of conflicts at a 3-way intersection from 9 to 7, the three cross conflicts still remain. However, it is effective in reducing the conflicts were directly opposite drives (or public streets) results in a 4-way intersection; in this case the total number of conflicts is reduced from 24 to 9 and the serious crossing conflicts are reduced from 16 to 3.

Also, as with cases 1 and 3, the ingress vehicles is able to make the left-turn from the major roadway with minimal interference with the through traffic. However, the capacity of the left-turn egress movement from the access drive to the major roadway is very limited even under moderate traffic volumes since this maneuver must yield to through traffic approaching from the right as the left-turn ingress traffic.

Case 5: **Left-turn egress from two approaches, Figure A-5-5.** This design provides egress opportunities when drives are located opposite each other. The number of conflicts are reduced from 24, of which 16 are crossing conflicts, to a total of 8, of which only 2 are major conflicts. Traffic turning left from a driveway must yield to all other movements; thus, the elimination of the crossing and the left-turn ingress maneuvers greatly increases the left-turn egress capacity of both access drives.

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY A: Limit The Number Of Conflict Points (Continued)

A-5:
Description
(Continued)

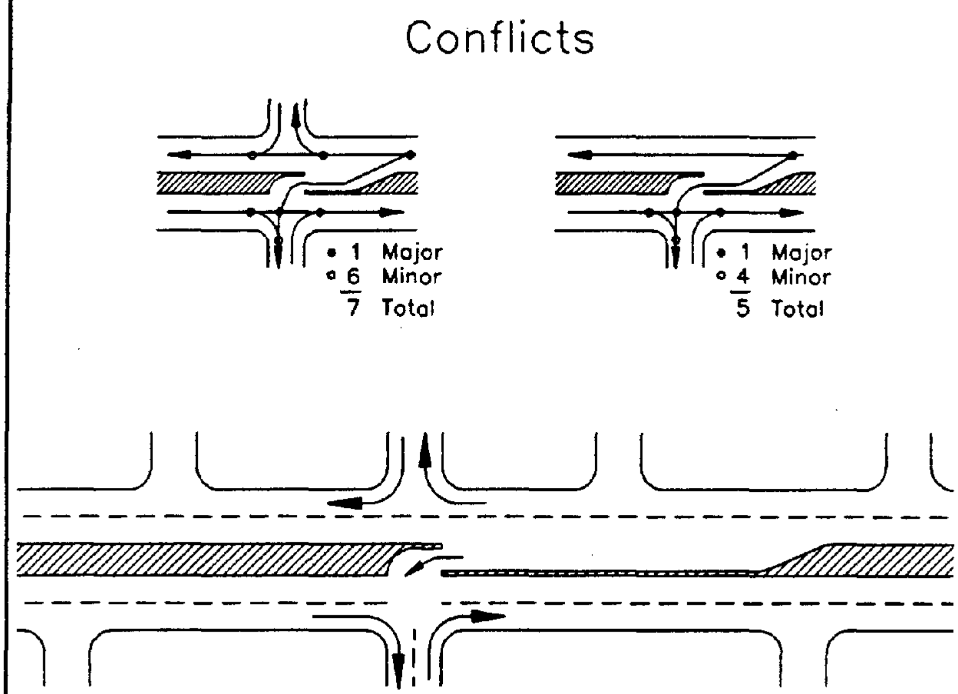


FIGURE A-5-1: LEFT TURN INGRESS FROM ONE DIRECTION ONLY

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY A: Limit The Number Of Conflict Points (Continued)

A-5:
Description
(Continued)

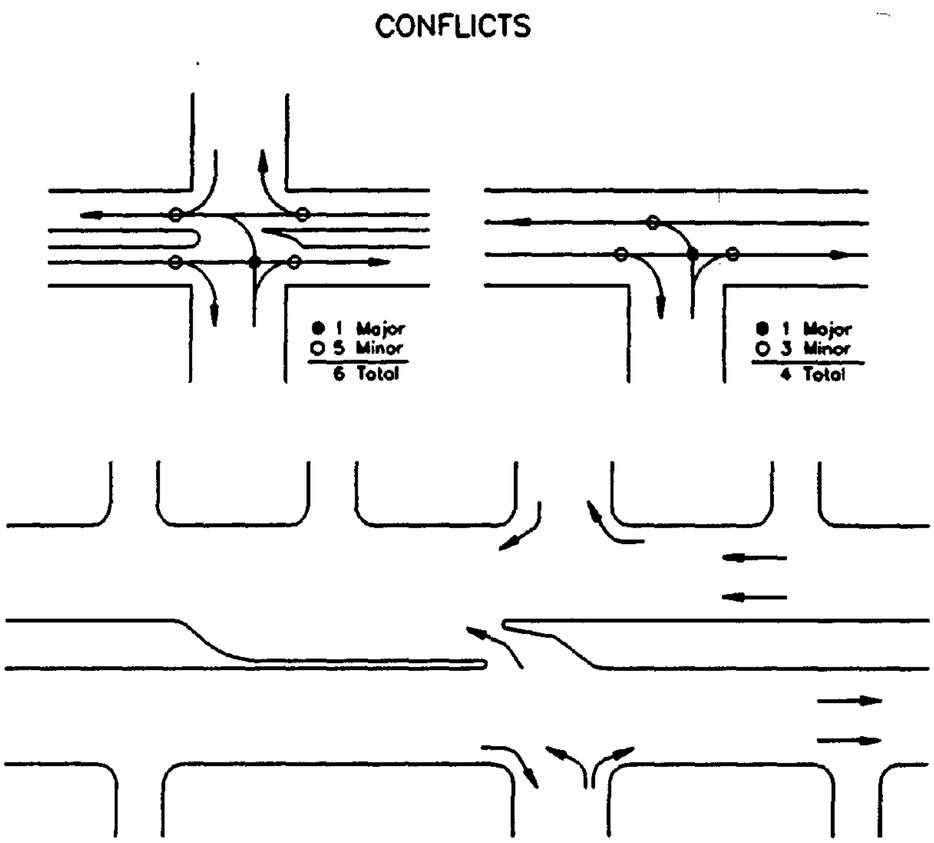


FIGURE A-5-2: LEFT TURN EGRESS FROM ONE APPROACH ONLY

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY A: Limit The Number Of Conflict Points (Continued)

A-5:
Description
(Continued)

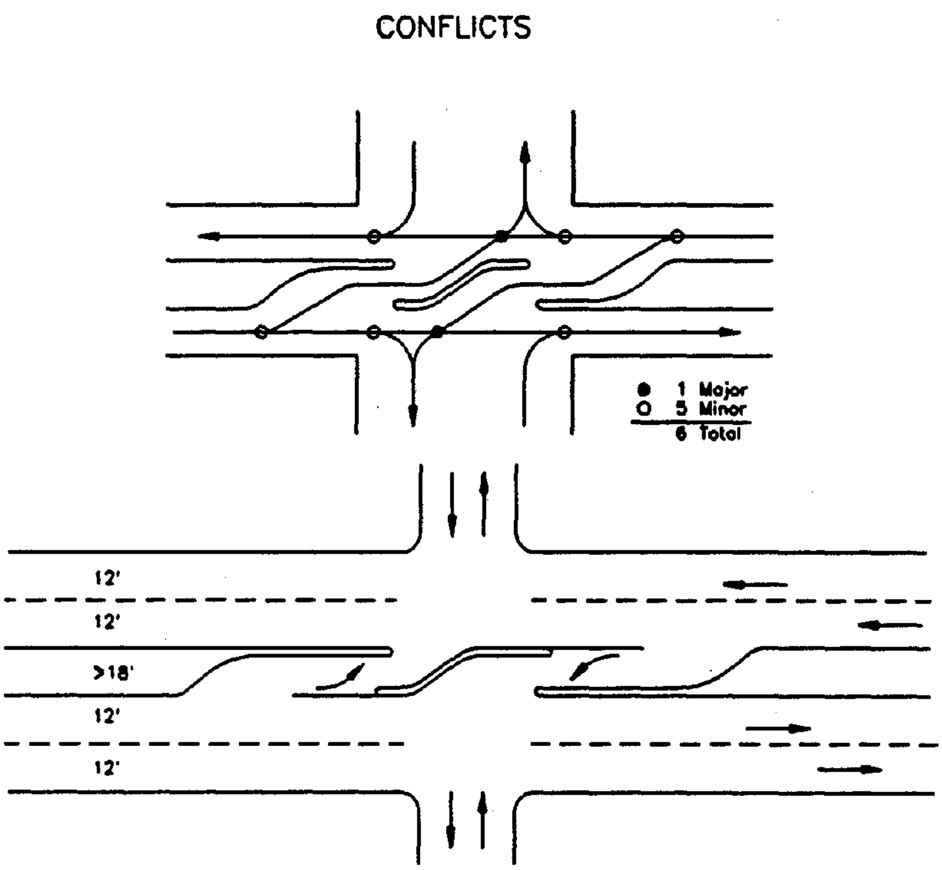


FIGURE A-5-3: LEFT TURN INGRESS FROM BOTH DIRECTIONS

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY A: Limit The Number Of Conflict Points (Continued)

A-5:
Description
(Continued)

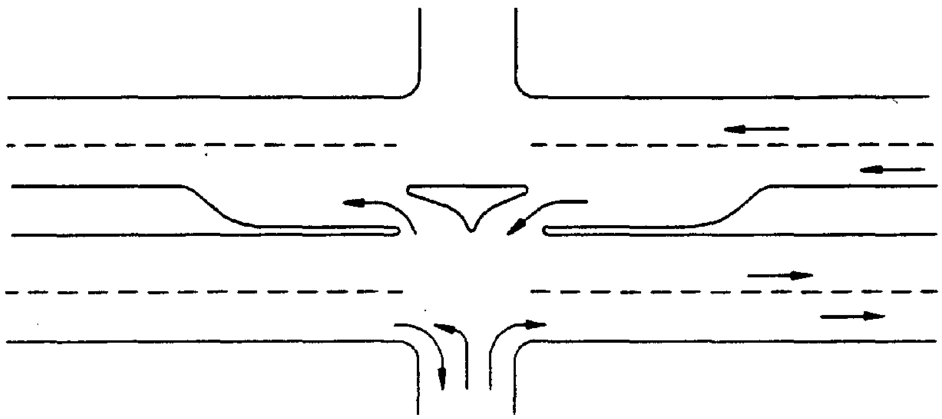


FIGURE A-5-4: LEFT TURN INGRESS FROM ONE DIRECTION AND LEFT TURN EGRESS FROM ONE APPROACH

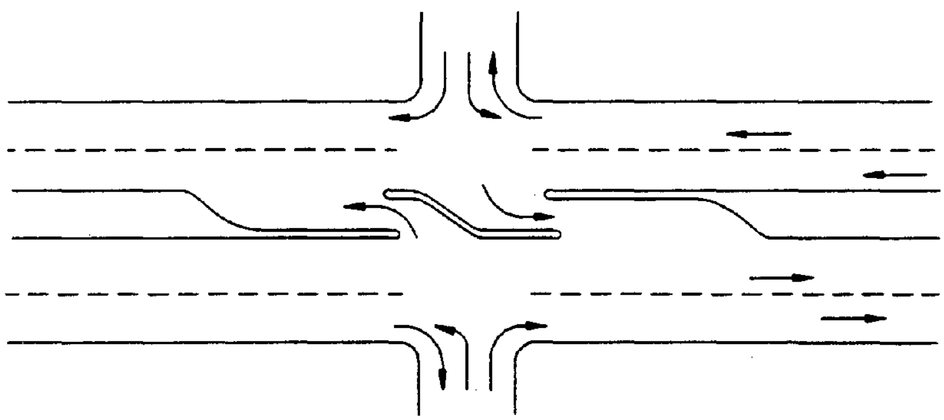


FIGURE A-5-5: LEFT TURN EGRESS FROM TWO APPROACHES

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY A: Limit The Number Of Conflict Points (Continued)

A-5: Application	The 5 variations of this technique are applicable to all major divided roadways. It has been found to have a lower accident experience than continuous left-turns lanes under the high volume conditions encountered on major urban arterials.
A-5: Design	A minimum median width, measured face-to-face of curbs of at least 18 feet is needed to accommodate the variations of this design. This width will accommodate a 12 feet turn lane with 3 feet wide non-traversable median noses at the opening. A median of 28 to 30 feet is desirable in order to provide a 12 foot turn-lane and median noses which are 7 to 8 feet wide face-to-face of curbs. This will provide 6 or 7 feet between the bulks of curbs for landscaping which will help delineate the location and the geometrics of the median opening. This landscaping will help the driver determine which maneuver(s) are and are not permitted at the particular median opening. Where right-of-way is extremely limited, a 14 foot median, face-to-face of curbs might be employed with 11 or 12 feet turn lane, this will result in median noses which are only 18, or 12 inches wide. The only treatments than can be applied to aid in making the curbs visible are reflectorized yellow paint with reflectorized yellow pavement markers and/or reflectorized 18 or 24 inch plastic pylons.

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY A: Limit The Number Of Conflict Points (Continued)

A-6: Median Closure To Restrict Ingress And Egress Vehicles

A-6: Description

This technique is a limiting application of Technique A-5. It is most commonly employed where a narrow median exists and/or where there are an excessive number of closely spaced median openings in a non-traversable median. A variation of the technique involves the installation of a concrete safety barrier (New Jersey barrier) to replace a continuous 2-way left-turn lane. Closure of median openings, or installation of a barrier eliminates left-turn ingress and left-turn egress maneuvers; at a 4-way intersection it also eliminates crossing maneuvers. Thus, the total number of conflicts is reduced from 9 to 2 at a 3-way intersection and from 24 to 2 of a 4-way intersection. All of the major conflicts are eliminated. See figure A-5-6.

A-6: Application

Closure of median openings is application on multi-lane divided highways with speeds over 30 mph. It is particularly applicable on highways having medians which are too narrow to provide channelized left-turn lanes or where a small number of left-turn ingress and/or egress movements (and/or crossing movements where two access points are situated directly opposite each other to create a 4-way intersection) result in a safety problem.

Installation of a concrete safety (New Jersey) barrier may be applicable to prevent left-turns and crossing maneuvers as either a permanent solution or a temporary measure until a non-traversable median with channelized left-turns can be constructed. Typical application includes sections of continuous 2-way left-turn where speeds exceed 30 mph, the ADT exceeds 40,000 vpd and there are more than 30 access points per mile.

A-6: Design

A median of at least 4 feet, face-to-face of curbs is necessary in order to provide a landscaping treatment which will provide visibility of the median. Where a 4-way intersection (either public streets or where two drivers are located opposite each) the median treatment must clearly indicate to the driver that a right-turn only is permitted. Particular care must be given to ensure communicate this information at night.

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY A: Limit The Number Of Conflict Points (Continued)

A-6: Design (Continued)

The landscaping materials must be selected with so that they delineate the median but do not obscure sight distances. Special care needs to be taken in the design and choice of landscaping so that very minimal maintenance is needed since it is extremely hazardous to maintain landscaping in narrow medians. If a median of less than 4 feet must be used, reflectorized pavement markers and 18 or 24 inch reflectorized pylons should be used.

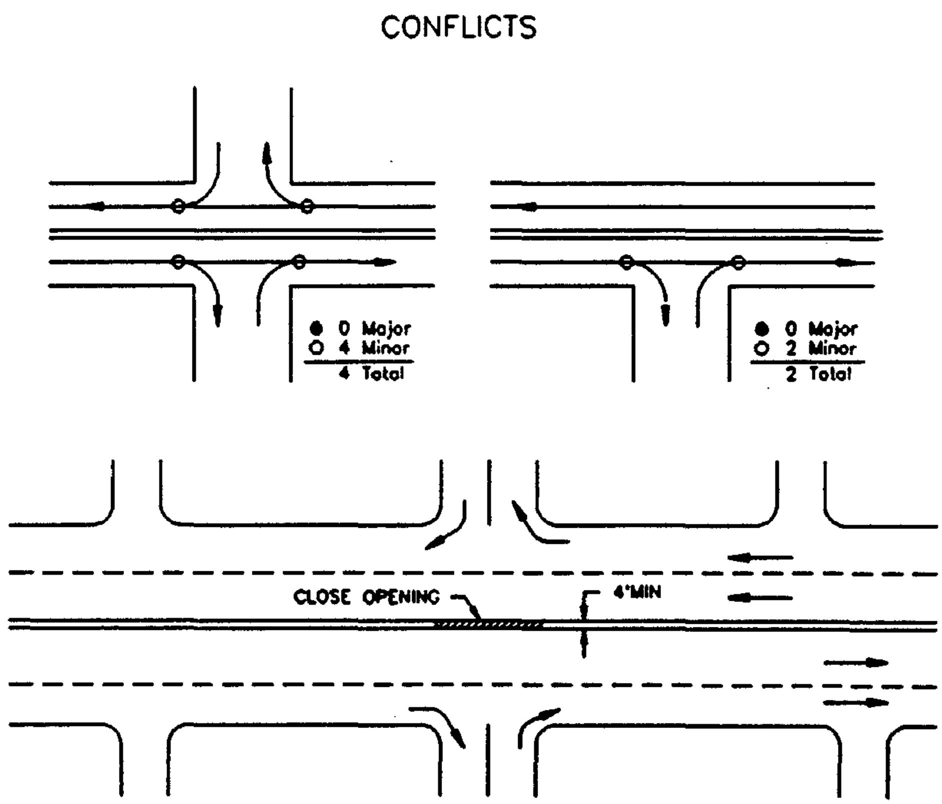


FIGURE A-6-1: MEDIAN OPENING CLOSURE TO RESTRICT INGRESS AND EGRESS VEHICLES

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY A: Limit The Number Of Conflict Points (Continued)

A-7: Install Divisional Island To Discourage Entry Into Left Turn Bay When Weave Area Is Inadequate

A-7: Description

When the location intersection of a public street, or private drive, drivers may execute a job maneuver into a left-turn bay as illustrated in Figure A-7-1. Installation of a properly designed raised barrier as illustrated in Figure A-7-2 will require drivers to make a right-turn to the outside through traffic lane and provide a positive control on access to the left-turn lane.

Implementation of this technique eliminates the dangerous conflict between the vehicles executing the jog maneuver and the through traffic lanes. It also eliminates the hazardous conflict between vehicles which have entered, or in the process of entering, the left-turn bay.

A-7: Application

This technique should be considered when a safety problem is evidenced by: (1) right-angle collisions between vehicles entering the roadway from the original marginal access; (2) collision between vehicles in the turn bay and vehicles entering downstream from the marginal access; (3) rear-end collisions in the turn bay, or; (4) Vehicles are observed to stop in the through traffic lane when attempting to enter the turn bay.

A-7: Design

Suggested minimum dimensions are given in Figure A-7-2. As illustrated in Figure A-7-3, it may be necessary to lengthen the turn bay when implementing this technique. The barrier should be at least two feet wide, preferably at least four feet, in order to give it reasonable visibility. Reflectorized pavement markers are suggested to enhance night-time visibility. A curb three or four inches in height will minimize the risk of a driver losing control of the vehicle in the event of contact with the curb and still present a positive deterrent for drivers to enter the turn bay by crossing the barrier. The leading, upstream, end of the barrier might be constructed with a 1:4, or flatter, slope to minimize the danger of the driver loosing control, or damage to the vehicle, if impact is made with the leading end.

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY A: Limit The Number Of Conflict Points (Continued)

A-7:
Design
(Continued)

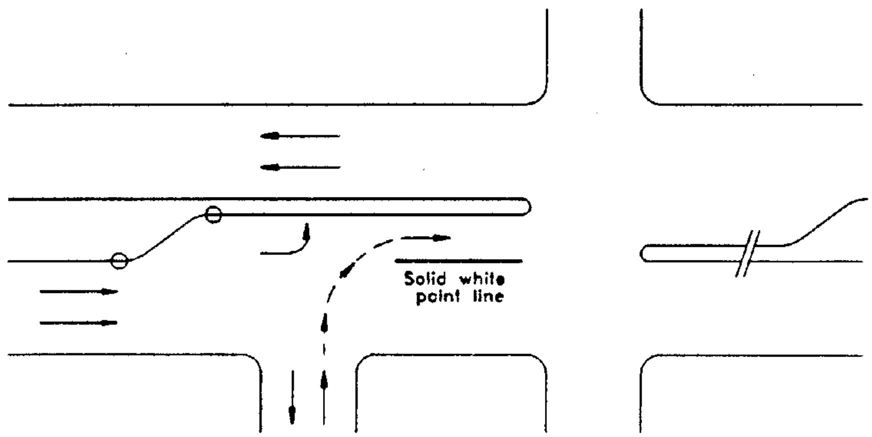
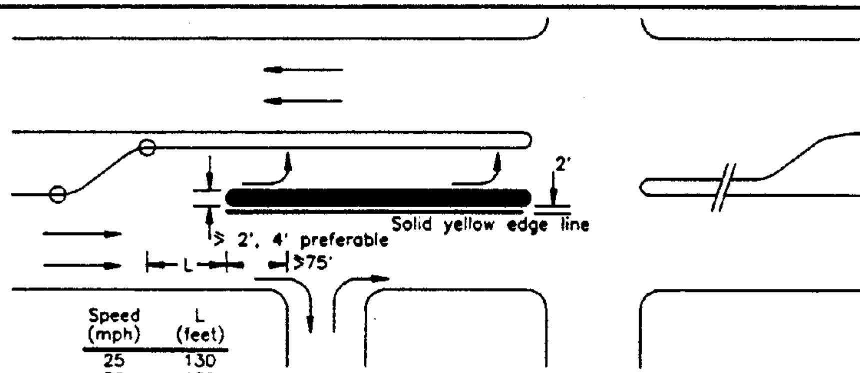


FIGURE A-7-1: SCHEMATIC ILLUSTRATION OF JOG MANEUVER WHERE WEAVE LENGTH IS INADEQUATE



Speed (mph)	L (feet)
25	130
30	130
35	150
40	175
45	200
50	220
55	250

FIGURE A-7-2: SCHEMATIC ILLUSTRATION OF RAISED BARRIER TO DISCOURAGE JOG MANEUVER WHEN WEAVING DISTANCE IS NOT ADEQUATE

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY A: Limit The Number Of Conflict Points (Continued)

A-7:
Design
(Continued)

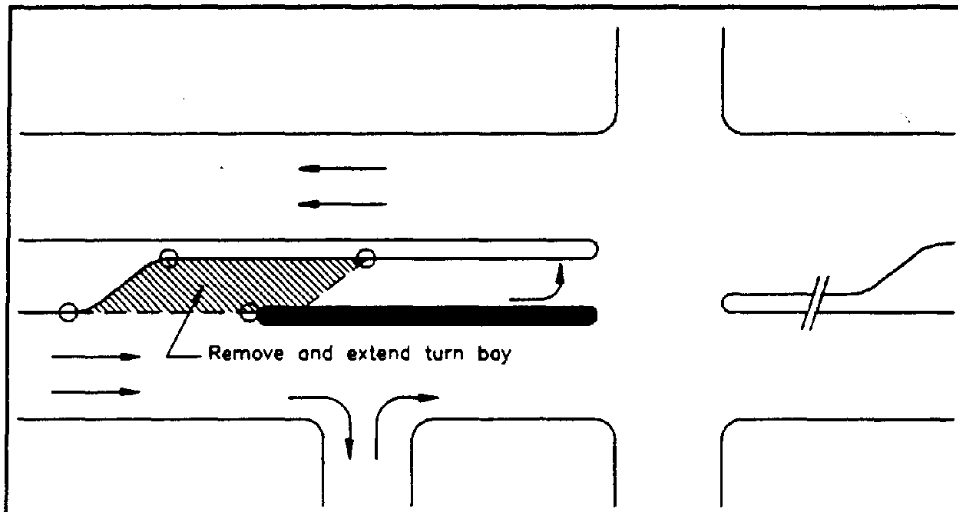


FIGURE A-7-3: IMPLEMENTING CONTROL ON ENTRY TO LEFT TURN BAY MAY REQUIRE INCREASING THE LENGTH OF THE TURN BAY

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY A: Limit The Number Of Conflict Points (Continued)

A-8: Install Physical Barrier To Prevent Uncontrolled Access Along Property Frontages

A-8: Description

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

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

A-8: Application

This technique is applicable on all roadways to which access is unrestricted. In general it will result in a benefit/cost ratio greater than one when the highway ADT exceeds 10,000 vpd and the level of development is greater than 45 driveways per mile, or, for individual properties, where the site traffic exceeds 500 vpd. High accident rates involving the open access situation will also warrant this technique.

A-8: Design

Regulation of uncontrolled access along property frontages can be accomplished by the following methods:

- Barrier
- Curbing
- Shrubbery
- Railing

Of the above, curbing is widely used due to: (1) ease of installation; (2) low maintenance; and (3) effectiveness. Care, however, must be exercised when placing curb to review not only the impact on control of access, but also its affect on the site and roadway drainage. A landscaped strip between the back of the curb and the on-site parking and circulation will help drivers identify the access drives by providing positive delineation of the edge of the roadway.

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY A: Limit The Number Of Conflict Points (Continued)

A-9: Install Median Channelization To Control Merge Of Left Turn Egress Vehicles

A-9: Description

The installation of a channelizing island in a median opening will serve to control driveway access by channeling left-turning vehicles into and from the driveway.

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

A-9: Application

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

A-9: Design

Application of this technique is best-suited for multi-lane divided highways.

Construction of the channelization island should reflect:

- Clearly-defined path for egress movement
- Adequate safety area to contain merging vehicles
- Adequate merging lane width
- Elimination of bottleneck conditions

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY A: Limit The Number Of Conflict Points (Continued)

A-9:
Design
(Continued)

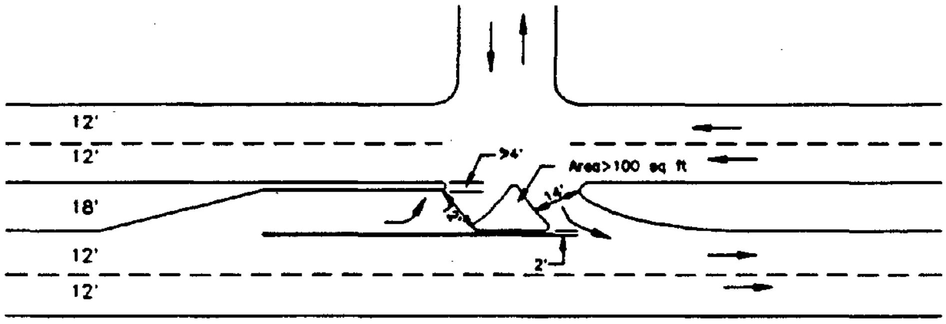


FIGURE A-9-1: CHANNELIZATION TO CONTROL LEFT TURN EGRESS

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY A: Limit The Number Of Conflict Points (Continued)

A-10: Offset Opposing Driveways

A-10: Description

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

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

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

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

A-10: Application

This technique can be implemented on undivided highways having an ADT of less than 10,000 vpd and with speeds between 30 and 45 mph. Property frontage must be sufficient to accommodate the 300-ft driveway separation. Accident experience could also justify the application of this technique.

A-10: Design

Greater interference with through traffic is likely when the driveways are offset as shown in Figure A-10-1-B. The right-turn egress to left-turn egress maneuver poses a greater threat to traffic safety than does the left-turn egress to right-turn ingress maneuver. Maximum benefits are obtained when driveways are separated by at least 300 feet.

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY A: Limit The Number Of Conflict Points (Continued)

A-10:
Design
(Continued)

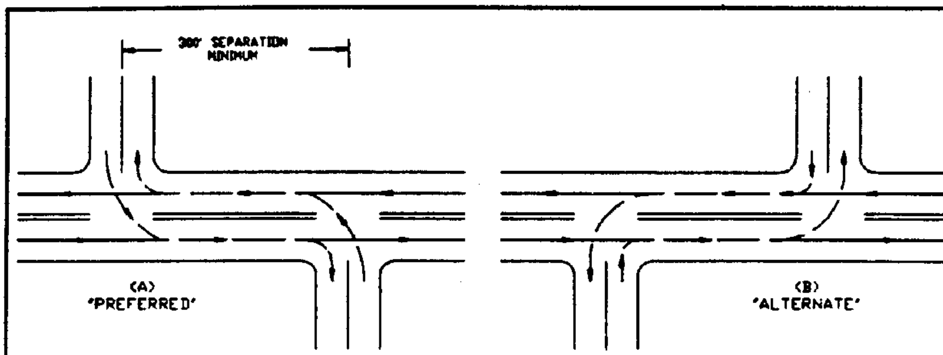


FIGURE A-10-1: DIFFERENCE IN WEAVING MANEUVERS RESULTING FROM DRIVEWAY OFFSET CONFIGURATION

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY A: Limit The Number Of Conflict Points (Continued)

A-11: Locate Driveway Opposite A Three-Leg Intersection Or Driveway And Install Traffic Signals Where Warranted

A-11: Description

This measure involves locating a driveway opposite a three-leg intersection which is suitably located for future signalization, or is already signalized. This can be accomplished either during the driveway permit authorization process or by relocating an existing driveway. Locating the driveway opposite an existing three-leg intersection rather than at a neighboring location will reduce the number of access drives and relocate the conflicts to the signalized intersection where they are separated in time.

The number of conflict points is reduced from 18 (9 each for the two separate three-leg intersections) to 10 for three-phase signalization of a 4-leg intersection. The more severe crossing conflict points are reduced from 6 to 3.

A-11: Application

This technique is applicable on all roadways where sufficient frontage is available to locate a driveway opposite a three-leg intersection or driveway.

A-11: Design

The geometric design of the intersection and the design of the signal installation should conform to the same criteria as the functional equivalent of the intersection of two public streets.

All traffic signal installations need to meet at least one of the warrants in the MUTCD.

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY A: Limit The Number Of Conflict Points (Continued)

A-12: Install Two One-Way Driveways In Lieu Of One Two-Way Driveway

A-12: Description

This access control technique involves the opening of two one-way driveways (see Figure A-12-1). Although it appears that this technique may decrease the overall safety of the location by increasing access points, it actually may increase safety through the reduction in total conflict points.

The two one-way driveways, by limiting the turning maneuvers that can be made at each driveway, will have 8 conflict points, 2 of which are crossing conflict points. A two-way driveway has 9 conflict points, of which 3 are crossing conflict points. The overall benefit of implementing this technique is that 1 crossing conflict point is eliminated.

A-12: Application

This technique is applicable on undivided roadways. (Note: not applicable at point locations) Highway speeds should be less than 35 mph. Frontage widths should be at least 150 feet, to ensure that minimum driveway separation distances can be attained.

A-12: Design

Several considerations must be made in order to effectively apply this technique including: traffic volume, geometry, and roadway width. As a rule, the greater the distance between the driveways, the more efficient and safer will be traffic operations.

Chapter 3 contains minimum driveway separation distances applicable under this control measure. It is important that adequate internal circulation be provided when using this technique so that traffic, once having entered the site, does not have to exit and then re-enter in order to circulate on the property.

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY A: Limit The Number Of Conflict Points (Continued)

A-12:
Design
(Continued)

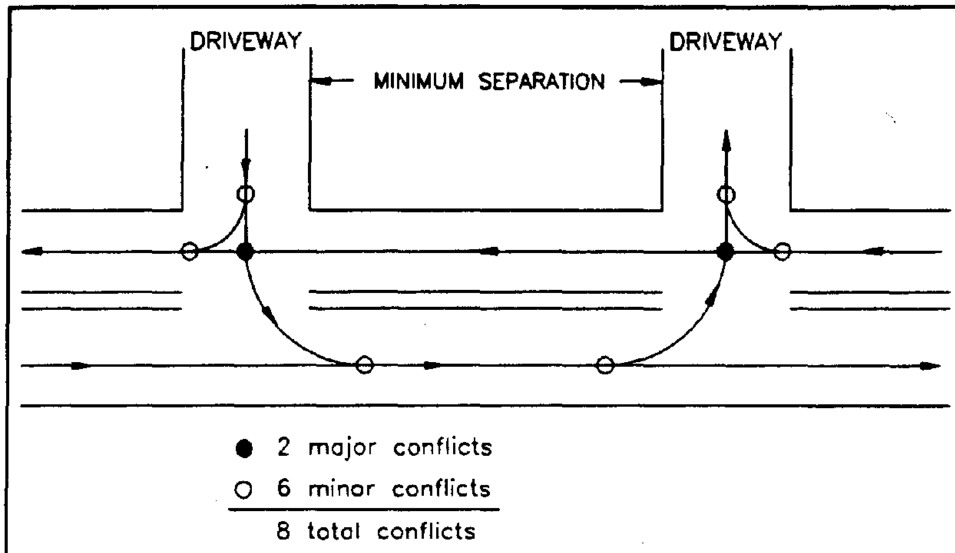


FIGURE A-12-1: MINIMUM DRIVEWAY SPACING

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY A: Limit The Number Of Conflict Points (Continued)

A-13: Install Two Two-Way Driveways With Limited Turns In Lieu Of One Standard Two-Way Driveway

A-13: Description	This access control technique is aimed at reducing conflicts at a single driveway location by replacing the single driveway with two limited-turn driveways. The immediate effect of this technique is that conflict points are reduced. A single two-way drive has 9 conflict points. The two driveways will have a total of 6 conflict points, 2 of which are crossing conflict points. A T-Intersection with two-way traffic on the driveway has 9 conflict points, 3 of which are crossing conflict points. Turning velocities can be increased by angling the driveways to receive turning vehicles.
A-13: Application	This technique is applicable at locations on divided highways with a median of sufficient width to provide for a left-turn ingress bay and to "shadow" egress vehicles. Highway ADT should be greater than 10,000 vpd, and highway speeds should be greater than 35 mph. Frontage widths should be at least 200 feet to ensure that minimum separation distances can be attained.
A-13: Design	The driveway angle with the through lanes is typically between 60° and 90° or 45° used in some cases. In urban areas the driveway angle is often nearer 90°. Careful attention must be given to the on-site circulation design to avoid conflicts which will cause traffic problems which will "spill back" to the public street.

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY A: Limit The Number Of Conflict Points (Continued)

A-13:
Design
(Continued)

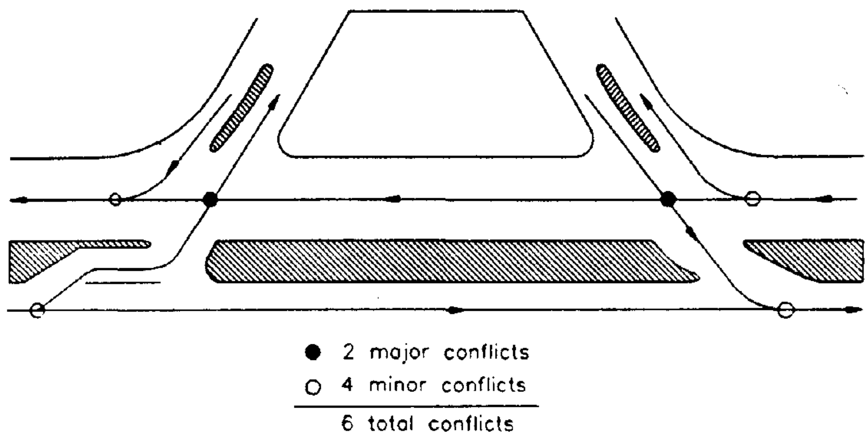


FIGURE A-13-1: CONFLICT POINTS FOR TWO-WAY DRIVEWAYS WITH LIMITED TURNS

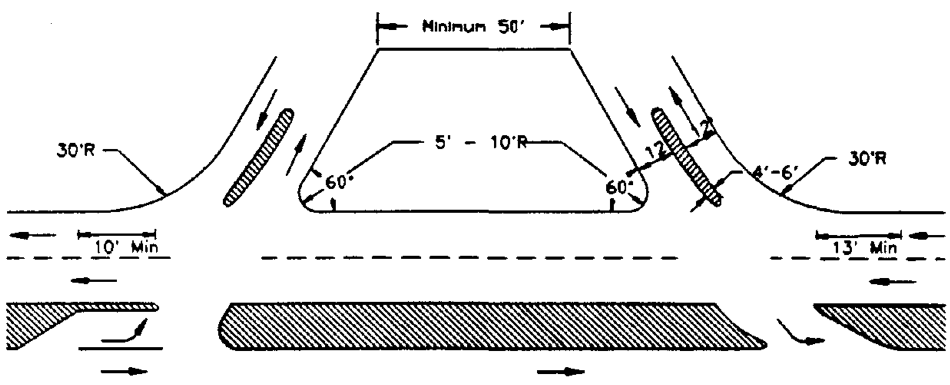


FIGURE A-13-2: TWO-WAY DRIVEWAYS WITH LIMITED TURNS

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY A: Limit The Number Of Conflict Points (Continued)

A-14: Install Two One-Way Driveways In Lieu Of Two Two-Way Driveways

A-14: Design (Continued)	This driveway operations technique is aimed at limiting the number of conflict points at a single property. Specifically, it reduces the number of crossing conflict points by changing driveway operations from two two-way driveways to two one-way driveways. This technique can be applied during the permit-authorization stage or at existing sites with appropriate reconstruction. The directional control accompanying one-way operations will result in improved driveway and highway operations by allowing a smaller variety of maneuvers to be made at each driveway. Accident frequencies are expected to decrease because the total number of conflicting points will be reduced from 18 to 8. Four crossing, three merge, and three diverge conflict points are eliminated at the two driveways. Accident severities are not expected to substantially decrease. Possible detrimental effects may occur because turns made into, or from, the wrong driveway may initiate a severe conflict. Also, if a vehicle misses the intended entrance driveway, no other opportunity will exist to enter the other driveway.
A-14: Application	This technique is applicable at point locations on all types of highways where highway speeds are less than 50 mph and traffic volumes greater than 10,000 vpd. Driveway volumes should be greater than 300 vpd. Frontage width requirements are determined by the driveway separation and highway speed. The minimum acceptable frontage width is 120 feet, for a highway speed of 20 mph.
A-14: Design	The driveways should be operationally arranged so that the one-way directions are egress and then ingress proceeding downstream. This does not conform to driver expectation. It also places weaving on the street. Table A-14-1 lists the recommended driveway separation distances to be used with this technique.

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY A: Limit The Number Of Conflict Points (Continued)

A-14:
Design
(Continued)

TABLE A-14-1: RECOMMENDED DRIVEWAY SPACING DISTANCES

Speed (mph)	Minimum Spacing	
	Eliminate Right Turn Conflict Overlap[a]	Minimum Maneuver Distance[b]
30	185	325
35	245	425
40	300	525
45	350	630

a) Values from Table 3-14
b) Values from Table 3-3

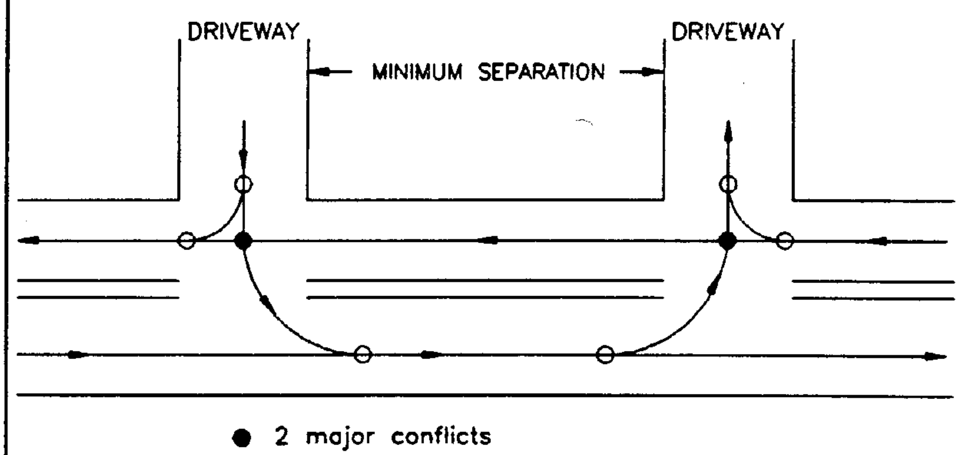


FIGURE A-14-1: TWO ONE-WAY DRIVEWAYS IN LIEU OF TWO TWO-WAY DRIVEWAYS

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY A: Limit The Number Of Conflict Points (Continued)

A-15: Install Two Two-Way Driveways With Limited Turns In Lieu Of Two Standard Two-Way Driveways

A-15: Description

This technique can be implemented during the permit authorization stage or at an existing location with appropriate reconstruction.

The technique reduces the frequency of conflicts at a single property from 18 to 6 by eliminating 4 crossing, 4 merge, and 4 diverge conflict points. Accident severities and vehicular delays are not expected to change substantially. Turning velocities can be increased by angling the driveway to receive turning vehicles.

A-15: Application

This technique is applicable at point locations on all types of highways. It is not applicable at point locations. It may be expected to be cost effective where the highway ADT exceeds 10,000 vpd, and highway speeds should be greater than 35 mph, and where at least 40 vph should turn left across through traffic to enter the driveway during peak periods. Frontage widths should be at least 200 feet to ensure that minimum separation distances can be attained.

A-15: Design

In the design of this technique, consideration should be given to limiting the number of conflict points between ingress/egress vehicles and through movements. Access driveway approaches preferably should be positioned between 90°-60° to the highway, and 45° in special cases. On high speed roads, an angle of 60° is preferred to facilitate a higher speed ingress maneuver. This will increase the deceleration distance that must be provided on site. The design is the same as Technique A-13 and special attention must be given to the site circulation design so that on-site conflicts do not result in problems on the public street.

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY A: Limit The Number Of Conflict Points (Continued)

A-15:
Design
(Continued)

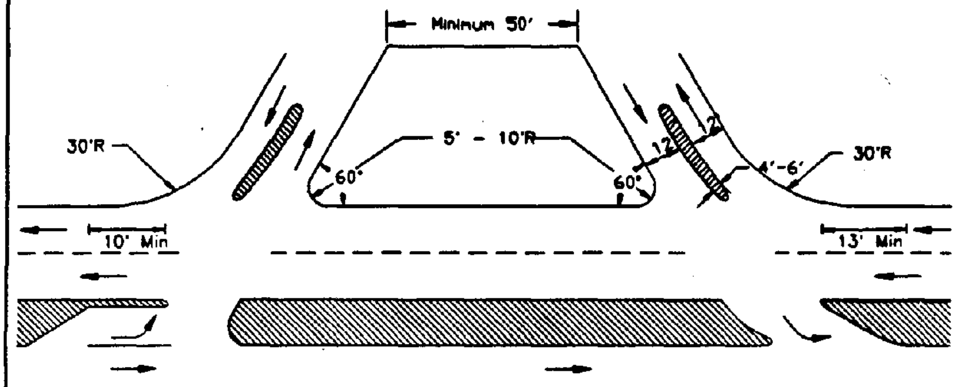


FIGURE A-15-1: ANGLED TWO-WAY DRIVEWAYS WITH LIMITED TURNS

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY A: Limit The Number Of Conflict Points (Continued)

A-16: Install Channelizing Island To Discourage Left Turn Maneuvers

A-16: Description

This driveway attempts to discourage left-turn ingress maneuvers. The left-turn maneuvers are restricted by a channelizing island in the driveway throat.

There are three variations of this technique. They are:

Case 1: Discourage left-turn ingress, Figure A-16-1. The number of conflicts are reduced from 9 to 4.

Case 2: Discourage left-turn egress, Figure A-16-2. Conflicts are reduced to 5, one of which occurs on-site.

Case 3: Discourage left-turn ingress and left-turn egress, Figure A-16-3. This design eliminates all but 2 of the conflicts.

However, the reduction in conflicts is moderated by a possible increase in right-turn and indirect left-turn maneuvers. Travel time may increase to vehicles denied the opportunity to make left turns.

A-16: Application

This technique is applicable as a point control on undivided highways with speeds of 30-45 mph and ADT's greater than 5,000 vpd. High left-turn accident rates will also warrant this technique.

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY A: Limit The Number Of Conflict Points (Continued)

A-16: Design

The island construction should be offset a minimum of 2 to 4 feet from the traveled throughway and be of sufficient width to effectively deter unwanted maneuvers.

A radius of between 75 feet and 100 feet should be used in order to make it more difficult for a driver to make a maneuver which the design is intended to discourage. Radii larger than 100 feet should not be used on egress (cases 2 and 3) unless an acceleration lane is provided because of the large angle a driver must rotate one's head in order to see vehicles approaching from the left. The acceleration lane allows the driver to use the rear view mirror to select a gap. This will also provide an island that exceeds the minimum 75 square feet area for triangular islands. A mountable curb, preferably no more than 4 inches high should be used. This curb design and the 2 foot to 4 foot offset will minimize the chances of the curb being hit and, if hit, reduces the chance of the driver losing control of the vehicle. The island should be landscaped with materials appropriate for the local in order to enhance the visibility of the island.

In addition, turn prohibition signs (R3-1, R3-2) as outlined in the MUTCD should be installed.

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY A: Limit The Number Of Conflict Points (Continued)

A-16:
Design
(Continued)

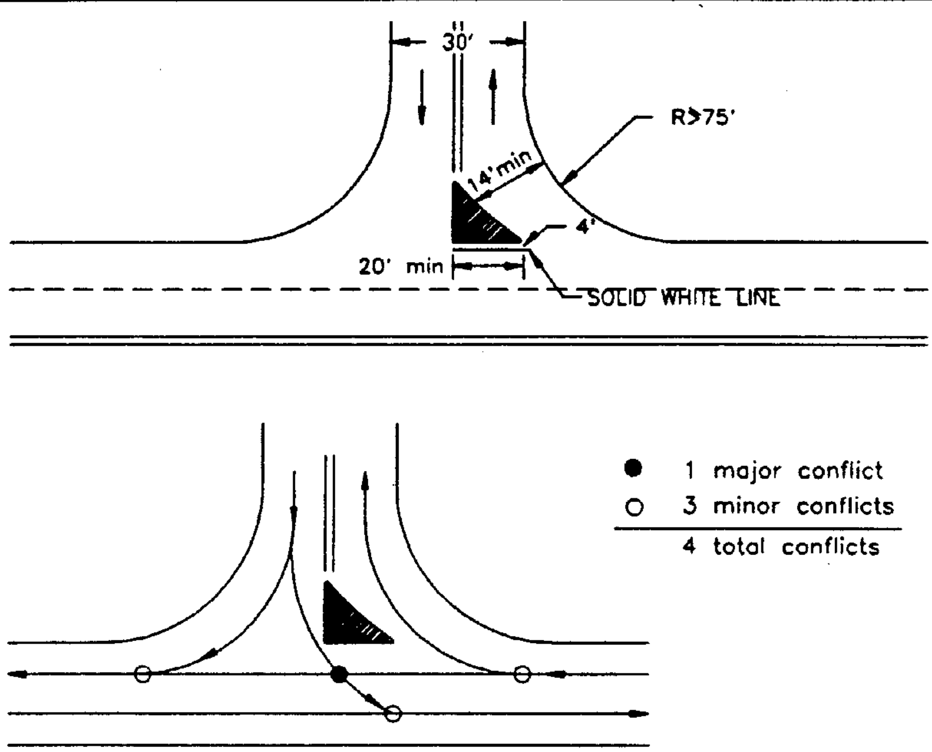


FIGURE A-16-1: DRIVEWAY CHANNELIZING ISLAND TO DISCOURAGE LEFT TURN INGRESS MANEUVERS

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY A: Limit The Number Of Conflict Points (Continued)

A-16:
Design
(Continued)

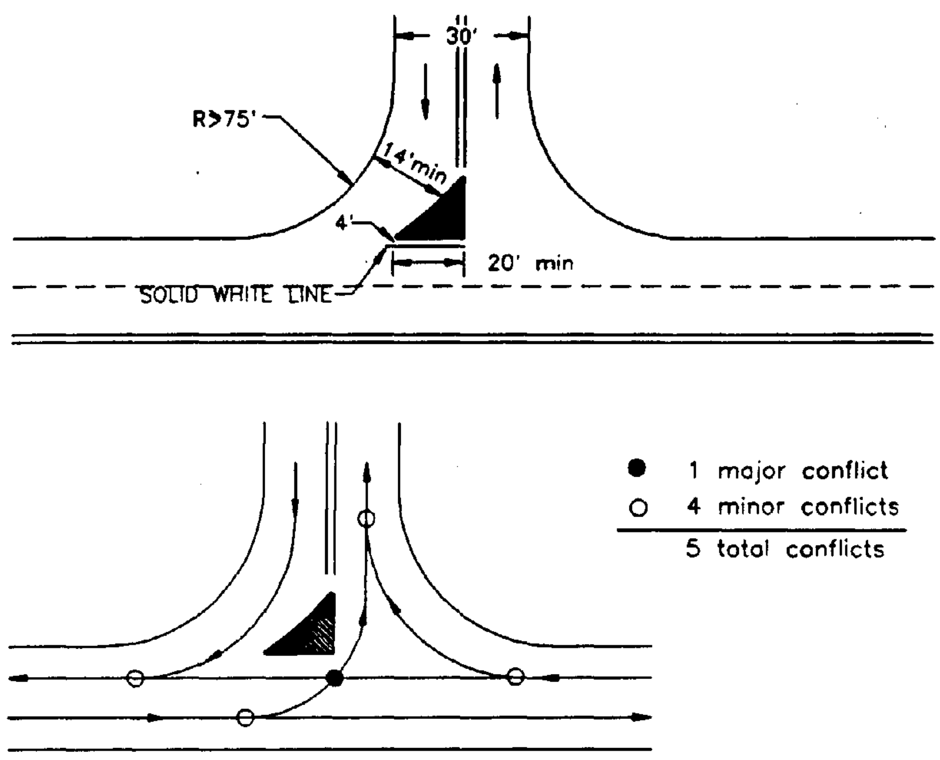


FIGURE A-16-2: DRIVEWAY CHANNELIZING ISLAND TO DISCOURAGE LEFT TURN EGRESS MANEUVERS

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY A: Limit The Number Of Conflict Points (Continued)

A-16:
Design
(Continued)

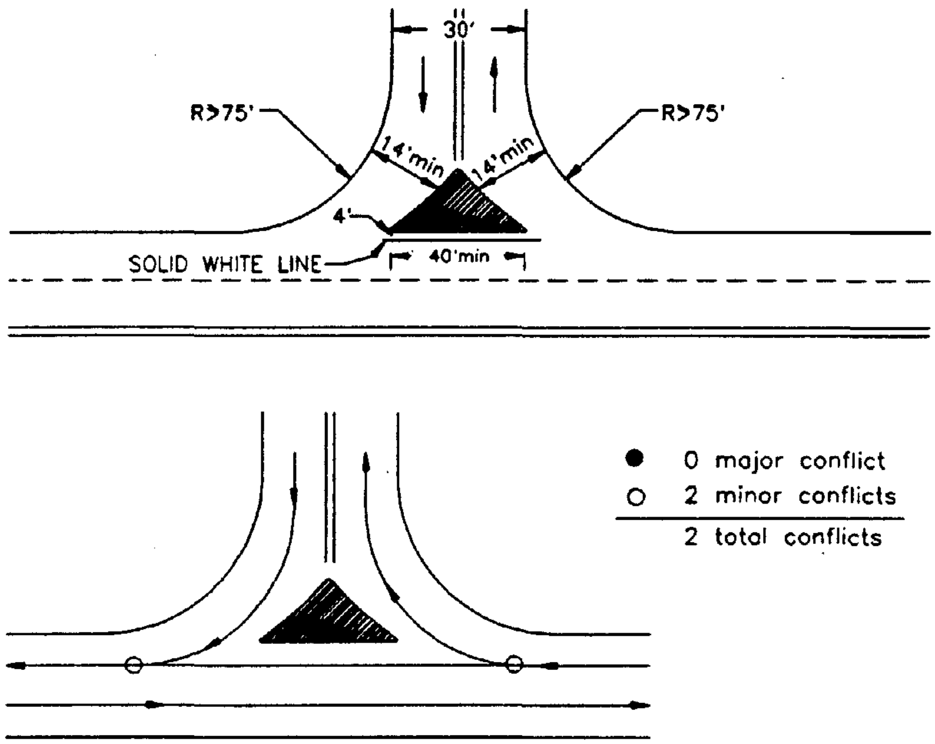


FIGURE A-16-3: DRIVEWAY CHANNELIZING ISLAND TO DISCOURAGE LEFT TURN EGRESS AND INGRESS MANEUVERS

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY A: Limit The Number Of Conflict Points (Continued)

A-17: Install Driveway Divisional Island To Prevent Driveway Encroachment Conflicts

A-17: Description

This access control measure involves the construction of a driveway median island to control ingress and egress vehicle maneuvers. The technique can be applied either to existing driveways or in the permit authorization stage.

The technique will reduce head-on encroachment conflicts between driveway ingress and egress vehicles. Ingress and egress traffic will be directed to separate sides of the driveway median island. Some increases in single-vehicle accidents can be expected due to driveway vehicles striking the island.

A-17: Application

This technique is applicable for driveways with two-way operations on all types of highways. It is particularly applicable to two-way driveways where the throat width is designed to accommodate left-turn and right-turn egress movements from separate lanes and there is a history of driveway head-on accidents between opposing vehicles or between entering and parking vehicles would justify reconstruction to add this treatment.

A-17: Design

Installation of a divisional island driveway should be made to prohibit encroachment by opposing vehicles. The width of the median should be from 4 feet to 10 feet; the length from 25 feet to 120 feet. The offset of the island with respect to the through lanes should be at least 5 feet. If the divisional island is at least 8 feet wide and 100 feet long it should be curbed (4" mountable). Landscaping should be used to provide visibility. Narrow and shorter islands should not be curbed. Instead, these islands should be flush or slightly raised with a contrasting surface. Reflectorized yellow pavement markers help provide delineation and are recommended on high volume driveways. Standard yellow edge lines should be used at the divisional island. Also, white pavement markings should be used to delineate traffic lanes when there are two, or more, lanes in the same direction. Where there is the possibility that truck wheel paths may track over a flush or slightly raised divisional island, a "full strength" pavement should be provided.

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY A: Limit The Number Of Conflict Points (Continued)

A-17:
Design
(Continued)

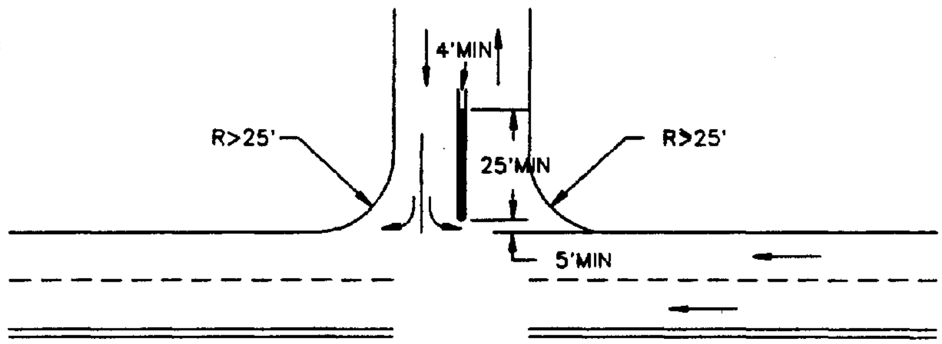


FIGURE A-17-1: DRIVEWAY MEDIAN CHANNELIZING ISLAND

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY A: Limit The Number Of Conflict Points (Continued)

A-19: Install Channelizing Island To Control The Merge Area Of Right Turn Egress Vehicles

A-19: Description	This driveway design technique reduces the frequency of conflicts by reducing conflict areas. The channelizing island will designate the correct right-turn egress path and more clearly define the merge area. The merge conflict is relocated longitudinally downstream from the immediate driveway intersection. Delay is not expected to change.
A-19: Application	This technique is applicable at driveways serving large development having access to major highways where long curb return radii (≥ 50 ft) are used and/or where it is desired to operate the right-turns under separate traffic control.
A-19: Design	The intent of this design is to control egress movements by directing flow to desired path. Island size and position must be such that presence and function are clearly delineated to the motorist. If the island is less than 75 square feet in area, it should not be curbed. Islands of 50 square feet or less should be delineated by paint (and perhaps reflectorized pavement markers). Islands between 50 and 75 square feet might be designed with a flush or slightly raised (≤ 1 1/2 inches) and contrasting surface; reflectorized pavement markers will help provide night-time delineation. Islands of at least 75 square feet may be curbed. Curb height should not exceed four inches to minimize loss of control in the event it is hit by a vehicle. Landscaping should be used to enhance visibility.

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY A: Limit The Number Of Conflict Points (Continued)

A-20: Regulate The Maximum Width Of Driveways

A-20: Description	This is a regulatory practice aimed at reducing conflict areas by defining the maximum width of driveway openings on the highway. The maximum width is a function of the types of vehicles using a facility as well as the nature of the development to be served. This technique is applicable at a point location or as a standard for all driveways. Curbing is usually used to define the extent of a driveway opening. The reduction in potential conflict areas is expected to be accompanied by a reduction in accident frequencies and severities. No tradeoffs are anticipated by regulating maximum driveway widths.
A-20: Application	This technique is warranted on all highways.
A-20: Design	Maximum driveway widths a function of design parameters appropriate to the expectant vehicle usage. Consideration must be given to highway operating conditions, volume, geometry, sight distance, angle of intersection, and alignment (vertical and horizontal).

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY B: Separate Basic Conflict Areas

Introduction

CATEGORIES OF TREATMENT FOR IMPROVING TRAFFIC FLOW

- A. Limit Number of Conflict Points.
- B. Separate Conflict Points.
- C. Limit Deceleration.
- D. Remove Turning Vehicles from Through Lanes.

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY B: Separate Basic Conflict Areas (Continued)

B-1: Regulate Minimum Spacing Of Driveways

B-1: Description

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

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

B-1: Application

This access control technique is generally applicable for all types of arterials where conflict areas overlap and delays are excessive. Highways with volumes greater than 5,000 vpd and speed greater than 25 mph are candidates for consideration.

B-1: Design

Table B-1-1 contains desirable separation distances applicable to driveways on all types of roadways.

TABLE B-1-1: DESIRABLE SEPARATION OF ADJACENT DRIVEWAYS

Speed (mph)	Minimum Spacing: Eliminate Right Turn Conflict Overlap[a]	Minimum Spacing: Minimum Maneuver Distance[b]
30	185	325
35	245	425
40	300	525
45	350	630

a) Values from Table 3-14
b) Values from Table 3-3

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY B: Separate Basic Conflict Areas (Continued)

B-2: Regulate Minimum Corner Clearance

B-2: Description	This access control standard regulates the distance between a crossroad intersection and the nearest driveway location. In this text, corner clearance is defined as the distance, measured along the back of the arterial curb, from the nearest edge of the intersection. This technique moves the basic driveway conflict area away from the vicinity of an intersection by regulating the distance from the driveway to the intersection. The major effect is that the minimum spacing of access points is increased, resulting in larger stopping sight distances and driver perception times. An additional effect is that driveway vehicles will be delayed less by standing queues at signal-controlled intersections. A possible tradeoff is that access to some corner commercial properties may be partially or totally denied.
B-2: Application	This technique may be applied on all types of highways where corner lot driveways create conflict and delay problems to through and driveway traffic.
B-2: Design	This technique is aimed at preventing the location of driveways within the functional area of an intersection. It will also minimize driveway/intersection conflicts by preventing blockage of driveways upstream of an intersection due to standing traffic queues. Minimum driveway setback distances should take into consideration typical traffic queue lengths while permitting sufficient movement to driveway vehicles.

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY B: Separate Basic Conflict Areas (Continued)

B-3: Regulate Minimum Property Clearance

B-3: Description	The regulation of minimum property clearance distances is an access control standard that helps increase the minimum spacing of access points. Property clearance is the distance, measured along the arterial curb, from the extended property line to the nearest edge of the driveway. Conflicts will be at adjacent driveways at properties having a common property line.
B-3: Application	This technique may be applied on all highway types in the permit authorization stage.
B-3: Design	On local and minor collector roadways the minimum property clearance will be the curb return radii. If no radius (a "dustpan design") is used, the minimum clearance should be at least 25 feet. On major arterials, the property clearance should be at least equal to the deceleration distance needed for the operating speed of the roadway.

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY B: Separate Basic Conflict Areas (Continued)

B-4: Optimize Driveway Spacing In The Permit Authorizing Stage

B-4: Description	This is a general operating practice that maximizes the spacing of adjacent driveways during the permit authorization stage. The technique is intended to supplement the operational benefits expected from Technique B-1, "Regulate Minimum Spacing of Driveways." This technique indirectly reduces the frequency of conflicts by separating adjacent conflict areas and limiting the number of basic conflict points per length of highway. The implementation of this technique is expected to reduce the severity of conflicts as it allows more deceleration distance and perception time between driveways.
B-4: Application	This technique is applicable on arterial and collective roadways. Application is limited to the permit authorization stage.
B-4: Design	This technique is aimed at maximizing the spacing between adjacent driveways along an arterial. Application of this technique is intended to supplement the information contained in Technique B-1. Figure B-4-1 contains two arrangements: (a) minimum non-optimized driveway spacing, and (b) optimized driveway spacing.

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY B: Separate Basic Conflict Areas (Continued)

B-4: Design (Continued)

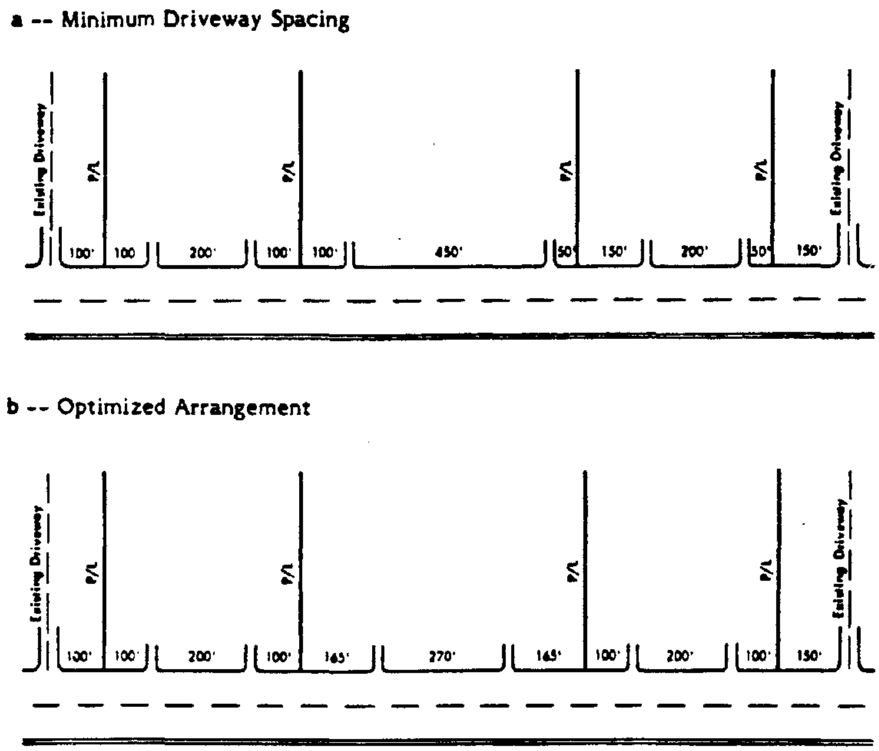


FIGURE B-4-1: OPTIMIZED DRIVEWAY PLACEMENTS

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY B: Separate Basic Conflict Areas (Continued)

B-5: Regulate Maximum Number Of Driveways Per Property Frontage

B-5: Description

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

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

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

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

B-5: Application

The application of this access control measure is applicable on all existing arterial highways or as a standard for all new facilities.

B-5: Design

- Neighborhood commercial development located on the corner of an arterial and collector should be restricted to access on the collector only.
- On major arterial roadways, access should be limited to a single drive unless the frontage exceeds 1/4 mile.

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY B: Separate Basic Conflict Areas (Continued)

B-6: Consolidate Access For Adjacent Properties

B-6: Description	This general operating practice encourages adjacent property owners to construct joint-use driveways in lieu of separate driveways. Strategies for implementing this technique include closing existing driveways or encouraging joint-use driveways. The feasibility of this technique is viewed primarily at the permit-authorization stage. The joint driveway will cause a reduction in the concentration of driveways along an arterial. The reduction in driveway concentrations is expected to be accompanied by a reduction in the frequency and severity of conflicts.
B-6: Application	This technique is applicable on all major roadways with speeds greater than 35 mph. Driveway pairs with more than 50 vehicles using each driveway per hour will be good candidates for this technique.
B-6: Design	The physical means by which access can be consolidated between two adjacent properties involves construction of a joint use driveway between the two properties. It is recommended that both owners have property rights in a joint-use driveway. That is, the drive should be located straddling the property line with each having a permanent easement on the other. This practice will not enable either owner the opportunity to deny or restrict access to his neighbor's property. The resulting parking area should have an efficient internal circulation plan.

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY B: Separate Basic Conflict Areas (Continued)

B-6:
Design
(Continued)

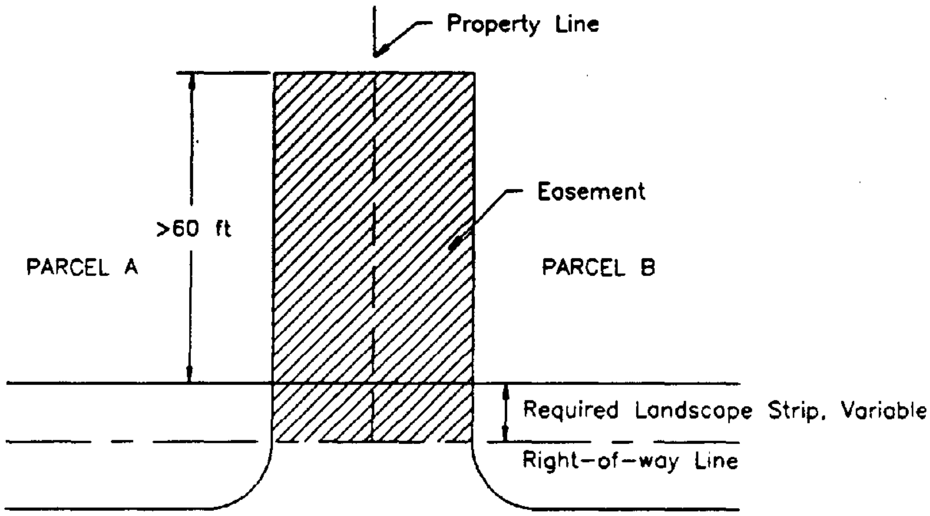


FIGURE B-6-1: SHARED ACCESS DRIVE

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY B: Separate Basic Conflict Areas (Continued)

B-8: Buy Abutting Properties

B-8: Description	This access control measure is aimed at reducing the frequency of access points by purchasing small parcels that remain after a highway improvement. The several parcels can be consolidated into large tracts and sold with access deed reservations or as a single parcel with only one access drive. This elimination of potential access points can aid substantially in protecting the functional integrity of the highway by minimizing the frequency and severity of conflict points.

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY B: Separate Basic Conflict Areas (Continued)

B-9: Deny Access To Small Frontage

B-9: Description

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

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

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY B: Separate Basic Conflict Areas (Continued)

B-10: Consolidate Existing Access Whenever Separate Parcels Are Assembled Under One Purpose, Plan, Entity, Or Usage

B-10: Description	This is a general operating practice that requires specific changes on commercial sites when they are assembled for development or redevelopment. The consolidation is accomplished by voiding existing driveway permits upon alteration of the property functions. The new permit authorization depends on the developer's plans to use some existing driveways and close or relocate other driveways. The objective of this technique is to increase average spacing of access points along the highway. The consolidation of driveways reduces the number of access points and thereby increases the spacing of driveways. The increase in driveway spacing provides motorists of turning vehicles more time and distance to properly execute their maneuvers. The severity of conflicts should decrease because deceleration requirements are lessened.

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY B: Separate Basic Conflict Areas (Continued)

B-11: Designate The Number Of Driveways To Each Existing Property And Deny Additional Driveways Regardless Of Future Subdivision Of That Property

B-11: Description

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

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

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

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY B: Separate Basic Conflict Areas (Continued)

B-12: Require Access On Collector Street (When Available) In Lieu Of Driveways On Major Highway

B-12: Description	This access control technique is aimed at maintaining the movement function of the major roadway by locating additional driveways on collector streets instead of on the arterial highway. This technique will reduce conflict frequency and severity by diverting some driveway vehicles to the collector street location where traffic volumes and speed are lower.

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY C: Limit Deceleration Requirements

Introduction

CATEGORIES OF TREATMENT FOR IMPROVING TRAFFIC FLOW

- A. Limit Number of Conflict Points.
- B. Separate Conflict Points.
- C. Limit Deceleration.
- D. Remove Turning Vehicles from Through Lanes.

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY C: Limit Deceleration Requirements (Continued)

C-2: Restrict Parking On The Roadway Next To Driveways To Increase Driveway Turning Speeds

C-2: Description	This technique increases the turning speed by removing constraining obstacles, specifically parked vehicles, from areas adjacent to driveways. Parked vehicles may indirectly contribute to driveway accidents by limiting the sight distance or influencing the turning paths of driveway vehicles. This technique is intended as a point measure, although route applications are also feasible. This technique will reduce the severity and frequency of conflicts by removing, and merging, driveway vehicles at higher speeds. Severity is reduced because the speed differential between turning and through vehicles is reduced. Conflict frequency also benefits from the increase in turning velocity. One possible tradeoff that accompanies this technique is a reduction in parking capacity.
C-2: Application	This technique is applicable at any driveway location where parking is permitted.
C-2: Design	Drivers in the outside through traffic lane must have adequate stopping sight distance. Driveway traffic must have adequate intersection sight distance to safely select a gap and to accelerate to the speed of through traffic.

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY C: Limit Deceleration Requirements (Continued)

C-3: Install Visual Cues Of The Driveway

C-3: Description

Adequate sight distance and visual realization of the driveway location are very important factors to the safe and efficient operation of driveways and highways. Many existing driveways, however, lack adequate visual cues and are the scene of many vehicular and pedestrian conflicts.

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

C-3: Application

Driveways should be highly visible to the approaching drivers in the through traffic lanes. Visual clues should provide information as to both the location and the geometrics of the driveway to the driver. On major roadways, the driver should be able to locate and identify the driveway at a distance at least equal to the decision sight distance (the perception-reaction distance plus the distance required to maneuver to a turn at a speed of 10 mph or less).

Visual clues should be provided to the presence of any driveway where sight distances equal to or exceeding AASHTO minimums and the sight distance problem cannot be corrected.

C-3: Design

Contrasting surfaces (or materials) are the best method of providing visual clues as to driveway location and geometrics. On major roadways, a landscaped strip should be required between the back of the curb and any paved area, including sidewalks. In no case should the paved site parking and circulation be allowed to extend to the back of the curb. The minimum width of the landscaped area along a major roadway should be at least 25 feet. On major collectors, locating the sidewalk one foot from the property line, and not permitting paving of the right-of-way, will provide visual clues as to a driveway. on minor collectors, a strip 2 to 4 feet wide, between the curb and sidewalk will provide adequate visual clue; if the sidewalk is contiguous with the back of the curb, landscaping at least 4 feet wide should be used.

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY C: Limit Deceleration Requirements (Continued)

C-3: Design (Continued)	If circumstances exist such that adequate sight distance can not be provided by removing obstructions or relocating the drive, advanced warning will be required. Consideration must be given to the geometric and grade layout, traffic level, and roadway type. Recommended visual cues include: flashing beacons, warning signs, contrasting pavements, reflectorized treatments, driveway lighting, or any combination of the above mentioned. Installation of warning devices must adhere to recommendations outlined in the MUTCD.

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY C: Limit Deceleration Requirements (Continued)

C-4: Improve Driveway Sight Distance

C-4: Description

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

There are numerous causes of reduced sight distance including horizontal and/or vertical alignment, topography, foliage and/or other landscaping, parked vehicles, and physical structures. Statutes should be adopted which authorize the governing jurisdiction to maintain a clear-visibility triangle which has the driveway and main street as two of its legs with the hypotenuse between these two enclosing a prescribed area.

Improved sight distance requires altering existing site conditions to increase the available sight distance at the driveway. The terrain can be altered by cutting down hillsides, removing walls and fences, or moving signs and billboards. Alterations to the roadway include flattening horizontal and vertical curves.

Often commercial establishments with insufficient setback distances and internal parking problems will use the unpaved highway right-of-way for parking. This should be discouraged by municipal or state authorities. If encroachment on public land has contributed to accidents on or off the traveled way, steps should be taken to prohibit and prevent the practice. Stepped-up enforcement of regulations may be an effective deterrent. Other remedies should be tried if more critical problems occupy police time.

C-4: Application

This technique is applicable at all existing driveways where adequate sight distance is not available.

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY C: Limit Deceleration Requirements (Continued)

C-4: Design (Continued)	In addition to utilization of information contained in Techniques C-2 and C-3 to increase driveway sight distance, elimination or alteration of physical and geometric barriers should be considered as an enhancement to driveway sight distances. Improved sight distance can result from altering roadway alignment (horizontal and vertical curves) and eliminating physical obstructions (shrubbery, fencing, walls, etc.).

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY C: Limit Deceleration Requirements (Continued)

C-5: Regulate Minimum Sight Distance

C-5: Description	This regulatory policy is designed to control driveway location by imposing minimum sight distance standards for driveways. The policy takes effect by closing and relocating existing driveways or by regulating new driveways in the permit authorization stage. Regulation of sight distance is generally more applicable to suburban-rural locations. The technique enables the driver of a vehicle, which is on the driveway, to see a sufficient distance in both directions along the highway and to enter the highway without creating a hazardous situation. The increased sight distance also decreases the speed differential between highway and driveway vehicles by allowing the through drivers more perception time which helps to reduce maximum deceleration requirements.
C-5: Application	Insuring that adequate sight distance is provided must always be considered in the permit authorization stage. At existing access locations where sight distance is found to be inadequate, corrective action needs to be taken immediately.
C-5: Design	Minimum sight distances should exceed the AASHTO minimums - especially on high volume and/or high speed major roadways.

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY C: Limit Deceleration Requirements (Continued)

C-6: Optimize Driveway Location In The Permit Authorization Stage

C-6: Description

This is a regulating reserve policy which considers driveway location through review of the site plan. The review enables the driveway to be located where maximum sight distance is available, consistent with other locational controls and to minimize impact on the public street. Careful location of the driveway enables the driver of a vehicle, which is stopped on the driveway outside the edge of the traveled way, to see a sufficient distance in both directions along the highway to enter the highway without creating a hazardous situation. Drivers in the through traffic lanes are afforded more perception time which helps to reduce maximum deceleration requirements. These conditions lead to a reduction in the severity of conflicts.

C-6: Application

Requests for driveway permits in the authorization stage warrant this access control treatment. All highway types are candidates with particular attention to major roadways.

C-6: Design

Although frontage widths pose some limitations on the actual location, driveways should be located at the point of optimum sight distance along the frontage. This technique attempts to achieve sight distances greater than AASHTO minimums.

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY C: Limit Deceleration Requirements (Continued)

C-7: Increase The Effective Approach Width Of The Driveway

C-7: Description

This technique is a driveway design technique aimed at limiting the maximum deceleration requirements on the highway. The technique affects driveway operations by decreasing the time required for the turning vehicle to clear the through traffic lane.

Conflict severity will be reduced with this technique by decreasing the maximum deceleration requirements for following vehicles. This will decrease the severity of the "shock wave" which is created by the turning vehicle.

C-7: Application

This technique has general application to all driveways. It should always be a part of the design process for all planned or reconstructed driveways. Also, it should be considered as a general accident countermeasure for medium-to-high volume existing driveways.

C-7: Design

The speed at which vehicles can safely and effectively negotiate turning maneuvers is governed by several design parameters including: driveway width, return radius, lateral offset, approach angle, and approach flare.

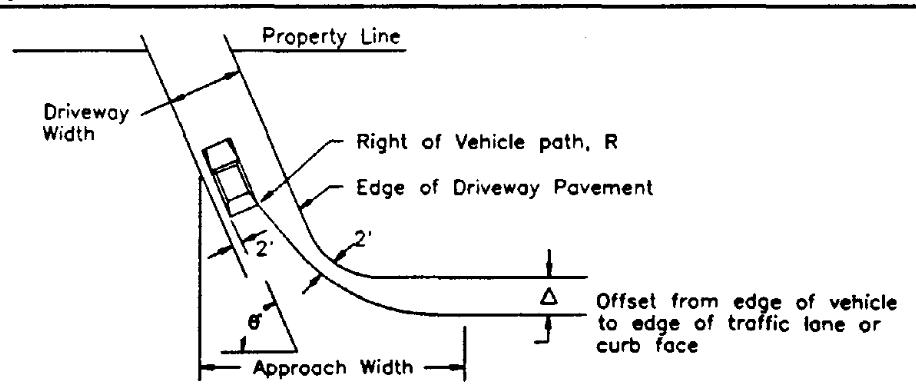


FIGURE C-7-1: DRIVEWAY DESIGN ELEMENTS

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY C: Limit Deceleration Requirements (Continued)

C-8: Improve The Vertical Geometrics Of The Driveway

C-8: Description

This technique is a general design standard for new and existing driveways in which driveway profile guidelines are specified. These guidelines allow vehicles to efficiently execute driveway maneuvers without the vehicle experiencing severe bouncing. Providing adequate driveway profiles will result in desirable driveway operation only when the other driveway geometric characteristics will permit such speeds.

Improving the driveway maneuver will decrease the duration and severity of the conflicts between vehicles in the following traffic which is caused by the turning vehicle.

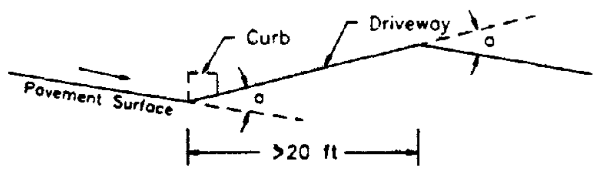
C-8: Application

Application of this technique is desirable on existing driveways and should be mandatory on all newly constructed or reconstructed driveways and on existing facilities where the driveway profile is adversely affecting traffic operations.

C-8: Design

Adequate design of driveway grades should reflect consideration for basic functions of the highway and the site which the driveway serves. Generally, in order to safely perform ingress/egress maneuvers, driveway profiles should provide for sufficient clearance between the vehicle and driveway surface.

Design guidelines often limit the change in grade that is permitted without the use of a vertical curve.



Functional Class	Maximum Angle a
Arterial	3-4%
Collector	5-6%
Local	< 8%

FIGURE C-8-1: VERTICAL DRIVEWAY GEOMETRY

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY C: Limit Deceleration Requirements (Continued)

C-9: Require Driveway Paving

C-9: Description	This technique is a general access control standard in which the structural integrity of the driveway is ensured by using a hard-surface treatment. Without driveway paving, desired driveway speeds are difficult to maintain because of potholes, ponding, and ill-defined maneuver paths. Also, loose material from the driveway causes a hazardous condition on the through traffic lanes. With paving, interference to through vehicles and conflict severity are reduced because the maximum deceleration requirement is limited.
C-9: Application	Paving should be required for all driveways intersecting major roadways.
C-9: Design	Appropriate driveway thicknesses and surfaces shall be installed to withstand expected driveway usage; and be applied to extend the entire length necessary for a smooth transition between the highway and driveway. Minimum recommended thickness for commercial usage should be based on soil conditions and type and volume of traffic. Typical guidelines include: • 6" base stone plus 1 1/2" asphalt, or • 4" reinforced concrete

(Continued)

CATEGORY C: Limit Deceleration Requirements (Continued)

C-10: Regulate Driveway Construction (Performance Bond) And Maintenance

C-10: Description	This technique is an access management policy that ensures a permanent and structurally adequate driveway surface. The strategy used in regulating construction is a performance bond that is required prior to construction. Maintenance is regulated by specifications included in the driveway permit, and regular enforcement of these regulations is needed to ensure adequate operations. The functional objective of the technique is to increase driveway speeds which in turn limits the deceleration requirements of through vehicles. A reduction in the severity of conflicts is the anticipated result.
C-10: Application	This technique is applicable for all driveways during the driveway permit process. This policy is most applicable to urban-suburban areas.
C-10: Design	In order to ensure that the construction of a driveway is sound and structurally adequate, a performance bond should be required from the contractor. This bond should be requested prior to construction and be of adequate value to cover any warranty period. Driveway maintenance is typically outlined in the permit-granting stage and plays a necessary function in maintaining adequate driveway operation and service life.

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY C: Limit Deceleration Requirements (Continued)

C-11: Install Right Turn Acceleration Lane

C-11: Description

This design technique reduces through-lane deceleration requirements by facilitating higher speed driveway merge maneuvers. The merge maneuver is facilitated by a right-turn acceleration lane for use by right-turn egress driveway vehicles. This technique can be applied both during the permit-authorization stage or at existing facilities.

The speed of driveway to highway merges is increased by allowing driveway vehicles the necessary length to accelerate. The merge maneuver can be accomplished more safely when the speed is more compatible with highway running speeds.

Merge and rear-end conflicts are expected to decrease because of a reduction in the deceleration requirement of through vehicles. Increased perception times will also result.

C-11: Application

This technique is applicable on all highway types. Highway volumes should exceed 10,000 vpd, and speeds should be greater than 35 mph. The technique should be implemented only at driveways that have at least 75 right-turn egress movements during peak demand periods. Property frontages should exceed the recommended length of the acceleration lane. high accident rates involving right-turn egress vehicles will also warrant this technique.

C-11: Design

A right-turn acceleration lane should be of sufficient width and length to allow safe, efficient merging maneuvers to occur (see Figure C-11-1).

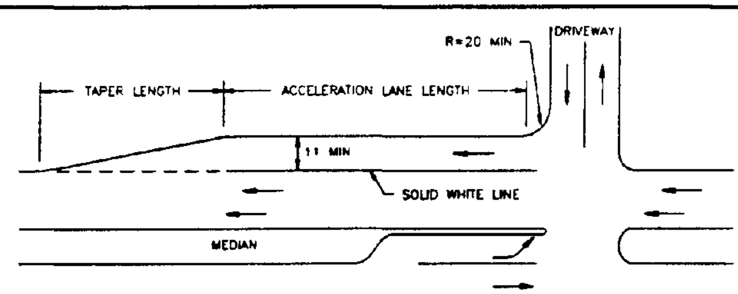


FIGURE C-11-1: RIGHT TURN ACCELERATION LANE

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY C: Limit Deceleration Requirements (Continued)

C-12: Install Channelizing Islands To Prevent Driveway Vehicles From Backing Onto The Highway

C-12: Description

This driveway design technique is aimed at reducing through-lane deceleration requirements by preventing driveway vehicles from backing onto the highway from a parking area. The strategy for achieving this objective is to construct channelizing islands at existing locations to prohibit this maneuver. The islands can be located either on the right-of-way or inside commercial properties. Candidate locations for this technique are characterized by commercial parking areas paved to the edge of pavement in back of curb, with no physical distinction between the two areas. This method will define where access to a property should be made.

The technique will reduce the total area of conflict by controlling and defining driveway openings. Conflict severity will be reduced by prohibiting uncontrolled access along property frontages. Possible detrimental effects may include an increase in through vehicle conflicts with the installed island.

C-12: Application

This technique is warranted on all highways where open access exists.

C-12: Design

The design of islands to accomplish this technique is dependent upon geometric layout and highway speeds. Islands should be of adequate size to discourage undesirable maneuvers but clearly define intent and direction for the turning vehicle.

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY D: Remove Turning Vehicles From The Through Lanes

Introduction

CATEGORIES OF TREATMENT FOR IMPROVING TRAFFIC FLOW

A. Limit Number of Conflict Points.

B. Separate Conflict Points.

C. Limit Deceleration.

D. Remove Turning Vehicles from Through Lanes.

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY D: Remove Turning Vehicles From The Through Lanes (Continued)

D-1: Install Continuous Two-Way Left Turn Lane

D-1: Description

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

D-1: Application

This technique is applicable on roadways with existing strip development which has frequent, but low volume driveways. Two moderate to high volume driveways should not be located in close proximity to each other. Continuous two-way left-turn lanes are compatible with the function of collective streets, and some minor arterials, serving commercial and industrial and multi-functional residential areas. Special care needs to be taken in the permit phase to ensure that moderate to high volume access points are NOT arranged as illustrated in Figure D-1-1. Continuous two-way left-turn lanes provide a level of access which is incompatible with the movement function of arterial roadways.

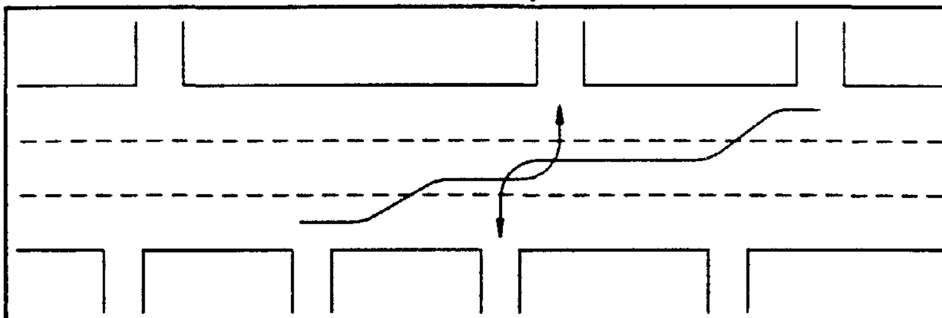


FIGURE D-1-1: SEVERE CONFLICT CREATED WHEN HIGH VOLUME DRIVES ARE LOCATED DOWNSTREAM ON OPPOSITE SIDES OF ROADWAY

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY D: Remove Turning Vehicles From The Through Lanes (Continued)

D-1: Design

Figure D-1-2 illustrates the major design considerations applicable under this Technique. Traffic lane widths of 12 feet are desirable, however, existing conditions, particularly in urban settings may dictate lane width modifications.

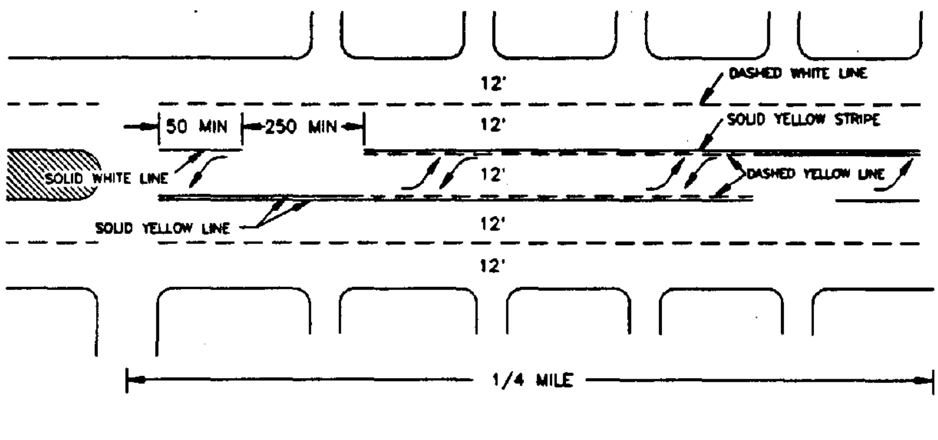


FIGURE D-1-2: CONTINUOUS TWO-WAY LEFT TURN LANE

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY D: Remove Turning Vehicles From The Through Lanes (Continued)

D-3: Install Alternating Left Turn Lane

D-3: Description

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

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

D-3: Application

This technique is applicable on all types of highways where sufficient space is available for construction of medial turn lanes. Median widths 12 feet or greater are necessary. Multi-lane undivided highways where the curb-to-curb width will accommodate an odd number of lanes can be achieved by removing parking or restriping the through traffic lanes are candidates for these techniques. Application is particularly appropriate where concentrations of driveways alternate from one side of the highway to the other.

D-3: Design

Alternating left-turn lanes can be used when property access is required and roadway width is limited. Figure D-3-1 exhibits typical usage.

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY D: Remove Turning Vehicles From The Through Lanes (Continued)

D-3:
Design
(Continued)

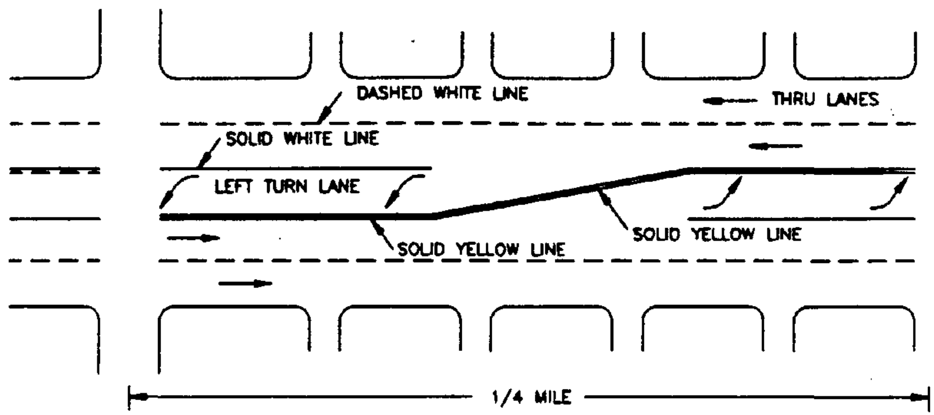


FIGURE D-3-1: ALTERNATING LEFT TURN LANE

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY D: Remove Turning Vehicles From The Through Lanes (Continued)

D-4: Install Isolated Median And Deceleration Lane To Shadow And Store Left Turn Vehicles

D-4: Description

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

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

D-4: Application

Installation of an isolated median left-turn is applicable on all undivided high speed roadways where an individual public road, or private driveway, has moderate to high volume left-turns in one or both directions.

Suggested applications are:

Speed (mph)	Left-Turn Volume (vpd)
35	200
45	150
≥ 55	100

D-4: Design

The decision components of this technique are the deceleration lanes (taper and storage), median islands, and the tapering length of the highway. The taper rates are a function of speed; suggested taper rates are shown in Table D-4-1. In many cases, additional rights-of-way will be needed to facilitate construction of needed deceleration lanes and median islands. Figures D-4-1 and D-4-2 provide design guidelines.

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY D: Remove Turning Vehicles From The Through Lanes (Continued)

D-4: Design (Continued)

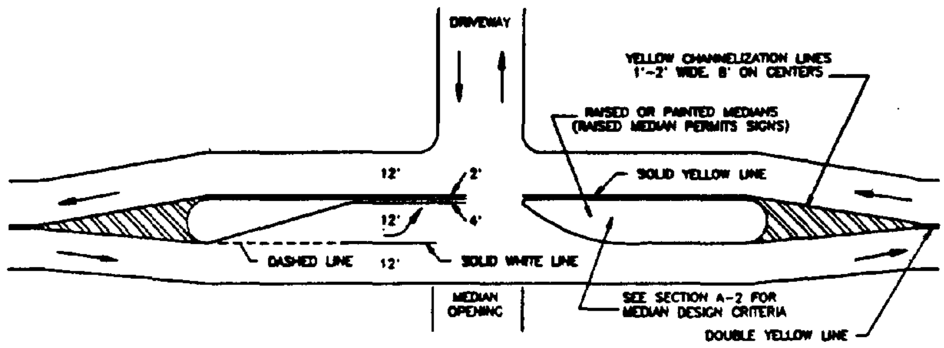


FIGURE D-4-1: ISOLATED DECELERATION LANE DESIGN

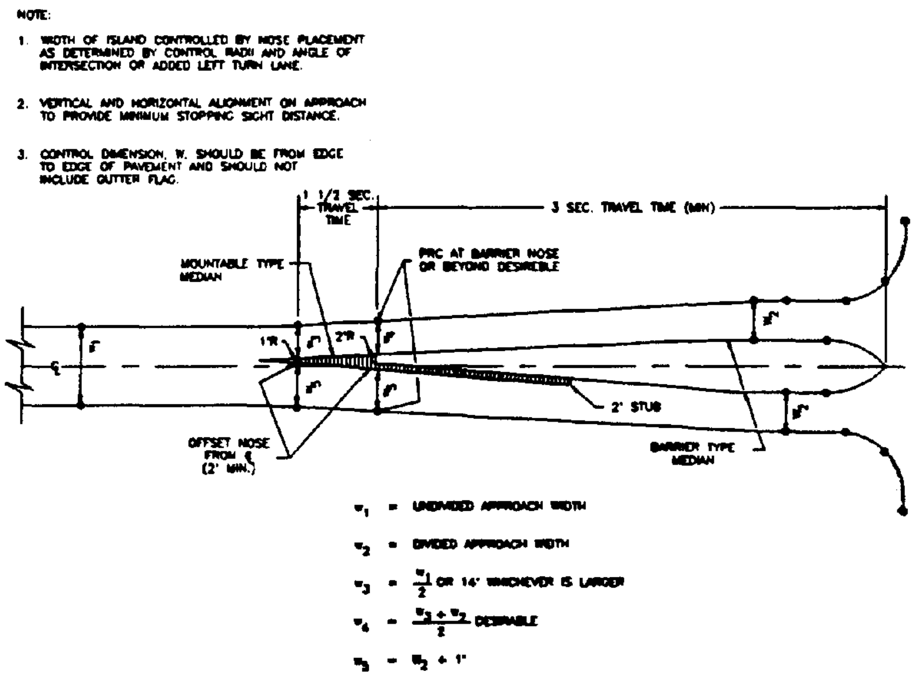


FIGURE D-4-2: DESIGN CRITERIA FOR CHANNELIZATION APPROACHES

(Continued)

CATEGORY D: Remove Turning Vehicles From The Through Lanes (Continued)

D-4:
Design
(Continued)

TABLE D-4-1: SUGGESTED TAPER RATES FOR ISOLATED LEFT TURN LANES

Posted Speed (mph)	Ratio for Straight Taper for Acceleration and Deceleration Lanes	Minimum Ratio for Deceleration Lane
20	7.5:1	7.5:1
25	7.5:1	7.5:1
30	10:1	8:1
35	12.5:1	10:1
40	15:1	11.5:1
45	15:1	13:1
50	20:1	15:1
55	22.5:1	18.5:1
60	50:1	25:1
65	50:1	25:1

Source: Reference (6)
Note: Colorado code includes speeds up to and including 55 mph.
Source: Reference (7)
Note: New Mexico regulations contain the same ratios through 55 mph but also includes ratios for 60 and 65 mph.

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY D: Remove Turning Vehicles From The Through Lanes (Continued)

D-5: Install Left Turn Deceleration Lane To Remove Turning Vehicle From Through Lane

D-5: Description

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

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

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

D-5: Application

All multi-lane divided highways with median widths of 14 feet or greater are potential locations for this application. A median opening must exist in order to provide for turning maneuvers.

D-5: Design

In rural areas the length of the taper should be a function of roadway speeds (see Table D-4-1). In urban areas a standard taper length of 120 feet is suggested for major arterials and 90 feet for streets of lower functional classification. The total length of the left-turn deceleration lane, including the taper, should be sufficient to allow the turning vehicle to decelerate from the speed of through traffic to a stop plus queue storage if a minimum length of the full-width lane must be sufficient to store the largest expected queue.

The width of the turn lane should be 12 feet. Where street width is limited, a 10-foot lane might be used. The minimum width of the median nose is four feet. Where pedestrians are present a minimum of 6 feet should be used.

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY D: Remove Turning Vehicles From The Through Lanes (Continued)

D-5:
Design
(Continued)

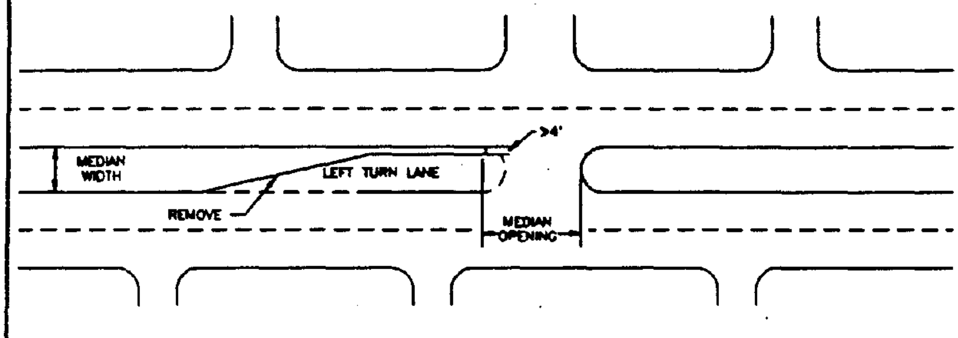


FIGURE D-5-1: LEFT TURN DECELERATION LANE

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY D: Remove Turning Vehicles From The Through Lanes (Continued)

D-6: Install Medial Storage For Left Turn Egress Vehicles

D-6: Description

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

D-6: Application

All multi-lane divided highways with median widths of at least 18 feet are applicable locations. A median opening has to exist in order to provide for the turning maneuvers.

D-6: Design

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

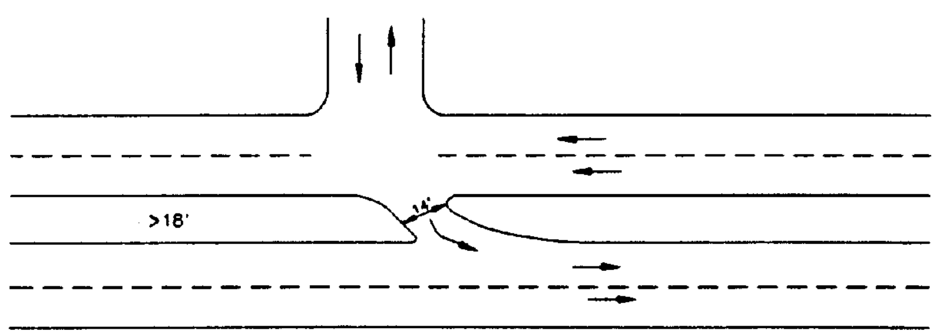


FIGURE D-6-1: MEDIAN STORAGE FOR LEFT TURN EGRESS VEHICLES

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY D: Remove Turning Vehicles From The Through Lanes (Continued)

D-7: Increase Storage Capacity Of Existing Left Turn Deceleration Lane

D-7: Description	The deceleration lane shadows and stores left-turning vehicles from the main stream of traffic. When the storage capacity becomes insufficient to handle the turning volume, the safety and capacity of the through lanes is adversely affected. An acceptable solution involves increasing the storage capacity of the deceleration lane to accommodate most peak-period turning vehicles. The effects on operation are reductions in the frequency and severity of rear-end conflicts.
D-7: Application	All multi-lane divided highways with existing deceleration lanes and insufficient storage lengths are applicable locations.
D-7: Design	The design of this technique involves two alternatives. These alternatives are: (1) increasing the length of an existing storage lane where sufficient median length is available; or (2) widening the highway to facilitate left-turning maneuvers from two lanes. The second condition considers the possibility of right-of-way acquisition. Several construction options exist under each of these conditions.

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY D: Remove Turning Vehicles From The Through Lanes (Continued)

D-7:
Design
(Continued)

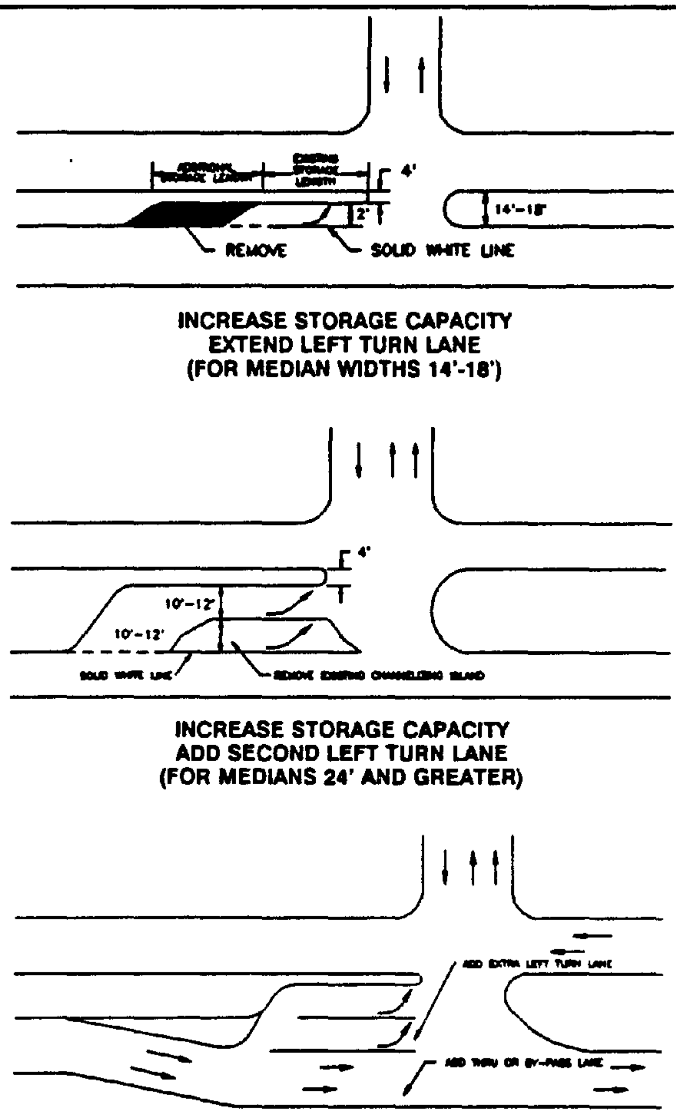


FIGURE D-7-1: INCREASE LEFT TURN STORAGE

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY D: Remove Turning Vehicles From The Through Lanes (Continued)

D-9: Install Continuous Right Turn Lane

D-9: Description

A continuous right-turn lane is essentially a combination of a right-turn acceleration and deceleration lane that is extended to accommodate several nearby driveways. It is used along a section of highway where driveways cannot otherwise accommodate right-turning queues and/or high enough right-turn speeds. This technique reduces the frequency and severity of rear-end conflicts by removing turning vehicles at higher speeds and by shadowing right-turn queues.

D-9: Application

This technique is warranted on all types of highways with existing driveways.

D-9: Design

Application of this technique is appropriate where access to driveways cannot be achieved at safe right-turn speeds. Figure D-9-1 exhibits typical guidelines. Left-turns should be prohibited where a continuous right-turn lane is used, preferably by a non-traversable median.

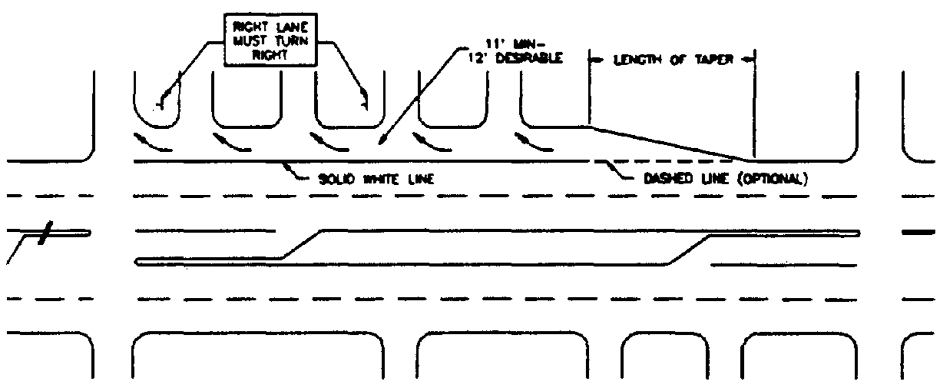


FIGURE D-9-1: CONTINUOUS RIGHT TURN LANE

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY D: Remove Turning Vehicles From The Through Lanes (Continued)

D-10: Construct A Local Service Road

D-10: Description

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

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

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

D-10: Application

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

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY D: Remove Turning Vehicles From The Through Lanes (Continued)

D-11: Construct A Bypass Road

D-11: Description

The continued growth of commercial strips along major arterials has magnified the problem of access control. Many highway agencies have been unable to alleviate congestion occurring in the vicinity of such commercial developments.

Bypasses provide motorists with the opportunity to avoid heavily developed or congested areas without conflicting with local traffic. As a result, this technique reduces the frequency and severity of conflicts on both facilities by separating longer-distance and faster-moving through traffic (including trucks) from slower local traffic. Removal of the intercity traffic from the existing roadway makes it more convenient for local traffic to enter and exit the business sites.

D-11: Application

Bypasses are applicable on major intercity routes where development along the existing route makes it impractical to reconstruct the facility or the existing location.

D-11: Design

Design and construction of a bypass route is subjected to the same standards applicable to major highways. Appropriate design standards based on intended use should be followed. Established documents such as "A Policy on Geometric Design for Rural Highways", "A Policy on Design of Urban Highways and Arterial Streets", "Design Standards for the Interstate System", "Geometric Design Standards for Highways Other Than Freeways", and "Geometric Design Guide for Local Roads and Streets" should be consulted.

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY D: Remove Turning Vehicles From The Through Lanes (Continued)

D-12: Reroute Through Traffic

D-12: Description	In this technique, the separation of through traffic from local traffic is achieved by using other adjacent facilities to reroute through traffic. The technique helps to reduce congestion and the frequency and severity of conflicts by separating and rerouting higher-speed through vehicles to where they have less potential of conflict with slower-speed local traffic.
D-12: Application	Rerouting through traffic is applicable where it is impractical to reconstruct the existing roadway and an alternative route having fewer access drives is available.

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY D: Remove Turning Vehicles From The Through Lanes (Continued)

D-13: Install Supplementary One-Way Right Turn Driveways To Divided Highway

D-13: Description

This driveway location technique is aimed at removing turning vehicles and queues from sections of the through lanes. Strategies for achieving this objective involve installing supplementary one-way right-turn driveways to an existing T-driveway on divided highways. The supplementary driveways can be installed to serve both egress or ingress vehicles.

This technique is intended at high-volume driveways to eliminate conflicts on the driveway and secondary rear-end conflicts on the highway associated with right-turn maneuvers. Where the T-driveway has only one lane, each for ingress and egress, this technique will add substantially to the total driveway capacity.

D-13: Application

This technique is warranted at high-volume driveways on multi-lane highways where a property has a very long frontage.

D-13: Design

This control measure is particularly applicable at large commercial or industrial complexes such as regional shopping centers and industrial parks. Sufficient frontage area is required to construct safe, adequate driveways, which do not present undue interference with through-moving vehicles. Figure D-13-1 presents a typical layout recommended for this technique.

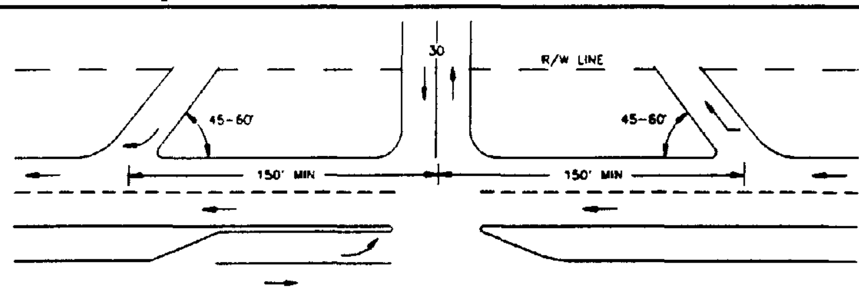


FIGURE D-13-1: SUPPLEMENTARY ONE-WAY RIGHT TURN DRIVEWAYS

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY D: Remove Turning Vehicles From The Through Lanes (Continued)

D-14: Install Access On Collector Street When Available

D-14: Description	This driveway location technique is aimed at removing turning vehicles or queues from sections of the through lanes. The strategy for achieving this objective is to provide supplementary access to a single property at a collector street location. The technique provides an additional access point for vehicles to use when entering or exiting a property. The average volume of all driveways to a property will decrease after the supplementary driveway absorbs some of the total volume. Conflict frequency will be reduced on the highway, and total conflict severity should be reduced by moving some of the conflicts to the lower speed collector. Delay to arterial and driveway vehicles will be reduced because the individual driveway volumes are smaller.
D-14: Application	This technique is applicable at all corner parcels having frontage on a major roadway and a collector.

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY D: Remove Turning Vehicles From The Through Lanes (Continued)

D-16: Install Right Turn Deceleration Lane

D-16: Description	This driveway design technique is aimed at removing turning vehicles or queues from sections of the through lanes. The deceleration lane will reduce the severity of rear-end conflicts on the highway by allowing right-turn vehicles to leave the through lanes at a high speed.
D-16: Application	This technique is applicable on all major roadways.
D-16: Design	The length of the right-turn lane, including taper, should be sufficient to allow vehicles to decelerate from the through traffic speed to a stop plus any necessary queue storage.

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY D: Remove Turning Vehicles From The Through Lanes (Continued)

D-17: Install Additional Exit Lane On Driveway

D-17: Description

This technique involves construction on an additional driveway exit lane to better facilitate egress maneuvers. Right-turn and left-turn egress maneuvers are made more efficiently because drivers are not delayed by egress vehicles wanting to turn in the opposite direction. The egress capacity of the driveway is also significantly increased.

Total driveway delay should decrease significantly because of the increased capacity due to the separation of egress-turning maneuvers. However, if insufficient approach length is available, a reduction in the capacity potential may result because of internal conflicts associated with considerable weaving at the exit.

D-17: Application

This technique is applicable for all highway types and at driveway locations where both left-turn and right-turn egress maneuvers are permitted.

D-17: Design

In the design of the technique, consideration must be given to driveway width, traffic volumes, internal circulation and highway operation. The additional lane should be sufficiently wide to safely accommodate turning vehicles and long enough to provide adequate storage with minimal impact to internal circulation. If the additional lane services left-turning vehicles, adequate signalization is necessary to facilitate traffic operation.

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY D: Remove Turning Vehicles From The Through Lanes (Continued)

D-17:
Design
(Continued)

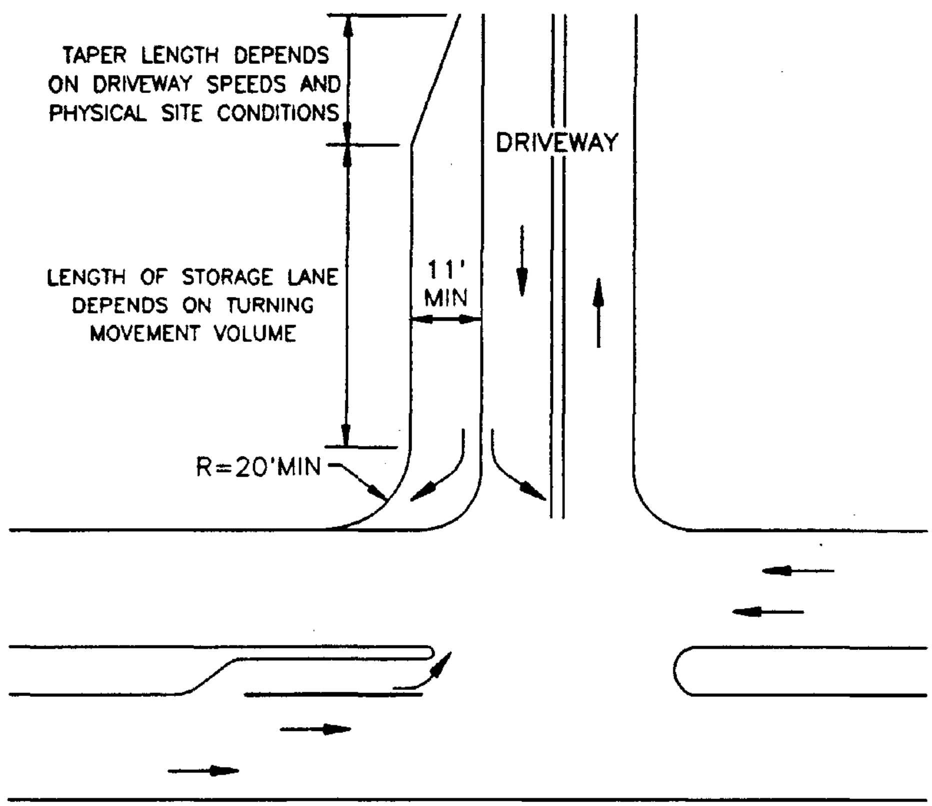


FIGURE D-17-1: INSTALLATION OF ADDITIONAL EXIT LANE ON DRIVEWAY

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY D: Remove Turning Vehicles From The Through Lanes (Continued)

D-18: Encourage Connections Between Adjacent Properties

D-18: Description	This driveway operation technique is aimed at removing turning vehicles or queues from the through lanes. The strategy for achieving this objective is to encourage adjacent property owners to permit property-to-property movements away from the highway. A prime example of this access control measure is the neighborhood shopping center, where several adjacent properties are served by one open parking lot area. The patrons frequenting nearby establishments do not need to exit onto the highway and then enter the neighboring driveway. Highway conflicts will be reduced because the highway will no longer be used in traversing from one property to the next.
D-18: Application	This technique is applicable on all highway types. Of particular interest are adjacent properties with small frontage widths.
D-18: Design	This technique is intended to serve adjacent properties through use of common access points. Thought must be given to internal circulation and storage space for driveway vehicles as well as geometric layout and existing highway operation.

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY D: Remove Turning Vehicles From The Through Lanes (Continued)

D-20: Require Adequate Internal Design And Circulation Plan

D-20: Description

This is a general access control policy that may be utilized on existing facilities or in the driveway permit stage. An adequate internal design and circulation plan is intended to ensure harmony between highway, driveway, and internal operations. Driveway and internal operations will be improved by providing adequate internal property design and controls. Through traffic will experience a decrease in interference because the internal design will minimize queuing on the highway and vehicles searching for parking places are able to circulate internally. Conflict frequency and severity are expected to decrease because deceleration requirements are lessened.

D-20: Application

This technique is applicable to all types of highways. Implementation is feasible on existing facilities but primary consideration should be given this policy during site plan approval.

D-20: Design

Internal circulation designs should provide adequate handling of limited parking and maneuvering areas; minimize internal interference by supplying storage areas to egressing movements; and distribute ingressing vehicles into the main circulation pattern with minimal hesitation and confusion. The following list reflects recommendations by which this technique can be properly applied.

1. General location of driveway entrances should be approved by code authorities before the major effort toward maximum capacity planning begins.

2. Rectangular-shaped parking areas are the most efficient.

3. Wherever possible, the long sides of parking areas should be parallel.

4. Curved, triangular, and other irregularly shaped parking areas should be avoided.

(Continued)

CATEGORIES OF ACCESS MANAGEMENT TECHNIQUES (Continued)

CATEGORY D: Remove Turning Vehicles From The Through Lanes (Continued)

D-20: Design (Continued)

5. Traffic aisles should be aligned parallel to the long dimension of the parking areas where feasible.

6. Irregularly shaped areas should be designed with the traffic aisles parallel to the longest side.

7. Traffic aisles should serve two rows for stalls; that is, they should be double-loaded.

8. The perimeter of the parking area should be lined with parking stalls to the maximum extent.

9. Parking areas serving combined parking-use functions, such as combined customer and employee parking, should be designed to provide distinctly separate areas and traffic control for each use function.

10. Traffic flow and control should be analyzed carefully for optimum efficiency.

11. Landscaping and lighting should be designed after the optimum maximum capacity design has been achieved. If the maximum capacity design is altered to suit other criteria (such as an owner's request for greater stall width, changes in direction of traffic aisles, etc.), lighting fixtures should be located so the parking area may be converted to the maximum capacity design without requiring relocation of the lighting standards. Where feasible, landscaping should be planned in the same manner, especially where irrigation and sprinkler systems with underground water piping are included.

ACCESS MANAGEMENT TECHNIQUES FOR RURAL TWO-LANE HIGHWAYS

Introduction

ACCESS MANAGEMENT TECHNIQUES FOR RURAL TWO-LANE HIGHWAYS

Turning movements at intersections and driveways may decrease the level of traffic service on two-lane highways by delaying following vehicles. Vehicles making a right turn off a highway must slow to a speed appropriate for the turning radius and width of the intersecting road or driveway and may cause the following vehicles to slow as well. Left turns off a two-lane highway typically involve more delay than right turns, because following vehicles may be forced to slow, or even stop, depending upon whether or not a gap in the opposing traffic stream is available for the left-turning vehicle to complete its turn.

The justification for turning improvements on a two-lane highway is usually to reduce delay or accidents at a specific intersection or series of driveways. In limited situations, on highways with high traffic volumes, turning improvements are needed to prevent the formation and growth of vehicle platoons.

Delay Reduction

Evaluation of the need for turning improvements to reduce delay on two-lane highways requires engineering data including counts of hourly traffic volumes in each direction of travel, counts of turning volumes at intersections and/or driveways, and field observations or HCM estimates of the level of vehicle platooning in the approaching traffic streams.

(Continued)

ACCESS MANAGEMENT TECHNIQUES FOR RURAL TWO-LANE HIGHWAYS (Continued)

Delay Reduction (Continued)

The need for turning improvements to improve traffic operations has been assessed by Hoban with a simple computer model of an intersection specified combination of traffic volume, composition, directional split, and percentage of left turns. Some of the key results obtained by Hoban are illustrated in Figures 4-4 and 4-5. Figure 4-4 shows the delay reductions which can be achieved by removing the effects of turns from the through traffic on a two-lane road, expressed as hours of delay reduced per hour of traffic. Figure 4-5 shows the effects of delays caused by turning vehicle on percent time delay over a road section. The top line in Figure 4-5 shows through traffic over a short road length. However, when these effects are averaged over a longer road section, the increase in percent time delay is greatly reduced, as shown by the center line in Figure 4-5.

The major results of this investigation are:

- At traffic volumes below 200 veh/hr in one direction of travel, there is virtually no delay to following vehicles. At such low flow rates, the probability that a left-turning vehicle will be closely followed by another vehicle is minimal.
- Turn delays have only small effects on overall traffic operations on a 0.5-mi (0.8-km) highway section at volumes below about 600 veh/hr with 5 percent turning vehicles or below about 400 veh/hr with 20 percent turning vehicles.
- At higher traffic volumes on a 0.5-mi (0.8-km) highway section, turn delays can cause substantial decrease in average speeds and increases in percent time delay, and individual vehicles can be delayed as much as three or four times their normal travel time.

(Continued)

ACCESS MANAGEMENT TECHNIQUES FOR RURAL TWO-LANE HIGHWAYS (Continued)

Delay Reduction (Continued)

- When turn delays are evaluated over a longer highway section (e.g., 10 mi or 16 km in length), their effect on overall traffic operations is quite small, even at high traffic flows. This is because turn delays are quite localized, while delays due to traffic platooning behind slow vehicles are typically experienced over many miles of travel.

- When turn delays are compared with an extreme case of a 10-mi (16-km) no-passing zone, the delays caused by the no-passing zone are considerably greater than those due to turning vehicles.

It is difficult to generalize about the traffic operational effects of delays caused by turning traffic, since there are many possible combinations of road and traffic conditions which may need to be considered. When traffic delays due to platooning are already severe, for example, the additional delays due to turning traffic may be unacceptable, and may be easier to remedy than the platooning delays.

One of the most important conclusions which may be drawn from this investigation is that both passing and turning problems must be considered in any evaluation of an extended road section. Improvements which reduce turn delays while creating no-passing zones, for example, may not provide a better overall quality of service on a road.

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ACCESS MANAGEMENT TECHNIQUES FOR RURAL TWO-LANE HIGHWAYS (Continued)

Delay Reduction (Continued)

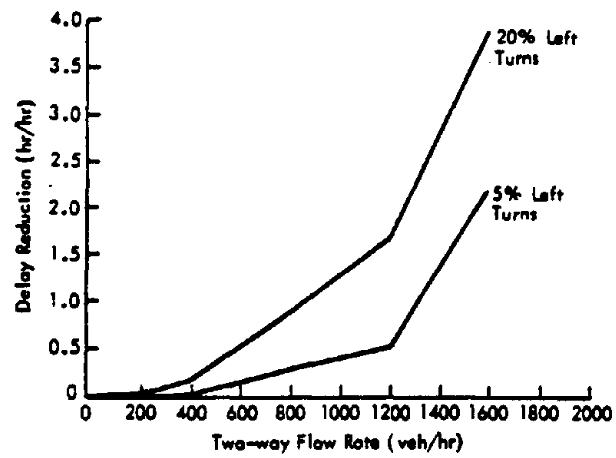

FIGURE 4-4: ESTIMATED DELAY SAVINGS FROM TURN LANES

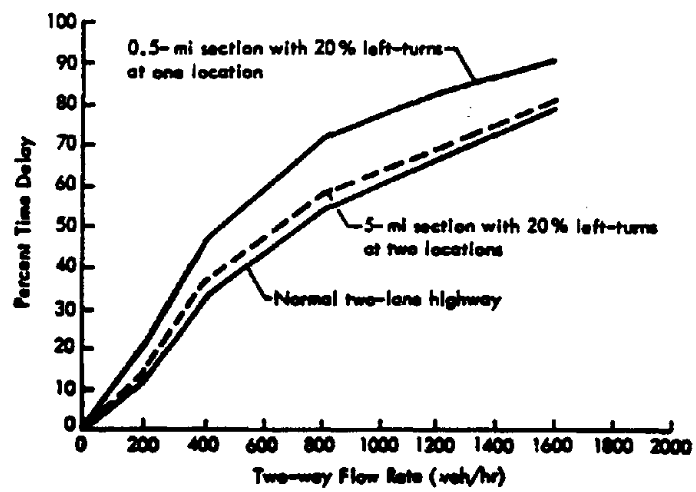

FIGURE 4-5: SIMULATED PERCENT TIME DELAY FOR THREE CASES

(Continued)

ACCESS MANAGEMENT TECHNIQUES FOR RURAL TWO-LANE HIGHWAYS (Continued)

Accident Reduction	The need for turning improvements to reduce accidents should be based on consideration of approach speeds, geometric factors such as sight distance, and accident history. Two types of accident analysis are typically used to justify turning improvements. First, turning improvements may be warranted at sites where accident rates are high; e.g., substantially higher than the statewide or areawide average. Accident rates for individual intersections should be expressed as accidents per million vehicles entering the intersection, while accident rates for highway sections should be expressed as accidents per million vehicle-miles. Second, turning improvements may be warranted at sites where collision diagrams or tabulations of accident types indicate persistent patterns of left-turn, right-turn, angle, or rear-end accidents associated with turning maneuvers at intersections and driveways.
Turning Improvement Alternatives	Three alternative turning improvements are available to reduce delay and accidents on two-lane highways. These are: • Intersection turn lanes. Separate right-turn and left-turn lanes can be provided at intersections and, in special cases, at high-volume driveways. • Should bypass lanes. Bypass lanes can be provided at T-intersections to enable through vehicles to pass to the right of vehicles that are stopped waiting to make a left turn. • Two-way left-turn lanes can be installed in the center of a two-lane highway to allow vehicles traveling in either direction to make left-turns into intersections and driveways.

(Continued)

ACCESS MANAGEMENT TECHNIQUES FOR RURAL TWO-LANE HIGHWAYS (Continued)

Intersection Turn Lanes

Intersection turn lanes are desirable at selected locations in order to reduce delays to through vehicles caused by turning vehicles and to reduce accidents related to turning maneuvers. Separate right-turn and left-turn lanes may be provided, as appropriate, to remove turning vehicles from the through travel lanes. Left-turn lanes, in particular, provide a protected location for turning vehicles to wait for a gap in opposing traffic to complete their turn. Such protection reduces the potential for rear-end accidents between left-turning and following vehicles, and may also encourage drivers of left-turning vehicles to wait for an adequate gap in opposing traffic before completing their turn. Figure 4-6 illustrates a typical two-lane highway intersection with left-turn lanes.

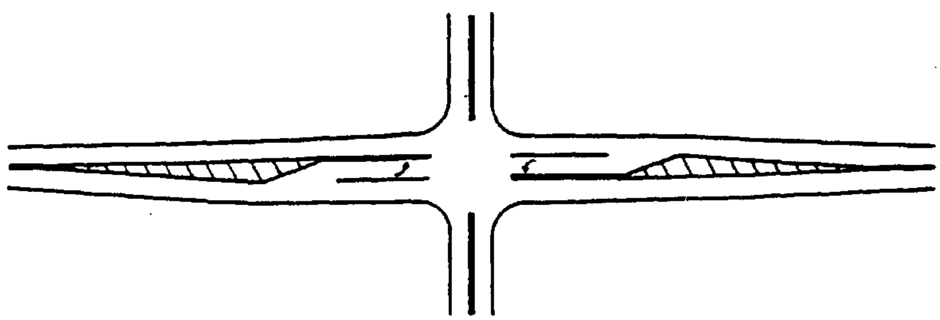

FIGURE 4-6: PLAN VIEW OF TYPICAL INTERSECTION WITH LEFT TURN LANES

Virtually every highway agency has established geometric design and traffic control criteria for channelized intersections. intersection turn lanes should be designed in accordance with the AASHTO Green Book and highway agency policies. Excellent design guides for intersection turn lanes have recently been published by Neuman in <u>NCHRP Report 279</u> on Intersection Channelization and by the California Department of Transportation. Similarly, signing and marking of channelized intersections is fully addressed in the MUTCD and in highway agency traffic control policies and handbooks.

(Continued)

ACCESS MANAGEMENT TECHNIQUES FOR RURAL TWO-LANE HIGHWAYS (Continued)

Intersection Turn Lanes (Continued)

Table 4-2 indicates the traffic operational conditions under which the installation of a left-turn lane is considered warranted to reduce delay at an unsignalized intersection on a two-lane highway. Table 4-2 is entered with the percentage of left turns at an unsignalized intersection and the opposing traffic volume; the entries in the table indicate the flow rate at which the installation of a left-turn lane is considered warranted. The table is based on the assumption that the volumes of left turns and right turns from the side road are less than or equal to the volume of left turns from the main highway.

TABLE 4-2: OPERATIONAL GUIDELINES FOR LEFT TURN LANES AT INTERSECTIONS ON TWO-LANE HIGHWAYS

Opposing Volume (veh/hr)	Advancing Volume to Warrant a Left-Turn Lane (veh/hr)			
	5 Percent Left Turns	10 Percent Left Turns	20 Percent Left Turns	30 Percent Left Turns
	50-mph Operating Speed			
800	280	210	165	135
600	350	260	195	170
400	430	320	240	210
200	550	400	300	270
100	615	445	335	295
	60-mph Operating Speed			
800	230	170	125	115
600	290	210	160	140
400	365	270	200	175
200	450	330	250	215
100	505	370	275	240

Note: 1 mile = 1.609 km.

(Continued)

ACCESS MANAGEMENT TECHNIQUES FOR RURAL TWO-LANE HIGHWAYS (Continued)

Intersection Turn Lanes (Continued)

Varying estimates of the effectiveness of intersection turn lanes in reducing through vehicle delay have been developed by Ring and Carstens, Lee, and McCoy et al. However, none of these sources considers the downstream effects of intersection delay on traffic operations, which are minimal at low flow rates but can be substantial at high flow rates. The TURNER model, developed by Hoban, is the only currently available method for assessing these downstream effects.

There are no widely accepted criteria that indicate when the installation of an intersection turn lane is warranted to improve safety. One agency considers installation of a left-turn lane to be warranted at an unsignalized intersection if four left-turn-related accidents occur in one year or if six occur in two years. Installation of intersection turn lanes may also be justified to improve safety at locations where restricted sigh distance on an intersection approach creates a potential for rear-end accidents.

Intersection turn lanes not only improve traffic operations and safety, but may also reduce fuel consumption, vehicle operating costs, and pollutant emissions by reducing vehicle stops and speed changes. These effects can be estimated using procedures presented by Dale.

Shoulder Bypass Lanes

Shoulder bypass lanes are a low-cost alternative to intersection turn lanes for reducing delays to through vehicles cause by left-turning vehicles. Where a side road intersects a two-lane highway at a three-leg or T-intersection, a portion of the paved shoulder opposite the intersection may be marked as a lane for through traffic to bypass vehicles making a left turn. While used most commonly at unsignalized intersections, shoulder bypass lanes may also be used at major driveways. Table 4-2 shows that relatively high flow rates are needed to warrant construction of a left-turn lane. Where an adequate paved shoulder is already available, however, installation of a shoulder bypass lane may be as simple as remarking the highway edge line. Thus, provision os a shoulder bypass lane is often much less expensive than construction of a paved shoulder for use as a bypass lane may be justified either to improve traffic operations or reduce accident experience.

(Continued)

ACCESS MANAGEMENT TECHNIQUES FOR RURAL TWO-LANE HIGHWAYS (Continued)

Shoulder Bypass Lanes (Continued)

Figure 4-7 illustrates a typical shoulder bypass lane at a T-intersection on a two-lane highway. If a vehicle is stopped in the through travel lane waiting to make a left turn, following vehicles can use the bypass lane to avoid having to stop themselves. if there are no turning vehicles present, drivers of through vehicles should continue in the through travel lane without entering the bypass lane. may drivers already use paved shoulder to bypass turning vehicles, although use of shoulders to this maneuver is illegal in many states. The marking of a bypass lane encourages drivers to avoid unnecessary delay and assures that the maneuver is legal by designating a portion of the paved shoulder as part of the traveled way.

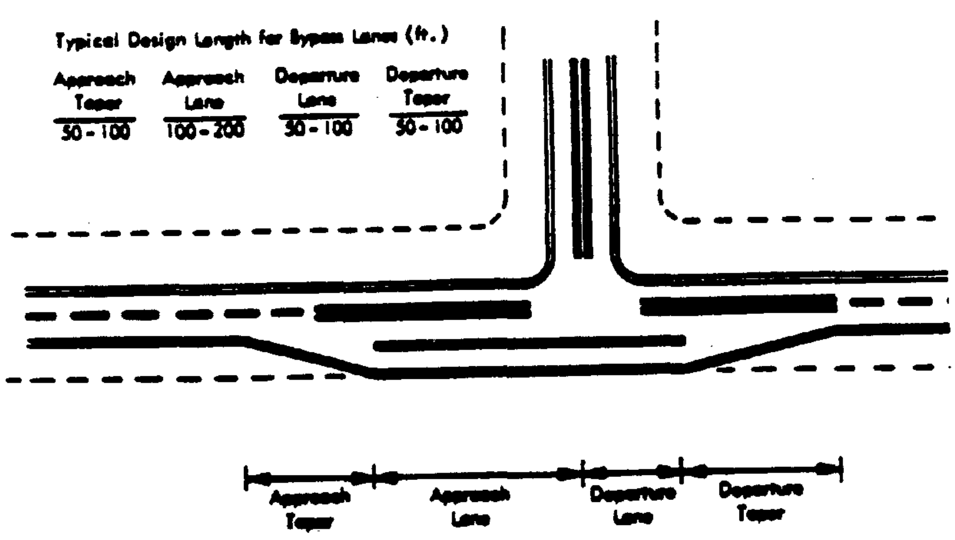

FIGURE 4-7: PLAN VIEW OF TYPICAL INTERSECTION WITH SHOULDER BYPASS LANE

Design Of Shoulder Bypass Lanes

The key geometric elements of shoulder bypass lanes at T-intersections are indicated in Figure 4-7. These elements are lane width, approach taper length, approach lane length, departure lane length, and departure taper length. For design purposes, the approach lane ends and the departure lane begins at the centerline of the intersecting road.

(Continued)

ACCESS MANAGEMENT TECHNIQUES FOR RURAL TWO-LANE HIGHWAYS (Continued)

Design Of Shoulder Bypass Lanes (Continued)

There are no established geometric design criteria for shoulder bypass lanes. A survey of state highway agencies by Buehler found that shoulder bypass lanes have been used in 23 states and operate effectively with a wide variety of geometric designs.

The minimum recommended width for a should bypass lane is 10 ft (3.1 m), with a width of 12 ft (3.6 m) considered desirable. Bypass lanes less than 10 ft (3.1 m) wide should be avoided because they encourage drivers to straddle the boundary between the bypass lane and the through travel lane. If a road carries substantial bicycle traffic, it may be desirable to provide a narrow shoulder outside the bypass lane.

Shoulder bypass lanes should be relatively short; if a bypass lane is too long, drivers may mistake it for a passing lane or feel that they are required to use the bypass lane even when no turning vehicle is present. The total length of a shoulder bypass lanes should typically be 250 to 500 ft (76 to 153 m) depending on traffic volumes and site conditions.

The approach and departure tapers should be relatively short because most vehicles use shoulder bypass lanes at reduced speeds. Typical taper lengths for shoulder bypass lanes are 50 to 100 ft (15 to 31 m). Where a shoulder bypass lane is used, it should be designed to encourage drivers to slow down before entering the bypass lane. It is probably preferable to provide a separate left-turn lane rather than providing a shoulder bypass lane with long tapers. Tapers as long as those used in passing lanes might encourage drivers to enter the bypass lane unnecessarily when no turning vehicles are present.

(Continued)

ACCESS MANAGEMENT TECHNIQUES FOR RURAL TWO-LANE HIGHWAYS (Continued)

Design Of Shoulder Bypass Lanes (Continued)	The length of the approach lane should be the same as the length of the left-turn lane that would be used if that intersection were channelized; i.e., long enough to accommodate the maximum number of left-turning vehicles expected to be stopped at any one time. At the flow rates found on most two-lane highways, an approach lane length of 100 to 200 ft (31 to 61 m) can be used. The departure lane is typically 50 to 100 ft (15 to 31 m) long. Buehler found that the most common operational problem at shoulder bypass lanes -- conflicts cause by a vehicle moving into the lane after its following vehicle has already entered -- could be minimized by making the approach lane shorter and the departure lane slightly longer. A shorter approach lane minimizes the potential for conflicts between vehicles entering the bypass lane. The paved shoulder must have adequate structural strength for the anticipated traffic loads.
Signing And Marking Of Shoulder Bypass Lanes	No specific signing is needed for shoulder bypass lanes. Pavement markings alone have been found adequate to encourage the intended usage. Edge line is tapered from the edge of the through travel lane to the outside of the shoulder, along the outside edge of the shoulder through the approach and departure lanes, and back to the edge of the through travel lane. A 4-in. (10-cm) solid white line should be provided at the edge of the through travel lane throughout the length of the approach lane and the departure lane. This use of a solid line discourages late entry into the bypass lane and premature return to the through travel lane. The breaks between the pavement edge line and the lane line in the area of the approach and departure taper areas define the locations where drivers are expected to enter and leave the bypass lanes.

(Continued)

ACCESS MANAGEMENT TECHNIQUES FOR RURAL TWO-LANE HIGHWAYS (Continued)

Legal Considerations

Many states prohibit driving on shoulders. In most states, however, no special legislation would be required to implement should bypass lanes because the pavement markings used designate the bypass lane as part of the traveled way. It should be noted that, even where shoulder bypass lanes are not provided, many drivers already used paved shoulders to bypass left-turning vehicles, although this may be illegal. The State of Delaware has adopted legislation to allow through vehicles to bypass left-turning vehicles on their right both on paved shoulders and at shoulder bypass lanes.

Effectiveness Of Shoulder Bypass Lanes

Shoulder bypass lanes have been shown to be effective in reducing delay to through vehicles at T-intersections, as well as reducing fuel consumption, vehicle operating costs, and pollutant emissions.

No quantitative estimates are available for the delay reduction effectiveness of shoulder bypass lanes. However, a Delaware study found that, where shoulder bypass lanes are provided, 97 percent of the drivers who needed them to avoid delay did in fact use them. Similarly, an Illinois study observed over 90 percent usage of shoulder bypass lanes by drivers who needed them. Even bypass lanes as short as 150 ft (46 m) were used effectively by drivers.

Shoulder bypass lanes were found to be more effective than paved shoulders alone in improving traffic operations. In Delaware, where use of both paved shoulders and shoulder bypass lanes to bypass left-turning vehicles is legal, only 81 percent of drivers used paved shoulders to bypass left-turning vehicles, whereas 97 percent of drivers used shoulder bypass lanes where necessary.

The accident experience of shoulder bypass lanes compared with that of separate left-turn lanes or compared with that of separate left-turn lanes or compared with that of paved shoulders alone has not been formally evaluated. However, Nebraska has reported a marked decrease in rear-end accidents at shoulder bypass lanes, and other states have reported relatively few accidents occurring at shoulder bypass lane installations.

(Continued)

ACCESS MANAGEMENT TECHNIQUES FOR RURAL TWO-LANE HIGHWAYS (Continued)

Two-Way Left Turn Lanes

Two-way left-turn lanes (TWLTLs) provide a deceleration and storage area in the center of the highway to reduce delay to through vehicles and rear-end accident potential caused by left-turning vehicles at intersections and driveways over a length of highway. The operational benefits of TWLTLs in rural areas with flow rates below 300 veh/hr are minimal, but TWLTLs in rural areas can reduce accident rates up to 85 percent. At flow rates above 300 veh/hr, TWLTLs provide both operational and safety benefits. In urban fringe areas, TWLTLs typically reduce accident rates by 35 percent.

TWLTLs have been used for many years on urban and suburban arterial streets with strip commercial development to improve safety and to reduce delays to through vehicles caused by turning traffic. Highway agencies have recently begun to use TWLTLs in rural and urban fringe areas to obtain these same types of operational and safety benefits.

Location And Configuration

TWLTLs are typically employed in rural areas at isolated developments (often roadside businesses), where speeds are higher and traffic flow rates are lower than those of TWLTL sections used in urban and suburban areas. TWLTLs are also employed in small towns and in urban fringe areas, which often have the potentially hazardous combination of dense development, frequent turning maneuvers, and high approach speeds. At a location with a single high volume intersection or driveway, a conventional left-turn lane is more appropriate than a TWLTL. However, TWLTLs are particularly appropriate at locations where high left-turn volumes are spread over several adjacent driveways and unsignalized intersections and at locations where there is a documented pattern of left-turn accidents spread over several intersections or driveways.

TWLTLs are also well suited for use in conjunction with passing lanes. A TWLTL can be provided for left-turning traffic at isolated developments while at the same time serving as a buffer between alternating passing lanes.

(Continued)

ACCESS MANAGEMENT TECHNIQUES FOR RURAL TWO-LANE HIGHWAYS (Continued)

Location And Configuration (Continued)

TWLTLs can also be provided through small towns on highways with passing lanes. Thus, extended sections of highway can be constructed with a mixture of passing lanes provided in one direction or the other and TWLTLs or left-turn lanes provided, as appropriate to site-specific geometries and roadside development. In some cases, this could be constructed with a continuous three-lane cross-section.

Care should be taken not to overuse TWLTLs on two-lane highways because passing is prohibited in TWLTL sections. If used in areas with minimal development, TWLTLs can be operationally detrimental by denying drivers the opportunity to pass slow-moving vehicles, without any corresponding safety benefit. When evaluating whether to install a TWLTL, highway agencies should consider the availability of passing opportunities on the adjacent highway section. If the only good passing zone for miles in either direction is replaced by a TWLTL, illegal passing maneuvers are likely, and the potential for conflicts between passing and turning vehicles is increased.

Signing And Marking Of TWLTLs

Figure 4-8 illustrates the recommended signing and marking practices for TWLTLs.

TWLTL sections should b signed in accordance with MUTCD requirements using the black-on-white regulatory symbol sign (R3-9b), shown in Figure 4-8, or a non-symbol sign with an equivalent message (e.g., CENTER LANE LEFT TURN ONLY.) These signs should be post-mounted outside the right shoulder in each direction of travel at the beginning of the TWLTL and should be repeated at appropriate intervals within the TWLTL section. Some highway agencies install the TWLTL signing overhead on span wires for increased visibility at the beginning of the TWLTL section in each direction of travel.

The pavement markings used to designate TWLTLs should comply with the requirements of MUTCD Sections 3B-1 and 3B-2. As shown in MUTCD Figure 3-5a, a TWLTL should be marked on each side with a double yellow line consisting of a solid yellow line on the side adjacent to the travel lane and a broken yellow line on the side adjacent to the TWLTL.

(Continued)

ACCESS MANAGEMENT TECHNIQUES FOR RURAL TWO-LANE HIGHWAYS (Continued)

Signing And Marking Of TWLTLs (Continued)

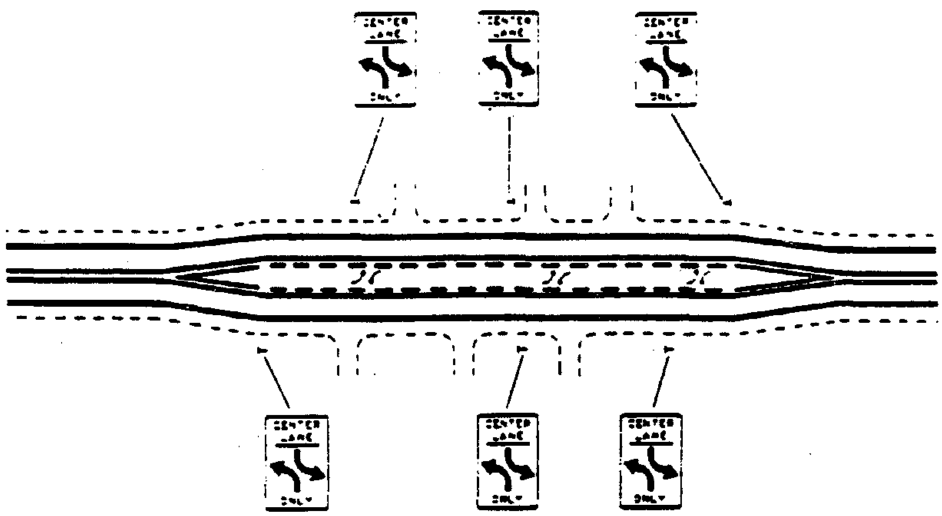

FIGURE 4-8: RECOMMENDED SIGNING AND MARKING PRACTICE FOR A TWO-WAY LEFT TURN LANE ON A TWO WAY HIGHWAY

Operational Effectiveness Of TWLTLs

Many studies have shown TWLTLs to be effective in reducing delay to through vehicles on multi-lane highways in urban and suburban areas. The operational effectiveness of TWLTLs on two-lane highways in rural and urban fringe areas was evaluated by Harwood ant St John at seven TWLTL sites located in six states. These TWLTL field studies estimated the potential delay to through vehicles that would have been caused by left-turning vehicles if the TWLTL had not been present. Through vehicles that could potentially be delayed by a left-turning vehicle included vehicles in the platoon immediately behind the left-turning vehicle and vehicles that passed the left-turning vehicle while it was stopped waiting for a gap in opposing traffic.

(Continued)

ACCESS MANAGEMENT TECHNIQUES FOR RURAL TWO-LANE HIGHWAYS (Continued)

Operational Effectiveness Of TWLTLs (Continued)

Very little potential delay to through vehicles was observed at rural TWLTL sites, especially those with flow rates below 300 veh/hr in one direction of travel. In fact, during 28 out of the 48 hr that data were collected at the rural TWLTL sites, there was no potential delay at all. The highest level of potential delay observed at a rural TWLTL site was 3.4 sec per left-turn vehicle. Thus, at rural sites with low flow rates the installation of TWLTLs is justified only on a safety basis because very few operational benefits can be expected.

Substantially more potential delay to through vehicles was observed at the higher volume urban fringe sites. The highest level of potential delay observed was 121 sec per left-turn vehicle at a site with strip commercial development and a flow rate over 500 veh/hr in one direction of travel. Under such conditions, TWLTL installation can be readily justified on an operational basis.

Figure 4-9 presents a model that can be used to predict the amount of delay reduced by a TWLTL on a two-lane highway in a rural or urban fringe area. There is some indication that the operational benefits of a TWLTL are minimal at low flow rates. There is no delay reduction due to a TWLTL at flow rates below 120 veh/hr in one direction of travel and less that 10 sec of delay reduction per left-turn vehicle at flow rates below 300 veh/hr.

In the Harwood and St. John study, the percent of vehicles platooned was essentially unchanged from upstream to downstream of TWLTL sites. This finding is another indication of the operational effectiveness of TWLTLs since, without the presence of the TWLTL, platooning would be increased by vehicles stopped in the travel lane waiting to make a left turn.

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ACCESS MANAGEMENT TECHNIQUES FOR RURAL TWO-LANE HIGHWAYS (Continued)

Operational Effectiveness Of TWLTLs (Continued)

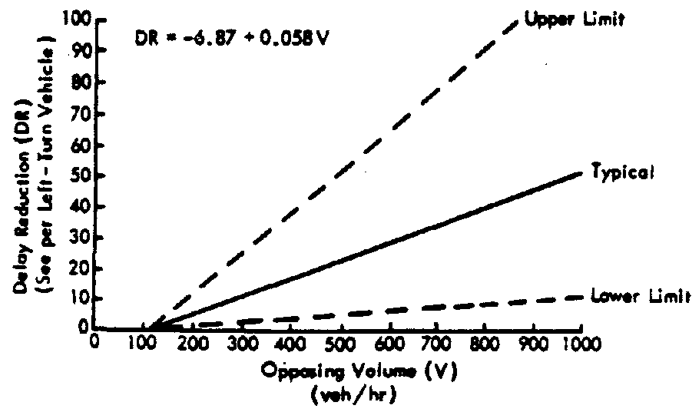

FIGURE 4-9: PREDICTIVE RELATIONSHIP FOR DELAY REDUCTION DUE TO TWO-WAY LEFT TURN LANE INSTALLATION ON A TWO-LANE HIGHWAY

Safety Effectiveness Of TWLTLs

TWLTLs are effective in reducing left-turn accident rates. TWLTLs have been found to reduce accident rates by approximately 35 percent, when installed at urban and suburban sites, primarily on multi-lane highways. Comparable accident reduction effectiveness was found by Harwood and St. John for installation of TWLTLs on two-lane highways in urban fringe areas. In rural areas, the number of accidents at candidate TWLTLs on two-lane highways is small, but TWLTLs can reduce these accidents by up to 85 percent.

When TWLTLs first cam into common use, many engineers were concerned about the potential for head-on collisions between left-turn vehicles travelling in opposing directions. However, there is no indication in the literature or in the operating experience of many highway agencies of any problem related to head-on collisions in TWLTLs

(Continued)

ACCESS MANAGEMENT TECHNIQUES FOR RURAL TWO-LANE HIGHWAYS (Continued)

Safety Effectiveness Of TWLTLs (Continued)	A field study of traffic conflicts and erratic maneuvers at four rural TWLTL sites on two-lane highways found only one problem that was consistent: illegal passing in the TWLTL was observed by a relatively small fraction (0.4 percent) of vehicles. Since it is evident that some drivers will pass illegally in TWLTLs, a careful evaluation is recommended of any proposed TWLTL installation that would eliminate an existing passing zone.

REFERENCES

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2. J. A. Azzeh, et. al., "Technical Guidelines for the Control of Direct Access to Arterial Highways; Volume I: General Framework for Implementing Access Control Techniques", Report FHWA-RD-76-86, August 1975.

3. J. A. Azzeh, et. al., "Technical Guidelines for the Control of Direct Access to Arterial Highways; Volume II: Detailed Description of Access Control Techniques", Report FHWA-RD-76-87, August 1975.

4. A Policy on the Geometric Design of Highways and Streets, American Association of State Highway and Transportation Officials, 1990.

5. A Policy on the Geometric Design of Highways and Streets, American Association of State Highway and Transportation Officials, 1984.

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CHAPTER 5

RETROFIT PROGRAMS

CHAPTER 5 - RETROFIT PROGRAMS

INTRODUCTION

Issues

CHAPTER 5
RETROFIT PROGRAMS

The problems of applying access control to a developed arterial pose one of the greatest challenges to the traffic manager today. Many studies have documented the damaging effects that access points have on the quality of traffic flow provided by a roadway. The official responsible for safe, efficient movement of traffic is certainly aware of increasing accident rates and reduced levels of service that occur with an increase in traffic, an increase in access points, or, as is usually the case, both.

Constraints to Retrofit Programs

- Physical Limitations
- Impacts on Business
- Traffic flow Effects
- Cost and Benefits
- Legal issues
- Political Considerations

(Continued)

INTRODUCTION (Continued)

Issues (Continued)

Implementation of access control techniques on existing roadways is commonly very difficult. Right-of-way limitations and development in close proximity to the right-of-way are commonly encountered. Opposition by the owners of the adjacent properties and the affected businesses often makes it difficult to obtain the necessary political acceptance.

In many instances, however, congestion is evidenced by long queues at intersections, traffic accidents, and extensive travel delays often result in a public demand that improvements be made to existing major streets.

In many cases, it can be demonstrated that the benefits of fewer accidents, time savings and reduced fuel consumption exceed the costs associated with the implementation of access management improvements. Furthermore, the federally mandated air quality requirements can be expected to be an incentive for communities to implement access management techniques which will reduce vehicular emissions by improving traffic flow and reducing idling delay. Locals which are designated as nonattainment areas will find such actions especially attractive, and perhaps essential.

Some of the legal issues involved in implementing access management on existing roadways are addressed in Appendix 5-A: "Legal Implications of Control of Access to Uncontrolled Access Highways" and Appendix 5-B: "Rights of Abutting Property Owner Upon Conversion of Uncontrolled-Access Road Into Limited-Access Highway".

Techniques Applicable To Retrofit

The variety of access techniques which can be used in the retrofit of existing roadways can be grouped as to the length of roadway affected (point improvement or route segment) and by the physical elements involved as identified in Table 5-1.

(Continued)

INTRODUCTION (Continued)

Techniques Applicable To Retrofit (Continued)

General methods by which these physical improvements might be implemented are identified in Table 5-2.

TABLE 5-1: CLASSIFICATION OF PHYSICAL IMPROVEMENTS

Physical Element	Point Improvement	Route Segment Improvement
Driveways	X	
Medians	X	X
Auxiliary Lanes	X	
Frontage Roads		X
Signal Removal	X	

(Continued)

INTRODUCTION (Continued)

Techniques Applicable To Retrofit (Continued)

TABLE 5-2: TECHNIQUES FOR IMPLEMENTING POINT AND ROUTE IMPROVEMENTS

Physical Element	Implementation Techniques
Driveways	• relocate • eliminate • consolidate • improve throat width/curb return radii and at vertical alignment • increase corner clearance
Medians, Point	• close • redesign to permit specific movement only • add turn bay/improve turn bay geometrics
Medians, Route Segment	• add nontraversable median • close/redesign median openings • 2-way continuous left-turn lane
Auxiliary Lanes	• right-turn deceleration lanes • continuous right-turn lane • right-turn acceleration lanes
Frontage Roads	• reverse frontage • increase separation from through roadway • one-way operation

DRIVEWAY IMPROVEMENTS

Location

It is important that driveways not be located in proximity to major intersections. AASHTO recognized this by the following statement:

> "Driveways should not be situated within the functional boundary of at-grade intersections. This boundary would include the longitudinal limits of auxiliary lanes." (*1*, p.841;*2*, p. 888)

Also driveways located near intersections are frequently blocked by a queue of stopped or slow moving vehicles, especially during peak periods.

Driveway Curb Return Radii

The combination of curb return radius and throat width should allow ingress and egress vehicles to complete right-turns with minimal impact on through traffic or other driveway traffic. Reconstruction of existing driveways to improve the radius and throat width can be readily made. However, in some jurisdictions, the driveway standards or practices need to be amended to permit appropriate designs.

Figure 5-1 shows a driveway serving a shopping center where the original departure radius was too short. This caused the egressing vehicles to encroach upon the inside traffic lane of a 4-lane divided arterial as schematically illustrated in Figure 5-2A. As can be seen in the photograph (Figure 5-1) the departure radius was increased so that egressing vehicles entered the curb lane without encroaching on the adjacent lane as schematically illustrated in Figure 5-2B.

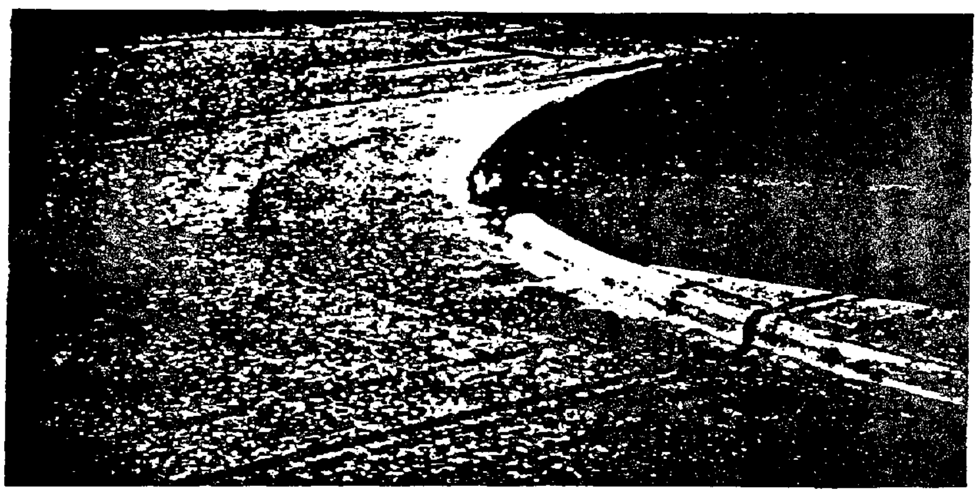

FIGURE 5-1: RETROFIT OF A DRIVEWAY TO INCREASE CURB RETURN RADIUS

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DRIVEWAY IMPROVEMENTS (Continued)

Driveway Curb Return Radii (Continued)

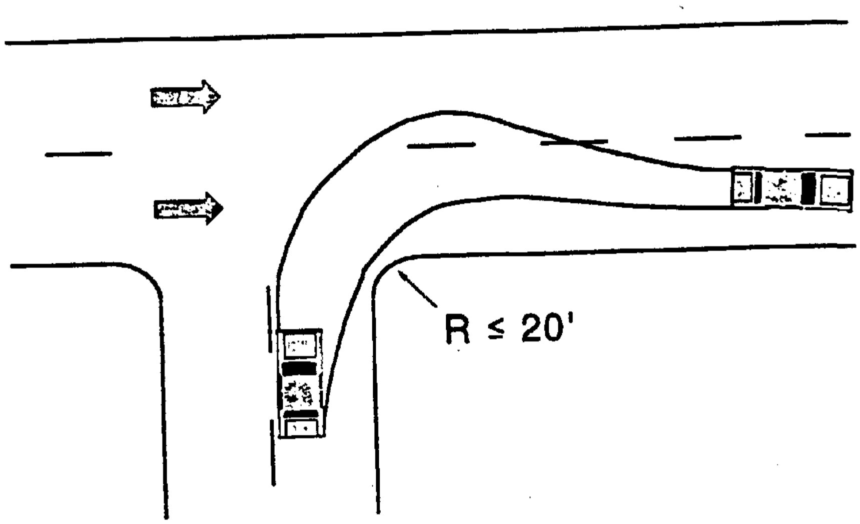

Figure 5-2A: Short Departure Radius Results In Encroachment On Inside Traffic Lane

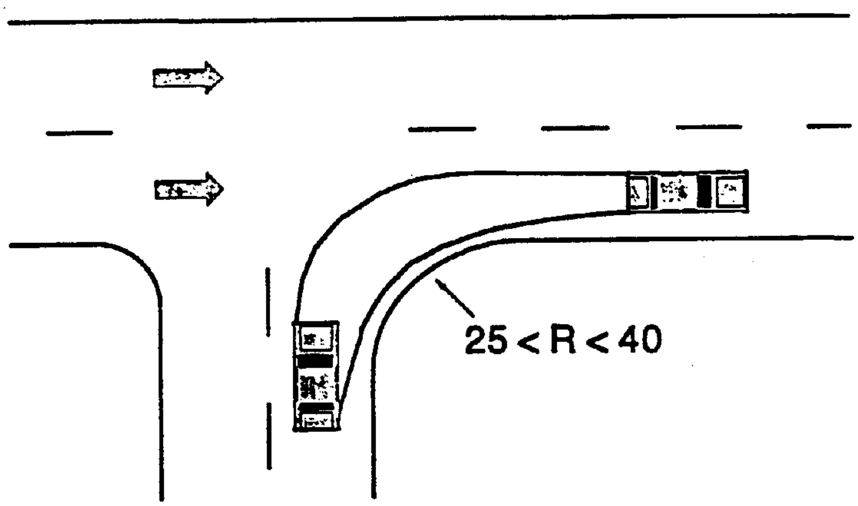

Figure 5-2B: Radius So Departure Vehicle Does Not Encroach On Adjacent Traffic lane

FIGURE 5-2: SCHEMATIC ILLUSTRATION OF VEHICLE TRAJECTORY OF DRIVEWAY DEPARTURE

(Continued)

DRIVEWAY IMPROVEMENTS (Continued)

Driveway Spacing

Locating access drives at spacings of at least 1.5 times the distance required to accelerate from zero to the speed of the through traffic maximizes the capacity of the highway to absorb vehicles entering the traffic stream, and hence, maximizes total egress capacity. Existing property frontage on existing roadways often makes it impossible to achieve such spacings. Nevertheless, any consolidation of existing access is to be encouraged as it will improve driveway capacity and traffic flow.

Essential to the control of driveway access is an effective driveway (or curb cut) permit program. Anyone wishing to create or alter a driveway must have a permit from the appropriate jurisdiction which has the authority to approve, disapprove, and assure compliance with stated specifications. Approval of the curb cut permit should be dependent upon the submittal and approval of a traffic study and a site plan.

MEDIANS

Left Turn Accidents

Left turns entering and exiting driveways account for the majority of total driveway accidents and a substantial amount of delay.

Box, in his studies in Skokie, Illinois, found that 70 percent of driveway accidents occurred from left-turning vehicles to or from a driveway. Medians, therefore, can be an effective way of eliminating left-turns or protecting left turns waiting to enter a driveway from the roadway.

Business Impact Of Raised Medians, Three Texas Cities

The introduction of a raised median on an existing roadway in a developed area is often controversial. The highway official recognizes that accidents and delays will be reduced if the median is installed. The owners of roadside businesses with no direct opening opposite their entrance often believe that their businesses will suffer financially. In one research effort, a study was conducted in three cities to measure the economic impact of medial access control. These results were as follows:

> Before and after studies where non-traversable medians were installed on roadways in three Texas cities found that some businesses experienced a decline in sales while others had increases in sales after the median was installed (Table 5-3). This occurred for both "traffic oriented businesses" (drive-in restaurants, service stations and motels) as well as "nontraffic oriented businesses." The rank correlation coefficient of 0.637 indicates that there is a positive correlation between rankings based on percent change in sales and percent change in left-turn volume. This relationship is statistically significant at the one percent level. Construction of a nontraversable median eliminated left-turns except at median openings; thus left-turns after construction of the median were accomplished by marking "U-turns". Average daily traffic (ADT) volumes were about 8,000 which is very low for an urban arterial.

(Continued)

MEDIANS (Continued)

Business Impact of Raised Medians Three Texas Cities (Continued)

TABLE 5-3: SALES VOLUME COMPARISON

	Sales Volume	
	Before Median	After Median
Pleasanton		
A. Traffic-Serving Businesses		
1. Study Group	100	95.8
2. Control Group	100	100.8
B. Nontraffic-Serving Businesses		
1. Study Group	100	82.4
2. Control Group	100	104.3
San Antonio		
A. Traffic-Serving Businesses		
1. Study Group	100	76.4
2. Control Group	100	102.0
B. Nontraffic-Serving Businesses		
1. Study Group	100	103.4
2. Control Group	--	--

Source: Adapted from References (*4*, *5*)

Using the combined results from all three study sites, Figure 5-3 shows the relationship between ADT and left-turns before and after construction of the medians. The left-turns after median construction were lower than before construction, regardless of the level of ADT. Also, the spread between the before and after curves is wider at sites with higher ADT than at sites with lower ADT. This indicates that the restriction in the number of left-turns per thousand vehicles was greater at high traffic volumes. Figure 5-4 shows the relationship between ADT and the percent change in business gross sales before versus after construction of a median as well as during construction.

(Continued)

MEDIANS (Continued)

Business Impact of Raised Medians, Three Texas Cities (Continued)

Apparently, businesses at sites with very low ADT are more likely to experience a negative percent change in gross sales than those at sites with higher ADT, especially for the before versus after construction period.

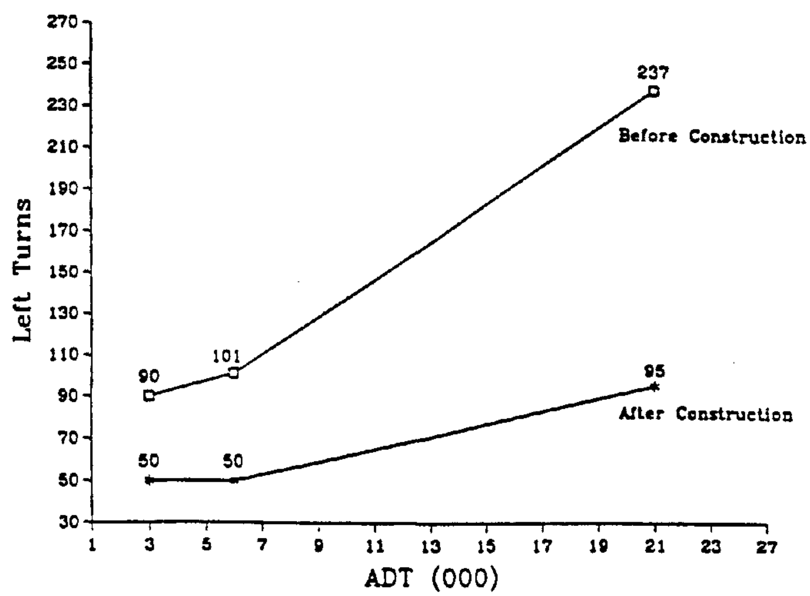

FIGURE 5-3: RELATIONSHIP BETWEEN TOTAL NUMBER OF LEFT TURNS BEFORE AND AFTER CONSTRUCTION OF A RAISED MEDIAN AND AVERAGE DAILY TRAFFIC

Source: Adapted from References (*3*, *4*, *5*)

(Continued)

MEDIANS (Continued)

Business Impact Of Raised Medians, Three Texas Cities (Continued)

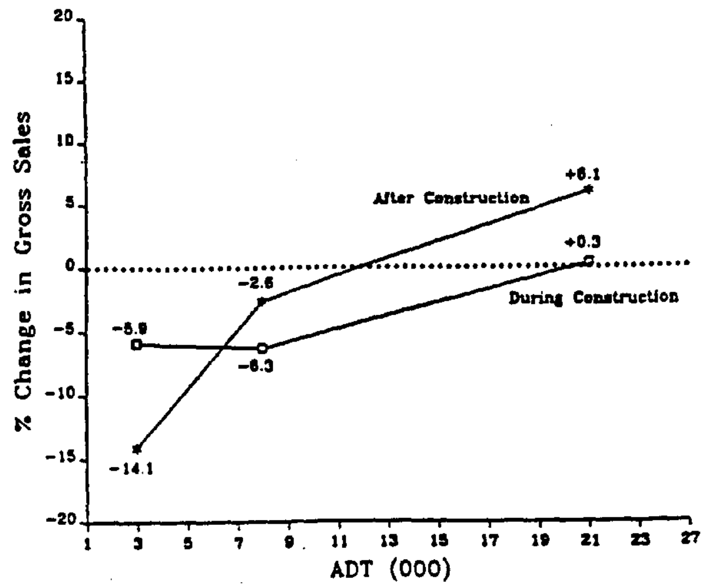

FIGURE 5-4: PERCENT CHANGE IN GROSS BUSINESS SALES DURING AND AFTER CONSTRUCTION OF A RAISED MEDIAN COMPARED TO GROSS SALES BEFORE CONSTRUCTION

Source: Adapted from References (3, 4, 5)

In another analysis, shown in Table 5-4, the sales of firms with median openings were compared with the sales of firms without median openings. In the aggregate, there appears to be no advantage for a firm to be located near a median opening. For traffic-serving businesses, however, there seems to be a distinct advantage of having a median opening. The variation in sales of firms, both with and without median openings, strongly supports the contention that "individual management or management's reaction to changing conditions exerts a much stronger influence on sales than does specific location in relation to median openings."

(Continued)

MEDIANS (Continued)

Business Impact Of Raised Medians, Three Texas Cities (Continued)

TABLE 5-4: EFFECT OF MEDIAN OPENINGS ON SALES VOLUME

	Before Median	After Median
Firms at Median Opening		
1. Traffic-Serving Businesses	100	99
2. Nontraffic-Serving Businesses	100	68
3. Total	100	89
Firms Not at Median Opening		
1. Traffic-Serving Businesses	100	56
2. Nontraffic-Serving Businesses	100	100
3. Total	100	94

Source: Adapted from References (3, 4, 5)

Regardless of the reasons for the change, medial access control clearly has an influence on customer traffic. Superficially, this seems of overwhelming importance to the commercial sector. But further analysis indicates that the total volume of traffic passing a property is not of paramount importance to the abutting operations; rather it is the economic composition of the customer traffic.

Continuous Two-Way Left Turn Lanes

A continuous two-way left-turn lane (CTWLTL) has worked well as a retrofit in developed areas on existing sections of roadway having moderate traffic volumes and low driveway traffic. It is not applicable on high volume, high speed roadways with moderate to high driveway volumes. Moreover, it is not compatible with the movement function appropriate for major arterial streets.

(Continued)

Continuous Two-Way Left Turn Lanes (Continued)

Research sponsored by the Georgia DOT concluded that on high volume roadways, raised medians have a lower accident experience than continuous two-way left-turn lanes (TWLTL's). As shown in Figure 5-5, this is true for both 4-lane and 6-lane facilities. Similar results were found in a Florida study (see Figure 5-6), and in Michigan (see Table 5-5).

Gwinette County, Georgia, recently adjusted a policy that all new and reconstructed principal and major thoroughfares should be designed with raised medians. Also, raised medians should be considered as retrofit treatment on all arterials having a TWLTL if the projected traffic volume reaches or exceeds 24,000 to 28,000 vehicles per day (12).

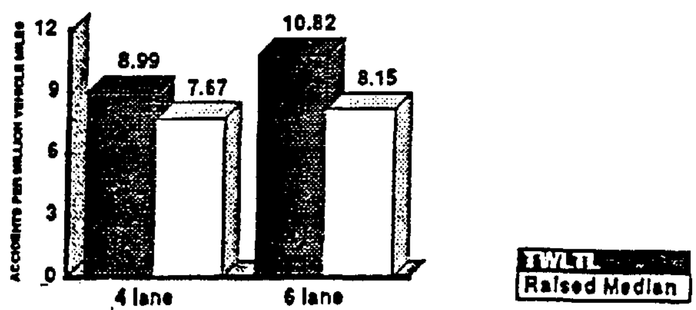

FIGURE 5-5: COMPARISON OF ACCIDENTS RATES ON GEORGIA ROADWAYS WITH RAISED MEDIANS AND TWO-WAY LEFT-TURN LANES

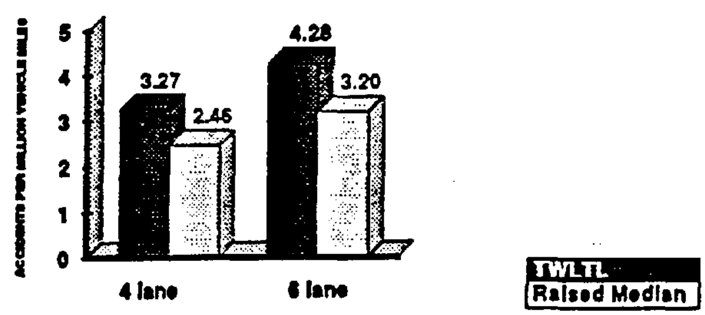

FIGURE 5-6: ACCIDENT RATES FOR RAISED MEDIANS AND TWO-WAY LEFT-TURN LANES IN FLORIDA

(Continued)

MEDIANS (Continued)

Continuous Two-Way Left Turn Lanes (Continued)

TABLE 5-5: MICHIGAN STATEWIDE ACCIDENT RATES FOR SELECTED TYPES OF ARTERIALS, 1985-1987

Arterial Type	Average ADT	Total Length, Miles	Reported Accidents per 100 Million Vehicle Miles		
			Total	Injury	Fatal
5-lane 2-way	22,000	223	956	276	2.55
4-lane divided	17,000	286	407	118	1.77
7-lane 2-way	35,000	29	1107	357	3.75
6-lane divided	50,000	44	563	166	0.94

Source: Reference (14)

(Continued)

MEDIANS (Continued)

Examples of Median Retrofits

US 1 in Stuart, FL, Oakland Park Blvd in Fort Lauderdale, FL, and Memorial Drive in the greater Atlanta, GA, metropolitan Area are recent examples of retrofit programs to change to amount and type of median access.

RECENT MEDIAN RECONSTRUCTION

- US 1,
  Stuart, FL
- Oakland Park Blvd,
  Fort Lauderdale, FL
- Memorial Highway,
  Atlanta, GA,
- Jimmy Carter Blvd.
  Atlanta,GA, Metro Area

(Continued)

MEDIANS (Continued)

US 1, Stuart, FL

Traffic accidents were reduced 22% when numerous closely spaced median openings on US-1 in Stuart were closed. Surveys indicated that the affected interest groups generally approved of the decrease in the number median openings.

Retrofit -- Before and After
US 1 -- Stuart, FL

- 22% Reduction in Accidents
- Perception of Smoother Traffic Flow
- 23% of Businesses Reported Reduced Sales While 63% Reported No Effect
- 57% of the Customers Favored the Project in Spite of Inconvenience
- 48% of the Adjacent Residents Favored the Changes Yet 63% Reported Being Inconvenienced
- Majority of Residents Felt Crime Would be Deterred
- 58% of Truckers Favored Access Control and Only 25% Felt They Were Inconvenienced
- 92% of Truckers Felt Safer

(Continued)

MEDIANS (Continued)

Oakland Park Blvd, Fort Lauderdale, FL

The median of a 2.25 mile section of Oakland Park Blvd, which is a major urban arterial in Fort Lauderdale, was reconstructed in the mid-1980's. Traffic volume was about 50,000 vpd; the posted speed was 45 mph. The adjacent development was strip commercial.

OAKLAND PARK BLVD

- 2.25 mile section
- 50,000 ADT
- 45 mph posted speed

Before

- 4 signalized intersections
- 33 unsignalized median openings, all movements permitted

After

- 4 signalized intersections
- 15 unsignalized median openings, left ingress and U-turn only
- 1 unsignalized median opening, left egress

The 2.25 mile section had 4 signalized intersections. The 16-foot median had 33 unsignalized median openings. The nature of the original median design is illustrated in Figure 5-9A. The reconstruction reduced the number of unsignalized median openings to a total of 16 , left-turn egress only is permitted at only one. The other 15 median openings were designed to accommodate left-turn egress and u-turns. The retrofit median design is illustrated in Figure 5-9B. The resulting spacing of the median openings range between 400 and 600 feet.

(Continued)

MEDIANS (Continued)

Oakland Park Blvd, Fort Lauderdale, FL (Continued)

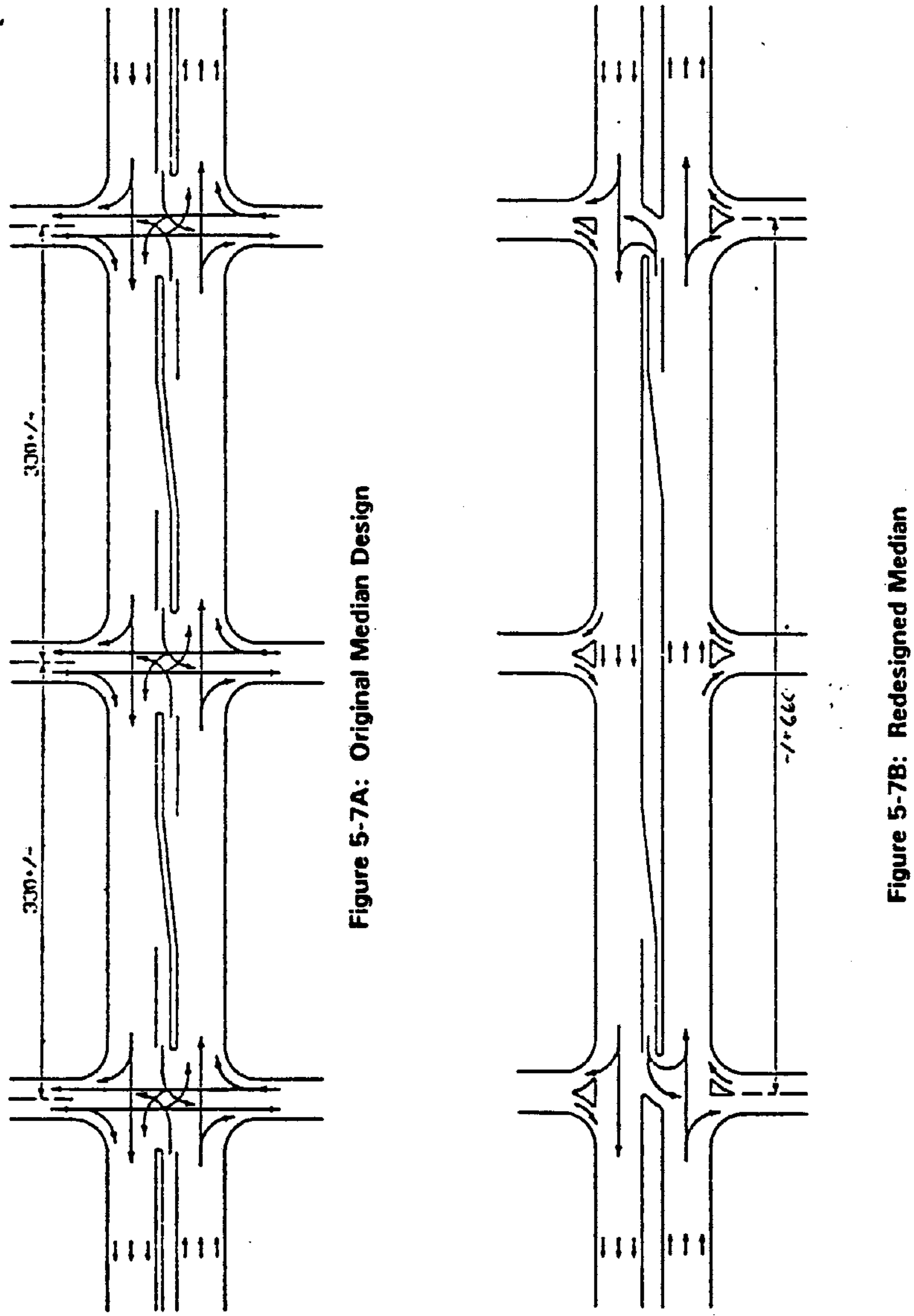

FIGURE 5-7: MEDIAN DESIGN ON OAKLAND PARK BLVD, FORT LAUDERDALE

(Continued)

MEDIANS (Continued)

Oakland Park Blvd, Fort Lauderdale, FL

The number of U-turns more than doubled after the reconstruction; left-turns from Oakland Park Blvd to intersecting streets and access drive decreased by over 35%. The total number of left-turns and U-turns remained essentially unchanged. This same left-turn egress movements were converted to right-turns followed by a U-turn. Some may have been diverted to other routes.

The accident rate was reduced from 4.9 accidents per million vehicle-miles to 4.4 (see Table 5-6). Although the fatal and injury accident rates reversed, that accident rate after reconstruction is substantially less than that of another Fort Lauderdale arterial (Sunrise Blvd) which has the same median design as Oakland Park Blvd it was reconstructed (see Table 5-7).

TABLE 5-6: OAKLAND PARK BLVD ACCIDENT RATES

	Accident Rate[1]		
Type	Before	After	Percent Change
Fatal and Injury	1.64	2.09	+27.4
Property Damage	3.30	2.37	-28.2
TOTAL	4.93	4.45	-9.7

(1) Accidents per million vehicle-miles

TABLE 5-7: A COMPARISON OF ACCIDENT RATES

Arterial	Fatal and Injury Accident Rate[1]
Oakland Park Blvd	2.09[2]
Sunrise Blvd	3.78[3]

(1) Accidents per million vehicle-miles
(2) Reconstructed median (Figure 5-7B)
(3) Median similar to Oakland Park Blvd before the Oakland Park Blvd median was reconstructed (Figure 5-7A)

(Continued)

MEDIANS (Continued)

Oakland Park Blvd, Fort Lauderdale, FL (Continued)

Simulation using TRAF-NETSIM indicated that average speed is expected to increase when a median of the of the design shown in Figure 5-7A is replaced by one shown in Figure 5-7B. Also, the average number of stops and the delay per vehicle will decreases the volume increases. (see Table 5-8)

TABLE 5-8: EFFECTS OF INCREASED SPACING AND LIMITATIONS OF MOVEMENTS

Vehicles/ Hour	Average Speed	Stops per Vehicle	Delay per Vehicle
1000	+ 4 %	- 60 %	- 22 %
1500	+ 10%	- 49 %	- 51 %
2000	+38 %	- 58 %	- 65 %

As shown in Table 5-9 surveys of various interest groups indicated that those individuals failure with the before condition expressed broad support for the change. Those not familiar with the median design prior to the reconstruction expressed less favorable opinions than those who were. (See Table 5-9).

(Continued)

MEDIANS (Continued)

Oakland Park Blvd, Fort Lauderdale, FL (Continued)

TABLE 5-9: PERCENT OF RESPONDENTS FAVORING THE CHANGED MEDIAN ON OAKLAND PARK BLVD

Respondent	Not Familiar With The Original Median	Familiar with The Original Median
Through Traffic	75	80
Travelers	67	64
Merchant	33	57
Customers	47	64
Total	47	64

The opinion survey also questioned merchants about the effort of the change in median design on business and property values. Seventy percent of the merchants indicated that the retrofit median did not adversely affect the truck deliveries. Most merchants (72 %) also reported no chant in property value; Interestingly, 13 % reported and increase in property value. As shown in Figure 5-8, a majority (over 60 %) of merchants reported no change in business.

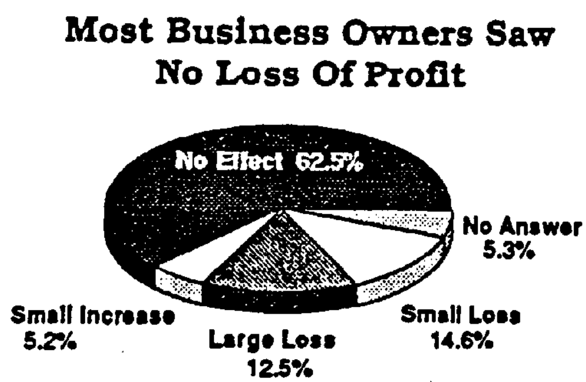

FIGURE 5-8: REPORTED EFFECT ON BUSINESS

(Continued)

MEDIANS (Continued)

Oakland Park Blvd, Fort Lauderdale, FL (Continued)

The opinion surveys also addressed the degree to which residents, customers and travelers were inconvenienced (see Table 5-10).

TABLE 5-10: OPINIONS REGARDING BEING INCONVENIENCED BY CHANGE IN MEDIAN ON OAKLAND PARK BLVD

	Merchants	Customers	Travelers
Feel Inconvenienced	63	55	45
U-Turn Affects Choice of Business Performance	41	51	---

Effect of Improved Median on Traffic Accidents

Figure 5-9 summarizes the accident reduction benefits of the reconstruction of medians to increase the spacing of median openings and the limitation of movements that can be made of the remaining openings. Accidents per million vehicle miles decreased significantly on both Oakland Park Blvd and US1, where as accidents increased slightly on a comperable arterial having a median similar to Oakland Park and US1 prior to their reconstruction.

(Continued)

MEDIANS (Continued)

Effect of Improved Median on Traffic Accidents (Continued)

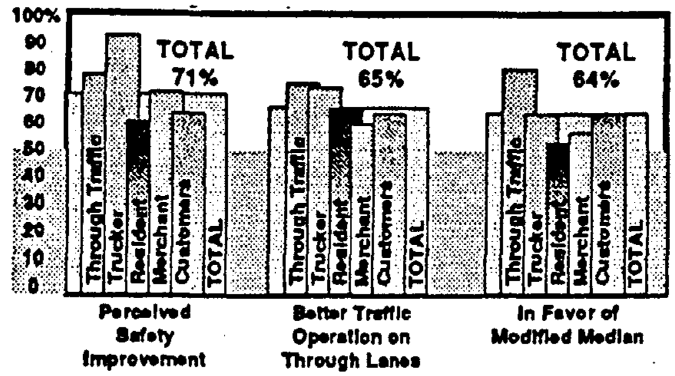

FIGURE 5-9: ATTITUDES REGARDING CHANGE IN MEDIAN DESIGN

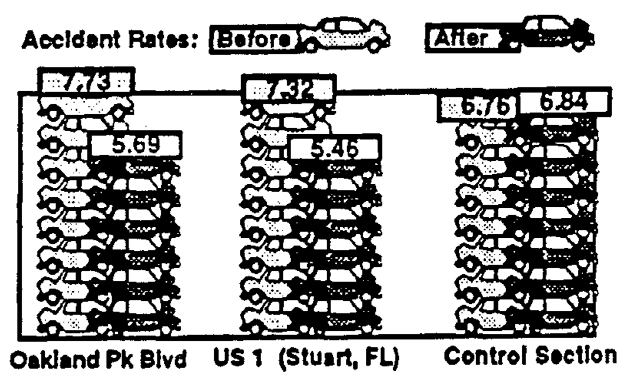

FIGURE 5-10: EFFECTS OF MEDIAN RECONSTRUCTION ON TWO SOUTH FLORIDA ARTERIALS

(Continued)

MEDIANS (Continued)

Memorial Highway, Atlanta, GA

A TWLTL on a 4.34 mile section of Memorial Drive in Atlanta, GA, was replaced with a raised median. Six through traffic lanes were provided before and after the median retrofit. Construction was completed between the end of July 1989 and the end of September 1990.

MEMORIAL HIGHWAY

- 4.34 mile section
- TWLT Lane Replaced By Raised Median
- No Median Break at 7 Public Roads
- 14 Signalized Intersections with Public Roads and Major Driveways

No median opening was provided at 7 minor street intersections when the raised median was installed. Fourteen signalized median openings were provided with public roads and major private access drives. All except one provided for U-turns. A 6-inch mountable curb was offset 2 feet from the edge of the traffic adjacent traffic lane.

A before and after accident study was performed to access the impact on safety. Table 5-11 summarizes the changes in accident rates. The rate for total accidents was reduced by 37 percent; the injury rate dropped 48 percent. The fact that accidents rates at those intersections which remained open demonstrates that improved design and traffic control can result in lower rates in spite of the increased activity that must necessarily be directed to these openings. Total injury accidents decreased by 40%.

(Continued)

MEDIANS (Continued)

Memorial Highway, Atlanta, GA

TABLE 5-11 : SUMMARY OF PERCENT CHANGE IN ACCIDENT-RATES ON MEMORIAL DRIVE

	Total Accidents		"Left-Turn" Accidents Only	
	Total Accident Rate	Injury Rate	Total Accident Rate	Injury Rate
Midblock	-55	-59	-90	-92
Intersections	-24	-40	-50	-48
Total	-37	-48	-64	-65

Source: Reference (12)

The total left-turn accident rate decreased by 50% (from 0.40 accidents per 100-million vehicles to 0.20). This demonstrates that improved design and traffic operation can reduce accident expectancy even though a raised median will result in increased U-turn volumes.

(Continued)

MEDIANS (Continued)

Jimmy Carter Blvd, Greater Atlanta Metro Area

Jimmy Carter Blvd is located in Gwinnett County in the greater Atlanta, GA, metropolitan area. A section of approximately 3.5 miles in length was reconstructed from 5-lanes (4 through lanes plus a CTWLT lane) to 6 lanes with a raised median. Traffic volumes prior to the reconstruction ranged from 11,000 to 14,600 vpd in 1987 and up to 12,000 vpd after the reconstruction in 1991. A "Jersey barrier was used temporally (27 April 1987 through 21 August 1988).

JIMMY CARTER BLVD

- 3.5 ± Mile Section
- 5-lane Before
- 6-lane With 10 Inch High Raised Median

Comparison of the accident frequencies and accident rates that the Jersey barrier was more effective than the permanent 10 inch raised barrier (see Tables 5-12 and 5-13).

TABLE 5-12: NUMBER OF ACCIDENTS ON JIMMY CARTER BLVD

	North Section		South Section	
Condition	Total	Injury	Total	Injury
Before [1]	198	69	193	37
Jersey Barrier	155	34	109	23
10" Raised Median	213	79	37	50

(1) 5-lane section; 4 through lanes plus CTWLT lane

(Continued)

MEDIANS (Continued)

Jimmy Carter Blvd, Greater Atlanta Metro Area (Continued)

TABLE 5-13: PERCENT CHANGE IN ACCIDENT EXPERIENCE ON JIMMY CARTER BLVD

		Accident Frequency		Accident Rate	
Condition	Overall	North[1] Section	South[2] Section	North Section	South Section
Total Accidents:					
• w/ Jersey Barrier	**-32 %**	**-22%**	**-44%**	**-27%**	**-47%**
• After 10" Raised Median	-2%	+8%	-11%	-9%	**-35%**
Injury Accidents:					
• w/ Jersey Barrier		**-51%**	-23%	**-54%**	-27%
• After 10" Raised Median		+16%	+16%	-1%	+22%

(1) North of I-85
(2) South of I-85
Note, bold number indicates change is statistically significant at $\alpha = 0.05$

SIGNAL REMOVAL

Benefits of Signal Removal

It is generally recognized that the removal of unwarranted traffic signals will improve traffic safety and reduce maintenance costs. Where signals are closely spaced, removal of signals at selected locations will improve traffic flow on major urban streets. Benefits of signal removal to improve spacing on major roadways include improved traffic flow, reduced stopped delay, reduced fuel consumption, lower vehicular emissions, and increased capacity.

Benefits of Signal Removal

- Improved Traffic Safety
- Lower Maintenance Costs
- Improved Traffic Flow
- Reduced Stopped Delay
- Reduced Fuel Consumption
- Lower Vehicle Emissions
- Increased Capacity

(Continued)

SIGNAL REMOVAL (Continued)

Conversion To Stop Control

Studies have demonstrated that the conversion of unwarranted signals have significant safety benefits.

Signal Removal Case Studies

1) 28 Urban Signals Converted to Multi-Way Stop Control
   - Annual Accident Frequency Reduced 60%
   - Injury Accidents Reduced 62%
   - Idling Reduced 5 Seconds per Vehicle
   - 4800 Gallons Fuel Saved per year for 10,000 ADT

2) 191 Urban Signals Converted to Two-Way Stop Control
   - Annual Accident Frequency Reduced 3%
   - Injury Accidents Reduced 10% from 0.70 to 0.63 per MEV
   - Right Angle Accidents Increased 51%; Rear-End Accidents Decreased 49%
   - Delay Reduced by 10 Seconds per Vehicle
   - Number of Stops Reduced by over 50%
   - Fuel Consumption Reduced 0.002 Gallons per Vehicle

(Continued)

SIGNAL REMOVAL (Continued)

Change in Accidents

As shown in Table 5-14, the average accident frequency decreased when signals were replaced by stop signs. However, the reduction was statistically significant only for total accidents at multi-way stops.

TABLE 5-14: CHANGE IN AVERAGE ACCIDENT FREQUENCY WHEN SIGNAL AT LOW VOLUME URBAN INTERSECTION REPLACED BY STOP

	Two-Way Stop	Multi-Way Stop
Number of Intersections	191	26
Total Accidents		
Average Annual Frequency per Intersection		
Before Signal Removal	2.46	1.70
After Signal Removal	2.38	0.68
Change	-0.08	-1.02 [1]
% Change	-3 %	-60 %
Injury Accidents		
Average Annual Frequency per Intersection		
Before Signal Removal	0.70	0.50
After Signal Removal	0.63	0.19
Change	-0.07	-0.31 [1]
% Change	-10%	-62%

[1] Statistical difference using the paired t test, $\alpha = 0.05$

Source: Reference (9)

(Continued)

SIGNAL REMOVAL (Continued)

Change in Accidents (Continued)

Signals at 5 signalized rural intersections were replaced by a two-way stop. The increase in both accident and injury accidents was statistically significant (at the 10% significance level). Average accident frequency was at 5 rural intersections where a signal was replaced by a multiway stop was essentially unchanged (a 13% inverse in total accidents). Injury accidents were zero after the signals of the 5 rural intersections were replaced by multi-way stops. However this change is neither statistically significant nor of practical significance due to the very small number of injury accidents at the 5 intersections before the signals were removed.

Fuel Savings

Excess fuel consumption is the difference between the fuel consumed with traffic control and that which would be used if there were no stops. Curves in excess fuel consumption for 4-way and 3-way intersections are given in Figures 5-11 and 5-12 respectively. Inspection of Figure 5-11 , for example, shows the following that for a main road value of 250 vph and a main road volume of 100 vph, Signalization results in 2.0 gallons per hour whereas a 2-way stop is only 1.0 gallons. Thus, replacement of the signal with stop signs on minor roads is expected to save 1.0 gallons of fuel per hour or about 0.0029 gallons per vehicle the intersection.

With main road and minor road volumes of 1000 vph and 250 vph respectively, the excess fuel saved in 2 gallons per hour (5 gallons with signalized and 3 gallons with multi-way stop). This amounts to about 0.0017 gallons per vehicle entering the intersection. For an intersection with an entering volume of 10,000 vehicles per day, the excess fuel savings is about 6200 gallons per year (0.0017 gal/veh x10,000 vpd x 365 day/yr).

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SIGNAL REMOVAL (Continued)

Fuel Savings (Continued)

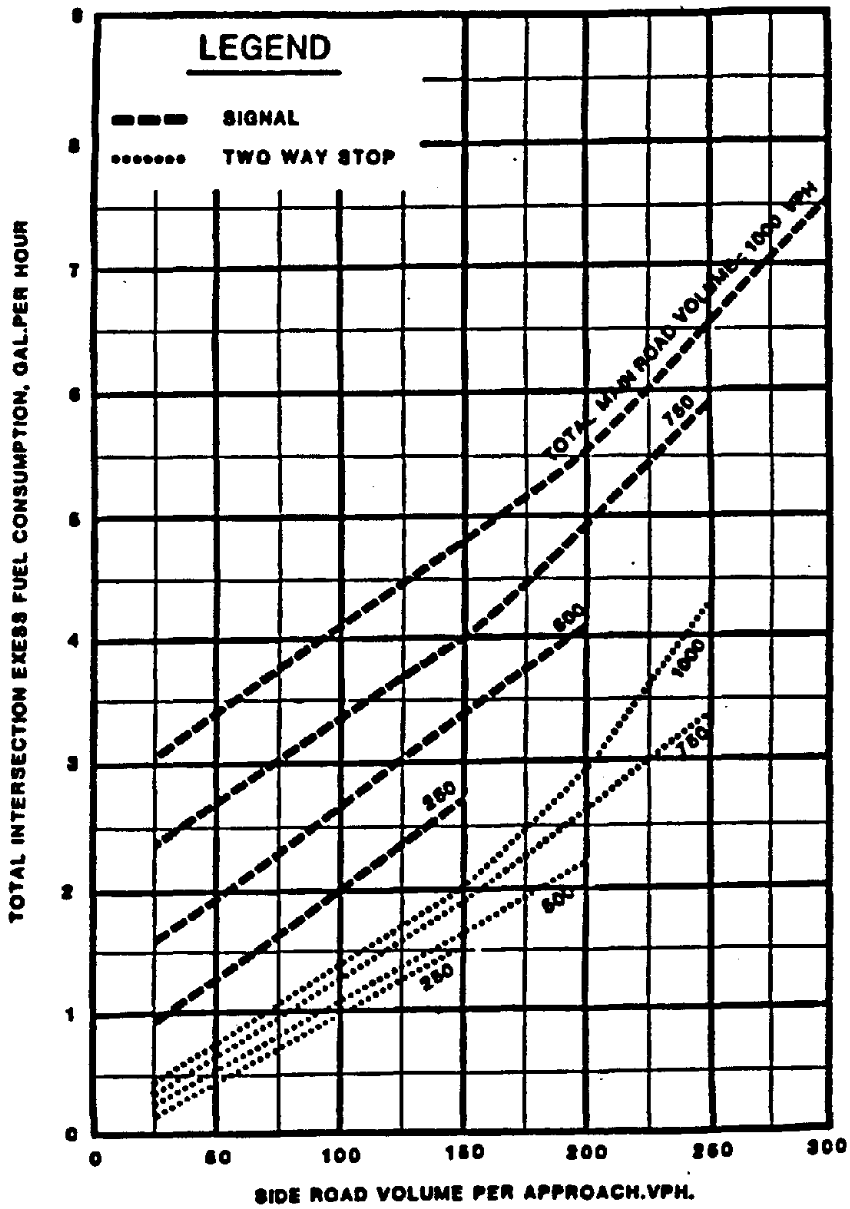

FIGURE 5-11: EXCESS FUEL CONSUMPTION AT FOUR-WAY INTERSECTIONS, FOUR-LANE MAJOR, TWO-LANE MINOR

Source: Reference (9)

(Continued)

SIGNAL REMOVAL (Continued)

Fuel Savings (Continued)

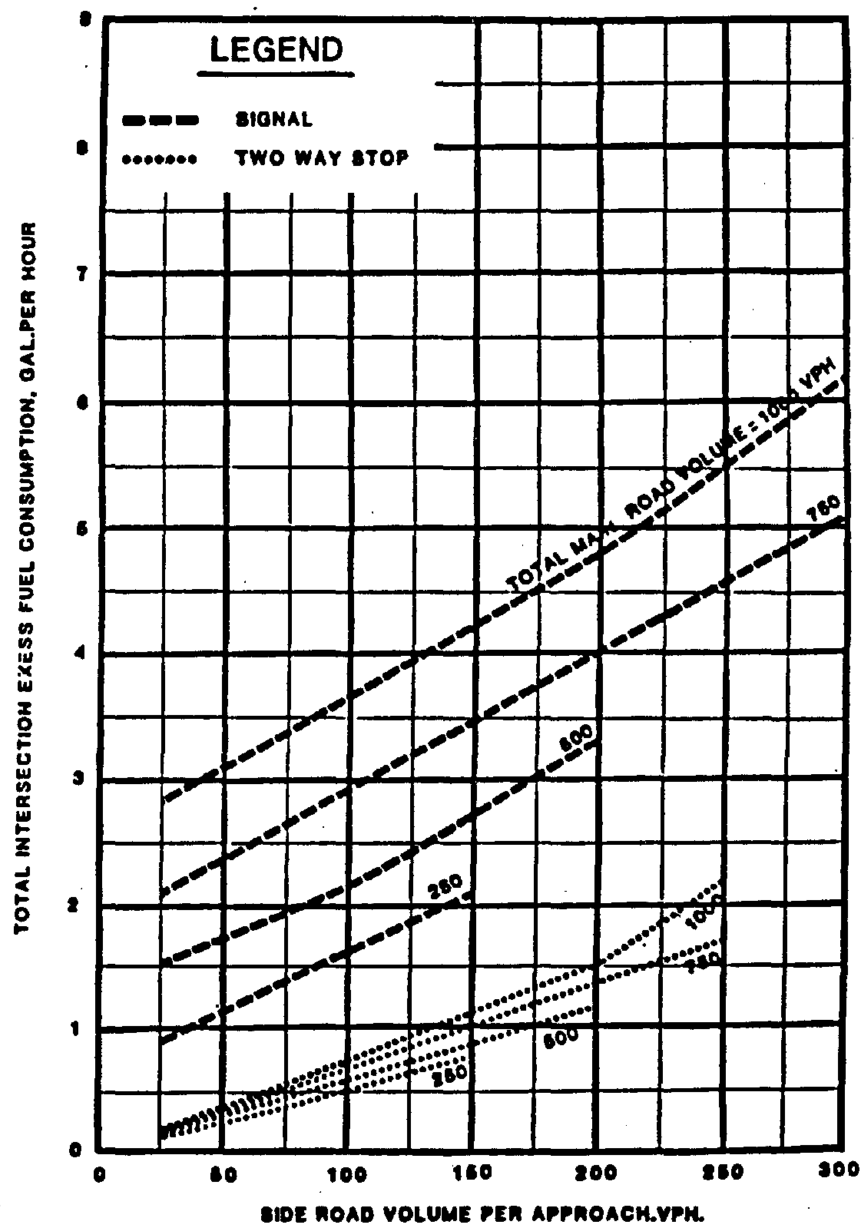

FIGURE 5-12: EXCESS FUEL CONSUMPTION AT A "T" INTERSECTIONS, FOUR-LANE MINOR, TWO-LANE MINOR.

Source: Reference (9)

(Continued)

SIGNAL REMOVAL (Continued)

Intersection Delay

Curves for total delay at 4-way intersections with stop signs for the minor roads are given in Figure 5-13. These figures clearly show that the use of stop signs on the minor roadway (2-way stop). Significantly reduces the expected delay. Expected delay a T-intersection is shown in Figure 5-14 . Inspection of the figure shows that the use of top signs on the minor road can be expected to result in substantially less total delay of all volume levels; however the difference in total delay, and delay per vehicle, decreases as the volume levels increase. For example consider the examples given in Table 5-15 .

TABLE 5-15 : DELAY SAVINGS WHEN SIGNAL REPLACED BY STOP SIGNS

		Difference in Delay	
Main Road Volume (vph)	Main Road Volume(vph)	Veh-hrs/hr	Veh Sec. per Entering Veh
250	100	1.4	14.4
1000	200	3.8	11.4

(Continued)

SIGNAL REMOVAL (Continued)

Intersection
Delay
(Continued)

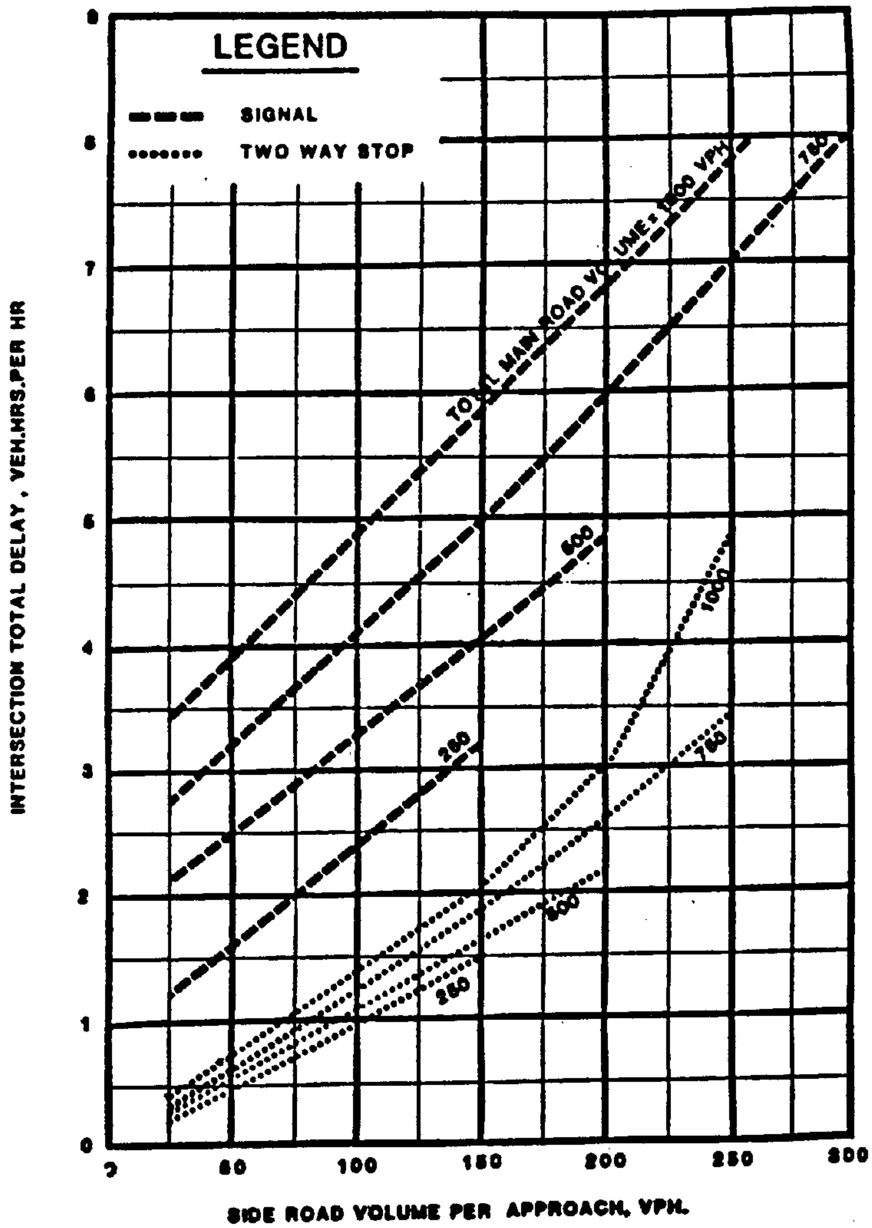

FIGURE 5-13: ESTIMATED TOTAL INTERSECTION TOTAL DELAY FOUR-WAY INTERSECTION, FOUR-LANE MAJOR, TWO-LANE MINOR

Source: Reference (9)

(Continued)

Intersection Delay (Continued)

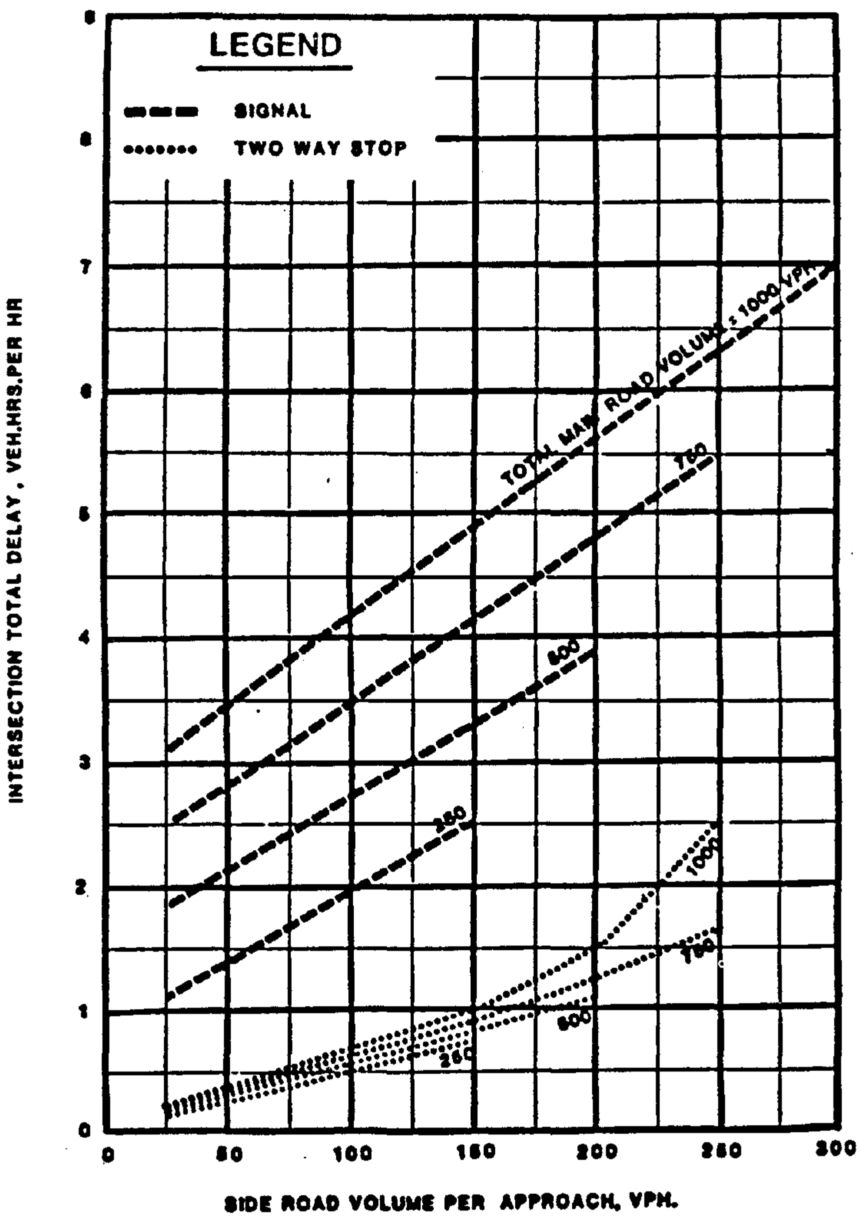

FIGURE 5-14: ESTIMATED TOTAL DELAY "T"-INTERSECTIONS, FOUR-LANE MAJOR, TWO-LANE MINOR

Source: Reference (9)

(Continued)

SIGNAL REMOVAL (Continued)

Cost

Although cost vary considerable the one-time cost of removing a signal and replacing it with stop signs has be estimated to be approximately equal to the annual cost of operation and maintenance. The pay-back period is thus estimated to be between one and two years in most cases. (9,p.96)

Unsuccessful Attempts at Signal Removal

Public opposition and the resulting political presence, is the common problem when if attempted to remove unwanted signals or those which only marginally need are of the minimum warrants. One study (9) which investigated why the proposals to remove 46 signals were unsuccessful, reported the following:

"At least 41 of the 46 intersections where signal removal attempts failed, the reason cited was strong public opposition. This opposition was expressed in the form of phone calls, letters and petitions to the traffic engineer and the city council from residents and business in the immediate locale of the intersection. In a few cases, complaints were received from parents of school children even though the signals in question were no in close proximity to schools. At one location, the opposition to signal removal came for transit operators that used the signal to turn onto the major street."

"The complaints usually concentrate on a perceived safety problem that would exist if the signal was removed. The safety problem that would exist if the signal was removed. The safety problems mentioned most frequently include an increase in accidents, traffic fatalities, high speeds, and difficulty for pedestrians, (particularity elderly people) in crossing the street.

"Signal removal attempts were unsuccessful at the other 5 intersections for technical reasons including increases in accidents during the interim control period and an increase in side street vehicular delay due to capacity constraints downstream of the intersection on the major street."

FRONTAGE OR SERVICE ROADS

Application

In situations involving high-volume, high-speed arterials, it is often feasible to consider the construction of frontage roads in a retrofit program. This is an expensive technique and often time-consuming when right-of-way has to be purchased.

Frontage roads allow the jurisdiction complete control of access to the arterial and provide for loading and parking which might otherwise have to be accepted on portions of the arterial.

Design and Operation

There are several general design considerations which will affect safe, efficient frontage road use.

- A separation of at least 400 feet (125 metres) is needed in order to separate between the intersection of the cross-road and the main road and the cross-road and the frontage road even when moderate volumes are encountered. In rural areas very low traffic volumes cross-road and frontage roads will be encountered, and moderate or higher volumes will never develop, a separation of at least 150 feet (50 metres) may be adequate.
- Frontage roads which can be terminated at or advance of each intersecting cross street operate well with respect to the arterial and its cross-streets. This type of design should be considered if continuity of the frontage road is not a requirement.
- One-way, rather than two-way frontage roads should be used, if possible.
- A minimum outer separation of 8 feet should be used for pedestrian refuge, safe placement of traffic control devices, and for landscaping.
- Visibility at intersections of frontage roads/cross-streets/arterials should be maximized due to complex and confusing movements.
- Pedestrian and bicycle movements should utilize the frontage roads.

IMPLEMENTATION

Guidelines

The application of access control techniques to existing situations requires a well-coordinated program involving the jurisdictional operating agencies and the general public. Above all, there needs to be a well-defined policy adopted by the jurisdiction defining access control in terms of public welfare and transportation safety and efficiency. Zoning regulations, subdivision requirements, site plan review, and the process for obtaining building permits, curb cut permits, and occupancy permits should all be reviewed and coordinated to project the same objectives relative to access control.

A well-documented engineering study complete with economic evaluation should be conducted. This study should outline objectives of improvements, define and quantify specific problems (accidents, delays), and develop alternative solutions to reduce the impact of these problems. Alternatives should be realistically evaluated and, where benefits clearly outweigh all costs, proposed for implementation.

In many cases a retrofit program will need to extend over a substantial period of time, perhaps several years, in order to take advantage of transient conditions such as the closing of a business and the opening of another at the same site. Therefore a comprehensive conditioning program is essential for successful implementation.

Throughout the entire retrofit process, it is very important that the public be kept informed. Public meetings should be held in the area to be affected as soon as it is decided that studies should be undertaken. The reaction of businesses along a roadway where it is proposed that a median be installed, excess driveways be closed or their width reduced is often very negative. A full understanding of the realistic projected impacts and benefits that can accrue is essential. It is also important that the general public, as well as the businesses directly affected, be made knowledgeable of potential impacts inasmuch as they are the ones who stand to gain the most.

(Continued)

IMPLEMENTATION (Continued)

Guidelines (Continued)

Politically, a retrofit program may be very difficult for elected officials to support due to the real and imagined impacts on affected businesses. It is very important to document these individual impacts as well as those accruing to the general public. The alternative cost of new construction or new rights-of-way in order to accommodate existing and projected traffic safely and at reasonable levels of service is often a very persuasive argument. Of utmost importance, however, is making sure that the elected officials have full documentation and adequate reasons if they are going to be asked to do something that may be construed as being detrimental to a segment of their constituency.

Some of the legal problems associated with implementation of access control are presented in the appendices to this chapter.

EXAMPLE OF A COUNTY ACCESS CONTROL PLAN

Introduction

ACCESS MANAGEMENT PLAN
WAUTOMA-SILVER LAKE HIGHWAY 21/73 CORRIDOR
JUNE 1989
(REVISED)

A proposed access management plan for the Wautoma-Silver Lake Highway 21/73 corridor was completed in July 1988.

Plan Development

Opportunity to discuss the proposed plan was provide at several meetings scheduled by the Access Planning Committee and the Chamber of Commerce. Written responses were also requested. Comments were evaluated by the Access Planning Committee and Chamber representatives. These comments were incorporated in the plan adopted in July 1989. These revisions had minimal impact on the number of accesses proposed for closure. Among the revisions:

(1) All proposed frontage roads were deleted. It was felt the same ends could be achieved by closing or sharing individual access points rather than by constructing frontage roads to access existing businesses. Businesses were concerned about loss of parking and the high cost of frontage road construction.

(2) For several businesses with more than one access, the access originally suggested for closure was exchanged for another. In a few of these cases, shared accesses were proposed, or an access was moved to a different location.

(Continued)

EXAMPLE OF A COUNTY ACCESS CONTROL PLAN (Continued)

Plan Development (Continued)

In the review process, comments were also received about the planning criteria and the implementation process. These were more fully explained in the revised plan. The section on implementation also has been updated to take into account activities which have occurred since completion of the original plan in July 1988.

Average daily traffic volumes in 1985 ranged from just over 4,700 vpd to slightly over 11,000 vpd. At the highest volume location, average daily traffic was projected to increase to 15,600 in the year 2001 and to 17,800 by the year 2011.

The 3.97-mile section of roadway passes through four local political jurisdictions as shown in Figure 5-15. A summary of the existing and proposed access by jurisdiction is given in Table 5-16.

The existing and proposed access on selected segments of Highway 21/73 are shown in Figure 5-16 through 5-21.

TABLE 5-16: SUMMARY OF MILEAGE AND DIRECT ACCESS BY LOCAL POLITICAL JURISDICTION

Jurisdiction	Number of Miles	Number of Existing Access Drives	Proposed Closures	Number of Remaining Access Drives
City of Wautoma	0.53	39	10	29
Town of Wautoma	0.59	32	12	20
Town of Dakota	1.16	58	26	32
Town of Marion	1.69	60	9	51
Total	3.97	189	57	132

Source: Reference (8), p. 4

(Continued)

EXAMPLE OF A COUNTY ACCESS CONTROL PLAN (Continued)

Location
Map

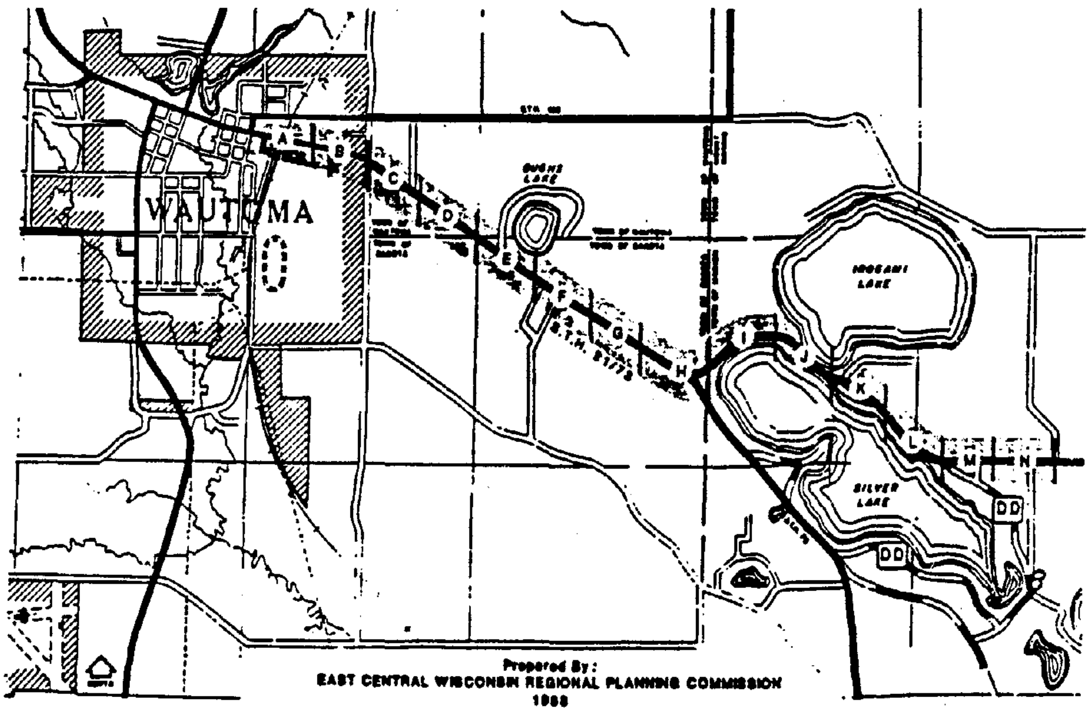

FIGURE 5-15: LOCATION MAP OF THE HIGHWAY 21/73 CORRIDOR

Source: Reference (8)

(Continued)

EXAMPLE OF A COUNTY ACCESS CONTROL PLAN (Continued)

Example of
Access Plan

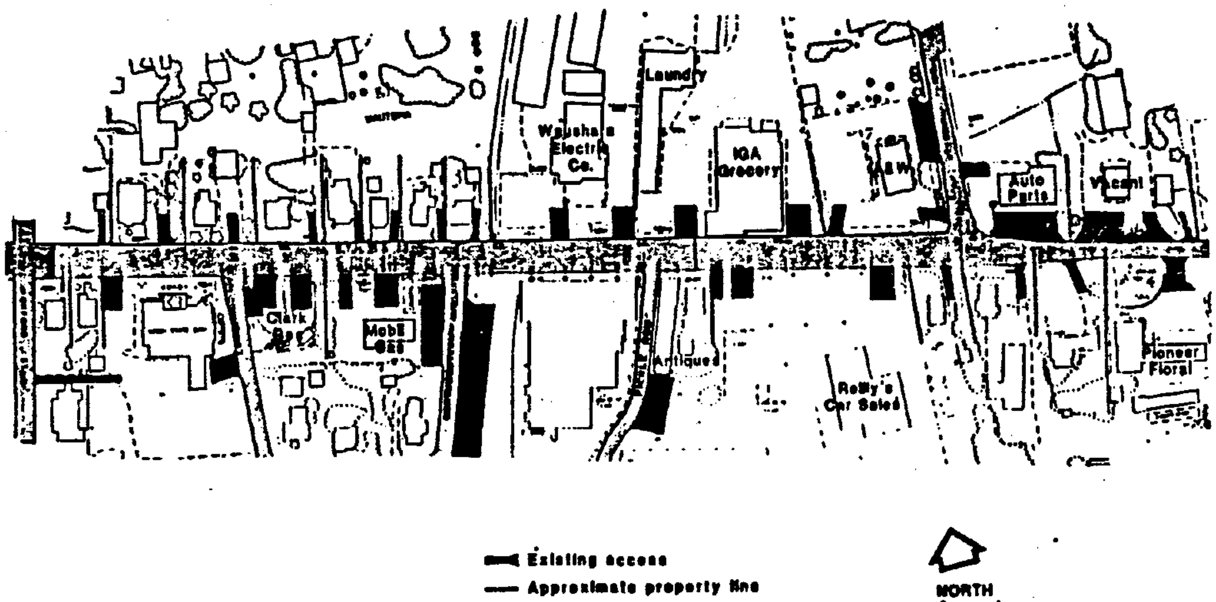

FIGURE 5-16: EXISTING ACCESS SEGMENT "A"CITY OF WAUTOMA

Source: Reference (8), p. 8

(Continued)

EXAMPLE OF A COUNTY ACCESS CONTROL PLAN (Continued)

Example of
Access Plan
(Continued)

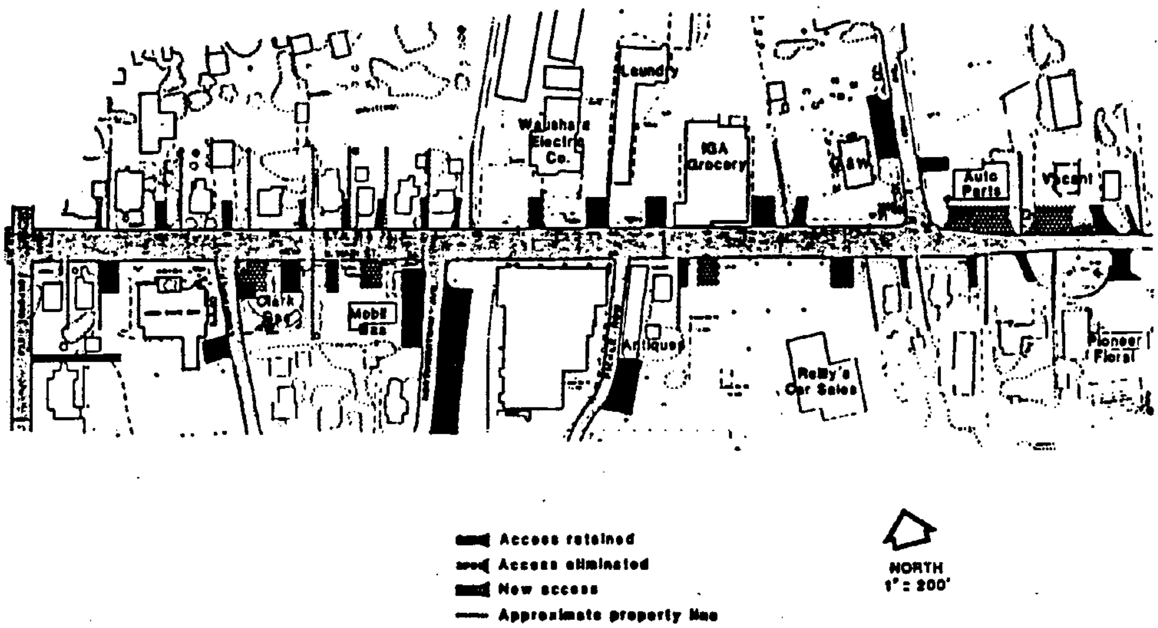

FIGURE 5-16: PROPOSED ACCESS SEGMENT "A"CITY OF WAUTOMA

Source: Reference (*8*), p. 9

(Continued)

EXAMPLE OF A COUNTY ACCESS CONTROL PLAN (Continued)

Example of
Access Plan
(Continued)

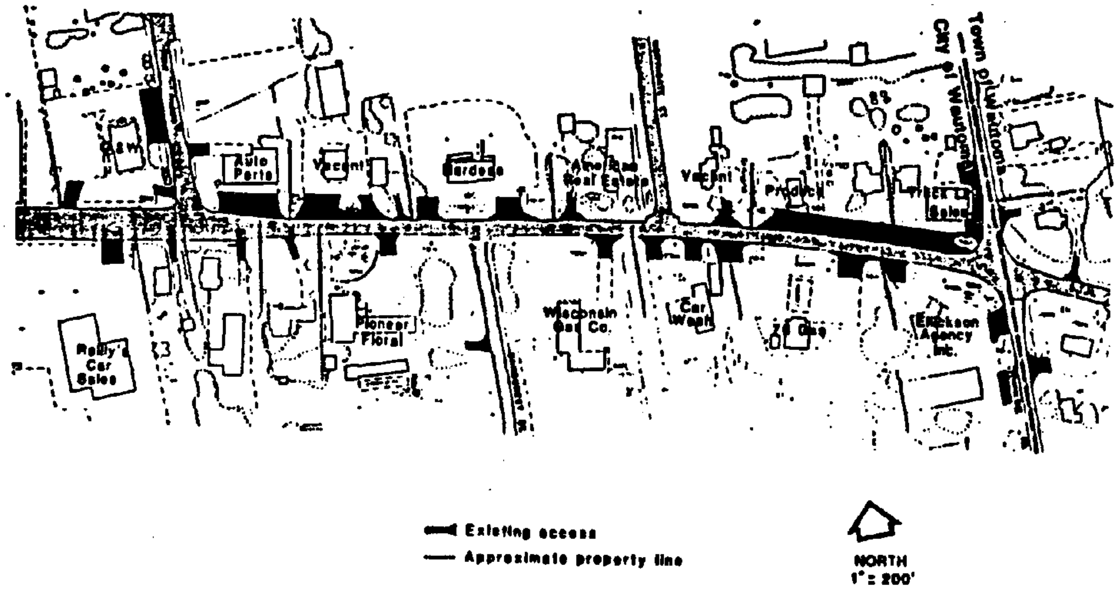

FIGURE 5-17: EXISTING ACCESS SEGMENT "B"CITY OF WAUTOMA

Source: Reference (8), p. 10

(Continued)

EXAMPLE OF A COUNTY ACCESS CONTROL PLAN (Continued)

Example of
Access Plan
(Continued)

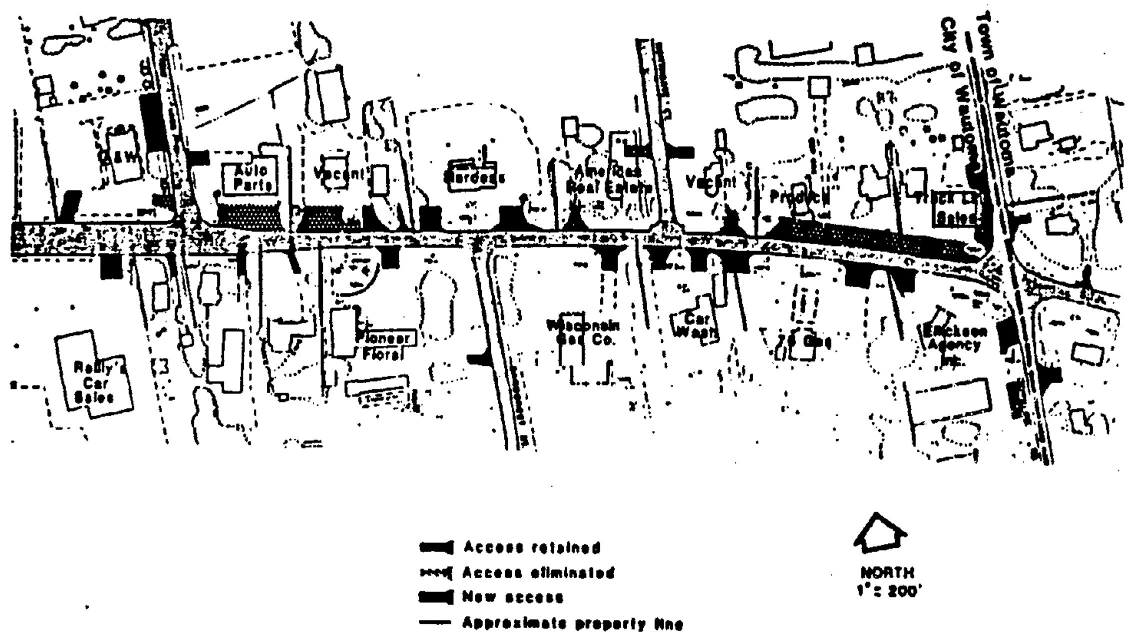

FIGURE 5-18: PROPOSED ACCESS SEGMENT "B" CITY OF WAUTOMA

Source: Reference (*8*), p. 11

(Continued)

EXAMPLE OF A COUNTY ACCESS CONTROL PLAN (Continued)

Example of Access Plan (Continued)

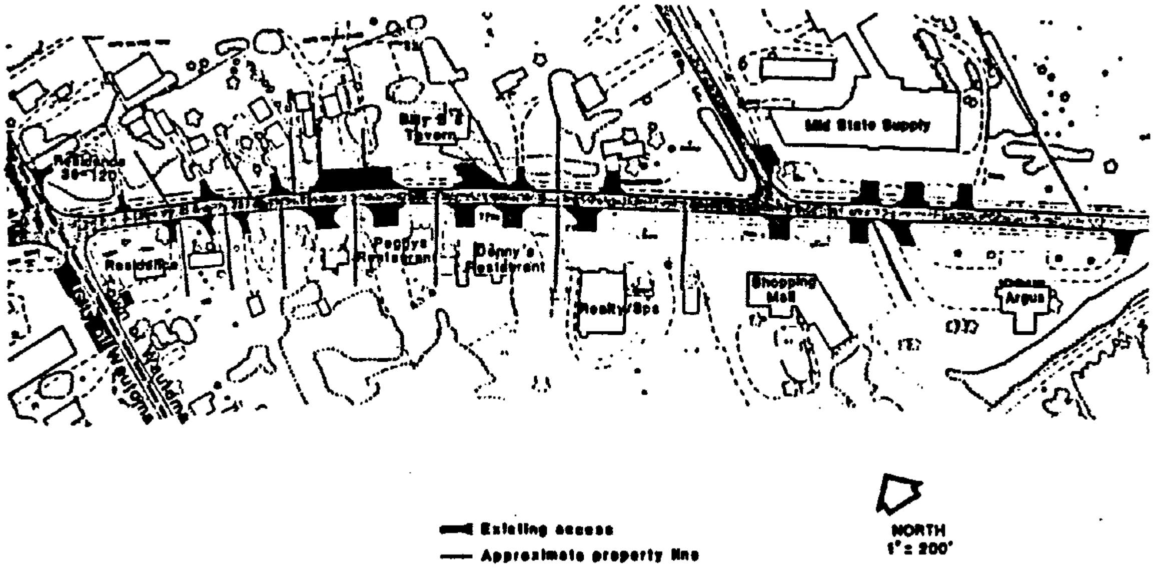

FIGURE 5-19: ACCESS SEGMENT "C" TOWN OF WAUTOMA

Source: Reference (8), p. 14

(Continued)

EXAMPLE OF A COUNTY ACCESS CONTROL PLAN (Continued)

Example of
Access Plan
(Continued)

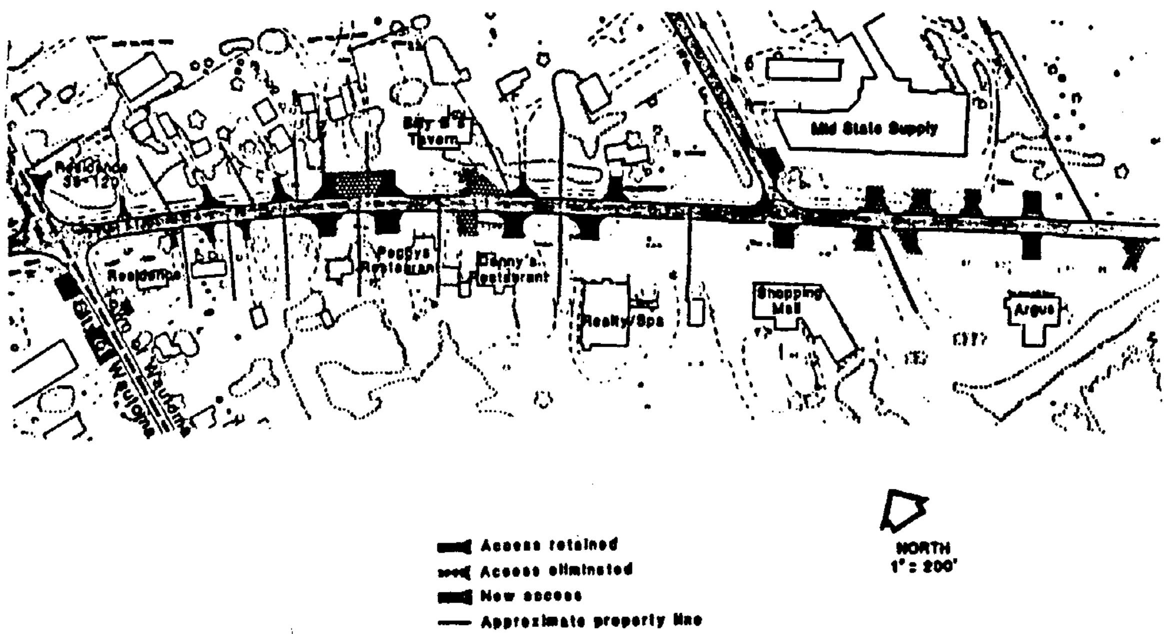

FIGURE 5-20: PROPOSED ACCESS SEGMENT "C" TOWN OF WAUTOMA

Source: Reference (8), p. 15

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APPENDIX 5-A

Legal Implication of Control of Access to Uncontrolled Access Highways

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NCHRP RESEARCH RESULTS DIGEST

DIGEST 112 - APRIL 1979

Legal Implications of Control of Access to Uncontrolled-Access Highways

A report submitted under ongoing NCHRP Project 20-6, "Right-of-Way and Legal Problems Arising Out of Highway Programs," for which the Transportation Research Board is the agency conducting the research. The report was prepared by Larry W. Thomas, TRB Counsel for Legal Research, principal investigator, serving under the Special Technical Activities Division of the Board.

THE PROBLEM AND ITS SOLUTION

State highway departments and transportation agencies have a continuing need to keep abreast of operating practices and legal elements of special problems involving right-of-way acquisition and control, as well as highway law in general. This paper deals with the legal aspects of access control on highways. It includes legal authority relative thereto.

This paper is included in a three-volume text entitled, "Selected Studies in Highway Law." Volumes 1 and 2 were published by the Transportation Research Board in 1976 and Volume 3 in 1978. Together they include 45 papers and more than 2,000 pages. Copies have been distributed to NCHRP sponsors, other offices of state and federal governments, and selected university and state law libraries. The officials receiving copies in each state are: the Attorney General, the Highway Department Chief Counsel, and the Right-of-Way Director. Beyond this initial distribution, the text is available through the TRB publications office at a cost of $90.00 per set.

CONTENTS

TRANSPORTATION RESEARCH BOARD

NATIONAL RESEARCH COUNCIL

Legal Implications of Control of Access to Uncontrolled-Access Highways

By Larry W. Thomas
Counsel for Legal Research
Transportation Research Board
Washington, D.C.

INTRODUCTION

A matter of continuing concern both of public authorities responsible for streets and highways and of the traveling public is the one of "functional obsolescence" of uncontrolled-access highways. This occurrence is the result of intense commercial development along highway corridors and the absence of proper access control resulting in highway congestion and reduction in traffic capacity. Important objectives of any highway program are the continuing capacity of roads and streets to carry high volumes of traffic for many years after construction and the ability to make adjacent land and facilities accessible. These objectives, however, often are incompatible. Although the highway authority may want access control to protect highway capacity, the abutting landowner, particularly one with a commercial establishment, recognizes that the value of his land and the success of his business depends in part on easy accessibility. Moreover, his concept of access may be one of direct access to the abutting road or street.

Functional obsolescence has been said to be a recurrent development. What happens so often is that construction of a new highway alters accessibility of adjacent land and tends to increase land values. Thereafter, strip development along the arterial generates an increasing amount of local traffic. Because of traffic growth and increased conflict between through and local traffic, the highway becomes so congested that it simply fails to function as planned. The highway authority may then be forced to acquire additional right-of-way or rights of access or be forced to construct a new facility on a new location.[1]

To prevent this deterioration it has been urged that access control be exercised to preserve the traffic-carrying capability and to enhance the safety of public highways in order to safeguard the public investment.[2] Clearly, improved safety is another reason for access control, because "the number of access points and the traffic entering the traffic stream at those points determine, in some measure, the over-all accident rate for any particular length of highway."[3] Studies have concluded that proper access controls have a powerful accident-reducing effect.[4]

Basically, there are four methods of controlling access: (1) eminent domain; (2) the police power; (3) contractual agreements; and (4) the law of nuisance.[5] The scope of this paper is limited to a consideration of some of the legal aspects of control of access to unlimited-access highways.[6] The issue is the extent to which the highway authority may restrict or impair existing access of abutting landowners on uncontrolled-access highways before having to pay compensation.

The term "uncontrolled-access" means that the highway authority does not limit the number of points of ingress and egress except through the exercise of control over the placement or the geometrics of connections as necessary for the safety of the traveling public.[7] That is, ingress and egress to the uncontrolled-access highway are generally unrestricted. By "partial control of access" it is meant that the public authority controls access to give preference to through traffic. In addition to access to selected public roads, there may be some crossings at grade and some private driveway connections.[8] Finally, there may be controlled-access highways where preference is given to through traffic by providing access connections with selected public roads only and by prohibiting crossings at grade or direct driveway connections.[9] Except to the extent that service roads may be used to control access or that uncontrolled-access highways may be converted to controlled-access highways, the law relating to partially or completely controlled-access highways is not treated in this paper.

The timeliness of this subject is demonstrated by the pending legislation in the Congress to authorize the Secretary of Transportation to carry out access control demonstration projects. The purpose of such projects would be "to demonstrate whether preserving the capacity of

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[1] "Guidelines for Medial and Marginal Access Control on Major Roadways," *National Cooperative Highway Research Program Report* 93 (1970) p. 4.

[2] *Id.* at 7.

[3] *Id.* at 83.

[4] *Id.* at 85; See also, Federal Highway Administration, Evaluation of Techniques for the Control of Direct Access to Arterial Highways, FHWA *Report No. 76-85* (Aug. 1975) [hereinafter Cited as FHWA REPORT No. 76-85].

[5] "Review of Transportation Aspects of Land Use Control," *National Cooperative Highway Research Program Report 31* (1966) p. 11. The reader may be interested in the views of Beuscher, in "Roadside Protection Through Nuisance and Property Law," *HRB Bull. 113* (1956) pp. 60-67, that unsafe access caused by abutting property owners may be enjoined by the courts on the basis of one of several principles: "(1) the roadside owner has violated his property law duty as owner of a 'servient tenement' not to interfere with the 'dominant' rights of the public; (2) the roadside abuse is enjoinable as a public nuisance; and (3) the roadside owner is guilty of continuing neglect or intentional conduct, in breach of his duty to permit free and safe passage on the highway." *Id.* at 66.

[6] Incidentially, by the phrase "control of access," it is meant that a public authority fully or partially controls the right of access of owners or occupants of abutting land or other persons in connection with a highway. *Highway Capacity Manual*, HRB SPECIAL REPORT 87, Washington, D.C. (1965) p. 8.

[7] *Highway Capacity Manual, supra* note 6, at 7.

[8] *Id.*

[9] *Id.*

existing highways to move traffic safely by acquiring and controlling the right of access to such a highway is a cost-effective alternative to the construction of additional highways." [10] As discussed in this paper there are various methods to control access without outright acquisition from the abutting landowners.[11]

The basic questions are whether the abutting landowner's access has been substantially impaired and whether the remaining access is suitable for the property's highest and best use. This paper attempts to illustrate where the courts draw the line between noncompensable and compensable impairments of access. However, it must be remembered that an analysis of the law of an abutter's right of access is a formidable task. The Supreme Court of the United States wrote: "The right of an owner of land abutting on public highways has been a fruitful source of litigation in the courts of all the States, and the decisions have been conflicting, and often in the same State irreconcilable in principle. The courts have modified or overruled their own decisions, and each State has in the end fixed and limited, by legislation or judicial decision, the rights of abutting owners in accordance with its own view of the law and public policy." [12]

HISTORICAL ORIGINS OF ACCESS AS A PROPERTY RIGHT

The United States Constitution provides that private property shall not be "taken" for public use without just compensation.[13] A similar provision exists in 16 states; however, in 22 states, the State constitutions require the payment of just compensation for property "taken or damaged." [14]

Certainly, land itself is property, but it has not always been that access to and from the street or highway was recognized as a right of property. Essentially, the early law of property in the United States required "little more than the landowner's right to be compensated for land taken and buildings destroyed in order to lay out and build a public highway." [15] The view that an abutter was not entitled to damages for loss of access changed little by the adoption of written constitutions with "taking" or "taking or damaging" provisions.

As abutting landowners began to experience hardship caused by highway construction, the courts were asked to award compensation for loss of access to the adjacent street. In 1821, the United States Supreme Court denied compensation to an abutting landowner for damage caused

[10] H.R. 11733, 95th Cong., 2d Sess § 123 (1978).

[11] One technical study has identified 70 access-control techniques. See FHWA REPORT No. 76-85, *supra* note 4.

[12] Sauer v. New York, 206 U.S. 536, 548, 51 L.Ed. 1176, 27 S.Ct. 686, 690 (1906).

[13] U.S. CONST., amend. V.

[14] See Netherton, "Damnum Absque Injuria and the Concept of Just Compensation in Eminent Domain," *Selected Studies in Highway Law*, Vol. 1, Ch I pp. 42-45.

[15] Netherton, CONTROL OF HIGHWAY ACCESS, (U. of Wis. Press, 1963) at 36.

by street grading.[16] In 1833, the Massachusetts Supreme Court likewise denied compensation where a landowner had to construct new access to the street after a grade alteration.[17]

As noted by Netherton, the refusal to award compensation for loss of access in the earlier decisions rested on three propositions:

> First, when a street or road was laid out, compensation was presumed to be given not only for the land actually taken, but also for damages that might subsequently occur as a result of highway improvement. Second, the public occupied a position in law similar to that of a private property owner to his neighbor, and so was free to improve its land as it deemed best, notwithstanding the fact that such improvements might compel its neighbor to adjust the use of his own land to these changes. And finally, injury to abutting land due to improvements made wholly within the highway right of way did not constitute a taking of property in the constitutional sense.[18]

As densely developed urban areas appeared in the United States and the value of land depended greatly on its accessibility, the legal concepts began to change. A Kentucky court in 1839 recognized that streets were designed to serve both the public and the persons who owned property adjacent to the streets: "The title to such lots carries with it, as essential incidents, certain servitudes and easements, not only valuable and almost indispensable, but as inviolable as property in the lots themselves." [19]

In a later Ohio case,[20] the Court held that injury to an abutting landowner's access could constitute a taking within the meaning of the State constitution. In that case the landowner had lost all access to the street because of a 6-foot change in grade. The Court held that access to and from the abutting street was a distinct property right just as was ownership of the lot itself.[21]

"Between 1850 and 1880 the concept that property was 'taken' in the constitutional sense only if it was physically appropriated or destroyed was extended to include instances of interference with the landowner's use of his land." [22] In 1882, in *Story v. New York Elevated R.R. Co.*,[23] the Court gave further impetus to the view that abutting landowner's access was a property right. The Court held that the abutting property owner could recover for interference with light, air, and existing access where elevated railroads were constructed on public

[16] Goszler v. Georgetown, 6 Wheat (U.S.) 593 (1821).

[17] Callendar v. Marsh, 1 Pick. (Mass.) 417 (1823).

[18] NETHERTON, *supra* note 15, at 38.

[19] Lexington & Ohio R.R. Co. v. Applegate, 9 Dana (Ky.) 289, 294 (1839).

[20] Crawford v. Village of Delaware, 7 Ohio St. 460 (1857).

[21] *Id.* at 470.

[22] Netherton, "A Summary and Reappraisal of Access Control," in *Limited Access Controls and Their Administration*, *HRB Bull. 345*, (1962) p. 5.

[23] 90 N.Y. 122 (1882).

streets. The right of access, in relation to the abutting physical property, was "an incorporeal hereditament," was "appurtenant" to the lot, and constituted a "perpetual incumbrance." [24]

The *Story* case and others that followed held that the right of abutters arose by virtue of the proximity of their land to the street and the necessity for access to the street. No longer could it be argued that a right of the abutting owner was not taken simply because his land was not physically disturbed.[25]

The modern view of abutters' rights of access is clearly stated in another, but much more recent, Massachusetts case, *Cayon v. City of Chicopee.*[26] The highest Court noted that limiting of an adjacent owner's access without an actual physical taking may be compensable:

> It is well settled that a taking of private property for which compensation must be paid is not necessarily restricted to an actual physical taking of the property. This rule has long been recognized in this Commonwealth. In *Old Colony & Fall River R. R. v. County of Plymouth*, we stated that private property can be "appropriated" to public use "by taking it from the owner, or depriving him of the possession or some beneficial enjoyment of it." Likewise, the Supreme Court of the United States has stated that "(g)overnmental action short of acquisition of title or occupancy has been held, if its effects are so complete as to deprive the owner of all or most of his interest in the subject matter, to amount to a 'taking.' In line with the above rule, we have stated that the taking of an interest in adjacent property thereby limiting access to the owner's property constitutes a compensable taking, and that the setting of a building line constitutes an encumbrance on the land in the nature of an equitable easement for the benefit of the public and that, as such, it is a taking of private property for public use." (Citations omitted.)

Although the courts have stated various reasons for the modern view [27] of the rights of abutters, it is clear that today the term "property" includes an abutter's access to the street or highway.[28]

[24] *Id.* at 145–146.

[25] *Id.*

[26] 277 N.E.2d 116, 118 (Mass. 1971).

[27] See Netherton, *supra* note 15, at 44–48.

[28] Stoebuck, *The Property Right of Access Versus The Power of Eminent Domain*, 47 TEX. L. REV. 733, 734 (1969). In addition to the judicial evolution, the right may be created by legislative grant or by express agreement. For example, the breach of an express agreement may give rise to a claim for damages: in People, Dep't of Public Works v. DiTomaso, 57 Cal. Rptr. 293, 302 (1967) the State, pursuant to a right-of-way-contract, had agreed to construct a "road approach." The Court held that the agreement could not be abrogated because of new traffic demands without the payment of compensation. See also, Kenco Petroleum Marketers, Inc. v. State Highway Comm'n, 269 N.C. 411, 152 S.E.2d 508 (1967) where the Court held that forbidding construction of a driveway at a point designated in a right-of-way agreement entitled the owner to compensation.

AN OVERVIEW OF THE ABUTTING LANDOWNER'S RIGHT OF ACCESS

The issue is no longer the abutter's right of access; that right has been established. Rather, the question now is the amount of access to which he is entitled.

Property that abuts a highway has been held to have certain incorporeal or intangible rights or easements appurtenant to the property. The abutting landowner has easements of light, air, view, and access that constitute property, the taking or damaging of which may give rise to a requirement of compensation.[29] As the Court stated in *Hillerege v. City of Scottsbluff*,[30]

> [T]he right of an owner of property abutting on a street to ingress and egress to and from his premises by way of such street is a property right in the nature of an easement in the street which the owner of abutting property has, not in common with the public generally, and of which he cannot be deprived without due process of law and compensation for his loss.

Although the abutter may have, for example, 100 or 1,000 feet of frontage along an uncontrolled-access highway available to him for easy, direct access to the highway, he may not have necessarily a compensable loss should his access be partially restricted along the boundary. In other words, the courts have held that not every impairment of an abutter's access is compensable. The abutter is not entitled to complete access, only reasonable access.[31] Thus, the abutter in the foregoing example is not entitled to access at every point along his boundary.[32] The reason, of course, is that the public has a valid interest in the safety and convenience of travel, both of which may be impaired where unrestricted access exists along arterials.

Although some decisions hold that the right of access extends along the entire boundary,[33] these authorities, nevertheless, seem to be in agreement that the abutter's right is subordinate to the public's right of passage, and, therefore, may be reasonably limited without the payment of compensation.

Moreover, the abutter is not entitled to ingress and egress at any

[29] NICHOLS ON EMINENT DOMAIN, § 6.442, at 6-243.

[30] 164 N.D. 560, 83 N.W.2d 76, 84 (1957).

[31] The abutter, of course, may not be deprived of all access to the street or highway. See Annot., 73 A.L.R.2d at 659.

[32] NICHOLS, § 5.72[1], n. 15; State v. Ensley, 240 Ind. 472, 164 N.E.2d 342 (1960); Mueller v. N.J. Highway Authority, 59 N.J. Super. 583, 158 A.2d 343, 349 (1960); State Highway Comm'n v. Smith, 248 Iowa 689, 82 N.W.2d 755 (1957); Johnson v. Burke County, 101 Ga. App. 747, 115 S.E.2d 484 (1960); State v. Lanzell, 163 Ohio St. 97, 126 N.E.2d 53 (1955); State Highway Dep't v. Strickland, 213 Ga. 785, 102 S.E.2d 3 (1958); Wilson v. Iowa State Highway Comm'n, 249 Iowa 994, 90 N.W.2d 161 (1958).

[33] *See, e.g.*, Smith v. State Highway Comm'n, 185 Kan. 445, 346 P.2d 259 (1959); *In re* Appropriation of Easement for Highway Purposes, 93 Ohio App. 179, 112 N.E.2d 411, 415 (1952).

point that he might desire.[34] He is entitled to reasonable access, a concept that depends on whether he has "suitable" access under the circumstances to the adjacent street and from there to the general highway system. Determining whether access is suitable may depend, for example, on the difficulties in gaining access to the premises or whether the remaining access is suitable to meet the needs of the property for its highest and best use.[35]

The abutter's access is subject to reasonable control and regulation of the public authority. Examples of reasonable restrictions are traffic regulations prohibiting left turns,[36] creating one-way streets,[37] regulating vehicle weights,[38] regulating driveway openings by permits,[39] or restricting parking or the making of deliveries.[40]

In *City of Phoenix v. Wade*,[41] the Court held that the City was entitled to a jury instruction that the following items are not compensable: installation of NO PARKING signs and a curb; installation of a stop light; yellow lines dividing the street for east-bound–west-bound traffic; and an increase or decrease in the flow of traffic past the property. Nor is there a compensable impairment of access where the landowner is required to back out into the street.

Although these forms of regulation may affect the abutter's ease or convenience of access, they generally, absent some unusual circumstances, come within the category of noncompensable restrictions on access pursuant to the public authority's police power and constitute *damnum absque injuria*.[42]

Thus, the public authority under its police power may reasonably regulate highway traffic with its resulting significant impact on abutters' access.[43] As noted by one court, one who acquires property abutting a public road acquires it subject and subordinate to the right to have the

[34] See Fowler v. City of Nelson, 213 Mo. App. 82, 246 S.W. 638 (1923).

[35] See discussion in text on reduction of highest and best use, *infra*, at footnotes 70 to 76.

[36] Cavanaugh v. Gerk, 313 Mo. 375, 280 S.W. 51 (1926); Jones Beach Blvd. Estate, Inc. v. Moses, 268 N.Y. 362, 197 N.E. 313 (1935).

[37] Commonwealth v. Nolan, 189 Ky. 34, 224 S.W. 506 (1920); Chissel v. City of Baltimore, 193 Md. 535, 69 A.2d 53 (1949).

[38] Ferguson Coal Co. v. Thompson, 343 Ill. 20, 174 N.E. 896 (1931); Wilbur v. City of Newton, 310 Mass. 97, 16 N.E.2d 86 (1938).

[39] Lydy, Inc. v. City of Chicago, 356 Ill. 230, 190 N.E. 273 (1934); Pure Oil Co. v. City of Northlake, 10 Ill. 2d 241, 140 N.E. 2d 289 (1956); Breinig v. County of Allegheny, 332 Pa. 474, 2 A.2d 842 (1938).

[40] Village of Wonewoc v. Taubert, 203 Wis. 73, 233 N.W. 755 (1930).

[41] 5 Ariz. App. 505, 428 P.2d 450 (1967).

[42] See further discussion of the concept of *damnum absque injuria* in Netherton, "Damnum Absque Injuria and the Concept of Just Compensation in Eminent Domain," *supra* note 14, at 25 *et seq.*

[43] See By and Through State Highway Comm'n v. Burk, 200 Or. 211, 265 P.2d 783, 792 (1954), where the court noted that the establishment of one-way streets and traffic lanes, regulations as to speeding, parking, and permissible U-turns are generally held to be a proper exercise of the police power.

way improved to meet the public need.[44] The abutting property owner has no absolute right, as against the public, to insist that the adjacent highway always remain available for his use in the same manner and to the same extent as when it was constructed.[45]

The abutter is not entitled to insist that the current volume of traffic that passes by his business establishment be maintained. He is not entitled to have, as an element of his property right, his economic status quo maintained.[46] "All traffic on public highways is controlled by the police power of the State, and what the police power may give an abutting property owner in the way of traffic, it may take away."[47]

The law of access "does not include any right to develop property with reference to the type of access granted or to have access at any particular point on the boundary line of the property."[48]

The abutter's right of access includes having his property reasonably accessible to others. Moreover, the abutter has the right to enter and leave the street from the abutting property in a reasonable manner to the general system of public roads. Many, if not all, the methods of controlling access to existing, uncontrolled-access highways cause the abutter, or his patrons, to travel some additional distance before being able to enter or leave the premises. This effect quite often is referred to as "circuity of travel." Many authorities point out that the abutter's right to access does not include the right to have the most direct, or the shortest, route to gain entry to the public highway. Although the courts state that there is no compensable damage for "mere circuity of travel," this phrase appears to be only another way of saying that distance in and of itself does not make the remaining or existing access unreasonable.[49] Where the access is changed and entails a more circuitous route, the abutter shares the same inconvenience as the general public, although perhaps to a greater extent. The question as always is whether the abutting property owner has suffered some special injury, as contrasted to that suffered by the general public.[50]

The public authority may go further than restricting direct access. It may eliminate direct access and provide the abutter with substitute

[44] Weir v. Palm Beach County, 85 So. 2d 865 (1956).

[45] By and Through State Highway Comm'n v. Burk, 200 Or. 211, 265 P.2d 783 (1954).

[46] Tubular Service Corp. v. Comm'r State Highway Dep't, 77 N.J. Super. 556, 187 A.2d 201 (1963).

[47] Wolf v. Commonwealth, Dep't of Highways, 422 Pa. 34, 220 A.2d 868, 875 (1966). See further discussion of diversion of traffic in text, *infra*, at footnotes 80 to 94.

[48] Surety Savings and Loan Ass'n v. State Dep't of Transp., 54 Wis. 2d 438, 195 N.W.2d 464, 467 (1972).

[49] NICHOLS, § 5.72(1), at 5–165.

[50] *See, e.g.*, State v. Hastings, 246 Ind. 475, 206 N.E.2d 874, 877 (1965) (giving jury instruction to consider loss of profits held error); State v. City of Terre Haute, 250 Ind. 613, 238 N.E.2d 459, 462 (1968); Hanson v. City of Omaha, 157 Neb. 403, 59 N.W.2d 622, 629 (1953). See discussion of circuity of travel in text, *infra* at footnotes 70 to 79.

access by a service or frontage road.[61] This substitution of an alternative means of access is held generally to be noncompensable under one of two theories as long as the access provided is reasonable to meet the needs of the affected property.[62]

COMPENSATION REQUIRED FOR A TAKING OR DAMAGING OF ABUTTING PROPERTY OWNER'S ACCESS

In 16 States and the United States Constitution, the constitutional provision is that private property shall not be "taken" for public use without just compensation; in 22 states, the constitutional language requires compensation for property "damaged" as well as "taken."[63] Two states, New Hampshire and North Carolina, apparently have no express constitutional provision that requires compensation to be made when private property is taken for public use; however, it is settled that private property in these states may not be taken without payment of just compensation.[64] The remaining ten states have some variation of the "taken" or "taken or damaged" clauses, such as "appropriated to," "taken or applied to," or "taken, damaged or destroyed for, or applied to."[65]

Appropriation by Condemnation

The public authority, where it is unable to acquire property by purchase, must acquire it by condemnation. Where it condemns the rights of access of the abutting landowner, just compensation must be paid. Although the outright acquisition of access rights is one method to inhibit functional obsolescence of highways, it is undoubtedly an expensive one.

Of course, in a condemnation proceeding for the taking of physical property, it is important not to condemn access rights unless that is the intent. Moreover, it should be borne in mind that the same result—

[61] See definition in *Highway Capacity Manual*, *supra* note 6, at 9.

[62] *See*, *e.g.*, State v. Danfelser, 72 N.M. 361, 384 P.2d 241 (1963); Iowa State Highway Comm'n v. Smith, 248 Iowa 869, 82 N.W.2d 755 (1957); Holbrook v. State, 355 S.W.2d 235 (Tex. 1962). See discussion in text of substitute or alternative access, *infra*, at footnotes 171 to 188.

[63] See Netherton, "Damnum Absque Injuria and the Concept of Just Compensation in Eminent Domain," *supra* note 14, at 42-45, 65, 73, Table 1. The existence of the "damaging" clause in the latter does not appear to have any significant impact on the decisions concerning access, Annot., 42 A.L.R.3d 13, 23, except possibly, according to some commentators, in those cases involving change of grade. STOEBUCK, *supra* note 28, at 758. See discussion of change of grade in text, *infra*, at footnotes 122 to 138.

[64] See Pistaque Bridge Proprietors v. New Hampshire Bridge, 7 N.H. 35 (1834) and Yancey v. North Carolina State Highway and Public Works Comm'n, 222 N.C. 106, 22 S.E.2d 256, 258 (1942).

[65] See Netherton, "Damnum Absque Injuria and the Concept of Just Compensation in Eminent Domain," *supra* note 14, at 42–45.

control of access—may be accomplished by a reasonable restriction of existing access without the necessity of purchase or condemnation.[66]

For example, *Smith v. State Highway Comm'n*[67] was a proceeding in eminent domain that involved on appeal the sole issue of restriction of access. As part of the proceeding, the State acquired the rights of access along a limited portion of the landowners' frontage on an existing highway. Although the landowners had the same entrance to their property as before the proceeding, they no longer had access along 1,410 feet of the property abutting the highway.

The State's position was that it was not acquiring the rights of access by eminent domain but that it had the right and the authority in the interest of public safety to regulate the property owner's access by limiting access to the existing entrance. The Court, however, held that there was a taking that required the payment of just compensation. The Court noted that

> if the Commission *acquires* the rights of access of an abutting property owner on an existing highway, pursuant to 68–1903, *supra*, the Commission has *absolute control* and may prohibit, at will, any further entrances to the portion of the land along which access rights have been *acquired*.[68]

Substantial or Unreasonable Impairment of Access

In order for there to be a "taking" or "damaging" in the constitutional sense, it is not necessary that access rights be acquired directly. Action of the public authority, in making highway improvements or alterations or implementing traffic regulations, may hamper, restrict, impede, or limit an abutting landowner's present access. However, not every governmental impairment of access gives rise to the requirement of compensation.

The extent of impairment that is compensable has been articulated in a number of ways by the courts and commentators. Only if the public authority unreasonably impairs or substantially impairs existing access will it be held liable. Loss of access is not compensable where the property owner retains a reasonable means of ingress and egress to the highway. "It follows that the owner must be entitled to show what

[66] It is possible for the highway authority to condemn a parcel of land for highway improvements and simultaneously impair access without paying compensation for the latter. For example, in Wolf v. Commonwealth, Dep't of Highways, 422 Pa. 31, 220 A.2d 868 (1966), the State condemned a portion of the property and, at the same time, constructed curbs that permitted access at two points and erected median dividers on the highway. The trial court admitted evidence of the construction of the medial barriers and curbs and permitted the jury to consider the impact of those factors in arriving at the after-value of the property. The decision was reversed, however, on the basis that the partial taking of the physical property bore no relation to the construction. The court held that Wolf retained reasonable and convenient, although circuitous, access.

[67] 185 Kan. 445, 346 P.2d 259 (1959).

[68] 346 P.2d at 271.

he will have left in the way of access before it can be determined whether it is reasonable."[89] Moreover, "whether or not a material impairment of access exists must be determined in each case upon the basis of the factual situation present, and each case must be considered on its own right. Material impairment of access cannot be fixed by abstract definition."[90]

When denying compensation, quite often the courts will state that the injury complained of falls within the "police power" of the government or is *damnum absque injuria*. Such statements are more like conclusions or a statement of the result rather than an analysis of the factors that lead to that result. In deciding these cases, the courts must weigh the facts of each case to determine whether the action is taking or damaging in the constitutional sense or is a reasonable exercise of the police power. As will be seen, drawing the line between eminent domain and the police power is not an easy one. Although the Supreme Court said in *Berman v. Parker*[91] that "an attempt to define its [police power's] reach or trace its outer limits is fruitless, for each case must turn on its own facts," this section attempts to identify some of the factors considered by the courts in deciding whether there has been a compensable interference with access.

One commentator has noted that a number of doctrines have been developed by the courts in attempting to define what is a compensable loss of access; however, he suggests the following analysis:

> When right of access is involved, we have only to establish that access has been diminished. Since we defined access as "reasonable" access, there can be a taking only if the diminution is "unreasonable" or "substantial." What is "substantial," of course, is a question of fact that poses practical problems of proof and of measurement of the facts as found against the legal standard.[92]

The following cases serve to illustrate the general principle that there is a compensable "taking" or "damaging" of access only when the access is substantially or unreasonably impaired.

Loss of Direct Access as a Factor

As noted, the abutter is not entitled to "direct" access. In *State Dep't of Transp. v. ABS, Inc.*,[93] a condemnee claimed severance damages for impairment of access to a shopping center caused by the construc-

[89] Roettger, G. & Dickson, A., *Improper Hybridization of Police Power*, 6 URBAN LAWYER 603, 616 (1974).

[90] *Id.* at 616.

[91] 348 U.S. 26, 32, 75 S.Ct. 98, 99 L.Ed. 27 (1954).

[92] STOEBUCK, *supra* note 28, at 765.

[93] 336 So. 2d 1278 (Fla. App. 1976). *Compare*, People v. Riccardi, 144 P.2d 799, 804 (1943) and State v. Thelberg, 87 Ariz. 318, 350 P.2d 988 (1960). See discussion in text on substitute access in lieu of direct access, *infra*, at footnotes 171–188.

tion of an overpass that deprived the property of direct access. Northbound traffic now had to travel an additional 100 yards and southbound traffic an additional 123 yards to reach the property. The Appellate Court held that the trial judge improperly instructed the jury when he charged that the condemnee was entitled to damages for loss of direct access:

> . . . the right to such compensation doesn't depend upon whether the right of access taken was a *direct* route of access; rather, it appears the question is whether, where as here some right of access is still available, there has been a *substantial diminution in access* as a result of the taking. It is rudimentary, of course, that is for the jury to determine whether such diminution in access is nominal or substantial.[94]

Difficulty of the Remaining Access

The difficulty in gaining access to property is clearly a factor in determining whether remaining access is unreasonable. In *State v. Dunard*,[95] it appeared that the access to the remaining property following the condemnation of a portion of farmland would be impaired to the extent that it would be difficult or impossible to move agricultural equipment unless a bridge was built over creeks and low-lying areas. At trial, the State sought to amend its petition to show the proposed construction of new access, to which the landowners objected on the basis that the same might not be constructed. Although the amendment was allowed by the Court, it should be noted that the Court indicated that, without the additional access, under those circumstances the owners should be compensated for loss of access.[96]

Merely because access is rendered more difficult, or even nearly impossible, by the highway improvement does not mean that the courts will find a compensable loss of access. It must be shown that the governmental action has interfered with the method of ingress and egress to an unreasonable extent. If the abutter has been injured by inconvenience (circuity) or by diversion of traffic, rather than an unreasonable impairment of access, then compensation may not be awarded.[97] The abutter may find it difficult to make a sufficient showing of loss of access if, for example, his access has been unsuitable all along.

This point is illustrated by *Tubular Service Corp. v. Com'r of State Highway Dep't*[98] involving a commercial structure fronting on a 4-lane highway. The abutter's business was such that steel rolls could be delivered only by trailer trucks. Before the highway improvements, which included a center barrier divider, the trucks when going south

[94] 336 So. 2d at 1280.

[95] 485 S.W.2d 657 (Mo. 1972).

[96] *Id.* at 658.

[97] See discussion of circuity of travel and diversion of traffic in text, *infra*, at footnotes 77 to 94.

[98] 77 N.J. Super. 556, 187 A.2d 201 (1963).

had to swing across the opposing traffic lanes in order to turn into the property. After erection of the barrier the trailer trucks could enter from neither direction. Vehicles proceeding north were prevented by the barrier from turning left to enter the property, and vehicles proceeding south were unable to cross the opposing lanes to make the turn.

It would appear that the barrier had rendered the access unsuitable for this type of use. However, the Court concluded that the abutter had access to the roadway; no impediment, it noted, existed between the boundary of the property and the roadway. Moreover, the Court held that the State's action did not deprive the owner of suitable access but merely exposed what had been unsuitable access all along:

> The State's action here has simply exposed the functional unsuitability of plaintiff's land and structure, as presently constituted, to accommodate reception of freight carriers of the size necessary to deliver the particular merchandise plaintiff handles. Different land dimensions or further setback of the structure from the curb line would solve plaintiff's problem. The State is not called upon to refrain from highway improvements to serve the general welfare at peril of having to compensate plaintiff for the inadequacy of its freight reception facilities.
>
> If plaintiff no longer has any suitable access to his property, this should be regarded, we repeat, as attributable not to the entirely proper action of the defendant but to the unsuitable disposition of his facilities for his particular commercial needs and purposes.[69]

Reduction in Highest and Best Use

Another factor to be considered in determining whether the remaining access is unreasonable is any reduction in the highest and best use of the property attributable to the impairment of access. An illustration is *Rose v. State*[70] in which the owner of abutting property, zoned industrial but used as a fruit orchard, had 118 feet of frontage on a street. In order to eliminate a railroad crossing, a subway was constructed in the middle of the street with traffic lanes on each side. The Court agreed with the landowner that there was particular inconvenience and impairment of access that was not shared generally by the public. The owner was entitled to compensation, because the traffic lanes were not capable of supplying the necessary ingress and egress for the industrially zoned property. Because of the nonaccessibility of

[69] 187 A.2d at 206. The Court noted that it could have decided the case on the basis that the previous method of access was unlawful in that it violated traffic laws: "It seems clear that where the action of the State complained of as impairing highway access to private property does not interfere with lawful means of access but only prevents vehicular access effected in a manner necessarily violative of reasonable highway safety statutes, no claim of compensable taking can be founded thereon." *Id.*, at 204.

[70] 19 Cal. 2d 713, 123 P.2d 505 (1942).

the property, it could not be put to the same uses after the construction as it had before the construction.

As stated, the reduction in the highest and best use must be attributable to unsuitable, remaining access. Two cases, *Priestly v. State,*[71] and *LaBriola v. State,*[72] addressed the problem of reduction in the highest and best use of the property and whether the cause was an unreasonable impairment of access.

Priestly v. State, supra, involved a partial taking of property for highway and bridge approach purposes. The parcels taken included frontage of about 200 feet on the east side of the bridge approach and were taken without any right of access to the bridge approach. The evidence established that the highest and best use of the property was reduced from commercial to residential and that the sole remaining access to the property was quite circuitous. The issue on appeal was whether the remaining access was merely inconvenient or was, in fact, unsuitable. The Appellate Court had set aside an award of damages to the remainder for loss of access on the basis that there could be no recovery for "mere circuity" of travel.

The highest court reversed, holding that the trial court, on the facts, could properly find that the access was unsuitable. The Court held that, although the remaining access may be "circuitous" or inconvenient, that fact does not mean that the remaining access is not also unsuitable.

> Case law has indicated that mere inconvenience of access is insufficient to constitute unsuitability and that "suitable access now is any access by which entrance may be had to a property without difficulty and, further, that the question of suitability is a factual one directly related to the highest and best use of the property."
>
> "Circuitous," in its commonly accepted understanding, indicates that which is round-about and indirect but which nevertheless leads to the same destination. "Suitable," in its commonly accepted understanding, describes that which is adequate to the requirements of or answers the needs of a particular object. The concepts are not mutually exclusive and, therefore, a finding that a means of access is indeed circuitous does not eliminate the possibility that the same means of access might also be unsuitable in that it is inadequate to the access needs inherent in the highest and best use of the property involved.[73]

In *Priestly,* the evidence established to the Court's satisfaction that the remaining access not only was circuitous and inconvenient but also was unsuitable for its previous highest and best use.

In *LaBriola v. State, supra,* the issue was whether the reduction in highest and best use was the result of loss of access or mere diversion of traffic. There the State had condemned a parcel of property and at

[71] 23 N.Y.2d 152, 242 N.E.2d 827 (1968).

[72] 36 N.Y.2d 328, 328 N.E.2d 781 (1975).

[73] 242 N.E.2d at 829–830.

the same time relocated much of the existing route on which the property had fronted previously. After the relocation, the property, zoned for retail business, had a reduced corner frontage on the old road and a 150-foot spur connection to the new route. The Court held that the reduction of the highest and best use of the property was not caused by a loss of access or the appropriation of the frontage but by the State's relocation of the highway that diverted traffic from the front of the property.

The Court in its opinion noted that diversion of traffic is not compensable:

> An owner is not entitled to compensation for loss of "frontage" resulting from the discontinuance of a highway on which his property abutted, as distinguished from the taking of frontage property. He had no vested interest in the continuance of a highway or its traffic. The highway and its traffic rise from a function of the State and are not a product or utility of the property, [sic] Even if the relocation diverts traffic, impairing the land's commercial value, it is *damnum absque injuria.* The benefits of highway contiguity having been freely bestowed may be freely and even arbitrarily retracted. (Citations omitted.)[74]

In both *Priestly* and *LaBriola,* before the State is required to pay compensation, there must be a loss of reasonable or suitable access that results in the property's inability to sustain its highest and best use.[75] In *LaBriola* the Court held that suitable access remained, whereas in *Priestly* the evidence supported the trial court's finding that access after the taking was unsuitable for the use to which the property had been best suited.

These three cases, *Rose, Priestly,* and *LaBriola,* illustrate the proposition that the reduction in highest and best use is a factor to consider but that it must be shown that it is the loss of access that has caused the change in the use of property. The cases demonstrate the difficulty the courts encounter in determining whether a substantial or unreasonable impairment of access exists. As the Court admitted in *LaBriola,* the question is largely one of fact.[76]

[74] 328 N.E.2d at 783.

[75] 328 N.E.2d at 784. *Compare* State v. Beatty, 288 So. 2d 900 (La. App. 1973), involving a partial taking in which the Court affirmed a trial court verdict awarding damages to the remainder for loss of access. Access had been reduced because the property had been limited to a dead-end service road three-quarters of a mile from the interchange with the result that the highest and best use of the property was reduced from highway commercial to residential. The Court held that "the inconvenience and diversion of traffic which will result from this expropriation diminished the value of defendant's remaining property by changing its highest and best use from highway commercial to residential. The inconvenience and diversion of traffic are thus proper elements of severance damages in this case."

[76] 328 N.E.2d at 785.

Circuity of Travel

Circuity of travel is not the only factor to be considered, but the distance that the abutting landowner, his patrons, or customers must travel to enter and exit the property after an impairment of existing access is considered in determining whether access is reasonable. Of course, the factors discussed previously may be equally or more important.

Standing alone, increased distance is probably insufficient in most cases to establish a compensable loss of access; however, one authority, after an analysis of numerous cases involving distances to access ramps or interchanges leading to limited-access highways, made the following conclusions concerning distance as a factor:

> Naturally, cases involving shorter distances, such as those of less than 500 feet or between 500 and 999 feet, are more likely to find that the landowner has not been deprived of reasonable, substantial, or natural access, and therefore deny him compensation while cases involving distances of from 1,000 to 2,999 feet, or even greater distances, are more evenly divided between those denying compensation for limitation of access and those allowing it.[77]

Each of these cases turns on its particular facts, and a precise standard or rule-of-thumb, unlike some cul-de-sac cases,[78] simply cannot be stated. Indeed, a circuitous distance of up to 4 miles has been held not unreasonable as a matter of law.[79] Although the abutter may have a greater distance to travel following highway improvements or alterations, his right of access is one of being able to enter and leave the highway and have a reasonable connection to the system of public roads.

Diversion of Traffic

Although a claimant may contend that many items should be included as elements of damage, the element frequently pressed for inclusion is diversion of traffic, which, of course, may result in loss of business.

Ordinarily, the abutting property owner may not recover damages for any loss of business or diminution in value of the property due to

[77] See Annot., *Abutting Owner's Right to Damages for Limitation of Access by Conversion of Conventional Road into Limited-Access Highway,* 42 A.L.R.3d 13, 25.

[78] See discussion of cul-de-sac cases in text, *infra,* footnotes 150 to 170.

[79] *See, e.g., In re* Condemnation, etc., and Commerce Land Corp. v. Commonwealth of Pennsylvania, Dep't of Transp., 361 A.2d 769, 471 (Commonwealth Court 1976); see also, State *ex rel.* Moore v. Bastian, 97 Idaho 444, 546 P.2d 399 (1976) (one-half to two blocks); LaBriola v. State, 36 N.Y.2d 328, 328 N.E.2d 781 (1975) (150 feet); New v. State Highway Comm'n, 297 So. 2d 821 (Miss. 1974) (400 feet); Wolf v. Commonwealth, Dep't of Highways, 422 Pa. 34, 220 A.2d 868 (Pa. 1966) (1500–1700 feet); Houghs v. Mackie, 1 Mich. App. 554, 137 N.W.2d 289 (1965) (½ to ¾ mile).

the impairment of his access.[80] For example, in *Wolf v. Commonwealth, Dep't of Highways,*[81] the State condemned a tract of land improved with a gasoline station, motel, and a residence. It constructed curbs and medians and provided for ingress and egress to the remaining property at two points. The trial court admitted evidence of the impact of the improvement on eastbound traffic and allowed the jury to consider that factor in arriving at the after-value of the property.

The decision was reversed on appeal. The Court held, first, that reasonable access existed to the property, even though eastbound traffic desiring to proceed to the Wolf property would have to proceed 1,500 to 1,700 feet east of the property and then make necessary turns to reach the premises.[82] Secondly, the Court held that the diversion of traffic, even though it resulted in a diminution of the value of the property, was not an element properly to be considered in determining the after-value of the property. The "injury" claimed to have been suffered was too remote to form an element of damage and constituted *damnum absque injuria.*[83]

Usually, courts are of the opinion that whatever the police power may provide an abutting landowner, it may take away.[84] The State has no duty to maintain the traffic on a certain highway for the business establishments that may abut the highway.[85]

As noted in the discussion of *LaBriola v. State,*[86] one must be careful to distinguish loss of access, which may be compensable, from diversion of traffic caused by a relocation of traffic, which is not compensable. No precise rule can be stated to define the distinction clearly, because the result in each case must depend on its particular circumstances.

A decision that has been read to permit an award for diversion of traffic is *People v. Riccardi,*[87] a 1944 Supreme Court of California case. In that case, substantial changes were made in the boulevard in front of the claimant's business, including substantial widening, use of an underpass, and service roads. The Court recognized that the owner was not entitled to damages for re-routing of traffic; however, the Court proceeded to distinguish re-routing of traffic from re-routing of the highway:

> But here we do not have a mere re-routing or diversion of traffic from the highway; we have, instead, a substantial change in the highway itself in relation to the defendant's property; i.e., a re-routing of the highway in relation to defendants' property rather than a mere re-routing of traffic in relation to the highway. Defendants' private property rights in and to that highway are to be taken and damaged. It is only for such private property rights that compensation has been assessed. The Court allowed no damages to be predicated on any diversion of traffic from the highway but it did properly allow damages to be based on diversion of the highway from direct access to defendants' property.[88]

The above-quoted language, as well as other pertinent rulings by the majority, brought a vigorous dissent: "If this language means anything, it creates in an abutting owner a vested right in a specific traffic avenue carrying a particular burden of traffic."[89] The dissent appears to be in accord with the majority rule, and other courts have declined to follow the reasoning of the majority opinion in *Riccardi.*[90]

In addition to *Riccardi*, another decision permitting testimony concerning diversion of traffic and loss of business in determining the after-value of the property is *State v. Wilson.*[91] In *Wilson*, very scenic property, including a motel and guest ranch, was situated on a 4-lane divided highway. In condemning a parcel of property for the conversion of the State route into an interstate highway, the State made access available at an interchange 800 to 900 feet from the property.

The Court held that expert testimony at trial that the market value of the property was substantially reduced by the loss of direct access to the highway was proper. In defining access, the Court stated that for it to have substantial utility, it must necessarily include the owner's invitees and licensees.[92] Although an abutting property owner may not insist that traffic pass over the highway in front of his property undiverted and unobstructed, "this does not mean that if traffic is using the highway an abutting property owner may not profit from its flow . . . manifestly it is the restriction of the access which has reduced the business profits and, therefore, the valuation as a commercial property."[93]

The Court stated that it is proper to instruct the jury not to consider any claim of loss or impairment of business and that the law permits damages for injury to property but not to business conducted thereon. However, the Court held that it is proper to consider the amount of traffic flow as support for the expert's opinion that the value of the property was diminished through loss of accessibility to such flow.[94]

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[80] State v. Peterson, 134 Mont. 52, 328 P.2d 617 (1958); Commonwealth, Dep't of Highways v. Wooton, 507 S.W.2d 451 (Ky. 1974). According to Narciso v. State, 328 A.2d 107 (R.I. 1974), the majority of courts have refused to grant compensation for diversion of traffic. People *ex rel.* v. Ayon, 54 Cal. 2d 217, 5 Cal. Rptr. 151, 352 P.2d 519 (1960); State v. Ensley, 240 Ind. 472, 164 N.E.2d 342 (1960); Jacobson v. State Highway Comm'n, 244 A.2d 419 (Me. 1968); Painter v. State Dep't of Roads, 177 Neb. 905, 131 N.W.2d 587 (1964); State Comm'r of Transp. v. Monmouth Hills, Inc., 110 N.J. Super. 449, 266 A.2d 133 (1970); State v. Fox, 53 Wash. 2d 216, 332 P.2d 943 (1958).

[81] 422 Pa. 34, 220 A.2d 868 (Pa. 1966).

[82] 220 A.2d at 870.

[83] *Id.* at 874.

[84] *Id.* at 875.

[85] *Id.*

[86] See discussion in text on reduction of highest and best use, *supra*, at footnotes 70 to 76.

[87] 144 P.2d 799 (1943).

[88] *Id.* at 804.

[89] *Id.* at 816.

[90] *See, e.g.*, State v. Peterson, 328 P.2d 617 (Mont. 1958).

[91] 103 Ariz. 194, 438 P.2d 760 (1968).

[92] 438 P.2d at 762.

[93] *Id.* at 763.

[94] See also, Commonwealth, Dep't of Highways v. Burns, 394 S.W.2d 923 (Ky. 1965); and Dep't of Highways v. Sea, 402 S.W.2d 842 (Ky. 1966). According to Narciso v. State, 328 A.2d 107 (R.I. 1974),

LEGAL IMPLICATIONS OF SPECIFIC ACCESS CONTROL METHODS

Not all the various methods of access control available to the highway agency are discussed in this paper. The legal principles and reasoning, however, that are applied in access cases are thought to be amply illustrated by the following cases having to do with the areas that are frequently the subject of litigation.

Medians

Certainly, there exist numerous cases involving alleged deprivation or unreasonable impairment of access caused by the installation of medians [95] in the street or highway.

Medians are said generally to be one of three types: [96] The traversable median as the name suggests is not a physical barrier to traffic movements and may be painted stripes, buttons, or contrasting colors or textures. The deterring median may have one or more of the aforementioned features and some type of physical barrier, such as a rolled asphalt curb, bars or corrugations, or a mountable curb. Finally, the barrier median is one that traffic cannot cross intentionally and may be a curb, guardrail, wall, or open ditch. Medians may be used to insulate opposing streams of traffic, protect and control turning traffic; protect pedestrians while crossing; channel traffic; and move traffic at higher speeds.[97]

The objections to such access control are readily apparent. Businesses, formerly having direct access to traffic in both directions, may be accessible from one direction only. Motorists may have to travel beyond the premises to the next median opening in order to turn or be forced to make several turns before reaching the premises. Commercial establishments may believe that the result of such access control is loss of business and a lower value of the abutting property.[98]

Following the construction of medians, the abutting landowner may bring an action in inverse condemnation claiming that he is entitled to damages for a taking or damaging of his access. However, unless the abutter can prove that his loss of access is substantial and that his

there is a line of cases that hold that loss of access due to rerouting of traffic has been held to be a relevant factor in determining the loss in fair market value suffered by the property. See McRea v. Marion County, 222 Ala. 511, 133 So. 278 (1931); State ex rel. Morrison v. Thelberg, 87 Ariz. 318, 350 P.2d 988 (1960); Riddle v. State Highway Comm'n, 184 Kan. 603, 339 P.2d 301 (1959); State Dep't of Highways v. Bagwell, 255 So. 2d 852 (La. App. 1971); South Carolina State Highway Dep't v. Wilson, 254 S.C. 360, 175 S.E.2d 391 (1970).

[95] A median may be defined as that portion of a divided highway separating the traveled ways for traffic in opposite directions. See *Highway Capacity Manual*, *supra* note 6, at 10. The Manual also defines lane separators, outer separators, and traffic islands.

[96] "Guidelines for Median and Marginal Access Control on Major Roadways," *National Cooperative Highway Research Program Report 93* (1970) p. 69.

[97] *Id.*

[98] *Id.*

remaining access is unsuitable, he will not be entitled to damages. The phrases often employed by the courts are that the injury caused by the highway improvement is *damnum absque injuria*, is a reasonable exercise of the police power, or amounts to "mere inconvenience." All of these statements are but a way of stating the principle that there must be a substantial or unreasonable impairment of access before the public authority is deemed to have taken or damaged access in the constitutional sense.

The courts have held that the abutting property owner is not entitled to damages for loss of business or for consequential damages for the diminution in value of the adjacent land where abutters and patrons are relegated to more circuitous access. In *Langley Shopping Center v. State Roads Comm'n*,[99] involving two large shopping centers, the State divided the street into a 4-lane, dual highway in front of the abutting properties with a planned median strip. The result of the construction was that left turns could not be made directly into the property; nevertheless, the Court held that there was reasonable access to the highway.

Construction of medians may accompany a taking of a parcel of the adjoining property. Again the rule is the same; the abutting landowner is entitled to damages for impairment of access as an element of severance damage only where he shows that there has been an unreasonable impairment of his access to his remaining property. For example, in *State ex rel. Moore v. Bastin*,[100] involving a partial taking of property used as a grocery supermarket and parking lot, the street bounding the south and west sides of the remainder were to be widened. The State proposed to construct a raised centerline median in one street that would prohibit traffic on that street from turning left across the flow of traffic at any point except at the street intersection. A yellow, double line median was proposed for the other street. The evidence established that all traffic could reach the property from either street by traveling no more than one-half to two blocks around the property. The defendants at trial were permitted to show, over the State's objection, that these medians would discourage patronage and injure the value of the land remaining following the actual taking.

The Court held that the State's requested instruction, that the jury be advised not to award damages for any injury that they might find to have been caused by the medians, should have been granted:

> The taking of defendants' property through the process of eminent domain and the consequent damage to the remaining property had no necessary relationship to the median construction. The placement of the medians and any consequent injury such might cause are the results of an exercise of the State's police power rather than a taking under its power of eminent domain.
>
> While it is true that defendants have a property interest in access to

[99] 213 Md. 230, 131 A.2d 690 (1957).

[100] 97 Idaho 444, 546 P.2d 399 (1976).

> public streets, nevertheless not all impairments of that right by the State are compensable or *per se* unreasonable. The right of access does not encompass a right to any particular pattern of traffic flow or a right of direct access to or from both directions of traffic and we find no compensable impairment of access here. All who wish to reach defendants' property could do so with relatively minor inconvenience. (Citations omitted.)[101]

Similarly, in *New v. State Highway Comm'n* [102] the Court held that the abutting landowners suffered mere inconvenience and not a compensable impairment of access where they would have to travel an additional 400 feet to reach a crossover after a median strip was built in the highway.

Curbs, Curb Openings, and Driveways

Public control over curbs, curb openings, and driveways is, of course, another method to control highway access. The abutting landowner may be either trying to secure additional openings or trying to retain the ones that he already has. If he is denied additional access or is deprived of existing openings, he may seek damages for denial or loss of access.

That this method of access control is important is revealed by a review of some of the findings of available technical publications. Current driveway design location and traffic control practices have resulted in through traffic suffering from poor access control.[103] Moreover, each direct access driveway can degrade the traffic service function of the highway. As land use intensifies along an arterial highway, the sequential effect of more closely spaced driveways with higher driveway volumes can jeopardize the travel time, capacity, and safety of the highway.[104] Highway safety, as it relates to driveways, although the statistical evidence is somewhat difficult to obtain, is thought to be an important objective when considering this type of access control.[105]

Whether there was reasonable access via curb openings was the issue in a partial taking case, *Painter v. State, Dep't of Roads.*[106] The plaintiffs sought to recover damages for the parcel taken, as well as damages to the remaining parcel for loss of access. The land was occupied by a building used as a tavern, a vacant cafe, and a garage. Because of heavy traffic and safety hazards at nearby intersections, the State undertook to widen streets and construct traffic islands. Prior to this construction, traffic moved in and out of plaintiffs' property from the west at any point. However, after the construction, access from the west was by three 30-foot curb cuts. To the south, an entrance of 28 feet in width remained as before, but it was claimed that a traffic island caused some interference with access. Southbound traffic was prevented from turning into the property from the west by a traffic island that extended along the west side of the property. Plaintiffs claimed to have lost parking space for six automobiles and alleged that one-way lanes at the traffic islands "fenced out" plaintiffs' customers.

The Court did not agree with plaintiffs' contentions that the curbs and islands constituted an unreasonable interference with access and held that three 30-foot curb cuts constituted reasonable access to the premises.[107] Moreover, the plaintiffs were not entitled to damages because the traffic islands prevented left turns into the property from the west, the Court holding that the plaintiffs were complaining merely of circuity of travel caused by a reasonable regulation of traffic.[108]

Similarly, in *State Highway Comm'r v. Kendall,*[109] the State erected curbing and a guardrail along the entire frontage. Although the State granted five curb opening permits, approximately 242 feet of the frontage of the property had no access. Not surprisingly, the Court held that the abutting property owner was not denied reasonable access.[110]

These cases illustrate the general rule that where the right of access to land abutting on a highway is impaired or diminished, there is not a taking or damaging requiring compensation unless the impairment is so substantial that the property is left without reasonable, suitable access. That is, a curb opening or driveway must be reasonably suited for the permitted use of the land.[111] Moreover, it has been held that it is reasonable exercise of governmental discretion to order the closure of certain curb cuts where it appears that it has been some years since they were used.[112]

Thus, public authorities may deny applications for driveway permits

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[101] 546 P.2d at 402; See Richley v. Jones, 38 Ohio St. 2d 64, 67 Ohio Op. 2d 78, 310 N.E.2d 236 (1974), holding that construction of a median strip resulting in inconvenience of access, and not loss of access, was not compensable and that the fact that the median strip was constructed on land taken from the abutting owner did not alter the result.

[102] 297 So. 2d 821 (Miss. 1974).

[103] See FHWA REPORT No. 76-85, *supra* note 4, at 16.

[104] *Id.*

[105] *Id.* at 6.

[106] 177 Neb. 905, 131 N.W.2d 587 (1964).

[107] 131 N.W.2d at 590; *See also*, Wilson v. Iowa State Highway Comm'n, 90 N.W.2d 161 (Iowa 1958), holding that three curb openings, each 34 feet wide, may afford reasonable access from the highway to a restaurant and service station serving cross-country trucks.

[108] 131 N.W.2d at 590. See discussion of circuity of travel in text, *supra*, at footnotes 77 and 79. See Narciso v. State, 328 A.2d 107 (R.I. 1974), where the record indicated that the trial court had awarded damages to the remainder for loss of access largely on the basis that the curbing required rerouting of traffic. The Court, holding that this was error, remanded the case for further finding on the question whether the installation of the curbing amounted to a substantial denial of access. *Id.* at 112.

[109] 107 N.J. Super. 248, 258 A.2d 33 (1969).

[110] 258 A.2d at 36. *See also*, State Highway Dep't v. Strickland, 213 Ga. 785, 102 S.E.2d 3 (1958) (all the highway curbing placed in the existing right-of-way and no physical property taken).

[111] *See, e.g.*, Elder v. Mayor of New Port, 57 A.2d 653 (R.I. 1948).

[112] Johnston v. Boise City, 390 P.2d 291 (Idaho 1964).

and curb openings or close existing ones in some instances without the payment of compensation where there exists reasonable access. In a few instances, it appears that on the basis of traffic safety all vehicular access was denied without the requirement of compensation.[113] Moreover, reasonable access need not be directly from the property to the street if the owner has access to and from one lot through another lot. It is proper for the city to consider the fact that an unsafe traffic situation already exists without another driveway.[114]

There is no compensable claim for loss of driveway access unless the owner can demonstrate that the remaining access is no longer suited to the highest and best use of the property. That the claimant's trucks, for example, must do substantial maneuvering after the impairment of access in order to use a semicircular driveway on the property may be inconvenient, but is not necessarily unsuitable, access.[115] Closing a filling station driveway has been held to be noncompensable.[116] On the other hand, it was held that a city may not deny a service station access to one business street without first paying compensation, even though there was a driveway to the property from another street.[117]

Fences and Barricades

The public authority may erect fences along the boundary of the right-of-way to control access without paying compensation as long as the abutting landowner retains reasonable access. In *Tucci v. State*,[118] a chain link fence was erected along the westerly boundary of two lots with 100 feet of frontage. The owner was in the business of manufacturing, displaying, and selling cemetery memorial stones. The entire frontage to one lot was destroyed as was 6 feet of frontage of the second lot, and the remaining 44 feet had two curb cuts. Although the claimants contended that there was a *de facto* expropriation of their easement of access to the street, the Court held that there was no right to compensation:

> While it may be that claimants have suffered damage or loss of business by reason of the existence of the barrier and the loss of frontage, suitable access did exist over the remaining 44 feet of frontage and the manner in which the state exercised its police power in deciding the position of the barrier is not compensable, since such decision was not arbitrary or unreasonable.

Arkansas State Highway Comm'n v. Kesner[119] held that the abutting owners suffered special damages because of the erection of barricades on one abutting street that rendered the owners' ingress and egress much more difficult and unsafe. Briefly, in *Kesner*, the State, in building a new highway, took several steps that affected the property. Along the right-of-way to the rear, the State constructed a guardrail across Sixtieth Terrace, which acted as a barricade crossing Sixtieth Terrace from Grand Avenue. The Commission contended that there was not a loss of access, because the owners had access to Grand Avenue, where their driveway was located. The Court, however, was concerned with the difficulty of the access to the Kesner property. It stated the test as follows:

> . . . before a landowner can recover for damage to his property where there has been no actual taking, he must suffer direct and substantial damage peculiar to himself, and not suffered by other members of the public, and this is true even though he may be actually more inconvenienced than the public in general. It is not enough that a landowner show that his damage is *different* from that suffered by the general public. He must show that a property right has been invaded, and the fact that the value of his lot has diminished is not, within itself, sufficient to establish special compensatory damages. Certain other conditions may arise, which might appear damaging to a complaining landowner, but which, under the law, are not compensable. We have held that circuity of travel, i.e., being compelled to go a few blocks out of the way is not compensable.[120]

Although the Kesners formerly were able to back into Grand Avenue and proceed in either direction, now, because of a median in the center of Grand, in order to go east it was necessary to back the car entirely across the opening in the median to the other side of the street. To proceed westerly, it was necessary to back the car into the street to the right, or with the back of the vehicle toward the east. Moreover, in backing out of the driveway, it was possible to observe traffic from the east only for approximately 100 to 150 feet. Finally, it was not possible to extend a new driveway to Sixtieth Terrace. Thus, the Court held that the owners "have suffered direct and substantial damage *peculiar to themselves;* i.e., not suffered by other members of the public, and, what is of equal significance, not suffered by any other person whose property abuts Sixtieth Terrace."[121]

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[113] See Alexander Co. v. City of Owatonna, 222 Minn. 312, 24 N.W.2d 244 (1946). It is not clear from the opinion whether the Court considered the access that existed to the other street from the same building. However, the Court noted that there were decisions holding that vehicular access could be denied to abutting property owners. See also, Wood v. City of Richmond, 148 Va. 400, 138 S.E. 560 (1927); Town of Tilton v. Sharpe, 85 N.H. 138, 156 A. 44 (1931); San Antonio v. Pigeonhole Parking of Texas, Inc., 311 S.W.2d 218, 73 A.L.R. 2d 640 (1958). One authority observes that the courts tend to review more strictly the cutting-off of existing access than the refusal to permit a new one. See Annot., 73 A.L.R.2d at 674.

[114] Delta Rent-A-Car Systems, Inc. v. City of Beverly Hills, 1 Cal. App. 3d 781, 82 Cal. Rptr. 318 (1970).

[115] Penningroth v. State, 35 A.D.2d 1024, 316 N.Y.S.2d 123 (1970).

[116] State Highway Comm'n v. Easley, 207 S.E.2d 870 (Va. 1974).

[117] State *ex rel.* Moore v. Bastian, 97 Idaho 444, 546 P.2d 399 (1976).

[118] 28 A.D.2d 774, 280 N.Y.S.2d 789 (1967). *See also*, Houghs v. Mackie, 1 Mich. App. 554, 137 N.W.2d 289 (1965) (construction of fence along and parallel to an expressway is not a taking of property where the fence does not eliminate indirect access ½ to ¾ mile from the property and is not erected on private property).

[119] 388 S.W.2d 905 (Ark. 1965).

[120] *Id.* at 909.

[121] *Id.* at 910.

Change of Grade

The public authority may undertake road and street improvements that result in a change or alteration of the grade of abutting property owners. Such construction, of course, may have a substantial effect on the abutter's means of access to the highway. More so than with the other limitations on access already discussed, there are disparate views among the courts on the question of compensability for change of grade of the abutting street or highway.

When discussing change of grade cases, it is necessary to begin with the 1823 decision of the Massachusetts Court in *Callendar v. Marsh.*[122] It may be recalled that the Court in that case ruled that the abutting property owner could not recover compensation for a loss of access to the public street resulting from a change of grade.

Although the modern law of abutters' rights of access differs sharply from the rule of noncompensability announced in *Callendar v. Marsh*, it appears that there are still some jurisdictions where the decision has viability when compensation is sought for change of grade. Some courts hold that the State may change the grade of the highway without having to pay the owner for impairment of access unless compensation is required or authorized by statute. Some authorities, particularly NICHOLS ON EMINENT DOMAIN, attribute the variance among the states on the issue of compensation for change of grade to the difference in the constitutional language. As noted, some State constitutions provide that just compensation must be paid by the State for "taking" private property for public use, while others provide that payment must be made when "taking or damaging" private property.

Although the difference in the constitutional language may account in part for the divergent rules, it does not explain the irreconcilable differences found in the cases from states with the same or similar constitutional language. The following rules relating to compensation for change of grade are set forth first for states with "taking" provisions and then those with "taking or damaging" provisions.

First, in those states with a "taking" constitutional provision, some courts have held that the owner of abutting land has no constitutional right to compensation for injury to his premises by reason of the raising or lowering of the grade of the road by the public authority when no part of the physical land is taken.[123] An example of this first view is *Smith v. State Highway Comm'n*[124] where it was claimed that a change of grade destroyed access to the abutting property. All the grading was done entirely within the right-of-way and no part of the

[122] 1 Pick. (Mass.) 417 (1823).

[123] See citations in NICHOLS, § 6.4441, footnote 2. As stated in Dunnla v. State, 72 Misc. 2d 687, 340 N.Y.S.2d 515 (Ct. of Cl. 1973), the anomaly is that the common law rule was and still is that the State is not liable for a change of grade not part of a direct taking.

[124] 257 N.C. 410, 126 S.E.2d 87 (1962).

property was taken. The Court held that there had not been a "taking" of access:

> When a public highway is established, whether by dedication, by prescription, or by the exercise of eminent domain, the public easement thus acquired by a governmental agency includes the right to establish a grade in the first place, and to alter it at any future time, as the public necessity and convenience may require. Consequently, it is the rule with us, and very generally held elsewhere, that, unless otherwise provided by statute or constitutional provision, an abutting property owner, even if he owns the fee of the land within the highway, may not recover for damages to his land caused by a municipal corporation or the State Highway Commission changing the grade of an established street or highway, when said change is made pursuant to lawful authority and for a public purpose, and there is no negligence in the manner or method of doing the work. Any diminution of access by an abutting landowner is *damnum absque injuria.*[125]

The second, and contrary, view is that in a state with a "taking" provision there is a taking of property within the meaning of the constitution where the change of grade unreasonably or substantially impairs access even though no part of the real estate itself is taken.

In *Thom v. State,*[126] the Court construed the "taking" provision of the Michigan Constitution and announced a "liberal" interpretation of that term. The Court said that it is not necessary for there to be a physical invasion of property in order for state action to constitute a taking. The Court in *Thom*, which involved a change of grade causing claimant great difficulty in moving his farm machinery to and from his property, held that the State had taken the plaintiff's property when it caused the access to the land to become very difficult, resulting in a substantial diminution in the value of the property.

The *Thom* Court in reviewing the authorities in that state found that several decisions had held that grade changes may result in a taking of the abutter's property. Moreover, it found that, where compensation for impairment of access due to change of grade had been denied, suitable access to the abutting property still remained. The Court expressly overruled *City of Pontiac v. Carter,*[127] that had held to the contrary, and adopted the rule that a substantial impairment of access caused by a change of grade may constitute a taking:

> We conclude then, that when a govenmental unit changes the grade of a highway in such a way as either to destroy or to interfere seriously with an abutting owner's right of access to that highway, and such interference results in a significant diminution in value of the property, then there has been a taking of the property to that extent. . . .[128]

[125] 126 S.E.2d at 90. *See also*, Look v. State, 267 A.2d 907 (Me. 1970).

[126] 376 Mich. 608, 138 N.W.2d 322 (1965).

[127] 32 Mich. 164 (1875).

[128] 138 N.W.2d at 331.

Similarly, in an Indiana decision, *Young v. State*,[129] it was contended that a change of grade constituted a taking. The Court referred to its duty to determine whether there was a taking of a "substantial" right in the property. The Court appears to treat the phrases "substantial right," "special and peculiar injury," and "materially and substantially impaired" as synonymous. The decision, noting that there was available access to the property at intersecting streets, appears to hold that there has not been a taking unless access is substantially impaired, which is not the case where the owner has suitable, remaining access.[130]

A third, and apparently uniform, view among the courts is that in "taking" states, compensation must be paid for an impairment of access where a change of grade accompanies a partial taking of abutting land.[131] For example, in *Pack v. Boyer*,[132] a partial taking case, it was held proper for the trial court to admit testimony relating to impairment of access caused by the construction of an embankment that raised the grade level of the highway.

A fourth view applies in those states that have a constitutional provision against the "taking or damaging" of private property for public use without payment of just compensation: compensation is required for an unreasonable impairment of access caused by a change of grade regardless of whether there is a partial taking of property.[133] A slight lowering of grade that does not impair the abutter's access directly, substantially, or peculiarly as compared to the injury suffered by the public, does not entitle him to compensation in a "taking or damaging" state.[134] "It is clear . . . that not every conceivable kind of injury to the value of adjoining property resulting from highway construction is 'damage' in the constitutional sense." [135] Similarly, in *Cheek v. Floyd County, Georgia*,[136] the Court held that a change in grade will give rise to a claim for damages for deprivation of access where there is a "substantial change" in access.

Finally, it should be noted that some states have adopted legislation requiring or authorizing compensation where the grade of a highway is changed or altered by highway improvements. Moreover, it has been held that such legislation authorizes the payment of damages even if

[129] 246 N.E.2d 377 (Ind. 1969).

[130] *See also*, State v. Preston, 170 Ohio St. 542, 166 N.E.2d 748, 751 (1960); "where an owner of land abutting on a highway has made improvements thereon with reference to an established grade for that highway, a substantial interference with his right of access to those improvements from that highway by a subsequent change of grade of the highway is a taking of property for which compensation must be provided."

[131] *See, e.g.*, Commonwealth, Dep't of Highways v. Roberts, 496 S.W.2d 343 (Ky. 1973).

[132] 438 S.W.2d 754 (Tenn. 1969). See NICHOLS, § 6.4441[1], at 6–207.

[133] See NICHOLS, § 6.4441[9], at 6–222—6–226.

[134] *See, e.g.*, Thomsen v. State, 170 N.W. 2d 575 (Minn. 1969); Troiano v. Colo. Dep't of Highways, 463 P.2d 448 (Colo. 1969).

[135] 170 N.W.2d at 579.

[136] 308 F.Supp. 777, 781 (N.D. Ga. 1970).

suitable access remains after the reconstruction or grading.[137] Reference is made to such statutes solely to alert the reader to their existence and possible application to a case involving change of grade. Claimants, however, may be barred from seeking compensation under such statutes if they fail to follow the specified procedural steps such as, for example, failing to file a claim within the prescribed period.[138]

Temporary Impairments of Access

As with other limitations on access, the general rule is that the public authority may be required to pay compensation for temporary impairments of access where there is a sufficient showing that the impairment is substantial. Thus, it was held in *Hadfield v. State* [139] that the abutting property owner may be entitled to damages where he shows that a 3-foot excavation, a barrier, and other construction reduced his accessible frontage and substantially impaired his acess to the highway. And in *Tarka v. Commonwealth*,[140] the Court held that the abutting owner of property used for a gasoline station could recover damages for substantial loss of access where the evidence was that street construction prevented or obstructed traffic from reaching the property for about 6 months.

Mere inconvenience caused by circuity of travel during highway construction is not a showing of substantial or unreasonable impairment. If, in the course of freeway construction, traffic to the abutting property is required to take a more circuitous route by traveling a half block north and two to three blocks east or west, then there has not been an unreasonable impairment of access.[141] In constructing a highway, the State may not bar access to abutting property completely.[142]

It is immaterial how the public authority causes the temporary impairment. Reasonable access may be "destroyed by design or by accident, whether by closing roads, by prohibiting access, or by physical obstruction, such as walls, fences, ditches, cults, and fills. The end result is the same." [143]

The abutting property owner, however, must recognize that he, as well as the general public, must endure reasonable temporary interference with access that is incident to performing street and highway functions. As noted in *Farrell v. Rose*,[144] the property owner recoups

[137] See 240 Scott, Inc. v. State, 18 N.Y.2d 209, 274 N.Y.S.2d 673, 676–677 (1966).

[138] *See, e.g.*, Jantz v. State Dep't of Transp., 63 Wis. 2d 404, 217 N.W.2d 266 (1974); Look v. State, 267 A.2d 907 (Me. 1970); see Annot., 156 A.L.R. 416 for further discussion of statutes authorizing compensation for change of grade.

[139] 388 P.2d 1018 (Idaho 1963).

[140] 275 N.E.2d 27 (Mass. 1971).

[141] Wagner v. State Dep't of Public Works, 51 Cal. App. 3d 472, 124 Cal. Rptr. 224 (1975).

[142] Wenton v. Commonwealth, 138 N.E.2d 609 (Mass. 1956).

[143] Commonwealth, Dep't of Highways v. Caudill, 388 S.W.2d 376, 379 (Ky. 1965).

[144] 253 N.Y. 73, 170 N.E. 498 (1930).

his damage in the benefits that he shares with the general public that are derived from the improvements. He may suffer compensable injury if, however, the work is done without proper authority, is prolonged unnecessarily, or is unreasonable.

Restriction of Access to Pedestrian Traffic

Access is usually thought of in terms of vehicular access, but the question has arisen in some instances whether the public authority may regulate streets by denying access to all vehicular traffic, thereby permitting access only by pedestrians.

The general rule is that a street may be closed to vehicular traffic if other reasonable means of access is available.[145] If such other access is not available, then the abutting landowner may be entitled to compensation. As the court stated in *Breinig v. County of Allegheny*,[146] "the absolute prohibition of driveways to an abutting owner's land which fronts on a single thoroughfare, and which cannot be reached *by any other means*, is unlawful and will not be sustained."

It has been held that the public authority may close a street to vehicular traffic where there is a serious traffic hazard presented without paying compensation when the abutting property owner has other, suitable access.[147]

An illustration of a situation when compensation was required for denial of vehicular access is *Metropolitan Atlanta Rapid Transit Auth. v. Datrey*.[148] There the abutting property owners challenged the Authority when the 100 block of Sycamore Street was closed to vehicular traffic and a MARTA transit station was constructed thereon.

The Court held that the agency could not properly exclude all vehicular traffic in the 100 block of Sycamore Street unless the owners were paid just compensation.

The Court said:

> . . . the question is limited to plaintiffs' right to vehicular access to their property. The prohibition of vehicular traffic in the 100 block of Sycamore Street will clearly deprive plaintiffs of the possibility of vehicular access to their property from Sycamore Street.
>
> Interfering with access to premises by impeding or rendering difficult ingress or egress is such [a] taking and damaging as entitles the party injured to compensation under a provision for compensation where property is damaged.[149]

[145] See Annot., 73 A.L.R.2d at 660.

[146] 2 A.2d 842, 847 (Pa. 1938) emphasis supplied; *compare* Brownlow v. O'Donoghue Bros., Inc. 276 F. 636 (D.C. App. 1921), holding that the owner of a lot that fronted two streets was entitled to have an entrance to the street that was traveled the most.

[147] See Segal v. Village of Scarsdale, 184 N.Y.S.2d 547 (S.Ct., Westchester Co., 1959).

[148] 235 Ga. 568, 220 S.E.2d 905 (1975).

[149] 220 S.E.2d at 911.

Cul-de-Sacs

In constructing new streets or in controlling traffic, it may be necessary for highway authorities to close or vacate streets. Properties that abut a highway that is closed may suffer diminished value because of the loss of direct access; however, the law does not recognize every loss of access as a compensable taking or damaging of property. In attempting to limit compensation to proper cases, the courts have devised rules that perhaps are easily stated but are quite difficult to apply. In cul-de-sac cases, it is the kind, and not the degree, of impairment of access that is paramount in deciding whether there has been a taking or damaging in the constitutional sense.

The point where the road is closed in relation to the abutting property is quite significant. The point of closure may be directly in front of the abutting property; it may be between the abutting property and the next intersection with another street or highway; or between the abutting property and some point beyond the next intersecting street. Presumably, the closer to the point of closure that the property is situated, the more likely that the property owner will be able to show that he has suffered special damage.

Generally, the rule is that the abutting landowner is not entitled to compensation for obstruction of the abutting street unless there is proof of special damage; that is, the abutting property must suffer an impairment of access that is not merely greater in degree than other abutting properties but one that is *different-in-kind*.

The clearest case of special damage is where the property abuts the highway on the closed or vacated portion, thereby depriving the landowner of his principal means of ingress and egress.[150] As stated in *State v. Silva*,[151] the majority rule is that

> one whose property abuts upon a road or highway, a part of which is closed or vacated, has *no special damage if his lands do not abut upon the closed portion thereof, if there remains a reasonable access to the main highway system*.[152] (Emphasis supplied.)

A departure from the rule that compensation is required when the land abuts on the closed or vacated portion of the highway is *Wolfe v. Town of Windham*.[153] In that case the road was closed along most of the 1,750 feet of frontage, leaving access from the remaining 227.5 feet

[150] NICHOLS, § 6.443[3], at 6-257; Dep't of Highways v. Jackson, 302 S.W.2d 373 (Ky. 1957).

[151] 71 N.M. 350, 378 P.2d 595 (1963). See also, Mississippi State Highway Comm'n v. Irby, 190 So. 2d 445, 447 (Miss. 1966) (holding that landowner whose land does not abut the public road is not entitled to damages for closing by highway department of private roads through lands of third parties which he had used to reach the public road system where he had no enforceable private right to use such roads.)

[152] 378 P.2d at 599.

[153] 327 A.2d 721 (N.H. 1974).

and three other roads. The Court held that, because there was alternative access, the plaintiffs were not entitled to compensation.[154]

The more distant the property from the point of closure, the more difficulty there is in showing special damage. In more distant street vacations, the courts often state that the abutting landowner is not entitled to compensation if left on a cul-de-sac, because he is no more inconvenienced than members of the general public. That is, both must suffer the inconvenience of the more circuitous route, and the property owner is no more affected than the general public.[155] Special damage must be shown from the facts of each case, and the following cases illustrate what may or may not constitute special damage.

In *Warren v. Iowa State Highway Comm'n*,[156] the Commission was engaged in building an Interstate highway in Clarke County, Iowa, that crossed a secondary road, which the Commission proposed to close at the intersection. The plaintiff owned a tract of land used as a farm on each side of the planned intersection and used the secondary road to travel between the two tracts. Because of the closing of the secondary road, plaintiff was required to use a circuitous route: instead of a direct, one quarter-mile road she was compelled to use a route of more than three miles.

The Court applied the special damage rule, which it stated as follows:

> It is that one whose right of access from his property to an abutting highway is cut-off or substantially interferred with by the vacation or closing of the road has a special property [sic] which entitles him to damages. But if his access is not so terminated or obstructed, if he has the same access to the highway as he did before the closing, his damage is not special, but is of the same kind, although it may be greater in degree, as that of the general public, and he has lost no property right for which he is entitled to compensation.[157]

The Court held that the plaintiff had not shown special damage. She had the same access to the general highway system after the closing as before. She and all other members of the public shared the same common injury. "Her damage is greater in degree than that suffered by the general public; but it is not different in kind, which is the ultimate test."[158]

The *Warren* case may be compared with *State v. Tolliver*.[159] The landowners in *Tolliver* operated a steel fabricating plant situated on a gravel road over which raw steel and iron were delivered by truck to

[154] A dissenting opinion in *Wolfe* noted that the majority failed to consider that (1) the alternative access must be reasonable and (2) the owners were entitled to recover damages because they abutted on the closed or vacated portion. *Id.* at 724. The dissenting opinion appears to be in accord with the rule in other jurisdictions.

[155] State Highway Comm'n v. Raleigh Farmers Market, 236 N.C. 622, 139 S.E.2d, 904 (1965).

[156] 93 N.W.2d 60, 65 (Iowa 1958).

[157] *Id.*

[158] *Id.* at 68.

[159] 246 Ind. 310, 205 N.E.2d 672 (1965).

their factory. The gravel road connected to US 136, about one and one-half miles from the property. The latter highway was the only improved public road available over which they could reach other improved roadways for receipt of their raw materials and delivery of their finished products. When the State had to close the gravel road between the plant and US 136, the only remaining access was south on the gravel road over a bridge that was unable to support the necessary trucks for the plant. Ultimately, the owners were compelled to relocate their plant north of US 136. The Court applied the special damage rule, but in contrast to *Warren*, held that the landowners indeed had established special damage.

> In view of the insufficient alternate route which was the only remaining outlet available to appellees, we must conclude this injury to appellees' steel fabricating plant was far greater and of a kind and nature different from the injury suffered by the general public and therefore comes within the exception to *damnum absque injuria* so as to be compensable. In fact, under these exceptional circumstances, the closing of the highway had the effect of depriving appellees of any suitable access to their steel fabricating business.[160]

In pleading his case, the abutting landowner must allege more than the fact that he is left on a cul-de-sac. Rather, he must specify how the property is used; the added distance, if any, which must be traveled to reach the general system of public streets or public highways; the lack of available, reasonable, alternative routes to reach the general system of public streets or highways; and he must allege that the closing has substantially impaired his right of access.[161]

It may be noted that whether the condemnee is deprived of all access to the highway is determined at the time of the taking and is not affected by the highway authority's subsequent construction of other means of access.[162] The abutter whose road is closed in only one direction usually is unable to show special damage or substantial impairment of access, if he has reasonable ingress and egress in the other direction.[163] For example, in *Wofford v. N.C. State Highway Comm'n*,[164] a street was terminated about 100 feet east of the plaintiff's property creating a cul-de-sac; however, access to the property existed at an intersection four blocks away. The Court stated that "an abutting landowner is not entitled to compensation because of circuity of travel to and from his property" and held that reasonable access existed.[165]

[160] 205 N.E.2d at 678.

[161] See Valenta v. County of Los Angeles, 39 Cal. Rptr. 909, 394 P.2d 725, 728 (1964).

[162] Honig v. Director of Public Works for State of R.I., 258 A.2d 73 (R.I. 1969).

[163] State v. Meier, 388 S.W.2d 855, 859 (Mo. 1965); State v. Silva, 71 N.M. 350, 378 P.2d 595 (1963) (interchange 350–400 feet of the premises afforded reasonable access); Wofford v. N.C. State Highway Comm'n, 263 N.C. 677, 140 S.E.2d 376, 379 (1965).

[164] 263 N.C. 677, 140 S.E.2d 376 (1965).

[165] 140 S.E.2d at 379.

In deciding where to draw the line, some courts consider whether the point of closing occurs between the property and the next intersection or between the property and some point beyond the intersection. In some cases, special damage is demonstrated if the obstruction is between the land and the nearest intersection.[166]

It may not be concluded, however, that as a matter of law the closing of a street between the land and the next intersection is special damage *per se*.

> The recognition that the easement of access includes a right not only to reach the general system of public streets, but to do so over either of the next intersecting streets in two directions, does not mean that in every case an allegation of impaired access to the next intersecting street in one direction will establish a compensable right. . . . Loss of access to the next intersecting street will be a significant factor in finding an impairment of the general right; and as *Barrick* held, obstruction of access to the next intersecting street serves as one element of such impairment.[167]

The loss of access to the next intersecting street does not necessarily create a right of action for impairment of the general right of access.[168]

As noted by one writer some courts have shifted from the different-in-kind test to one of substantial impairment of access.[169] It has been argued that departing from the special damage rule generally recognized could lead to "all sorts of difficulties in determining where to draw the line."[170]

COMPENSATION WHERE SUBSTITUTE OR ALTERNATIVE ACCESS IS PROVIDED

In those situations where access must be partially or fully controlled, the highway department may find it necessary to convert an uncontrolled-access highway into a limited-access highway and limit ingress and egress to the main road at specified interchanges via service roads. For business establishments that lose direct access to the highway a real and substantial economic loss may result in terms of customers, profits, going concern value, or fair market value of the property.[171]

The loss of direct access may arise in several ways. First, the limited access highway may be constructed on an entirely different location pursuant to a statute that authorizes such highways and denies access to newly created abutting landowners. Although this method of access control is not treated extensively in this paper,[172] it may be noted that

[166] See State v. Wineberg, 444 P.2d 787, 9 (Wash. 1968).

[167] Breidert v. Southern Pacific Co., 39 Cal. Rptr. 903, 394 P.2d 719, 722 (1964).

[168] *Id.*

[169] Stoebuck, *supra* note 6, at 745, n. 33.

[170] Nichols, § 6.4443[3], at 6-265; *See also, Annot.*, 43 A.L.R.2d 1070.

[171] See discussion of diversion of traffic in text, *infra*, at footnotes 80 to 94.

[172] See Annot., *Abutting Owner's Right to Damages for Limitation of Access Caused by Conversion of Conventional Road Into Limited Access Highway*, 42

the general rule is that access to the highway may be denied without paying compensation. The reason is that the abutter is not entitled to compensation for something that he never had in the first place, and, therefore, could not lose. As stated in *State v. Fonburg*,[173]

> There is no inherent right of access to a newly relocated highway. . . . The condemnee never having had access to the new highway there is no easement of access taken in this proceeding."

Second, the highway authority may choose to locate and build the highway near the existing road that is converted into a service road for the new highway. Another variation is to construct the limited-access road over the old road with a new service road to provide ingress and egress. Ordinarily, it is immaterial whether the service road was made from the old highway or is entirely new.[174]

The abutting landowner, who by virtue of the conversion is relegated to service road access to the main highway, may find that his access is more circuitous. His customers may have to travel to a point beyond his property, exit at an interchange, and travel in the opposite direction in order to reach the premises. Moreover, a significant amount of traffic (i.e., business) may be diverted entirely because of the circuitous access. The issue is whether the abutting landowner may recover compensation for his loss of direct access and the substitute access with which he has been provided.

In the substitute access situation, three rules have been stated by the courts concerning the effect of the existence of the service road on the question of compensation. They are:

1. Any loss should be compensated and the existence of the frontage road should be considered in mitigation of the loss.
2. The loss should be compensated only when accompanied by a taking of a parcel of the land by eminent domain.[175]
3. Any loss of access that results from being placed on a service road should not be compensated where the substitute access is suitable.[176]

A.L.R.3d 13; *Measure and Elements of Damage for Limitation of Access Caused by Conversion of Conventional Road Into Limited Access Highway*, 42 A.L.R.3d 148. See *Compensation Claims for Loss of Access to Interstate Highways*, 14 DePaul L. Rev. 130; *Limited Access Highways—Right of Abutting Landlords*, 3 Willamette L.J. 52; *Eminent Domain—Damages—Compensation for Loss of Access to New Limited Access Highways*, 14 Ala. L. Rev. 160; *Limited-Access Highway—Some Aspects of Compensation*, 8 Utah L. Rev. 12.

[173] 328 P.2d 60, 64 (Idaho 1958); *see also* City of Los Angeles v. Geiger, 94 Cal. App. 2d 180, 210 P.2d 717 (1949); South Meadow Realty Corp. v. State, 144 Comm. 289, 130 A.2d 290 (1957); Smick v. Commonwealth, 268 S.W.2d 424 (Ky. 1954); State v. Clevenger, 365 Mo. 970, 291 S.W.2d 57 (1956); State v. Burk, 200 Ore. 211, 265 P.2d 783 (1954).

[174] State v. Manney, 76 N.M. 36, 411 P.2d 1009, 1013 (1966).

[175] This second view, however, appears to be immaterial in nearly all jurisdictions, and is, therefore, not treated here. See Annot., 42 A.L.R.3d 13, 81.

[176] Stefan Auto Body v. State Highway

Substitute Access as Mitigation of Damages

Where the highway authority eliminates direct access and provides other access by a service road, it is not relieved of its obligation to compensate the abutting landowner for the impairment of direct access, but the new method of access may be considered and mitigate the amount of damages that would otherwise be paid.

In *Muse v. Mississippi State Highway Comm'n*,[177] involving a partial taking and access to a frontage road, the Court noted

> . . . the owner of the abutting land has no absolute right, as against the public, to insist that the adjacent highway always remain available for his use in the same manner and to the same extent as when it was constructed.

Holding that the introduction of evidence of the existence of the frontage road was proper, the Court noted that its exclusion would require the jury "to award damages based upon a false assumption that the taking of the strip of land sought to be condemned would leave the appellant without any right of access to the highway."[178]

Similarly, *Dep't of Public Works & Buildings v. Wilson Co., Inc.*,[179] held that a frontage road may not be substituted for direct access:

> We do not agree with the Department's suggestion that the frontage road in this case was a traffic control device of the same character [as the median divider cases]. Here, the effect of the partial taking was not merely a limitation of the existing direct access to Roosevelt Road nor simply a change in the flow of traffic on the street, but rather a complete elimination of all direct access with the substitution of a frontage road. . . .

Of course, it may be that the abutter has not been damaged by the substitute access, for it is possible that the "frontage road or otherwise will so nearly equal the original direct access as to eliminate any question of damage to the remaining property."[180]

Similarly, *State v. Thelberg*[181] held that a destruction or substantial

Comm'n, 21 Wis. 2d 363, 124 N.W.2d 319 (1963).

[177] 103 So. 2d 839, 847 (Miss. 1958).

[178] *Id.* at 848–49.

[179] 62 Ill. 2d 131, 340 N.E.2d 12, 18 (1975). The Court noted that on this question there is very little judicial unanimity. 340 N.E.2d at 14. *See also*, Dep't of Public Works & Buildings v. Mohres, 28 Ill. App. 3d 422, 328 N.E.2d 637 (1975); Dep't of Public Works & Buildings v. Kelly, 40 Ill. App. 3d 696, 353 N.E.2d 195 (1976) (proffered stipulation of substitute access is a recognized procedure to mitigate damages and should have been admitted).

[180] 340 N.E.2d at 19.

[181] 87 Ariz. 318, 350 P.2d 988, 992 (1960). See also, State v. Wilson, 103 Ariz. 194, 438 P.2d 760 (1968), involving condemnation of land and conversion of a state route into an interstate highway. The Court noted that a number of states "have adopted the principle that the right of direct access to a public highway may be limited to frontage roads and possibly to other circumstances in which access is not unreasonably circuitous. But we do not have such a situation here for there is no

impairment of access is compensable where a service road is provided in lieu of direct access:

> The damages may be merely nominal or they may be severe. Other means of access such as frontage roads as in the instant case may be taken into consideration in determining the amount which would be just under the circumstances. . . . Other means of access may mitigate damages but does not constitute a defense to the action however.

Although agreeing on the basic rule of mitigation of damages, *Thelberg* and another partial taking case, *South Carolina State Highway Dep't v. Allison*,[182] differ on whether it is significant that the old highway is used as a frontage or service road. The *Thelberg* Court stated that no compensation for loss of access is required in those partial taking cases where the controlled-access highway is constructed on a new right-of-way beside the old road, where the latter is retained as a service road. The reasons are that access to the old highway is not disturbed, and there is no right of access to the new highway.

In *Allison, supra*, right-of-way was acquired for a controlled-access facility, one lane of which was to be constructed on top of the existing highway leaving the abutter with identical access after the taking via the frontage road being constructed. The Court held that the loss of access was compensable to the extent that the loss adversely affected the fair market value of the remainder of the property; the frontage road is a benefit and may mitigate or be offset against compensation.[183]

Reasonable Substitute Access—No Right to Compensation

As stated, a second view is that, if alternative access is provided, the abutting landowner is not entitled to damages to the remainder for impairment of direct access.[184] In *Surety Savings and Loan Ass'n v. State Dep't of Transp.*,[185] the department condemned a strip of land across the appellant's land causing a severance of the northeast and southwest portions. The severance, coupled with the declaration of controlled access, resulted in loss of access to the other parcels, except by a frontage road. The Court held: "there is no compensable taking

frontage road and the substitute access road is, in our opinion, unreasonably circuitous. Accordingly, we hold, consistent with our former decisions, that the complete destruction of direct access to a public highway constitutes a damaging of property within the meaning of the Constitution of Arizona." *Id.* at 763.

[182] 143 S.E.2d 800, 802 (1965).

[183] *See also* State v. Mauney, 76 N.M. 36, 411 P.2d 1009 (1966); Ray v. State Highway Comm'n, 196 Kan. 13, 410 P.2d 278 (1966); and Haymore v. North Carolina State Highway Comm'n, 14 N.C. App. 691, 189 S.E.2d 611 (1972).

[184] Bock v. U.S., 375 F.2d 479 (9th Cir. 1967); Gagne v. Morton, 102 N.H. 114, 151 A.2d 588 (1959); Arkansas State Highway Comm'n v. Bingham, 237 Ark. 934, 333 S.W.2d 728 (1960); Houghs v. Mackie, 1 Mich. App. 554, 137 N.W.2d 289 (1965); State *ex rel.* State Highway Comm'n v. Brockfeld, 388 S.W.2d 862 (Mo. 1965), and State Highway Comm'n v. Central Paving Co., 240 Or. 71, 399 P.2d 1019 (1965).

[185] 54 Wis. 2d 438, 195 N.W.2d 464 (1972).

when direct access to a controlled access highway is denied . . . where other access is given or otherwise exists." [186]

This second view was adopted by New Jersey in *State, Com'r of Transp. v. Charles Investment Corp.*[187] There, as a result of highway reconstruction, property that had fronted directly on the westbound lanes was caused to abut a service road. The points of access were 300 and 1,500 feet from the property. The issue, one of first impression in the State, was whether compensation was required for a taking of direct access where there was reasonable alternate access to the main highway. It was held that because reasonable access existed there could be no recovery of damages for loss of direct access.

> There is no deprivation of access such as would entitle the owner to compensation. While it is true that the nature of the abutting road has changed, this does not create a right to compensation, for, as previously noted, the landowner has no property right in the flow of traffic.
>
> Further, if one were to assume *arguendo* that the relevant access was to the main road rather than the access road, the owner's land would still not have received any compensable injury. Access from Route 3 to the service road is provided 1,500 feet to the east and access from the service road to Route 3 is provided 200 feet to the west. As a matter of law, this is reasonable access.
>
> . . . fairness dictates noncompensability. Fairness with respect to this particular case because the owner is not charged for the benefits, if any, resulting from the fact the abutting road is now a feeder from the New Jersey Turnpike any more than the state is charged for the detriment, if any, which may result from the fact the abutting road is now a service road [sic].[188]

The difference in these two views is important. Where the Court rules as a matter of law that the substitute access is reasonable, then under the second view the jury would be precluded from considering loss of access as an element of damage. However, in jurisdictions following the first view, the jury would be entitled to consider loss of access as an element of damage, although it would be further advised to consider the effect of the service road in mitigation of damages.

SUMMARY AND CONCLUSIONS

As noted at the beginning of this paper, a matter of extreme concern is the loss of highway capacity because of inadequate or nonexistent access control. This paper has discussed the extent to which access control to existing uncontrolled-access highways may be utilized without the necessity of compensation to abutting landowners for loss of access.

[186] 195 N.W.2d at 467. See also, Stefan Auto Body v. State Highway Comm'n, 21 Wis. 2d 363, 124 N.W.2d 319 (1963).

[187] 143 N.J. Super. 541, 363 A.2d 944 (1976).

[188] 363 A.2d at 946.

Clearly, the abutting landowner's access is a constitutionally protected right of property; it cannot be taken, or taken or damaged as the case may be, without the payment of just compensation. Of course, access can be acquired by purchase or condemnation. Moreover, access can be impaired significantly by various methods of State action as long as the impairment is not so unreasonable or substantial as to result in a taking or damaging in the constitutional sense.

The cases discussed herein identify some of the elements considered and suggest some limits to the ability of the State to impair access without paying the abutting landowner. The decisions demonstrate that the underlying, central issue is whether the landowner retains reasonable access that is suitable to the requirements of the abutting property. Consideration is given to the difficulty of the remaining access; the impact, if any, that loss of access has on the highest and best use of the property; the availability of other, suitable access; the degree of circuity of travel to some extent; and any other special hardship the impairment of access has wrought.

The decisions, as noted by the courts, are often conflicting and irreconcilable. Some of the inconsistency is attributable, of course, to the divergent facts of these cases. In addition, in some key areas, notably change of grade, diversion of traffic, or substitute access, the courts apply different legal standards. Adding further to the uncertainty and lack of uniformity of result is that the factfinder, usually the jury, must ultimately determine the severity of the impairment and assess damages accordingly.

In spite of this apparent inconsistency in the case law, it is apparent that many forms of access control, where reasonably applied, may be used to control access to uncontrolled-access highways. In sum, as long as the impairment of access is reasonable and the abutting landowner retains suitable access to his property, there is no requirement of compensation.

APPLICATIONS

The foregoing research should prove helpful to highway and transportation administrators, their legal counsel, and those responsible for land acquisition and use. Officials are urged to review their practices and procedures to determine how this research can effectively be incorporated in a meaningful way. Attorneys should find this paper especially useful in their work as an easy and concise reference document in eminent domain and land use.

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APPENDIX 5-B

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Rights of Abutting Property Owner Upon Conversion of Uncontrolled-Access Road Into Limited-Access Highway

A report prepared under NCHRP Project 20-6, "Legal Problems Arising Out of Highway Programs" for which The Transportation Research Board is the Agency conducting the Research. The report was prepared by John C. Vance. Robert W. Cunliffe, TRB Council for Legal Research, was principal investigator, serving under the Special Technical Activities Division of the Board at the time this report was prepared.

THE PROBLEM AND ITS SOLUTION

State highway departments and transportation agencies have a continuing need to keep abreast of operating practices and legal elements of specific problems in highway law. This report describes the various considerations in determining if a property owner is due compensation for loss of direct highway access.

This paper will be included in a future addendum to a text entitled, "Selected Studies in Highway Law." Volumes 1 and 2, dealing primarily with the law of eminent domain, were published by the Transportation Research Board in 1976; and Volume 3 dealing with contracts, torts, environmental and other areas of highway law, was published in 1978. An addendum to "Selected Studies in Highway Law," consisting of five new papers and 15 supplements, was distributed early in 1981, and a third addendum consisting of eight new papers, seven supplements, and an expandable binder for Volume 4 was distributed in 1983. The text now totals more than 2,200 pages comprising 56 papers. Copies have been distributed to NCHRP sponsors, other offices of state and federal governments, and selected university and state law libraries. The officials receiving copies in each state are: the Attorney General, the Highway Department Chief Counsel, and the Right-of-Way Director. Beyond this initial distribution, the text is available through the TRB publications office at a cost of $90.00 per set.

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Rights of Abutting Property Owner Upon Conversion of Uncontrolled-Access Road Into Limited-Access Highway

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BACKGROUND AND SCOPE

This paper deals with the rights of a landowner whose property abuts on a conventional road that is converted into a limited-access highway. In the typical situation prior to the conversion the owner has direct access to the adjoining unlimited access highway and after the conversion his means of ingress to and egress from the new controlled-access highway is limited either to travel along a frontage road that has a point or points of connection with the new highway, or, in the event his property abuts on another existing public road, he is relegated to travel along such road to a point where it connects directly, or through other roads in the public highway system, with the new highway. In either case his travel is circuitous when compared to his former right of direct access. The question is whether he is entitled to damages for the impairment of his former right of direct access.

This paper does not cover the situation where the limited-access highway is constructed on an entirely new location. The law is now clearly settled that where a limited-access highway is constructed on a wholly new location the abutting owner does not acquire any right of direct access to the new controlled-access thoroughfare, nor are any rights of access taken or destroyed for the reason that no prior rights of access existed.[1]

Neither does the paper cover the situation where after the conversion the owner is landlocked and has no means of access to the new highway.[2] The law is now equally well settled that an owner of property abutting on a conventional road has a right of access in the nature of a property right that cannot be taken or destroyed without payment of compensation.

The rule is stated in NICHOLS, EMINENT DOMAIN (Rev. 3d Ed.), Vol. 3, Sec. 10221[2], as follows: "An owner of property abutting upon a public street has a *property right* in the nature of an easement in the street which is appurtenant to the abutting property and *which right is his private right*, as distinguished from his right as a member of the public." (Emphasis appears in the text.) See also 39A C.J.S., *Highways*, Sec. 141(2), wherein it is stated that: "An abutting landowner on a public highway has a special right of easement and user in the public road for access purposes . . . and this is a property right which cannot be interfered with or denied him, without due compensation."[3]

The question, therefore, is basically one of the adequacy of substitute access. And the answer is that if the substitute access is *reasonably* adequate, the owner is not entitled to compensation, but if the substitute access is not *reasonably* adequate, or constitutes a *material* or *substantial* impairment of the former right of access, the owner is entitled to compensation. The measure and elements of damage where compensation is required are considered later herein.

Because the controlled-access highway is today common-place it is sometimes forgotten or overlooked that the concept of the limited-access highway is relatively new. This is pointed out in NICHOLS, EMINENT DOMAIN (Rev. 3d Ed.), Vol. 3, Sec. 10.2211[2], where it is stated that: "A limited-access highway, sometimes referred to as a thruway or freeway, is not an ordinary highway but an entirely new concept in highways which has made its appearance in recent years as a result of many changes in the lives and mobility of the general public brought about by the introduction and increasingly prevalent use of the automobile."

Nichols goes on to define and describe the limited-access highway as follows: "It is a highway where ingress and egress may be had only at certain designated points which are to be determined by the highway authorities. The very purpose of such roads is to provide fast and through traffic. To bring this about, it is necessary that there be limited access to the highway, thereby eliminating danger of accidents and also affording economic advantages which would best serve the public interests. Limited-access highways are of no use, however, if the public is not provided reasonable access to enter and leave the highway system. It is imperative, therefore, that although the access be limited, reasonable access be granted to those requiring use of the highway."

It is thus to be noted that "reasonable access" is specified as fundamental to the concept of the limited-access highway.

No exact date can be specified when the limited-access highway came upon the scene. However, although limited-access thoroughfares, such as, for example, the Pennsylvania Turnpike toll road, were constructed and in use well before 1956, such date can perhaps be ascribed, both for convenience's sake and as a practical matter, as the inauguration of the era of the limited-access highway. It was in that year that the Congress of the United States enacted into law the Federal Interstate and Defense Highway System,[4] and almost immediately following its passage the States began to enact such legislation, or promulgate such regulations, as would enable them to comply with Federal Highway Administration standards in respect to roads in the Interstate System, and hence enable them to receive the 90 percent Federal funding authorized for the acquisition of lands for and construction of highways included in the System. While many of the Interstate highways were constructed on entirely new locations, a substantial number utilized all or part of the rights-of-way of existing conventional roads. Because of the decline in recent years in the acquisition of entirely new right-of-way for road construction, it is reasonable to suppose that in the future many of the newly constructed limited-access highways will be built in the same fashion, i.e., by utilizing the rights-of-way of existing conventional roads. For the reason that census reports and demographic studies foreshadow a continuous increase in the nation's population, which increase will inevitably be accompanied by an increase in the number of vehicles on the highways, and for the reason that limited-access highways have fulfilled the initial prediction that they would contribute to the economical, efficient, and safe movement of traffic, the same will continue to be built. This paper is concerned with one aspect of such future construction, that is, the *cost* of relegating landowners to substitute access when a conventional road on which their properties abut is converted into a limited-access highway.

This paper does not undertake to provide an in-depth historical perspective of the origins and development of the law of substitute access, nor is attempt made to provide an exhaustive review of all the decided cases. Such treatment would extend the paper to unjustifiable lengths. Instead, it seeks to provide a condensed overview of the rules of law that today must be taken into consideration by State highway departments in projecting the cost of converting conventional roads into limited-access highways. The early cases were characterized by a measure of confusion, but today certain rules are well established, and it is these that are the subject of consideration herein.

A brief word is first in order with respect to the ancient (and largely unsolvable) problem of where does police power end and eminent domain begin. One approach to the problem of the compensability of substitute access could be to decide *a priori* whether the provision of such access by the State is a police power function or an exercise of the power of eminent domain, and a decision one way or the other would dispose once and for all of the question of compensability.

However, this is not the approach taken by the courts. Instead, the approach taken has been first to decide whether or not the substitute access is adequate. If found to be adequate, the provision of substitute access is characterized as a noncompensable police power function. If found not to be adequate, the provision of substitute access is characterized as a compensable taking. Thus, in any particular case, the provision of substitute access may be *either* a police power activity or the injury to a constitutionally protected right. The answer depends entirely on the facts of the case. And the test to determine whether the provision of substitute access is a police power function or a compensable taking is whether on the particular facts of the case the substitute access provided was *reasonable*.

A further background matter requiring brief mention is that of circuity of travel. The statement is repeated over again in the cases that circuity of travel is noncompensable. Yet in determining whether substitute access is reasonable or unreasonable it is obvious that one of the major factors to be taken into consideration is circuity of travel. In fact the question may well be asked: If damages for impairment of access are not for circuity of travel, what are they for?

The courts insist that the damages are not for circuity of travel, but for injury to the property right of access. However, little or no attempt is made in the cases to draw a clear distinction between damages resulting from circuity of travel and damages resulting from injury to the property right of access. The matter is, quite surprisingly, either glided over or ignored. The result is that we are left with two possibly inconsistent rules, both of which are equally well established, that damages are not recoverable for circuity of travel but damages are recoverable for material impairment of access. Suffice it to say that in determining material impairment of access there is no escaping the fact that circuity of travel is involved and that it is taken into consideration by the courts in making determination as to the adequacy of substitute access.

It need also be pointed out as a preliminary matter that it does not appear to make any significant difference whether the question of impairment of access arises in a jurisdiction having the constitutional "taking" provision, or in a jurisdiction wherein the constitutional "taken or damaged" clause is in force and effect, recovery for impairment of access being just as liberal in the "taking" States as in those States having the "taken or damaged" provision.[5]

And finally it is to be noted that the provisions of local statute law in respect to the construction of limited-access highways are, generally speaking, not governing or controlling because the award or denial of compensation is based squarely on the constitutional guarantees of payment of just compensation and due process of law.

Turning now to the cases, it is to be noted that the great majority of the significant cases were decided in the period immediately following the enactment of the law creating the Interstate System, and it is hence these cases that are the principal subject of review herein. There has, in fact, been a precipitous decline in the number of cases reaching the courts in recent years that involve the subject matter under consideration, and it is a fair inference from the sharp fall-off in the number of litigated cases that the law in the premises has become fairly well settled.

The general rule that today represents the solid majority view is next for consideration.

GENERAL RULE

As has been seen an abutting property owner has a constitutionally protected right of access to an existing public road that adjoins his property. However, this right does not encompass the right to access to the public road at any and all points along the boundary between his property and the road. The State may under its police power restrict the owner to access at a designated point or points in the boundary in order to provide for the safe movement of traffic on the public road.[6] Thus, the property owner's right of access is restricted to the right of *reasonable* access. It follows where all direct access to the adjacent road is cut off, upon conversion of the road into a limited-access facility, that the owner must be provided with such substitute access as provides reasonable ingress to and egress from his property. Hence, the general rule is now firmly established that the test of whether or not the State is liable in damages for impairment of access resulting from the conversion of a conventional road into a limited-access highway is whether or not the substitute access provides reasonable ingress and egress to and from the owner's property. As pointed out previously, the substitute access may be by way of a new frontage road, or the owner may be left with the access provided by an existing road that adjoins his property and connects either directly or through the system of public roads with the limited-access highway. Or put another way, as the courts frequently do, the test is whether or not the substitute access results in a material or substantial impairment of the abutting owner's former right of access. Thus, if the substitute access is found either to be unreasonable or to constitute a material or substantial impairment of the former right of access, the State is liable in damages. And conversely, if the substitute access is found to be reasonable, or not to constitute a material or substantial impairment of the former right of access, the State is not liable in damages.

The following cases, by way of holding, dictum, or necessary implication, support the general rule as above stated:

Federal: *Creasy v. Stevens,* 160 F.Supp. 404 (D.C. Pa., 1958).

Alabama: *Blount County v. McPherson,* 268 Ala. 133, 105 So.2d 117 (1958).

Alaska: *B. & G. Meats, Inc. v. State of Alaska,* 601 P.2d 252 (Alaska, 1979).

Arizona: *State ex rel. Morrison v. Thelberg,* 87 Ariz. 318, 350 P.2d 988 (1960); *Fletcher v. State,* 90 Ariz. 251, 367 P.2d 272 (1961); *State ex rel. Herman v. Schaffer,* 105 Ariz. 478, 467 P.2d 66 (1970); *State ex rel. Herman v. Wilson,* 103 Ariz. 194, 438 P.2d 760 (1968); *Phoenix Title and Trust Company v. State,* 5 Ariz. App. 246, 425 P.2d 434 (1967); *State ex rel. Herman v. Jacobs,* 7 Ariz. App. 396, 440 P.2d 32 (1968); *State ex rel. Herman v. Southern Pacific Company,* 8 Ariz. App. 238, 445 P.2d 186 (1968).

California: *People v. Ricciardi,* 23 Cal.2d 390, 144 P.2d 799 (1943); *Blumenstein v. City of Long Beach,* 143 Cal.App.2d 264, 299 P.2d 347 (1956); *People v. Murray,* 172 Cal.App. 2d 219, 342 P.2d 485 (1959); *People v. Becker,* 262 Cal.App.2d 634, 69 Cal.Rptr. 110 (1968); *People v. Home Trust Investment Co.,* 8 Cal.App.3d 1022, 87 Cal.Rptr. 722 (1970).

Colorado: *State Department of Highways v. Davis,* 626 P.2d 661 (Colo., 1981).

Florida: *State, Department of Transportation v. ABS, Inc.,* 336 So.2d 1278 (Fla.App., 1976).

Georgia: *Clayton County v. Billups Eastern Petroleum Company,* 104 Ga.App. 778, 123 S.E.2d 187 (1961).

Idaho: *James v. State,* 88 Idaho 172, 397 P.2d 766 (1964).

Illinois: *Department of Public Works and Buildings v. Wilson and Company, Inc.,* 62 Ill.2d 131, 340 N.E.2d 12 (1976).

Iowa: *Iowa State Highway Commission v. Smith,* 248 Iowa 869, 82 N.W.2d 755 (1957); *Wilson v. Iowa State Highway Commission,* 249 Iowa 994, 90 N.W.2d 161 (1958); *Belle v. Iowa State Highway Commission,* 256 Iowa 43, 126 N.W.2d 311 (1959); *Linge v. Iowa State Highway Commission,* 260 Iowa 1226, 150 N.W.2d 642 (1967).

Kansas: *Brock v. State Highway Commission,* 195 Kan. 361, 404 P.2d 934 (1965); *Teachers Insurance and Annuity Association of America v. City of Wichita,* 221 Kan. 325, 559 P.2d 347 (1977).

Kentucky: *Commonwealth, Department of Highways v. Denny,* 385 S.W.2d 772 (Ky., 1964).

Minnesota: *Hendrickson v. State,* 267 Minn. 436, 127 N.W.2d 165 (1964); *State v. Kohler,* 268 Minn. 77, 128 N.W.2d 90 (1964); *State v. Widen,* 268 Minn. 209, 128 N.W.2d 755 (1965); *State v. Gannons, Inc.,* 275 Minn. 14, 145 N.W.2d 321 (1966); *State v. Prow's Motel, Inc.,* 285 Minn. 1, 171 N.W.2d 83 (1969).

Nebraska: *Balog v. State, Department of Roads,* 177 Neb. 826, 131 N.W.2d 402 (1964).

Nevada: *State ex rel. Department of Highways v. Linnecke,* 468 P.2d 8 (Nev., 1970).

New Jersey: *State, Commissioner of Transportation v. Charles Investment Corporation,* 143 N.J. Super. 541, 363 A.2d 944 (1976).

New Mexico: *State ex rel. State Highway Commission v. Silva,* 71 N.M. 350, 378 P.2d 595 (1962); *State ex rel. State Highway Commission v. Danfelser,* 72 N.M. 361, 384 P.2d 241 (1963); *State ex rel. State Highway Commission v. Lavasek,* 73 N.M. 33, 385 P.2d 361 (1963); *State ex rel. State Highway Commission v. Mauney,* 76 N.M. 36, 411 P.2d 1009 (1966).

New York: *Bopp v. State,* 19 N.Y.2d 368, 280 N.Y.S.2d 135, 227 N.E.2d 37 (1967); *Northern Lights Shopping Center, Inc. v. State,* 20 App.Div.2d 415, 247 N.Y.S.2d 333 (1964); *Slepian v. State,* 34 App.Div.2d 880, 312 N.Y.S.2d 338 (1970).

North Carolina: *Department of Transportation v. Harkey,* 57 N.C. App. 172, 290 S.E.2d 773 (1982).

North Dakota: *Chandler v. Hjelle,* 126 N.W.2d 141 (N.D., 1964); *Filler v. City of Minot,* 281 N.W.2d 237 (N.D., 1979).

Ohio: *State ex rel. Noga v. Masheter,* 42 Ohio St. 471, 330 N.E.2d 439 (1975).

Rhode Island: *Saints Sahag and Mesrob Armenian Church v. Director of Public Works,* 116 R.I. 735, 360 A.2d 534 (1976).

South Carolina: *South Carolina State Highway Department v. Allison,* 246 S.C. 389, 143 S.E.2d 800 (1965).

Utah: *Utah Road Commission v. Hansen,* 14 Utah2d 305, 383 P.2d 917 (1963).

Wisconsin: *Stefan Auto Body v. State Highway Commission,* 21 Wis.2d 363, 124 N.W.2d 319 (1963); *Surety Savings & Loan Association v. State, Department of Transportation,* 54 Wis. 2d 438, 195 N.W.2d 464 (1972).

Wyoming: *State Highway Commission v. Peters,* 416 P.2d 390 (Wyo., 1966).

The application of the general rule is illustrated in the following representative cases:

Creasy v. Stevens, 160 F.Supp. 404 (D.C. Pa., 1958), involved a statute of the Commonwealth of Pennsylvania authorizing the creation of limited-access highways and providing that the Commonwealth "shall not be liable for consequential damages" in the establishment of such highways. In holding that the statute was unconstitutional insofar as it authorized the destruction of access rights without payment of compensation, the Court stated that: "Most authorities on limited-access highways recognize that where an established 'land-service' road ... is converted into a limited access highway in such manner that the existing rights of access are destroyed, the owners of such rights are entitled to compensation. ... The right of access has been recognized universally as a property right which cannot be taken or *materially interfered with* without just compensation." (Emphasis supplied.)

In *State ex rel. Herman v. Schaffer,* 105 Ariz. 478, 467 P.2d 66 (1970), a limited-access highway was constructed entirely within the boundaries of an existing conventional road. The owners of the properties abutting on the old road were provided access to the new limited-access highway by means of two frontage roads constructed on either side of the new highway, both of which had lanes for two-way traffic. The point of connection with the new highway was some 2,000 ft distant from the affected properties.

The Court first pointed out that there are two fact situations that admit of no doubt in respect to the applicable law. In the first situation the limited-access highway is constructed on an entirely new location, in which case there is clearly no right of compensation on the part of owners abutting the new highway. In the second situation the new limited-access highway is constructed on the location of the old conventional road, but the owners abutting on the old road are completely deprived of access to the new road. The Court stated that in this situation the owners are unquestionably entitled to compensation.

The Court went on to say that in the instant situation, where frontage roads were constructed to provide access to the new limited-access highway, the determinative question was whether the frontage roads provided reasonable access to the new highway. Noting that such frontage roads provided for two-way traffic in either direction the Court found that ingress and egress in either direction was not unreasonably circuitous, and stated that: "We hold that under the principles of law, set forth herein, relating to the standards of *reasonable* ingress and egress, the frontage road provided by the State for the benefit of these defendants was not *unreasonably* circuitous. Therefore, the limitation of access is not compensable." (Emphasis supplied.)

However, in applying the "reasonableness" test in another Arizona case, *State ex rel. Herman v. Wilson,* 103 Ariz. 194, 438 P.2d 760 (1968), the Supreme Court of Arizona reached the opposite result, holding that the substitute access remaining to the landowner after conversion of the abutting conventional road into a limited-access highway, which was by way of an existing road in the public highway system rather than by way of a new frontage road, resulted in "unreasonable" circuity of travel, and hence the State was liable in damages for impairment of access.

In adopting the "reasonableness" test to determine whether or not there was a compensable impairment of access when abutting owners were placed on a frontage road after the road adjacent to their property was changed into a limited-access highway, the Supreme Court of Kansas, in *Brock v. State Highway Commission,* 195 Kan. 361, 404 P.2d 934 (1965), stated:

> We adhere to the rule that the owners of abutting lands have a right of access to the public road system but it does not follow that they have a right of direct ingress and egress to and from a controlled access thoroughfare. The right of access ... is the right to *reasonable,* but not unlimited, access to and from the abutting lands. ... The [owners'] property abuts on a frontage or service road. Appellants have access to the frontage road at all points at which it abuts their property. There is no suggestion that the frontage or service road is not of property quality. ... Appellants are granted access to the main highway at the east and west ends of their property. ... We are forced to conclude that appellants were not denied access to the highway system since the frontage road is a part of the highway system to which appellants admittedly have access at all points at which it abuts their property. The frontage road in turn provides them access to the through-traffic lanes by points of connection between the frontage road and the through-traffic lanes.... (Emphasis supplied.)

In invoking the "reasonableness" test to determine whether or not there had been a compensable impairment of access, the Supreme Court of Iowa, in *Iowa State Highway Commission v. Smith,* 248 Iowa 869, 82 N.W.2d 755 (1957), stated that: "No hard and fast rule can be stated as to whether an abutting property owner has been denied access that is reasonable.... In most instances the question is one of fact, not of law, and its determination depends largely upon the evidence in the particular case." The Court went on to rule that on the facts of the case *sub judice* the abutting owners were provided with all the access that was "reasonably necessary" after the conversion of a conventional road into a limited-access highway, and, therefore, there was no such impairment of access as would entitle the owners to damages.

In holding that the substitute access provided an abutting landowner was not of such nature as to constitute a material impairment of access rights, the Court of Appeals of Kentucky, in *Commonwealth, Department of Highways v. Denny,* 385 S.W.2d 776 (Ky., 1964), enunciated the principle that "as long as a property owner has *reasonable* access to his property after the closing of an existing road by construction of a limited access highway, he has suffered no compensable damages." (Emphasis supplied.)

It appeared in *Hendrickson v. State,* 267 Minn. 436, 127 N.W. 2d 165 (1964), that at the time the action below was brought seeking damages for impairment of access, a conventional road had already been made into a limited-access highway and a frontage road constructed for the benefit of abutting landowners. However, no determination had as yet been made by the State highway department as to the nearest permissible point of entry from the frontage road onto the limited-access highway. In reversing a summary judgment entered below for the State, the Court remanded with directions that the trial judge "determine by appropriate inquiry the proposed location of the nearest permanent interchange," and, stating that "what is reasonable ingress and egress is a fact question," the Court instructed that the jury make determination as to whether the proposed location of the nearest interchange would provide reasonable access to the new highway, or instead constitute a substantial and therefore compensable abridgement of the abutting owners' former right of access.

The plaintiffs bringing suit in *Balog v. State, Department of Roads,* 177 Neb. 826, 131 N.W.2d 402 (1964), were lessees of a tract of land used for commercial purposes that abutted on a road converted into a controlled-access highway. Upon conversion of the conventional thoroughfare a frontage road was constructed by the State providing plaintiff with access to the new highway at a distance of approximately 310 ft in one direction and 385 ft in the other direction. On trial of the action to recover for impairment of access the jury returned a verdict of no damages. Plaintiffs appealed and the State contended, *inter alia,* that the mere construction of the frontage road allowing ingress and egress was sufficient in itself to deny plaintiffs any right to damages. In rejecting this contention the Supreme Court of Nebraska stated that "the weight of authority in the United States is to the effect that either the destruction or the material impairment of the access easement of an abutting property owner ... is compensable," and that the "measure of the right of the owner of property abutting on a street to access to and from it by way of the street is reasonable ingress and egress under all the circumstances." Stating that the "evidence in this case would support a finding of substantial impairment of the right of access," the matter was remanded for trial in conformance with the general rule as stated by the Court.

In *State ex rel. Department of Highways v. Linnecke,* 468 P.2d 8 (Nev., 1970), the owners of property abutting on a State road that was converted into a controlled-access Interstate highway were awarded damages for impairment of access, where the evidence established that the frontage road constructed to provide connection with the new Interstate highway permitted ingress and egress to and from the owners' property at a distance of more than one mile at the nearest point. The State apparently contended on appeal that the construction of the frontage road was sufficient in and of itself to deny compensation. In rejecting this contention the Supreme Court of Nevada, after reviewing the applicable case law from other jurisdictions, aligned itself with what it described as "the emerging weight of authority," and, in affirming judgment below, stated that it adopted the generally prevailing view that the test of compensability is whether the frontage road provides reasonable access to and from the new highway, or instead results in a material or substantial impairment of the abutting owners' former right of access. It stated that: "An abutting owner on a public highway has a special right of easement in a public road for access purposes. This is a property right of easement which cannot be damaged or taken from the owner without due compensation. But an owner is not entitled to access to his land at *all* points in the boundary to it and the highway, although *entire* access to his property cannot be cut off. If he has free and convenient access to his property and his means of egress and ingress are not substantially interfered with, he has no cause for complaint." (Emphasis by the Court.)

In holding that landowners abutting on a State road that was converted into a limited-access Interstate highway were not deprived of compensable access rights when placed on a frontage road which connected with the Interstate highway at points not specified, the Supreme Court of New Mexico, in *State ex rel. State Highway Commission v. Danfelser,* 72 N.M. 361, 384 P.2d 241 (1963), announced the rule determinative of liability for access impairment in the language as follows:

> We take the position that abutters (the defendants in this case) have a right of access to the public roads system; but it does not necessarily follow that they have a right of direct access to the main-traveled portions thereof. Circuity of travel, as long as it is not *unreasonable,* and any supposed loss in land value by reason of the diversion of express traffic, are non-compensable.
>
> In other words, the right of access ... is merely a right to *reasonable,* but not unlimited, access to and from the land. (Emphasis supplied.)

The same Court in a case involving a similar fact situation stated that: "An abutter having access to a frontage road which provides *reasonable* access to the main traveled highway is afforded access to the public road system, and any circuity of travel, once that access is given, is noncompensable." (Emphasis supplied.) *State ex rel. State Highway Commission v. Lavasek,* 73 N.M. 33, 385 P.2d 361 (1963).

The New York Court of Appeals addressed the problem of access rights in *Bopp v. State,* 19 N.Y.2d 368, 280 N.Y.S.2d 135, 227 N.E.2d 37 (1967), where the owners of property abutting on a conventional State highway were placed on a frontage road when the old road was changed into a controlled-access highway. It stated that "we wish to make clear what we believe to be the law in this State regarding damages incurred by the owner of property located on a State highway, with unlimited access thereto, when a new highway is constructed which no longer affords the property owner direct access to the State highway but requires travel on a new or old access route to the new highway."

The Court first stated that "under these circumstances the owner of the property is not entitled to damages incurred because access is no longer as direct as it once was or because the new or remaining access is less than ideal. Nor are damages recoverable because traffic no longer passes in front of the claimant's property or because his property is no longer visible to those traveling on the main highway. ... Now that the State has determined that it would be in the public interest to construct a new and modern highway, capable of providing safer and speedier travel, the *claimants may not complain.* The State's obligation to them is fulfilled if they have a *reasonably adequate means of access* to and from the new highway." (Emphasis supplied.)

Without further multiplication of authority it is seen that under the majority rule the test of whether an owner of land abutting on a conventional highway is entitled to damages for impairment of access when such road is converted into a limited-access highway is one of reasonableness. If there is a whole deprivation of access, the owner is clearly entitled to damages; but if the access remaining to him, whether by way of frontage road or other roads in the public highway system, constitutes reasonable access to the new highway, he is not entitled to damages. And conversely, if the remaining or substitute access constitutes a material or substantial impairment of the former right of access enuring to the landowner, he is entitled to recover in damages. As stated by one commentator: "When right of access is involved, we have only to establish that access has been diminished. Since we defined access as 'reasonable access', there can be a taking only if the diminution is 'unreasonable' or 'substantial'. What is 'substantial', of course, is a question of fact that poses practical problems of proof and of measurement of the facts as found against the legal standard."[7]

Exceptions to the General Rule

A scant few cases are to be found that require mention chiefly because they have sometimes been interpreted by courts or commentators as constituting exceptions to the general rule.

For example, a small number of cases have been cited or construed as standing for the proposition that the construction of a frontage road to provide ingress and egress for an abutting owner is sufficient in and of itself to deny any compensation for impairment of access. See, *e.g.*, *Houghs v. Mackie*, 1 Mich.App. 554, 137 N.W.2d 289 (1965); *State ex rel. State Highway Commission v. Brockfeld*, 388 S.W.2d 862 (Mo., 1965).[8]

The *caveat* is offered that caution should be exercised in accepting such interpretation. It is true that in these cases a frontage road was constructed and compensation denied without mention of the reasonableness doctrine, but an equally plausible interpretation of the rationale of these cases is that compensation was denied for the reason that the courts rejected the claim of the abutting owners that they were entitled to compensation for diversion of traffic. Whatever the correct interpretation of these cases it may safely be said that a rule of law that would deny recovery for impairment of access without any regard to the adequacy of substitute access does not commend itself to reason.

Another so-called exception to the general rule is the isolated view that an abutting owner is not entitled to recover for impairment of access except and unless part of his property has been taken in condemnation. This view was expressed in *Nick v. State Highway Commission*, 13 Wis.2d 511, 109 N.W.2d 71 (1961), in the language as follows: "An impairment of the use of property by the exercise of the police power, where the property is not taken by the state, does not entitle the owner of such property to a right to compensation. ... [I]f no land is taken for the converted highway but the abutting landowners' access to the highway is merely made more circuitous, no compensation should be paid."

The view seems to be based on the reasoning that recovery for impairment of access may only be had as part of severance damages, and where there is no partial taking of land (and hence no severance damage) recovery for impairment of access cannot be allowed.

This reasoning has been the subject of strong criticism. For instance, Professor Stoebuck states that:

> Some courts ... profess to award compensation for loss of access only when part of the ... land is physically taken. This betrays a fundamental lack of knowledge of the nature of access rights. We allow compensation for loss of access at all only because the right of access is a species of property within the panoply of a constitutional eminent domain clause. Why then should we refuse to compensate for its loss unless other forms of property no doubt compensable separately in their own right, are taken along with it? To refuse compensation is to deny legitimacy in the long historical process by which various forms of intangible rights in land, including access rights, were recognized as 'property.' It is an anachronism and a source of confusion.[9]

In keeping with this line of doubtless legitimate criticism the doctrine that compensation for impairment of access cannot be paid unless accompanied by a physical taking of property has either been ignored by the majority of the courts or made the subject of express repudiation.[10]

It has also been said that an exception to the general rule exists in the situation where the State converts the paved surface of the existing conventional road into the frontage road for the use of the abutting property owner. It has been argued that under these circumstances the abutting owner's right of direct access to the old road has not been changed in the slightest degree and that it cannot therefore be said that he has been made to suffer any impairment of access upon conversion of the way to limited-access. Such rule was announced in *State ex rel. Morrison v. Thelberg*, 87 Ariz. 318, 350 P.2d 988 (1960), as follows:

> It seems to be the law ... that where land is condemned or purchased for the construction of a controlled-access highway ... that an abutting owner of land on the old highway, which is retained as a service road, cannot recover damages for destruction or impairment or loss of access for the reason that his access to the old highway has not been disturbed in the slightest degree.

This rule carried to its logical conclusion would deny recovery even in the situation where the old road never made connection with the new highway. That this is a wholly untenable result was recognized by the Court in *Teachers Insurance and Annuity Association of America v. City of Wichita*, 221 Kan. 325, 559 P.2d 347 (1977), where an existing conventional road was converted into a frontage road that never made connection with the newly constructed limited-access highway, and the property owners abutting on the frontage road were awarded compensation for impairment of access without regard to the fact that their direct access to the frontage road remained completely unchanged.

In order to make supportable the rule that impairment of access does not take place in the situation where the old road is used as a frontage road, it is necessary to imply in the statement of the rule that the frontage road makes connection with the limited-access highway at some point; and this being the case, the question inevitably must arise whether the point of connection is so located as to provide reasonable access, or is so situate as to constitute a material or substantial impairment of access. What would appear to be the correct rule, and the one followed by the great majority of the courts, is stated in *State ex rel. State Highway Commission v. Mauney*, 76 N.M. 36, 411 P.2d 1009 (1966), as follows:

> This court cannot understand why a person's rights as to compensation should differ if the state should decide to use the old road for a frontage road or use it for the through lanes of a limited-access highway. . . . [S]uch a difference should make no change in the right to compensation for deprivation of access.

Finally, it may be noted that although the statement has been made by at least one commentator that certain cases support the proposition that an abutting owner is entitled to damages in any and all instances where direct access to a limited-access highway has been denied, and that the frontage road then becomes a mitigating factor in determining the amount of damages (*i.e.*, whether nominal or severe), the cases cited in support simply do not square with such statement, and hence are omitted from consideration or discussion herein.

This concludes the review of cases dealing with exceptions to the general rule. Next for consideration is the question whether the determination of impairment of access is one of law for the court, or fact for the jury to decide.

IMPAIRMENT OF ACCESS AS CONSTITUTING QUESTION OF LAW OR FACT

There appears to be a fairly clean split of authority on the question of whether impairment of access is a question of law for the court to decide or a question of fact for jury determination. The cases dividing themselves rather evenly on this question are noteworthy for the fact that the decision in most instances appears to be arbitrary, that is to say, the courts simply announce that the question is one of law or one of fact, without any discussion of the reasons that support or compel the conclusion reached.

Question of Law

In the following cases the courts, without elaboration, announced the conclusion that impairment of access is a matter of law for the court to decide.

In *People v. Ricciardi*, 23 Cal.2d 390, 144 P.2d 799 (1943), involving conversion of a conventional road into a limited-access highway, the Supreme Court of California stated that: "It was therefore within the province of the trial court and not the jury to pass upon the question whether under the facts presented, the defendants' right of access will be substantially impaired. If it will be so impaired the extent of the impairment is for the jury to determine. This is but another way of saying that the trial court and not the jury must decide whether in the particular case there will be an actionable interference with the defendants' right of access."

In *Ray v. State Highway Commission*, 196 Kan. 13, 410 P.2d 278 (1966), a frontage road was constructed within the right-of-way of a conventional road converted to limited access. Plaintiffs, whose properties formerly abutted on the old conventional road and subsequently fronted on the new service road, brought suit to recover for impairment of access. The Court stated, without elaboration, in respect to the issue of impairment of access, that: "This is a question of law to be determined by the court in the first instance."

In *State ex rel. Department of Highways v. Linnecke*, 468 P.2d 8 (Nev., 1970), involving claimed damages for impairment of access when abutting property owners were placed on a frontage road, the Court stated in respect to impairment of access that: "The determination of whether such substantial impairment has been established must be reached as a matter of law. The extent of such impairment must be fixed as a matter of fact."

It was urged in *Stefan Auto Body v. State Highway Commission*, 21 Wis.2d 363, 124 N.W.2d 319 (1963), that the determination of impairment of access was a fact question that would defeat a motion for summary judgment. In rejecting this contention the Court stated that: "This is a question of law and depends upon the nature and scope of the right of access."

Question of Fact

Other cases have reached a contrary result and ruled that the determination of whether or not there has been a material or substantial impairment of access is a question of fact for the jury to decide.

Thus, in *Hendrickson v. State*, 267 Minn. 436, 127 N.W.2d 165 (1964), the Court stated that: "What is reasonable ingress and egress is a fact question. If the jury decides that the location of the proposed interchange substantially impairs plaintiffs' right to reasonably convenient and suitable access to the main thoroughfare, plaintiffs are entitled to damages."

In *Balog v. State, Department of Roads*, 177 Neb. 826, 131 N.W.2d 402 (1964), involving the conversion of an existing conventional highway into a limited-access way, the Court said that: "Whether the right of access has been destroyed or substantially impaired is a question of fact which must be determined upon the particular facts of each case."

The Court ruled in *State ex rel. Herman v. Schaffer*, 105 Ariz. 478, 467 P.2d 66 (1970), that "whether the ingress and egress provided by the frontage road is reasonable is a question to be resolved by the trier of fact in the first instance."

In *Linge v. Iowa State Highway Commission*, 260 Iowa 1226, 150 N.W.2d 642 (1967), the Court committed itself to the rule that the determination of impairment of access is a jury matter, stating that "the question is one of fact not law."

In taking leave of this matter the suggestion is made that the courts have come down on both sides of the issue because the question is a mixed question of law and fact. There appears to be no reason why the courts should be required to decide the question outside the facts of the particular case. A workable approach might be that if the facts were such that reasonable men could not differ on the question of impairment of access, the court could then properly take the matter from the jury, and if on the other hand the facts were such that reasonable men could differ, the matter could properly be left for jury determination. Indeed, if such approach were given application to the facts of many of the decided cases, it would appear adequate to explain the result reached.

EFFECT OF DISTANCE REQUIRED TO BE TRAVELED

The distance required to be traveled along the frontage road or through the public roads system to gain access to the new limited-access highway is, of course, of importance in determining whether recovery may be had. However, no footrule exists by which to measure what distance will be deemed reasonable and what distance will be deemed unreasonable. Such determination is made in the light of the facts of the particular case.

For what it is worth, it may be noted that in many of the cases where the nearest interchange or other point of entry was one-quarter mile or less from the abutting owner's property, the access was held to be reasonable, and hence noncompensable.[11] And in several cases where the distance was more than one mile the access was held to be unreasonable, and therefore compensable.[12] The cases involving intermediate distances appear to be about evenly divided in result.[13]

Conclusive significance cannot be ascribed to the actual distance required to be traveled for the reason that other factors are to be taken into consideration. These include the physical condition of the road, the number and type of curves, the grade of ascent and descent along the frontage road, the attainable rate of safe speed thereon, the amount of traffic, number of intersecting roads, and any and all other factors that make for ease or difficulty, and the amount of time consumed in motor vehicle travel. The decision as to reasonableness is made on the basis of the aggregate of all these factors. The actual distance required to be traveled is a prime consideration but at the same time no more than one of the factors to be taken into account.

This brings to a conclusion the review of the principal matters that are to be taken into consideration in determining the rights of abutting owners when a conventional road is converted into a limited-access highway. Although this paper is concerned with the rights of abutting owners, not their remedies, a few words may be in order with respect to the computation of damages once it is determined that there has been a compensable impairment of access.

MEASURE OF DAMAGES

The determination of impairment of access generally arises in one of three procedural ways, as follows: (1) where the State brings suit to condemn the abutting owner's access rights; (2) where the State institutes action to condemn part of the abutting owner's property and compensation for impairment of access is treated as an element of severance damage; or (3) where the State institutes no legal proceeding and the abutting owner brings an action in inverse condemnation to recover for the taking or damaging of the right of access. In whichever way the question arises the "before and after" rule is, generally speaking, the measure of damages. That is to say, the measure of damages for destruction or impairment of access is the difference between the market value of the property immediately before and immediately after the taking or damaging of the right of access, based upon the highest and best use of the property immediately before and after the destruction or impairment of the right of access.

Thus, in *State ex rel. Morrison v. Thelberg,* 87 Ariz. 318, 350 P.2d 988 (1960), involving damages for impairment of access caused by the conversion of a conventional road into a limited-access highway, the Court stated that:

> The measure of damages for the destruction or impairment of access to the highway upon which the property of an owner abuts is the difference between the market value of the abutting property immediately before and immediately after the destruction or impairment thereof. The damages awarded the abutting landowners for destruction or impairment of access therefore is based, not upon the value of the right of access to the highway, but upon the difference in the value of the remaining property before and after the access thereto has been destroyed or impaired. This in turn is based upon the highest and best use to which the land involved is best suited before and after the right of access is molested.

In *Boxberger v. State Highway Commission,* 126 Colo. 526, 251 P.2d 920 (1952), involving claimed compensation for impairment of access resulting from the conversion of a conventional State road into a controlled-access freeway, the Court said in respect to the measure of damages: "It would seem difficult to establish the true or market value of access rights since they are not a commodity dealt in on a buying and selling market; however, the right of ingress and egress to and from a person's property adds or detracts from the property value and it would seem that the true value of such rights could only be found in the difference between the value of the land and its use for any and all kinds of purposes before the disturbance or destruction of such rights, and the value of the land minus any access or disturbed or inconvenient access to the highway."

In holding that the owners of property abutting on a conventional road were entitled to damages for impairment of access when such road was converted to limited-access, the Court in *Hurley v. State,* 82 S.D. 156, 143 N.W.2d 722 (1966), stated in respect to the measure of damages:

> The measure of damages for the obstruction or substantial impairment of an abutting landowner's right of access to a street or highway is the difference between the market value of the property considered at its highest, best, and most profitable use immediately before and immediately after the destruction or impairment.

See to the same effect: *State ex rel. Herman v. Schaffer,* 105 Ariz. 478, 467 P.2d 66 (1970); *County of Santa Clara v. Curtner,* 245 Cal. App.2d 730, 54 Cal.Rptr. 257 (1966); *Anhoco Corporation v. Dade*

County, 144 So.2d 793 (Fla., 1962); ***Hendrickson v. State***, 267 Minn. 436, 127 N.W.2d 165 (1964); ***Muse v. Mississippi State Highway Commission***, 233 Miss. 694, 103 So.2d 839 (1958); *State ex rel. Department of Highways v. Linnecke*, 468 P.2d 8 (Nev., 1970); *State ex rel. Department of Highways v. Bowles*, 472 P.2d 896 (Okla., 1970).

Next for consideration are those elements of damage that are generally excludable in computing the amount of damages suffered as a result of impairment of access. The chief among these is the claim to compensation based on losses suffered as a result of diversion of traffic.

DIVERSION OF TRAFFIC

Commercial establishments are the chief victims of diversion of traffic when a limited-access highway is constructed on the right-of-way of an existing conventional road. In the usual situation prior to the conversion the motoring public has direct access to the commercial property at one or more convenient points. After the conversion such point or points of access are closed, and not infrequently the entire property is completely separated from the controlled-access road by fencing. The traveling public can gain entry to the commercial establishment only by use of the frontage road, and then only at such points of entry as are permitted. The frequent result is that the permissible point of entry is passed before the motorist even has a chance to see the commercial establishment, and then, rather than double back, the motorist continues on his way. Loss of business from such diversion of traffic is, of course, an inescapable fact, and many roadside businesses have been forced to close their doors because of the loss of patronage caused by the conversion of a conventional road into a limited-access highway.

Although the damage to roadside businesses resulting from diversion of traffic is often too clear to admit of argument, the courts are, nevertheless, firmly committed to the rule that damage resulting from diversion of traffic is noncompensable. The courts reason that an abutting property owner has no vested right in the flow of traffic past his property and when such flow is changed or altered there is consequently no cause to complain.

The following cases illustrate the application of this rule:

The principal question for consideration in *Arkansas State Highway Commission v. Bingham*, 231 Ark. 934, 333 S.W.2d 728 (1960), was whether the lessee of property used for a gasoline service station was entitled to damages for diversion of traffic, when the conventional road on which it abutted was converted into a limited-access highway, and lessee's customers were forced to use a frontage road to gain access to the property. In holding that the lessee was not entitled to damages for diversion of traffic, the Court stated:

> [L]oss occasioned by the diversion of traffic is not compensable. It is not denied in this case that Lessee's major loss of business was the result of a diversion of traffic . . . from its filling station after the limited access road was completed. For us to hold that such loss by Lessee is compensable would amount to erecting an almost intolerable barrier in the way of further construction of super-highways. The right here claimed by Lessee is not to be confused with its right of ingress and egress. The latter right . . . is a property right which is compensable, but Lessee has that right undiminished by virtue of the access road in front of its station.

In *People v. Becker*, 262 Cal.App.2d 634, 69 Cal.Rptr. 110 (1968), a conventional road was converted into a controlled-access highway and a frontage road was constructed to provide ingress to and egress from the abutting property, upon which a gasoline service station business was conducted. In ruling on the issue of claimed compensation for impairment of access, the Court made clear that damages for diversion of traffic from the business carried out on the property could not be allowed, stating that: "The diversion of traffic is not a proper element to be considered in computing damages inasmuch as a landowner has no property right in the continuation of traffic past his property."

In *Brock v. State Highway Commission*, 195 Kan. 361, 404 P.2d 934 (1965), where the issue before the Court was whether a frontage road provided reasonable access to a newly constructed limited-access highway, the Court said in respect to the diversion of traffic caused by the conversion of the abutting road into a controlled-access facility: "As for diversion of traffic, an abutting owner has no right to the continuation of a flow of traffic in front of his property. The state's exercise of its police power in such situations is predominant and controlling. The owner of abutting land has no property right in the traveling public using the highway."

And in *James v. State*, 88 Idaho 172, 397 P.2d 766 (1964), the Court stated in respect to damages for diversion of traffic that: "Diversion of traffic occasioned by the relocation of the highway does not cause a compensable injury, for appellants have no property right in any flow of traffic over a particular highway."[14]

Consistent with the rule that damages are not recoverable for diversion of traffic is the general rule that evidence of loss of patronage, or business earnings or profits due to diversion of traffic, is not admissible.[15]

FRONTAGE ROAD AS FACTOR IN MITIGATION OF DAMAGES

It has been held in a few cases that the construction of a frontage road is a factor that may be taken into consideration in mitigation of damages after determination has been made by the court or jury that the conversion of a conventional road into a limited-access highway has resulted in material or substantial impairment of the abutting property owner's right of access. See ***State ex rel. Morrison v. Thelberg***, 87 Ariz. 318, 350 P.2d 988 (1960); ***People v. Ricciardi***, 23 Cal.2d 390, 144 P.2d 799 (1943); ***Hendrickson v. State***, 267 Minn. 436, 127 N.W.2d 165 (1964); ***Balog v. State, Department of Roads***, 177 Neb. 826, 131 N.W.2d 402 (1964); ***State ex rel. Department of Highways v. Linnecke***, 468 P.2d 8 (Nev., 1970); ***South Carolina State Highway Department v. Allison***, 246 S.C. 389, 143 S.E.2d 800 (1965).

The courts adopting this view thus accord the frontage road the dual role of being both a consideration in the determination of whether reasonable substitute access has been provided, and a factor in determining the amount of the award, once it has been determined that reasonable substitute access has not been provided.

This brings to a conclusion the overview of the general rules that obtain in respect to computation of damages once determination has been made that access rights have been materially or substantially impaired. There follows next a brief review and synopsis of the rules of law that govern the rights of abutting owners when a conventional road is converted into a limited-access highway.

SUMMARY

When the relatively recent concept of the limited-access highway came upon the scene and was upheld by the courts as a valid exercise of the police power, the rule was already well established that an owner of property abutting on an existing conventional road has a right of access thereto. Such right had been determined to be a private as distinguished from a public right, and was denominated as an easement appurtenant to the land. Being a right in property, it was, like other vested interests in property, subject to the protection of the constitutional guarantees in respect to due process of law and the payment of just compensation for private property taken for a public use.

However, such right was never regarded as being unlimited. It had long been settled that in order to provide for the safe movement of traffic on the public way, the State could, under its police power, limit access to and from the property to a designated point or points in the boundary line between the property and the public way. Thus, it was held at an early date, that the abutting owner's right of access could, consistent with constitutional guarantees, be restricted to that measure of access which, under all the circumstances, was *reasonable.*

In the situation where the limited-access highway was constructed on an entirely new location, little in the way of problem was presented to the courts, but where the new controlled-access highway was constructed on all or part of the right-of-way of an existing conventional road, the courts were faced with the more difficult task of adjusting between the abutting owner's constitutionally protected right of access and the right of the general public to receive and enjoy the benefits of the safe, swift and economical form of travel provided by the growing network of "superhighways."

Since it was clear that the abutting owner's right of reasonable access could not be completely destroyed without payment of compensation, it appeared from the outset equally clear that the abutting owner could not, without payment of compensation, be left landlocked and denied all access to the new highway, as well as being foreclosed from all access to the adjoining conventional road. The balance of equities between the abutting owner's private rights and the rights of the general public in safe and secure automotive travel was eventually struck by adopting the principle that the owner's private rights would not be violated so long as he was provided with some form of *reasonable* access to the highway systems.

The rule evolved that the owner's limited right of *direct* access could be taken without molestation of constitutional principles so long as adequate *indirect* access was substituted in its place. Such indirect access could take the form of travel on a frontage road to a point of connection with the new highway, or, in the event the owner's property abutted on another public road, travel along such road, or other connecting roads, to a point of entry on the new highway. And the test of whether or not the indirect access was adequate came to be whether, under all the circumstances, the access so provided was *reasonable.* In other words, the rule that the abutting owner's right of access to the adjoining conventional road may be limited to that which is reasonable was translated and made applicable to the abutting owner's rights in respect to ingress to and egress from the new limited-access highway.

Hence, the general rule, supported by the overwhelming weight of authority, came to be that if on the facts of the particular case the indirect or substitute access was reasonable, the abutting owner was not entitled to compensation. The provision of reasonable substitute access by the State was deemed under such circumstances to be a noncompensable police power function or activity. If, on the other hand, the substitute access was adjudged to be unreasonable, or to constitute a material or substantial impairment of the existing right of access, the owner was then held to be entitled to compensation. Under these circumstances the failure to provide reasonable access was deemed to result in a taking or damaging of the owner's right of access, and hence constituted an exercise of the power of eminent domain requiring payment of compensation.

The courts became divided, however, on the issue of whether determination of reasonableness was a question of law or fact. In some jurisdictions the determination of reasonableness is today treated as a matter of law for the trial judge to decide, whereas in others, the rule obtains that the trier of fact makes determination both as to reasonableness of access, and the extent or amount of damage suffered where material impairment of access is found to exist.

In determining the amount of compensation, damages are not awarded for mere circuity of travel. However, the distance required to be traveled to gain entry to the new highway is a factor to be taken into consideration in determining whether the substitute access is reasonable. No exact or even approximate distance can be specified as constituting that which is reasonable. Where a frontage road is provided, the condition of the road, the amount of time consumed in travel thereon, and all other factors pertaining to ease or difficulty in travel, are taken into consideration. The same test applies where the owner is relegated to the use of another road or roads in the public highway system to effect ingress to and egress from his property.

Once it has been determined, by the court or jury, that material impairment of access has occurred, the measure of damages is the difference in market value of the affected property immediately before and after the impairment of access occurs, based on the highest and best use of the property before and after the damage takes place. In computing the amount of the injury, damages resulting from diversion of traffic (such as lost earnings and profits of commercial establishments) are, generally speaking, to be excluded, for the reason that a property owner abutting on a public road has no property interest in the continuing flow of traffic past his property.

In some jurisdictions mitigation of damages may be accomplished by taking into consideration the effect of the existence of a frontage road. Thus, in such jurisdictions the frontage road plays the dual role of being b th a significant factor in the determination of the basic question of reasonableness of access, and also a factor in determining the amount of damage suffered, once it has been established that material and hence compensable impairment of access exists.

The foregoing are the principal rules that govern the rights of abutting owners upon conversion of a conventional road into a limited-access highway. And it is by the application of these rules that the cost of conversion (at least insofar as the rights of abutting owners are concerned) can be projected in highway planning with a reasonable measure or degree of accuracy or precision.

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[1] See 26 Am.Jur.2d, *Eminent Domain*, Sec. 204, wherein it is stated that "there is no right to consequential damages to land not taken for lack of access to a new limited-access highway built where no road existed before."

[2] See 26 AM.JUR.2d, *Eminent Domain*, Sec. 203, stating that "where an established 'land-service' road, in which the normal right of access had already come into being, is converted into a limited-access way in such manner that the existing rights of access are destroyed, the owners of such rights are entitled to compensation, exactly as they would be if such rights were destroyed by any other type of construction."

[3] For a more detailed discussion of the historical background, development, legal nature and elements of an abutting owner's property right of access, see the paper by Larry W. Thomas, entitled "Legal Implications of Control of Access to Uncontrolled-Access Highways," appearing in *Selected Studies in Highway Law*, Vol. 2, at pp. 936-N23 to 936-N29.

[4] 23 U.S.C. 101, *et seq.*

[5] As exemplary, see the cases cited in this paper decided in the "taking" States of New York, New Jersey, Pennsylvania, and Wisconsin.

[6] Filler v. City of Minot, 281 N.W.2d 237 (N.D., 1979).

[7] Stoebuck, *The Property Right of Access Versus the Power of Eminent Domain*, 47 TEX. L. REV. 733, 765 (1969).

[8] For cases expressly repudiating the view that the mere construction of a frontage road is sufficient to deny compensation, see Balog v. State, Department of Roads, 177 Neb. 826, 131 N.W.2d 402 (1964) and State ex rel. Department of Highways v. Linnecke, 468 P.2d 8 (Nev., 1970), *supra*.

[9] Stoebuck, n. 4, *supra*, p. 753.

[10] State Department of Highways v. Davis, 626 P.2d 661 (Colo., 1981).

[11] See, for example, Brock v. State Highway Commission, 195 Kan. 361, 404 P.2d 934 (1965); Ray v. State Highway Commission, 196 Kan. 13, 410 P.2d 278 (1966); State v. Gannons, Inc., 275 Minn. 14, 145 N.W.2d 321 (1966); Berlowitz v. State, Department of Roads, 180 Neb. 164, 141 N.W.2d 764 (1966); State ex rel. State Highway Commission v. Silva, 71 N.M. 350, 378 P.2d 595 (1962).

[12] See State ex rel. Herman v. Jacobs, 7 Ariz. App. 396, 440 P.2d 32 (1968); People by Department of Public Works v. Renaud, 198 Cal.App.2d 581, 17 Cal.Rptr. 674 (1961); State ex rel. Department of Highways v. Linnecke, 468 P.2d 8 (Neb., 1970).

[13] See denying recovery: State ex rel. Herman v. Schaffer, 105 Ariz. 478, 467 P.2d 66 (1970); People by Department of Public Works v. Home Trust Investment Co., 8 Cal.App. 3d 1022, 87 Cal.Rptr. 722 (1970); State ex rel. State Highway Commission v. Mauney, 76 N.M. 36, 411 P.2d 1009 (1966). See allowing recovery: State ex rel. Morrison v. Thelberg, 87 Ariz. 318, 350 P.2d 988 (1960); People ex rel. Department of Public Works v. Murray, 172 Cal.App.2d 219, 342 P.2d 485 (1959); South Carolina State Highway Department v. Allison, 246 S.C. 389, 143 S.E.2d 800 (1965); State Highway Commission v. Peters, 416 P.2d 390 (Wyo., 1966).

[14] See to the same effect: State ex rel. Herman v. Schaffer, 105 Ariz. 478, 467 P.2d 66 (1970); People v. Ricciardi, 23 Cal.2d 390, 144 P.2d 799 (1943); Blumenstein v. Long Beach, 143 Cal.App.2d 264, 299 P.2d 347 (1956); Ray v. State Highway Commission, 196 Kan. 13, 410 P.2d 278 (1966); State ex rel. Department of Highways v. Hunt, 219 So.2d 602 (La.App., 1968); State v. Gannons, Inc., 275 Minn. 14, 145 N.W.2d 321 (1966); State ex rel. State Highway Commission v. Danfelser; 72 N.M. 361, 384 P.2d 241 (1963); State ex rel. State Highway Commissioner v. Lavasek, 73 N.M. 33, 385 P.2d 361 (1963); A. E. Nettleton Co. v. State, 11 App.Div.2d 899, 202 N.Y.S.2d 102 (1960); Hall & McChesney, Inc. v. State, 15 Misc.2d 748, 182 N.Y.S.2d 560 (1959); Stefan Auto Body v. State Highway Commission, 21 Wis.2d 363, 124 N.W.2d 319 (1963).

[15] James v. State, 88 Idaho 172, 397 P.2d 766 (1964); State v. Hastings, 246 Ind. 475, 206 N.E.2d 874 (1965); Wilson v. Iowa State Highway Commission, 249 Iowa 994, 90 N.W.2d 161 (1958); Hendrickson v. State, 267 Minn. 436, 127 N.W. 2d 165 (1964); Balog v. State, Department of Roads, 177 Neb. 826, 131 N.W.2d 402 (1964); Kirkman v. State Highway Commission, 257 N.C. 428, 126 S.E.2d 107 (1962).

APPLICATIONS

This paper should be useful to highway administrators and right-of-way officials, their legal counsel, and others involved in assessing damages to property owners due to the loss of direct highway access. The discussion on the various factors affecting the determination of a reasonable level of access should be particularly helpful.

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

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CHAPTER 6

ACCESS DESIGN GUIDELINES

CHAPTER 6 - ACCESS DESIGN GUIDELINES

INTRODUCTION

CHAPTER 6

ACCESS DESIGN GUIDELINES

Design Influences

Intersection design, including driveways must consider the following:

- Total approach traffic, design hourly volumes, and turning volumes.
- Composition of traffic (percent of passenger cars, buses, trucks, etc.)
- Operating speed of vehicles.
- Adjacent land use.
- Available funding.

Design Objectives

Major objectives of traffic design concern safety, traffic efficiency and driver expectation through consideration of the following:

- The design should fit the natural transitional paths and operating characteristics of drivers and vehicles. Smooth transitions should be provided for changes in direction.
- Grades at intersections should be as nearly level as possible.
- Sight distances must be sufficient to enable drivers to prepare for and avoid potential conflicts.

(Continued)

INTRODUCTION (Continued)

Design Objectives (Continued)

- On major roadways, intersections should be evenly spaced to the greatest extent possible. This will enhance the synchronization of signals, increase driver comfort, improve traffic operation, and reduce fuel consumption and vehicular emissions.

Intersection Design Principles

Intersection Design Principles
• Limit Number of Conflict Points
• Coordinate Design And Traffic Control
• Avoid Complex Maneuvers
• Separate Conflict Points

The same intersection principles apply to the design of access drives as public roadways. These include the following:

- Limit the number of conflict points. The number of conflict points among vehicular movements increases significantly as the number of intersection legs increases. For example, an intersection with four two-way legs has 32 total conflict points, but an intersection with six two-way legs has 172 conflict points. Intersections with more than four two-way legs should be avoided wherever possible.

- Coordinate design and traffic control. Maneuvers at intersections accomplished at low relative speeds require a minimum of traffic control devices. Maneuvers accomplished at high relative speeds are unsafe unless traffic controls such as stop signs or traffic signals are provided. Designs should physically divert or block the path of vehicles making dangerous movements. Intersection design should be accomplished simultaneously with the development of traffic control plans.

(Continued)

INTRODUCTION (Continued)

Intersection Design Principles (Continued)

- Avoid multiple and compound merging and diverging maneuvers. Multiple merging or diverging requires complex driver decisions and creates additional conflicts.

- Separate conflict points. Intersection hazards and delays are increased when intersection maneuver areas are too close together or when they overlap. Conflicts should be separated to provide drivers with sufficient time (and distance) between successive maneuvers for them to cope with the traffic conflicts one at a time.

> **Intersection Design Principles (Continued)**
>
> - Favor Major Flows
> - Minimize Conflict Areas
> - Segregate Movements

- Favor the heaviest and fastest flows. The heaviest volume and higher speed flows should be given preference in intersection design to minimize hazard and delay.

- Minimize the area of conflict. Excessive intersection area causes driver confusion and inefficient operations. Large areas are inherent with long curb return radii and in skewed and multiple-approach intersections. Channelization should be employed to limit the intersection area and to guide drivers.

(Continued)

INTRODUCTION (Continued)

Intersection Design Principles (Continued)

- Segregate movements. Separate lanes should be provided at intersections when there are appreciable volumes of traffic traveling at different speeds. Separate turning lanes should be provided for left and right turning vehicles. Left turns necessitate direct crossings of opposing vehicle paths and are usually made at speeds of 10-mph or less for reasons of safety and economy. Right turns are also usually made at minimum speeds. However, right turns do not involve potential conflicts of such severity as left turns, and are more suited to individual treatment because they take place at the outside of the intersection area. Therefore, right turns may be designed for higher than minimum speeds where adequate right-of-way is available for wider turns.

Intersection Design Principles (Continued)

- Consider Pedestrians and Bicyclists
- Consider Different Vehicle Types

- Consider the needs of pedestrians and bicyclists. For example, when pedestrians must cross wide streets, refuge islands should be provided.

- Consider different vehicle characteristics. The shapes and dimensions of turning paths vary for different turning speeds, different angles of turn, and for different types and sizes of vehicles.

(Continued)

INTRODUCTION (Continued)

Access Control Elements

The objective of access design and management is to preserve the intended function of the roadway. Some roadways are intended to accommodate a different functional mix of movement-v-access than others. Therefore, different access design guidelines must be developed for each of the different roadway design classes. These access elements will include the following.

Access Control Elements

- **Signal Spacing and Progression**
- **Medians**
- **Auxiliary Lanes**
- **Channelization**
- **Driveway Design and Location**
- **Frontage Roads**
- **Sight Distance**

(Continued)

INTRODUCTION (Continued)

Design Factors

The elements involved in roadway and intersection design, including access drives, are primarily concerned with the following:

Design Factors

- **Operational Controls**
- **Geometric Design Criteria**
- **Physical Site Characteristics**

The modification of access must consider the unique factors pertaining to that location or roadway section. Thus, it is imperative that design criteria presented in this course be used as guidelines; they do not constitute standards which are to be blindly followed. Figure 6-1 identifies some of the individual factors that need to be considered. It might be noted that the operational controls as well as geometric design criteria are, or should be, the same for retrofit as for new design. However, modification of the access of an existing roadway will generally be more severely constrained by site characteristics.

(Continued)

INTRODUCTION (Continued)

Design Factors (Continued)

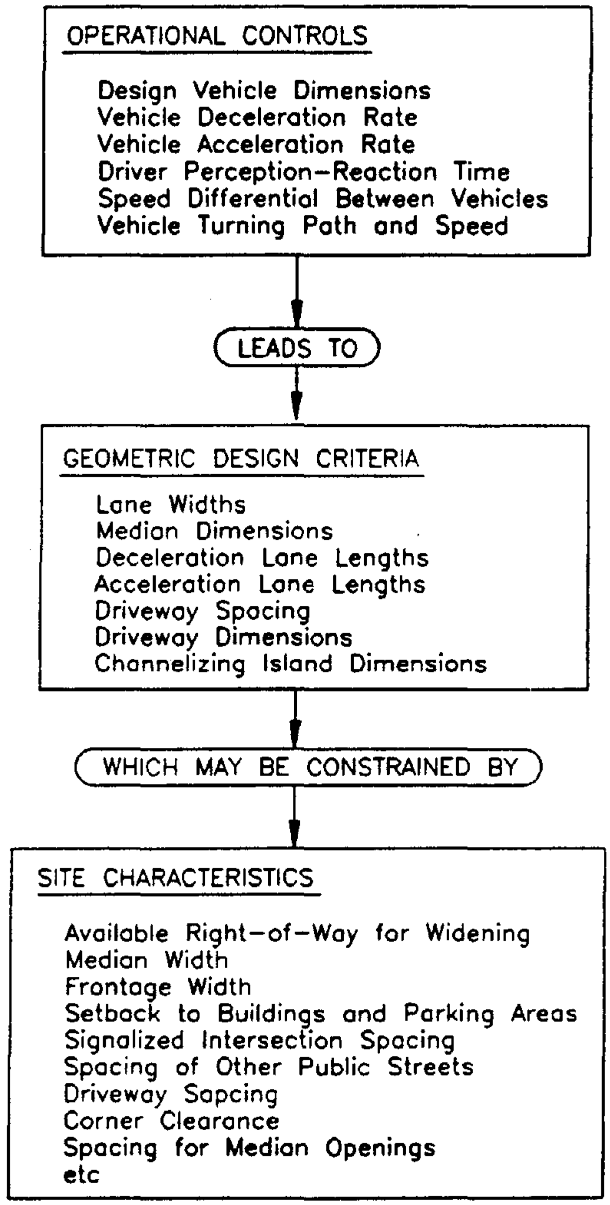


FIGURE 6-1: STEPS IN DEVELOPING DESIGN CRITERIA

Source: Reference Adapted from (*1*)

(Continued)

INTRODUCTION (Continued)

Design Vehicles

Design Vehicles

The physical characteristics of the vehicles using an access location determine, to a large extent, its geometric requirements. Different types of vehicles can be expected to use a given driveway depending on the characteristics of the roadway and property served.

Driveway and median access should be designed to accommodate the design vehicle that can be expected to use the access regularly (one time per day or more). Table 6-1 lists the roadway and access classifications along with the suggested design vehicle for each classification. These should be used unless it can be demonstrated that a particular design vehicle is more appropriate for a specific access design.

(Continued)

INTRODUCTION (Continued)

Design Vehicles (Continued)

TABLE 6-1: DESIGN VEHICLE SPECIFICATIONS

Roadway Classification	Access Classification(1)	Minimum Design Vehicle[2]
Rural Arterial	Private	SU
	Commercial	WB-50
	Public	WB-50
Rural Collector	Private	SU
	Commercial	WB-50
	Public	WB-50
Rural Local	Private	SU
	Commercial	SU
	Public	WB-50
Urban Arterial	Private	SU
	Commercial	SU
	Public	WB-50
Urban Collector	Private	P/SU
	Commercial	SU
	Public	WB-50
Urban Local	Private	P/SU
	Commercial	SU
	Public	SU

(1) Private Driveway
A private driveway is an entrance to and/or exit from a residential dwelling or dwellings, farm, or ranch adjacent to a state highway for the exclusive use and benefit of the owners.

Commercial Driveway
A commercial driveway is an entrance to and/or exit from any commercial, business, or similar type of establishment adjacent to a state highway.

Public Access Driveway
A public access driveway includes all approaches to a state highway from county or city dedicated or maintained roads and streets and approaches to schools, churches, cemeteries, and other public places or buildings of a like character.

(2) P — Passenger Vehicle
SU — Single Unit Truck
WB-50 — Tractor Semi-Trailer Combination

Source: Reference (5)

(Continued)

INTRODUCTION (Continued)

Desirable Lane Widths

Lane widths of 12 feet are desirable on all through traffic lanes and auxiliary lanes or major roadways. The lane width is exclusive of the gutter. Recommended lane widths for different conditions are given in Table 6-2.

TABLE 6-2: RECOMMENDED LANE WIDTHS

Functional Class	Lane Width (feet)	
	New Construction[1]	Reconstruction[2]
Major Roadways		
40 mph or greater	12	11
less than 40 mph	11	11
Minor Roadways		
40 mph or greater	11	11
less than 40 mph	11	10

(1) New construction includes construction on new location and major reconstruction where additional right-of-way is available.

(2) Reconstruction where the design is limited by right-of-way restrictions.

LEVELS OF ACCESS

Roadway Design Classes

Different Levels Of Access Should Be Established For Rural/Urban Area By Roadway Class

An initial step in preparing access design guidelines is to establish design characteristics for each category of roadway. The various jurisdictions may adopt different functional class design criteria in response to their individual circumstances.

The following functional design categories are used to illustrate a functional hierarchy of roadways and the application of functionally related access design criteria.

Generalized Roadway Classes
Freeways
Principal Arterial
Minor Arterial
Major Collector
Minor Collector
Local

(Continued)

LEVELS OF ACCESS (Continued)

Freeways

Freeways have the capacity for high speed and high volume traffic movements over long distances in an efficient and safe manner, including interstate, interregional, intercity, and in very large urban regions, intraurban travel.

All opposing traffic movements should be separated by physical constraints such as median separators. Access should be via grade separated interchanges only. Interchanges should be spaced so that the on-ramp traffic at one interchange will not interfere with the off-ramp traffic of a downstream interchange and visa-versa. Access should be suitably spaced and designed to provide the minimum differential between the speed of the through traffic stream and the speed of the merging or diverging vehicles. Access to interstate highways must comply with federal regulations and receive Federal Highway Administration approval.

Principal Arterial

Principal arterial roadways have the capacity for efficient traffic flow at high speeds and high volumes. They provide for interstate, interregional, and intercity, travel needs and some intracity travel needs in very large urban regions. Service to abutting land is subordinate to providing traffic movement. It is the highest category that permits at-grade intersections.

Principal arterial roadways should be capable of safely and efficiently accommodating high volume, high speed traffic. In urban areas, progression speeds of at least 30 mph should be achievable in peak hours; off-peak (posted) speeds should be between 45 mph and 55 mph. Opposing traffic streams are separated by a non-traversable median of sufficient width to allow for dual left turns at major intersections.

The principal arterial category may include roadways involving several different levels of access depending upon the needs of the individual state or local governmental jurisdiction. Three different levels of access (LOA) are suggested within the principal arterial category.

(Continued)

LEVELS OF ACCESS (Continued)

Minor Arterial	Minor arterials have the capacity for medium to high speeds or medium to high volume traffic movements over medium and long distances in an efficient and safe manner, providing for regional, intercity, and intracity travel needs. Direct access service to abutting land is subordinate to providing service to traffic movement. Minor arterials should be capable of achieving a posted speed limit of at least 40 mph in urban signalized segments and at least 55 mph in undeveloped areas. Intersecting highways, streets, or access where crossing movements are permitted need to meet spacing criteria which will allow signalization when volumes warrant. While progression is desirable in urban areas, efficiency may be poor or absent during high volume peak periods.
Major Collector	Major collectors have the capacity for moderate travel speeds and moderate traffic volumes for medium and short travel distances providing for intercity and intracity travel needs. There is a reasonable balance between direct access and mobility needs within this category. Major collectors should be capable of a posted speed of at least 35 mph in urban areas and 55 mph in undeveloped areas. Traffic progression is rarely a consideration on collector facilities.

(Continued)

LEVELS OF ACCESS (Continued)

Minor Collector	Access and movement functions are of equal consideration. Signalized intersections are at the junction with arterial roadways; progression along the collector class facilities is not an issue. Posted speeds in urbanized areas are commonly 30 or 35 mph. In rural areas speeds may vary considerably depending topography alignment, and roadway surface.
Local Roads	This category of roadway provides access to abutting properties. Travel distances are short and movement is to an intersecting roadway of collector classification.
Concept	Functional design philosophy is based on the concept that roadways should be designed based upon the degree to which each roadway is to serve the function of movement versus the function of access. The increasingly common use of level of access (LOA) is a convenient means of recognizing the functional classification of roadways. The use of numerical symbols to define the ordinal hierarchy is simpler and somewhat more flexible than the use of word descriptions (i.e. freeway, major arterial, minor arterial, etc.). It is a particularly convenient system to recognize that some major arterials roadways are of regional or interregional significance while others are of major importance in providing primary movement, but in a subregional context.
LOA Classes	Level of access classification is based upon the spacing, and, to an extent, the design of access. The number of levels of access which may be rationally identified is quite large. Indeed, two or more LOA's can be recognized for freeways based upon interchange spacing. Some jurisdictions have established ten or more levels of access. However, four or five levels (exclusive of freeways, the highest LOA and, local roads, the lowest) are appropriate for most jurisdictions. Suggested LOA criteria are given in Table 6-3 for urbanized areas and for rural areas in Table 6-4.

(Continued)

LEVELS OF ACCESS (Continued)

LOA Classes (Continued)

TABLE 6-3: SUMMARY OF SUGGESTED LEVEL OF ACCESS GUIDELINES FOR URBANIZED AREAS[1]

Functional Design Type	LOA	Signal Spacing	Medial Access		Marginal Access Spacing (feet)
			Median	Spacing (feet)	
Freeway	1	—— full control of access ——			
Major Arterial	2	1/2 mile	non-traversable	no median opening	1320
	3	1/2 mile	non-traversable	≥880[2]	≥880
Minor Arterial	4	1/4 mile	non-traversable	≥880[2]	≥440
Minor Arterial or Major Collector	5	1/4 mile	continuous two way left turn lane	NA	≥220
Major Collector	6	as may meet volume warrants	none	NA	≥220
Minor Collector or Local Street	7	NA	none	NA	as determined by property frontage

(1) Includes roadways in areas which may become urbanized in the future.
(2) Medial access to allow left turn ingress or left turn egress movement only.

(Continued)

LEVELS OF ACCESS (Continued)

LOA Classes (Continued)

TABLE 6-4: SUMMARY OF SUGGESTED LEVEL OF ACCESS GUIDELINES FOR RURAL AREAS

LOA	Cross Section Characteristics	Major Intersection Spacing(1)	Medial Access Spacing	Marginal Access
1	full control of access			
2	divided	one mile	one mile	only if no other access is available
3	divided multi-lane undivided two lane	one mile one mile one mile	1/2 mile NA(2) NA(2)	1/4 mile(3) 1/4 mile(3) 1/4 mile(3)
4	multi-lane undivided or two lane	1/2 mile	NA(2)	four per mile per side(4)
5	multi-lane undivided or two lane	1/4 mile	NA	six per mile per side(4)
6	multi-lane undivided or two lane	1/4 mile	NA	ten per mile per side(4)
7	two lane	NA	NA	as determined by property frontage

(1) Highways and other major public or private access
(2) Widening to provide left turn lanes may be required
(3) Shoulder provided for right turn deceleration
(4) Corner clearance may limit spacing from a major intersection

SIGNALIZED ACCESS SPACING

Introduction

Signalized Access Spacing

A long, uniform spacing is essential in order to be able to develop signal timing plans of signalized intersections, including access drives, which will provide for efficient traffic progression. Table 6-5 gives the required signal spacings needed to maximize progression efficiency at different operating speeds and cycle lengths. Table 6-6 gives similar information showing the progression speed attainable for different cycle lengths and signal spacings.

TABLE 6-5: REQUIRED SIGNAL SPACING FOR EFFICIENT TRAFFIC PROGRESSION

Cycle Length (sec)	Speed (mph)						
	25	30	35	40	45	50	55
	Distance in Feet						
60	1,100	1,320	1,540	1,760	1,980	2,200	2,430
70	1,280	1,540	1,800	2,050	2,310	2,500	2,820
80	1,470	1,760	2,050	2,350	2,640	2,930	3,220
90	1,630	1,980	2,310	2,640	2,970	3,300	3,630
120	2,200	2,640	3,080	3,520	3,960	4,400	4,840
150*	2,750	3,300	3,850	4,400	4,950	5,500	6,050

* Represents maximum cycle length for actuated signal if all phases are fully used. One-half mile (2,640 ft.) spacing applies where optimum spacing exceeds one-half mile.

(Continued)

SIGNALIZED ACCESS SPACING (Continued)

Introduction (Continued)

Selection of the appropriate signal spacing interval must be made based upon the desired progression speed and longest cycle length that is anticipated. Once spacing interval is selected, arterial-to-arterial intersections must be located at the selected interval, or at even multiples of the interval. Attention to the location of intersections in rural and urban fringe areas which may become urbanized in the future is critical if major roadways are to maintain their movement function in the long term. Table 6-7 gives suggested minimum band widths for different functional street design types and levels of access.

TABLE 6-6: PROGRESSION SPEED IN MILES PER HOUR AS A FUNCTION OF SPACING AND SIGNAL CYCLE LENGTH

Cycle Length	Spacing In Miles (Feet)			
	One Eighth (660 ft)	One Fourth (1,320 ft)	One Third (1,760 ft)	One Half (2,640 ft)
	Speed in MPH			
60	15	30	40	60
70	13	26	34	51
80	11	22	30	45
90	10	20	27	40
100	9	18	24	36
110	8	16	22	33
120	7.5	15	20	30

$$V = \frac{S(1.3636)}{C}$$

$$\text{Velocity} = \frac{\text{Spacing (in feet)} \times 1.3636\text{(a constant)}}{\text{Signal Cycle Length (in seconds)}}$$

$$\text{Spacing} = \text{Feet} = \frac{VC}{1.3636}$$

(Continued)

SIGNALIZED ACCESS SPACING (Continued)

Signalized Intersection Guidelines

Efficient traffic progression is a principal feature of access control, especially on major roadways. On less important facilities progression speed and efficiency is less critical. Table 6-7 gives suggested minimum through band width to determine signal location by LOA.

TABLE 6-7: SUGGESTED ACCEPTABLE THROUGH BAND WIDTH CRITERIA FOR SIGNAL LOCATION (1), (2)

Functional Design Type	Level of Access	Peak Periods(3)		Off-Peak Periods(4)	
		Speed (mph)	Minimum Band Widths (%)	Speed (mph)	Minimum Band Widths (%)
Freeway	1	NA	NA	NA	NA
Major Arterial	2	≥30	50%	≥45	≥45%
	3	≥30	50%	≥45	≥40%
Minor Arterial	4	≥30	40%	≥35	≥40%
	5	≥20	30%	35	30%
Major Collector	6	NA	NA	NA	NA
Minor Collector or Local Street	7	NA	NA	NA	NA

(1) Minimum cross street green must be sufficient for pedestrians to cross major roadway.
(2) Band width as a percent of cycle length = [(green and yellow) ÷ cycle length] 100
(3) 90 to 120 second cycle lengths
(4) 60 to 90 second cycle lengths

(Continued)

SIGNALIZED ACCESS SPACING (Continued)

Colorado Regulations

The State Highway Access Code of Colorado establishes 1/2 mile as the minimum spacing for intersecting roads, and other major accesses. In urban areas, or where future signalization may be required, a progression analysis must be performed.

The signalized standards contained in the State Highway Access Code of Colorado are summarized in Table 6-8. These standards pertain to all state highways, including those within municipalities.

TABLE 6-8: COLORADO STANDARDS FOR SIGNALIZED ACCESS SPACING

Highway Category	Posted Speed (mph)	Signal Spacing	Progression Criteria		
			Cycle Length (sec)	Progression Speed (mph)	Progression Band Width[1] (%)
1	(freeways, not applicable)				
2	≥55	—	—	45	50
3	≥45	1/2 mile	90 to 120	45	40
4	≥35	1/2 mile	90 to 120	35	30

Source: Adapted from Reference (4)

In order to help insure that access in rural, undeveloped areas, the Colorado Code also sets forth design standards for intersection spacing which are summarized in Table 6-9.

(Continued)

SIGNALIZED ACCESS SPACING (Continued)

Colorado Regulations (Continued)

TABLE 6-9: COLORADO REGULATIONS FOR INTERSECTION SPACING IN UNDEVELOPED AREAS

Highway Category	Intersection Spacing
1	(freeways, not applicable)
2	1 mile based on section lines; 1/2 mile only where no reasonable alternative exists
3	1/2 mile ± 200 feet, based on section lines, for all intersecting highways, streets, and other major accesses.
4	1/2 mile ± 200 feet, based on section lines for major intersecting highways and streets; minor access with the potential for signalization may be permitted at the 1/4 mile intervals

Source: Adapted from Reference (4)

MEDIANS

Introduction

Medians

A median is that portion of the roadway which separates traffic traveling in opposite directions. It is significant to note that the median is a part of the "traveled way". Thus, restrictions in median access can be more readily made with the exercise of the police power than can be made on marginal access.

Median design as an access control measure involves the following related elements: median type, median width, the geometrics of median openings, and spacing.

Median Design Elements

- Type
- Width
- Geometrics of Openings
  - End Treatment
  - Length of Opening
- Spacing of Median Openings

Median Types

Median designs can be grouped as follows:

- Non-traversable: A raised or depressed median which cannot be crossed or actively discourages crossing.
- Traversable: A flush or slightly raised median which a vehicle may easily cross.
- Continuous 2-way left turn lane: A flush center lane used to provide storage of vehicles making left turns.

(Continued)

MEDIANS (Continued)

Median Types
(Continued)

Median Types

- **Non-Traversable**
- **Traversable**
- **Two-Way Left Turn Lane**

A non-traversable median provides positive physical restriction of left turn and crossing maneuvers. A non-traversable median should be a feature incorporated in major arterial roadways.

Although pavement markings and signing will indicate that left turns or crossing maneuvers are prohibited, drivers can and will make such maneuvers where a traversable median is present.

The two-way left turn lane is intended to accommodate left turn ingress maneuvers. In areas where numerous low volume driveways already exist, installation of a continuous two-way left turn lane has been shown to reduce accidents and delays to through traffic as well as increasing capacity. The level of access provided is incompatible with the movement function of major arterial roadways and will encourage "strip development". It is, however, compatible with, and an appropriate treatment, on major collectors and minor arterials.

Median Width

Medians should be as wide as feasible but of a dimension that is in balance with other design components of the roadway cross section. The general range of median widths is from a minimum of 2 feet for the "narrow barrier" median up to 80 feet or more which permits each roadway to be independently designed.

(Continued)

MEDIANS (Continued)

Median Width (Continued)

Where pedestrians may be present, a minimum of 6 feet should be used. In access control, one of the most important functions of medians is to provide for left turns at intersections. To achieve this, it is desirable to have a median width of at least 18 feet which provides for a 12 foot turning lane and a 6 foot separator. The practical minimum for left turns at extremely restricted locations is a median width of 14 feet which provides for a 10 foot turning lane and a 4 foot median separator.

Very narrow medians provide poor delineation and experience frequent vehicular hits because drivers are unable to see the median, especially at night. The minimum width of a divisional island (non-traversable median) is 4 feet. A width of at least 8 feet (face to face of curb) is needed to provide minimum landscaping. Where the median is not of adequate width to accommodate a left turn bay, median breaks should not be provided since the turning vehicle must turn from the through traffic lane.

Where a wide median is used, unsignalized median openings can be designed to accommodate specified movement(s) only (such as left turn ingress) and all other movements physically prohibited. A width of 18 feet is a practical limit. In order to make the median noses large enough to enhance visibility a width of at least 28 to 30 feet should be used.

A width of 28 to 30 feet will also enable the design of dual left turn lanes (two 11 foot or 12 foot lanes plus a 6 foot median width) of signalized intersections. This will permit a U-turn or a left turn from the inside left turn lane with a left turn lane the outside lane. Such an operation is commonly used in California where a major arterial intersects a lower volume cross street. This facilitates access to properties fronting the arterial without the provision of median openings.

Table 6-10 summarizes median width for various applications. Median widths for U-turns are given in Figure 6-2.

(Continued)

MEDIANS (Continued)

Median Width (Continued)

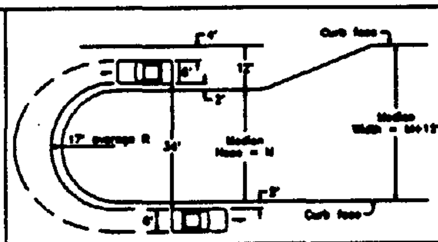
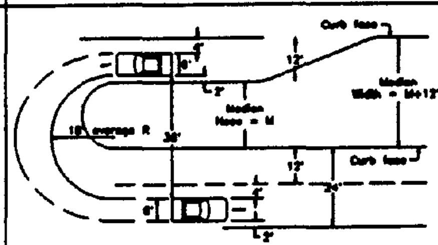
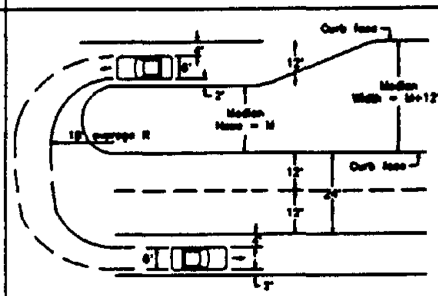
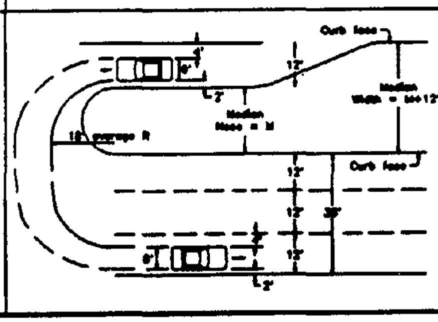
Type of Maneuver		M-Min.width of median-feet for design vehicle						
		P	[illegible]	SU	[illegible]	[illegible]	[illegible]	[illegible]
		Length of design vehicle						
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	115'
Inner Lane to Inner Lane		30	61	63	63	71	71	101
Inner Lane to Outer Lane on 4-Lane Divided Roadway		18	49	51	51	59	59	89
Inner Lane to Shoulder		8	39	41	41	49	49	79
Inner Lane to Outer Lane on 6-Lane Divided Roadway		4	37	39	39	47	47	77

FIGURE 6-2: MINIMUM DESIGNS FOR U-TURNS

Source: Adapted from Reference (2), Figure IX-67, p.825

(Continued)

MEDIANS (Continued)

Median Width (Continued)

TABLE 6-10: RECOMMENDED MEDIAN WIDTHS

Median Function	Minimum Width	Desired Width
Separation of Opposing Traffic Streams	4	10
Pedestrian Refuge and Room for Signs and Appurtenances	6	14
Storage of Left Turning Vehicles:		
Single Left Turn Bay	14	18
Dual Left Turn Bay	25	30
Protection for Vehicles Crossing or Turning Left Onto the Mainline	25	30
Design for Selected Ingress or Egress Movements Only	18	30

Median End Treatments

The nature of the end treatment is largely a function of the width of the median nose. When the width is 4 feet or less, the semicircular design (Figure 6-3a) is generally used. For widths of over 4 feet the bullet nose (Figure 6-3b) design should be utilized as this design better conforms to the path of the turning vehicle. At 3-way intersections, the half-bullet nose (Figure 6-3d) is appropriate.

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MEDIANS (Continued)

Median End Treatments (Continued)

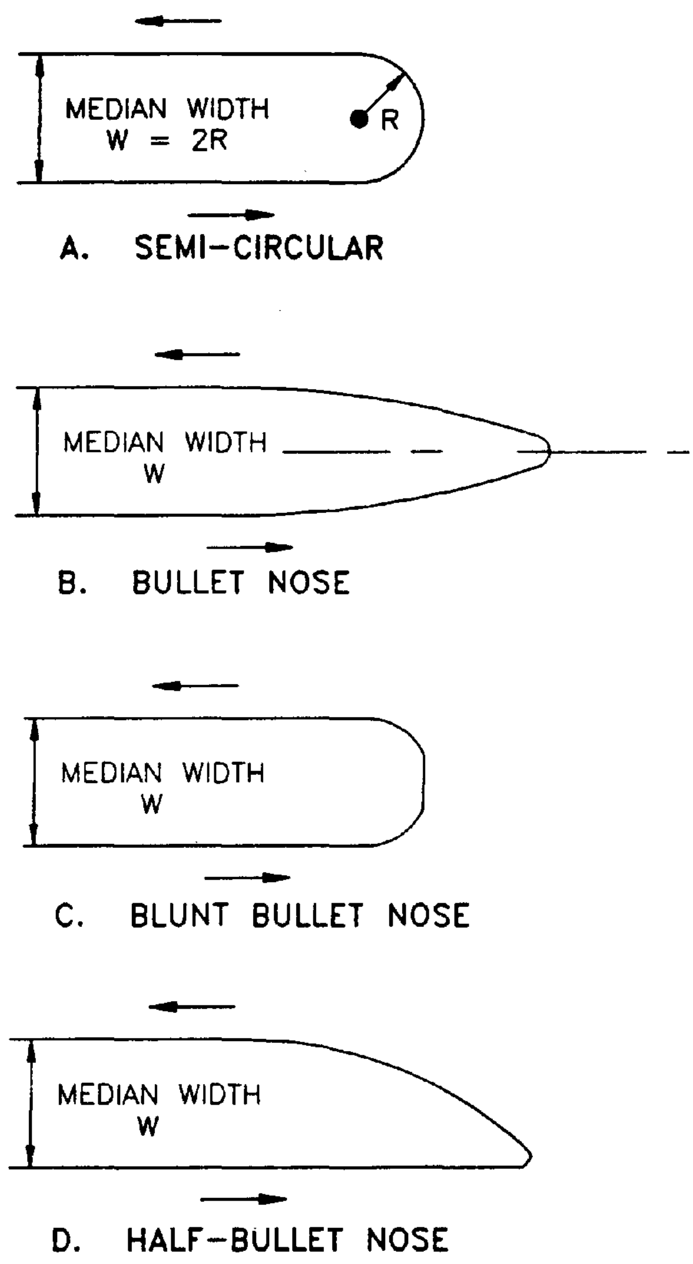


FIGURE 6-3: MEDIAN END TREATMENTS

(Continued)

MEDIANS (Continued)

Median Openings

For any typical 3 or 4 leg intersection on a divided roadway, the length of the median opening should be as great as the width of the crossroad pavement plus 10 feet, but in no case less than 40 feet.

Where the crossroad is a divided highway, the length of the opening should be at lease equal to the width of the crossroad roadway plus that of the median width plus 20 feet.

Minimum lengths of median openings as a function of median width and the design of the median ends are given in Table 6-11.

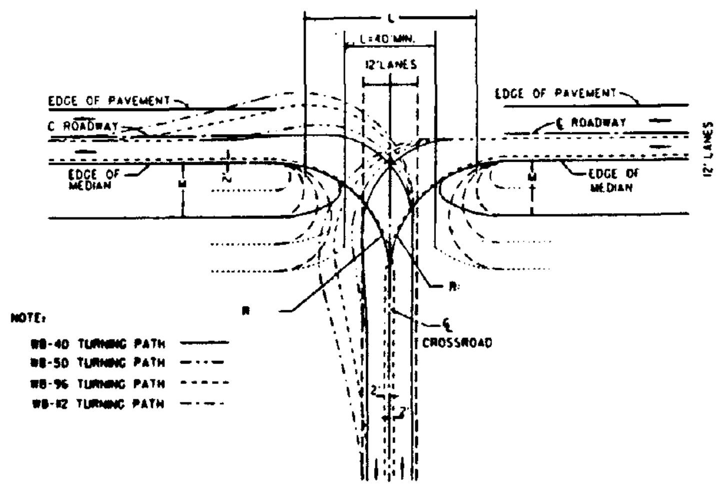
TABLE 6-11: MINIMUM LENGTH OF MEDIAN OPENINGS

Width Median M	L = Minimum Length of Median Opening, Feet	
	Semicircular	Bullet Nose
4	76	76
6	74	60
8	72	53
10	70	47
12	68	43
14	66	40' Min.
16	64	40' Min.
20	60	40' Min.
24	56	40' Min.
28	52	40' Min.
32	48	40' Min.
36	44	40' Min.
40	40 Min.	40' Min.
50	40 Min.	40' Min.
60	40 Min	40' Min

Minimum design of median openings (P design vehicle, control radius of 40 ft).

Width Median M	L = Minimum Length of Median Opening, Feet	
	Semicircular	Bullet Nose
4	146	122
6	144	115
8	142	110
10	140	105
12	138	100
14	136	96
16	134	92
20	130	85
24	126	78
28	122	73
32	118	67
36	114	62
40	100	57
60	90	40' Min.
80	70	40' Min.
100	50	40' Min.
110	40' Min	40' Min
120	40' Min.	40' Min

Minimum design of median openings (WB-40 design vehicle, control radius of 75 ft).



Source: Adapted from Reference (2), Figure IX-60, p. 803, Tables IX-16, p. 804, and IX-18, p. 807

(Continued)

MEDIANS (Continued)

Median Opening Spacing	AASHTO states that a driveway should not be located within the functional boundary of an intersection (2 p. 841). Hence, the location and spacing of median openings should begin with establishing the minimum corner clearance. As illustrated in Figure 6-4, a left turn egress can be located closer to a major intersection than a left turn ingress. Inspection of Figure 6-4b shows that minimum corner clearance for a left turn ingress is approximately the sum of the functional limits of the two maneuvers. The minimum corner clearance for a left turn egress is slightly more than the functional length of the left turn at the major intersection.

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MEDIANS (Continued)

Median Opening Spacing (Continued)

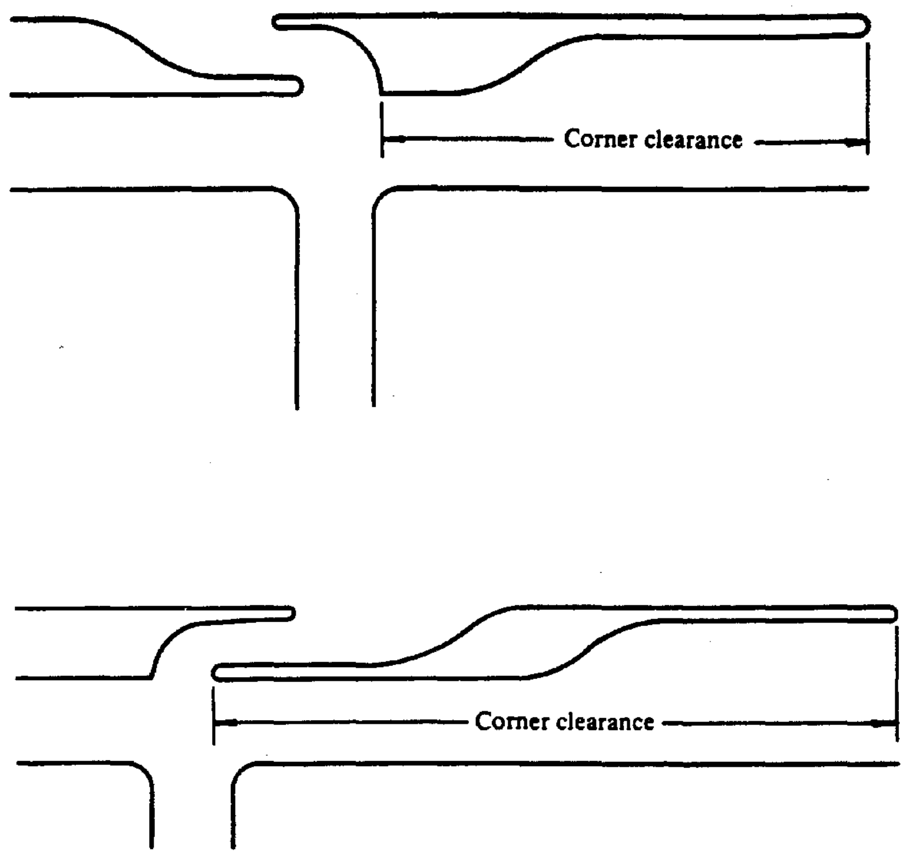

FIGURE 6-4: DEFINITION OF MEDIAN CORNER CLEARANCE

Source: Reference (3), p. 140

(Continued)

MEDIANS (Continued)

Median Opening Spacing (Continued)	The minimum spacing of other median openings is a function of the pattern of the movements permitted as well as the functional limit of the maneuver(s). The functional limit is comprised of the deceleration distance plus storage as discussed in Chapter 3. As illustrated in Figure 6-5a, the minimum spacing of median openings for ingress movements for opposite directions is equal to the sum of the functional length (deceleration plus storage) of the two movements. The minimum median spacing for ingress and egress to access on the same side of the roadway is the sum of the acceleration distance of the upstream egress opening plus the deceleration plus storage in the downstream ingress opening, see Figure 6-5b. As illustrated in Figure 6-5c, the spacing of median openings for ingress and egress alternating on opposite sides of the roadway is the sum of the two acceleration distances.

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MEDIANS (Continued)

Median Opening Spacing (Continued)

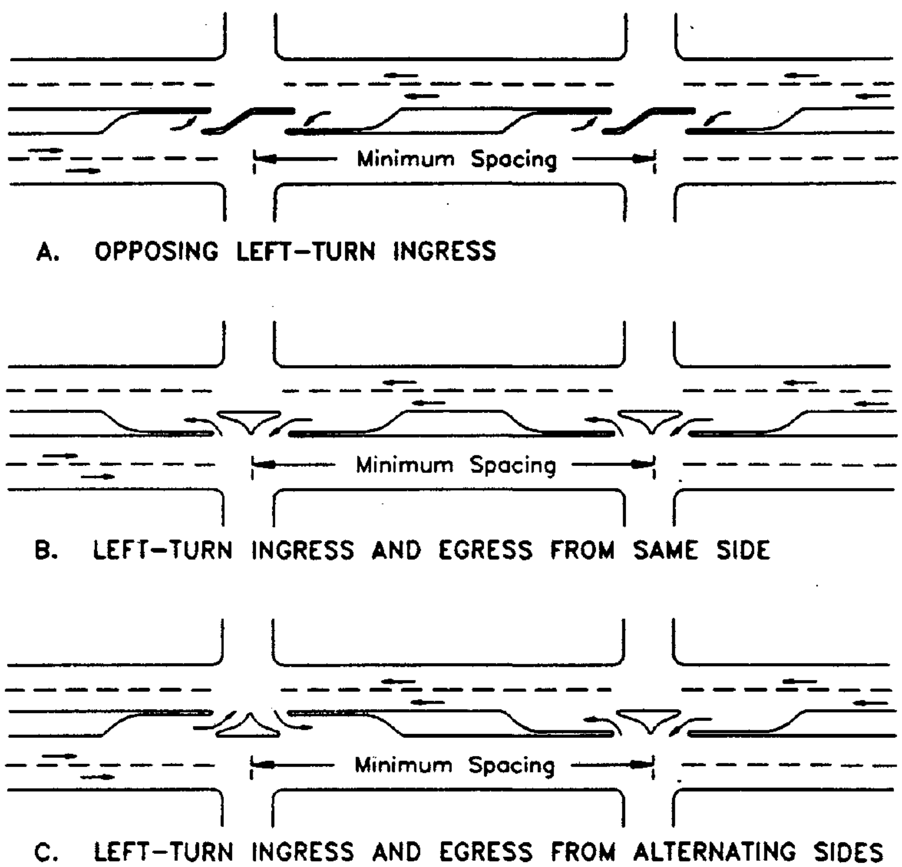


FIGURE 6-5: MINIMUM SPACING OF MEDIAN OPENING

AUXILIARY LANES

Introduction

Auxiliary Lane Functions

- **Speed Change**
  - **Deceleration**
  - **Acceleration**
- **Storage for Turning Vehicles**

Auxiliary lanes for left and right turns allow turning vehicles to leave the through traffic lanes while minimizing interference with through traffic plus provide storage of vehicles waiting to complete the turn maneuver. Auxiliary lanes may also be used to allow vehicles entering the roadway to accelerate. On transit routes auxiliary lanes are also used to allow buses to load and discharge passengers without blocking the through lanes.

Auxiliary lanes should be at least 10 feet wide and preferably 12 feet wide. As with through lanes, the gutter should not be considered as part of the lane width.

Turn Lanes

Left and right turn lanes are comprised of two elements, namely a taper and a full width section. The length of a turn lane should allow turning vehicles to clear the through traffic lane with an acceptable speed differential and decelerate to a stop plus provide storage for vehicles waiting to complete the maneuver.

(Continued)

AUXILIARY LANES (Continued)

Taper Length

Common practice is to specify taper lengths as a ratio, with the ratio increasing with speed. AASHTO suggests a taper rate of 8:1 for speeds up to 30 mph and 15:1 for design speeds up to 50 mph (*2*, p. 831). Many state highway agencies use a more elaborate series of taper rates as illustrated in Table 6-12.

In urbanized areas the peak period speeds are considerably less than the off-peak or posted speed and a taper length based on the peak period, rather than posted or design speed, is appropriate. During the off-peak, drivers simply steer a longer transition from the through to the auxiliary lane. At a peak period speed of 30 mph a driver will travel approximately 120 feet while moving laterally 12 feet. Table 6-13 gives taper lengths recommended for urban design.

TABLE 6-12: TAPER RATIOS

Posted Speed (mph)	Ratio for Straight Taper for Acceleration and Deceleration Lanes	Minimum Ratio for Deceleration Lane
20	7.5:1	7.5:1
25	7.5:1	7.5:1
30	10:1	8:1
35	12.5:1	10:1
40	15:1	11.5:1
45	15:1	13:1
50	20:1	15:1
55	22.5:1	18.5:1
60	50:1	25:1
65	50:1	25:1

Source: Reference (*4*)
Note: Colorado code includes speeds up to 55 mph.
Source: Reference (*5*)
Note: New Mexico regulations contain the same ratios through 55 mph but includes ratios for 60 and 65 mph.

(Continued)

AUXILIARY LANES (Continued)

Taper Length (Continued)

TABLE 6-13: RECOMMENDED TAPER LENGTHS FOR URBAN DESIGN

	Taper Length (feet)	
Street Class	Single Turn Lane Desirable Minimum	Dual Turn Lane Desirable Minimum
Major Arterial	120-90	180-150
Minor Arterial	90-60	150-100

Taper Design

Straight line tapers are easily constructed and are therefore, commonly used on highways in undeveloped areas and is a suitable design where curbs are not used. In urban areas the distinct "corner" at the beginning of the taper presents an unnatural vehicular pattern. Observation of tire marks on the curb at the beginning of the taper indicates that this design often results in numerous vehicle impacts.

AASHTO suggests that a short curve be used at either end (2, p. 831) to provide a more natural path.

A taper with a symmetrical reverse curve is suggested for urban design. The curves at the end of this taper design have the same radius and arc length.

(Continued)

AUXILIARY LANES (Continued)

Taper Design (Continued)

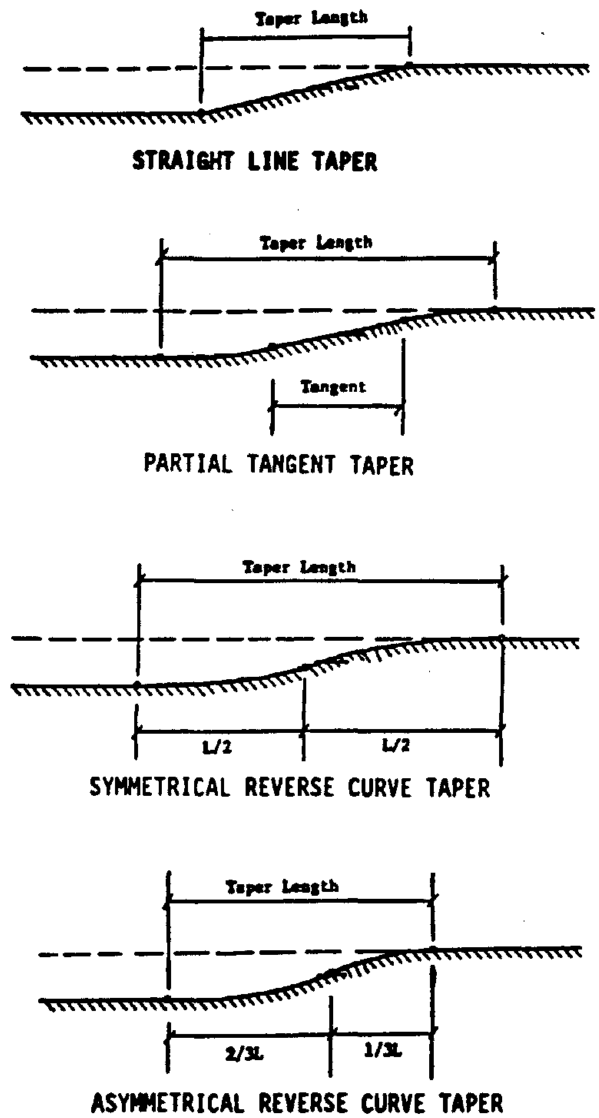


FIGURE 6-6: COMMONLY USED TAPER DESIGNS

Source: Reference (2)

(Continued)

AUXILIARY LANES (Continued)

Deceleration Lane Length

Table 6-14 gives suggested length of turn bay, including taper but excluding storage. These design lengths will permit turning vehicles to clear the through lane with a speed differential of 10 mph or less with the driver of the turning vehicle using a deceleration rate acceptable to about 85% of all drivers.

Table 6-15 gives minimum lengths for different deceleration rates and speed differentials. A 6.0 fps^2 deceleration rate is acceptable to about 85% of all drivers whereas 9.0 fps^2 can be expected to be used by about 50% of all drivers. Given a length of deceleration lane, the resulting speed differential can be approximated by interpolation of the values given in Table 6-15.

TABLE 6-14: SUGGESTED LEFT TURN AND RIGHT TURN DECELERATION LANES INCLUDING TAPER BUT EXCLUSIVE OF QUEUE STORAGE[(1)]

Speed (mph)	Turn Lane Length (feet)
30	230
35	290
40	370
45	460
50	550
55	660
60	770

(1) Assumes 3.5 fps^2 deceleration while driver moves laterally for through lane to turn lane and 6.0 fps^2 deceleration when lateral movement has been completed. Six fps^2 deceleration has been found to be acceptable to about 85% of drivers and a speed differential of ten mph or less between the turning vehicle and through lane traffic.

(Continued)

AUXILIARY LANES (Continued)

Deceleration Lane Length (Continued)

TABLE 6-15: MINIMUM LENGTH OF LEFT TURN AND RIGHT TURN LANES INCLUDING TAPER BUT EXCLUDING STORAGE

Speed (mph)	Minimum Length in Feet											
	6.0 fps² Deceleration(1)						9.0 fps² Deceleration(1)					
	Speed Differential (mph)(2)						Speed Differential (mph)(3)					
	10	15	20	25	30	35	10	15	20	25	30	35
30	230	150	140	110	—	—	140	100	60	—	—	—
35	290	230	180	140	110	—	190	140	100	60	—	—
40	370	290	230	180	140	110	250	190	140	100	60	—
45	480	370	290	230	180	140	300	250	190	140	100	140
50	550	460	370	290	230	180	380	300	250	190	140	100
55	660	550	480	370	290	230	450	380	300	250	190	140
60	770	660	550	460	370	290	530	450	380	300	250	190

(1) Average deceleration rate after turning vehicle completes lateral movement from through lane into turn lane. Deceleration during lateral movement is one half the average.

(2) Turning vehicle will complete lateral movement when a speed differential indicated occurs.

(3) Turning vehicle will not have completed lateral movement but a following through vehicle will be able to pass without physically encroaching upon the adjacent through lane when the indicated speed differential occurs.

(Continued)

AUXILIARY LANES (Continued)

Turn Lane Storage

It is essential that sufficient queue storage be provided for all turn vehicle arrivals a high percentage of the time. It is recommended that the design have at least a 95% probability of storing all turning vehicles during the peak hour. Factors which influence the storage length are:

Factors Affecting Storage Length

- **Design Turn Volume for the Peak Hour**
- **Type of Intersection Traffic Control**
- **Cycles Per Hour**
- **Signal Phasing and Timing**
- **Percent of Trucks and Buses**

The required storage for any selected probability of storing all vehicles can be determined using the queuing analysis. Various tables, charts and nomographs such as shown in Figures 6-7 and 6-8 have been developed to facilitate estimation of the storage length needed to accommodate the queue. Rules-of-thumb have also been developed. Additionally, many jurisdictions have established minimum storage lengths of 100, 125, or 150 feet.

Flexibility is a very important but often overlooked aspect of designing for adequate storage length. Its importance lies in the fact that either traffic demand or traffic control or both may change, dictating a change in queue storage requirements. This may necessitate lengthening of the left turn storage at a major intersection which in turn may necessitate the elimination of left turns at a nearby minor intersection of a public street or private access.

(Continued)

AUXILIARY LANES (Continued)

Nomograph For Signalized Intersections

The queue storage for a single turn lane of a signalized intersection can be found using the nomograph shown in Figure 6-7.

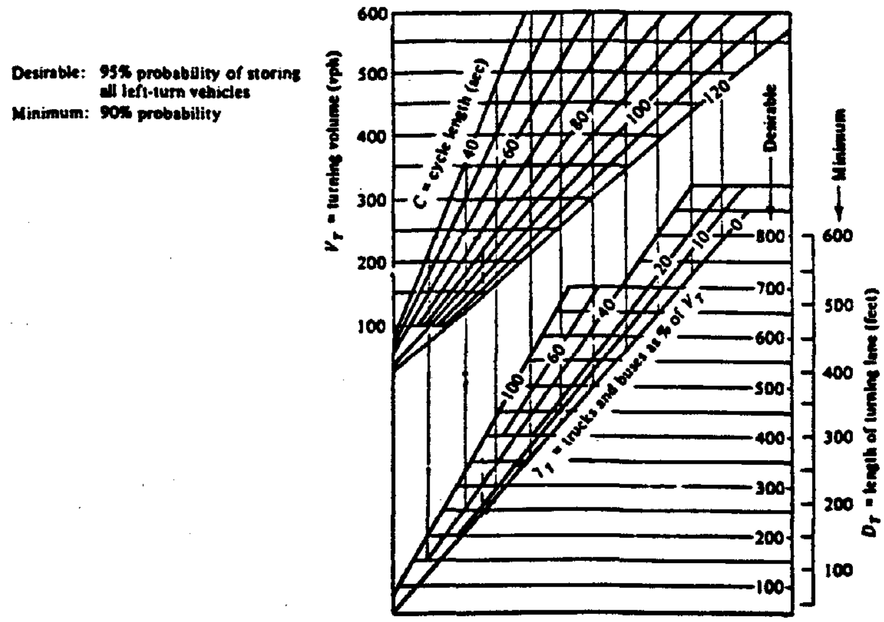


FIGURE 6-7: SINGLE LANE QUEUE STORAGE FOR SIGNALIZED INTERSECTIONS

Source: Reference (6), p. 4.52

Use of the nomograph shows that for a left turn volume of 240 vehicles per hour (vph), a 70 second cycle, and 0% trucks, a storage length of about 250 feet is required for desirable conditions and about 200 feet for a minimum. These storage lengths would accommodate 10 or 11 vehicles for the desirable conditions and about 8 for the minimum. The nomograph can be used to estimate the storage length of a dual left turn bay by dividing by 1.8. Thus, for the desirable conditions, a dual left turn bay of about 150 feet (excluding deceleration distance) would be required. (NOTE: Storage length should be rounded to multiples of the average length of a vehicle plus the space between vehicles, or 25 feet.)

(Continued)

AUXILIARY LANES (Continued)

Nomograph For Unsignalized Intersections

The nomograph given in Figure 6-8 applies to left turn storage at unsignalized intersections on four lane highways. The nomograph is used by reading horizontally from the opposing traffic volume, V_O, on the vertical axis and reading vertically from the left turn volume, V_L, on the horizontal axis and locating the minimum storage length, S_l, at the point where the horizontal and vertical lines cross. For example, 100 left turning vehicles per hour, V_L, with an opposing through volume, V_O, of 950 vph, will require a minimum storage length of about 150 feet.

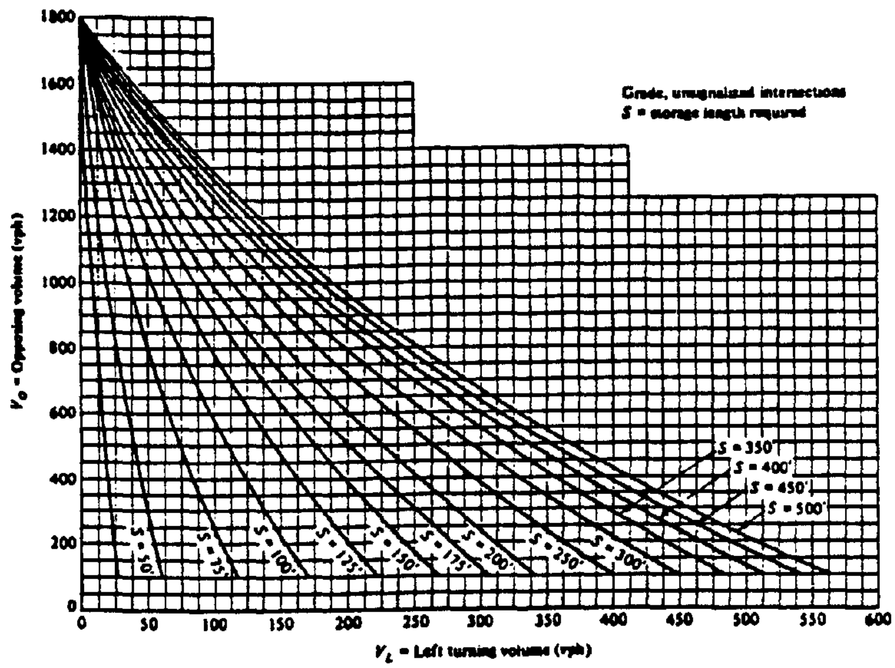


FIGURE 6-8: QUEUE STORAGE FOR UNSIGNALIZED INTERSECTIONS ON FOUR LANE HIGHWAYS

Source: Reference (7), pp. 1-18

Similar graphs have been developed for two lane roadways. These graphs, together with the one for four lane highways, are provided in Appendix A to this chapter.

(Continued)

AUXILIARY LANES (Continued)

Rules-of-Thumb

One commonly accepted procedure for calculating left turn queue storage is the following:

$$L = (\frac{V}{N})ks$$

where:

L = the design length for the left turn storage-feet

V = the estimated left turn volume in vehicles per hour

N = the number of cycles per hour (V/N is the average number of turn vehicles per cycle).

k = a constant, generally assumed to be 2.0

s = the average length per vehicle, including the space between vehicles; generally assumed to be 25 feet

The value of 2.0 for k is based upon the generally accepted assumption that turning vehicles are distributed according to the Poisson Distribution which has the characteristics that the standard deviation is equal to the mean. Thus 2.0 (V/N) is the mean plus one standard deviation.

An even simpler rule-of-thumb for left turn storage is to use one foot of storage times the turning volume in vehicles per hour.

(Continued)

AUXILIARY LANES (Continued)

Comparison of Storage Length

Use of the nomograph for signalized intersections (Figure 6-7) found that a 250 foot of storage was needed. The two rules-of-thumb provide similar values.

Comparison of Queue Storage

Turn Volume = 240 vph
60 Second Cycle

- Nomograph = 250 ft. desirable
- L = (V/N)(k)(25)
  = (240/60)(2)(25) = 200 ft.
- (1 ft.)(240 vph) = 240 ft.

Guidelines for Left Turn Storage

Storage Length Guidelines

- Assume 25 Feet Per Vehicle in Calculations
- Use a Minimum Storage Length of 100 Feet for Less Than 60 Vehicles Per Hour
- For Calculated Lengths Greater Than 300 Feet of for Left Turn Volumes Exceeding 300 Vehicles Per Hour Consider Dual Left Turn Lanes
- Use Protected Plus Permitted Phasing Whenever Possible

In cases where traffic progression is poor, very long queues will develop in the through traffic lanes. During peak periods these queues may block entry into the turn lane. This problem is especially acute whenever an efficient timing plan calls for a leading green phase for left turns.

GUIDELINES FOR REQUIRING TURN LANES

Deceleration Lanes

Auxiliary lanes to allow left turning and right turning vehicles to decelerate and complete the turn maneuver should be provided on all major roadways. Warrants adopted by state and local jurisdictions commonly involve a combination of the volume on the main roadway and the turning volume. Examples of left turn and right turn requirements are given in Figures 6-9 through 6-12. It may be noted that the Virginia DOT has identified their practice as guidelines. Whereas, the Colorado criteria for turn lanes is mandated by state law and identified as warrants in the State Access Code, adopted by the Colorado Legislature.

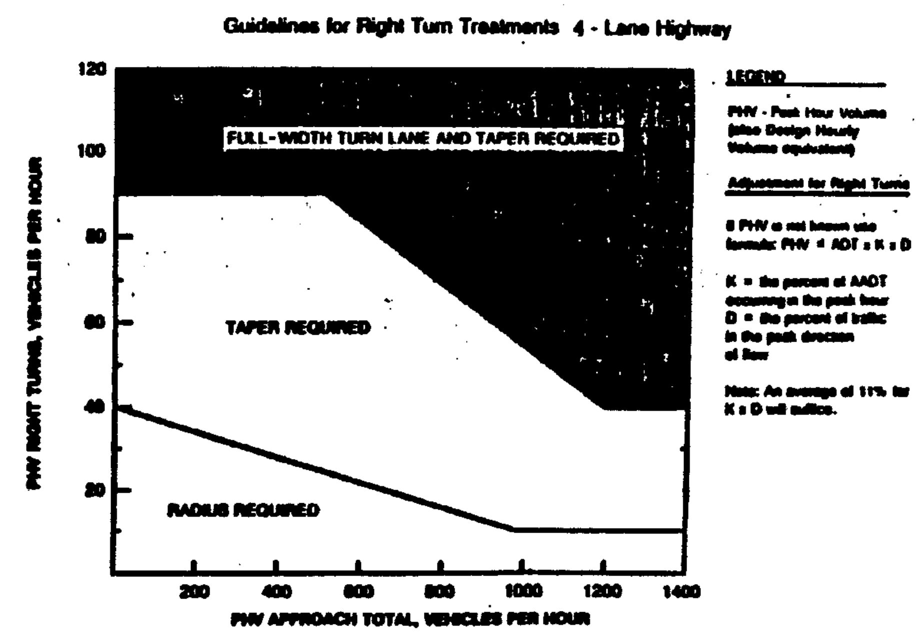


FIGURE 6-9: VIRGINIA DOT GUIDELINES FOR RIGHT TURN LANES ON FOUR LANE HIGHWAYS

(Continued)

GUIDELINES FOR REQUIRING TURN LANES (Continued)

Deceleration Lanes (Continued)

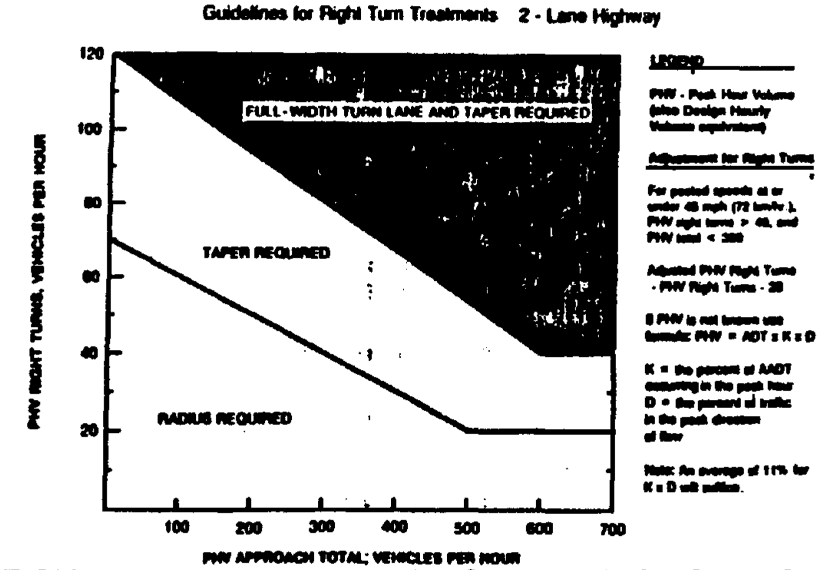


FIGURE 6-10: VIRGINIA DOT GUIDELINES FOR RIGHT TURN LANES ON TWO LANE HIGHWAYS

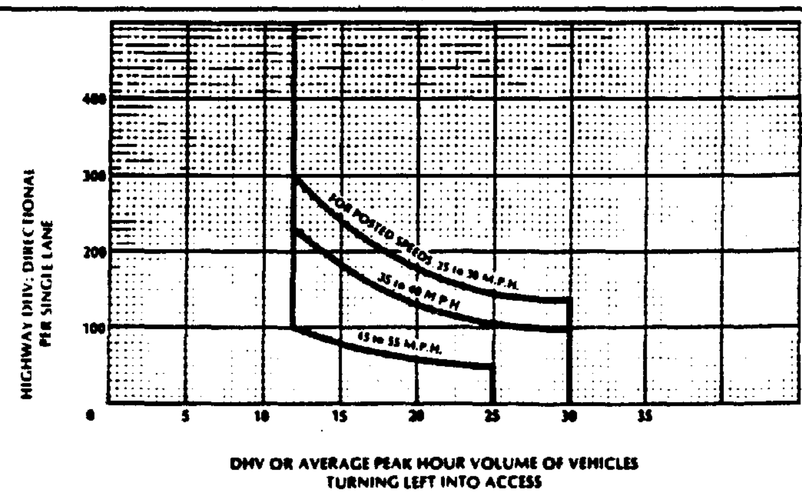


FIGURE 6-11: COLORADO'S WARRANT FOR LEFT TURN LANES

Source: Reference (4)

Note: The entire Colorado State Access Code is provided in Appendix A to Chapter 6. The reader is referred to page 32 of the Colorado Access Code for details relating to the application of this warrant.

(Continued)

GUIDELINES FOR REQUIRING TURN LANES (Continued)

Deceleration Lanes (Continued)

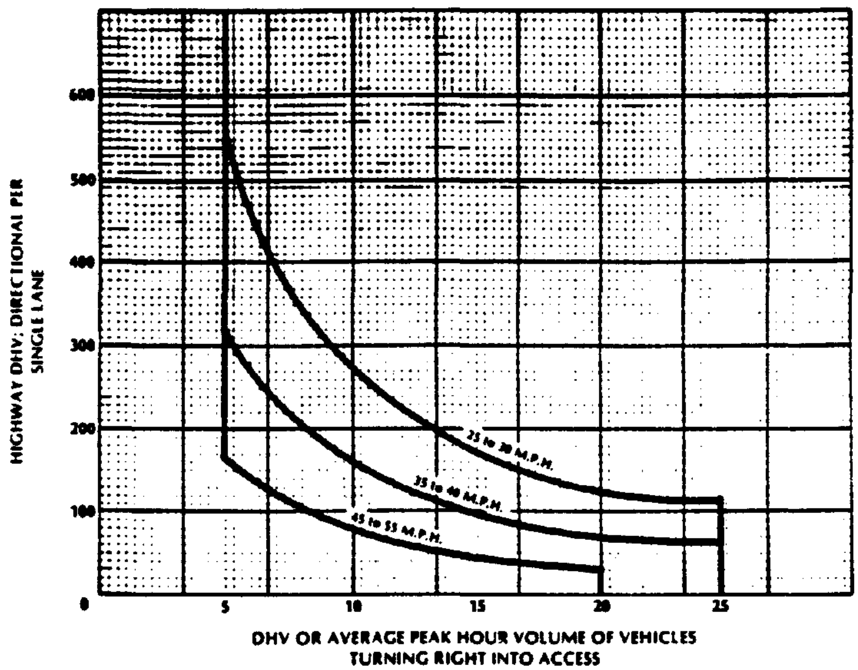


FIGURE 6-12: COLORADO'S WARRANT FOR RIGHT TURN LANES

Source: Reference (4)

Note: Refer to page 30 of the Colorado State Access Code, Appendix 6-A for details regarding this warrant.

(Continued)

GUIDELINES FOR REQUIRING TURN LANES (Continued)

Acceleration Lanes

An acceleration lane allows the driver of a vehicle entering the roadway to accelerate and then merge laterally into the through traffic lane. The size of the necessary gap in the traffic stream is much less than if the driver must turn directly into the through traffic stream and then accelerate. Acceleration lanes are desirable where high speeds and a lack of gaps in traffic make it difficult for vehicles to enter the roadway. An example of criteria for the provision of right turn acceleration lanes is given in Table 6-13. Left turn acceleration lanes may be also desirable at unsignalized median openings where high speeds and a lack of acceptable gaps prevails.

The substantial frontage required for an acceleration lane as well as a deceleration at the downstream intersection limits the use of acceleration lanes. In urban areas, long signal spacings (half mile or more) are needed to accommodate both an acceleration and a deceleration lane and still have a significant section of standard roadway. Where an acceleration lane is desired at short signalized intersection spacings (quarter mile), a continuous auxiliary lane to serve as an acceleration and deceleration lane has been used effectively. A street section of standard cross section as illustrated in Figure 6-14 should be avoided.

(Continued)

GUIDELINES FOR REQUIRING TURN LANES (Continued)

Acceleration Lanes (Continued)

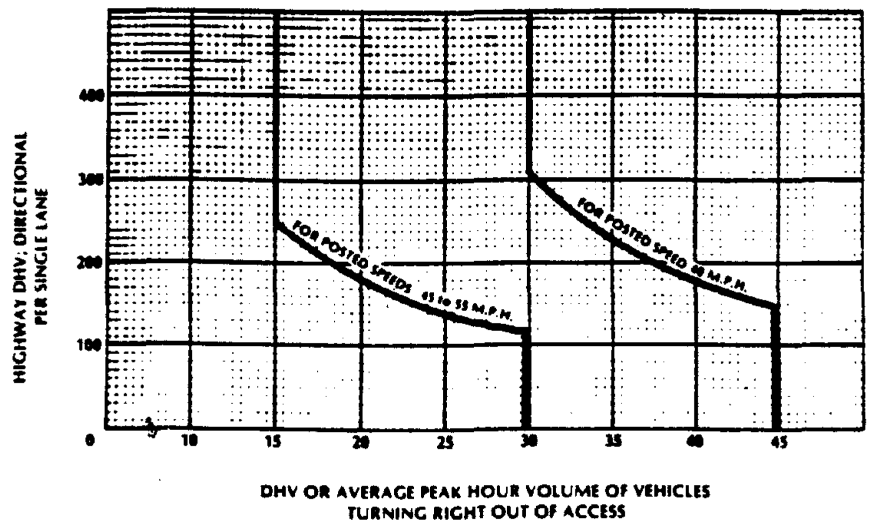


FIGURE 6-13: COLORADO'S WARRANT FOR RIGHT TURN ACCELERATION LANES

Source: Reference (4)

Note: Refer to page 31 of the Colorado State Access Code, Appendix 6-A for details.

(Continued)

GUIDELINES FOR REQUIRING TURN LANES (Continued)

Acceleration Lanes (Continued)

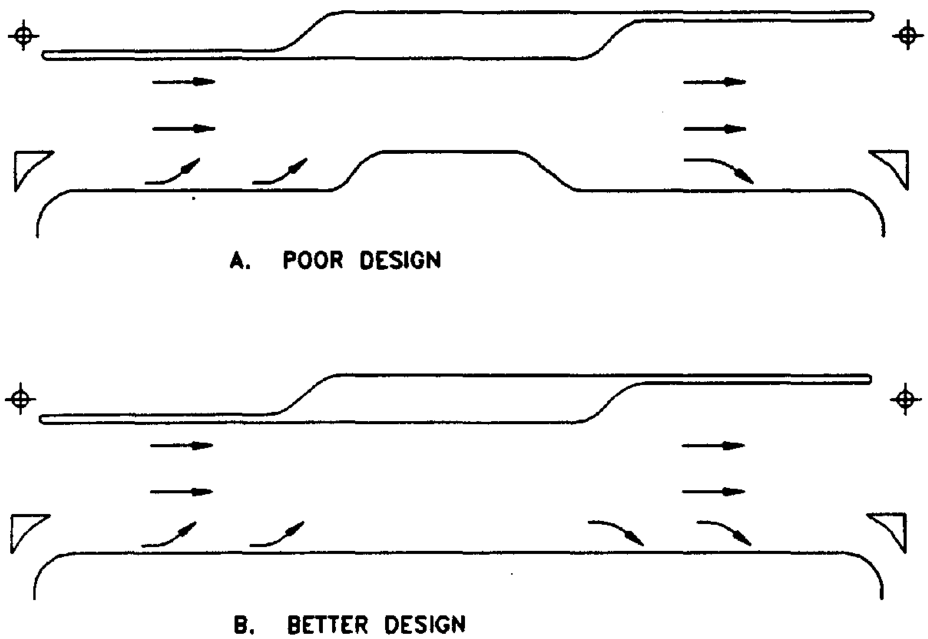


FIGURE 6-14: ACCELERATION LANE WHERE INTERSECTION SPACING IS LIMITED

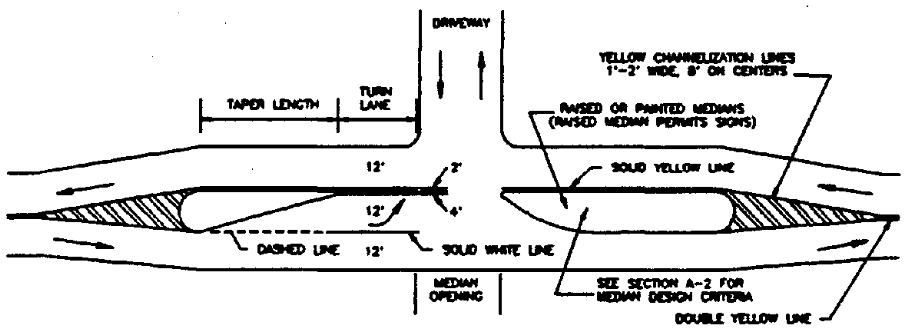
TURN LANES ON TWO LANE HIGHWAYS

Left Turns on Two Lane Highways

Left turn lanes should be provided on two lane highways where through and turn volumes create an operational or a potential accident problem. Table 6-16 gives an example of guidelines for their provision.

Inspection of the graphs in Appendix 6-A for left turn lanes on two lane highways indicate suggested "warrants" for left turn lanes. These are based on queue storage only; they indicate that a left turn lane is not warranted when the queue storage is less than 75 feet (about 3 cars). More recently accepted criteria gives much greater consideration to speed differential, accident potential, and functional design concepts. Therefore, it is suggested that the figures in Appendix 6-A be used for estimating storage length, but not as warrants per se.

Typical design information is given in Figure 6-15. At three way intersections where conditions are less critical and a wide shoulder (≥12 feet) is available, the shoulder is sometimes used to allow through vehicles to bypass the left turning vehicle.



Taper Ratios						
Speed (mph)	30 or less	35	40	45	50	55 and above
Straight Taper Ratio	20:1	25:1	30:1	40:1	45:1	50:1

FIGURE 6-15: LEFT TURN LANE ON A TWO LANE HIGHWAY

Source: Reference (3)

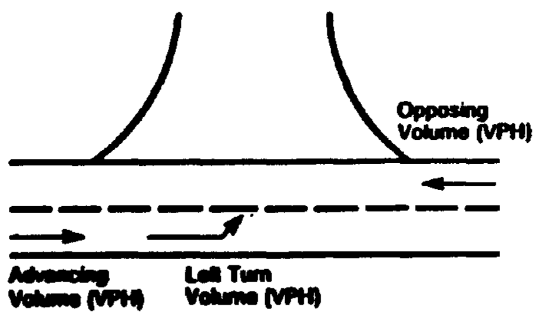
(Continued)

TURN LANES ON TWO LANE HIGHWAYS (Continued)

Left Turns on Two Lane Highways (Continued)

TABLE 6-16: GUIDELINES FOR LEFT TURN LANES ON TWO LANE HIGHWAYS

	Advancing Volume			
Opposing Volume	5% Left Turns	10% Left Turns	20% Left Turns	30% Left Turns
40-mph Operating Speed				
800	330	240	180	160
600	410	305	225	200
400	510	305	275	245
200	640	470	350	305
100	720	515	390	340
50-mph Operating Speed				
800	280	210	165	135
600	350	260	195	170
400	430	320	240	210
200	550	400	300	270
100	615	445	335	295
60-mph Operating Speed				
800	230	170	125	115
600	290	210	160	140
400	365	270	200	175
200	450	330	250	215
100	505	370	275	240



Source: Reference (2), p. 791

DRIVEWAY DESIGN

Introduction

AASHTO states that "Driveways are, in effect, at-grade intersections and should be designed consistent with the intended use" (2, p. 841).

Elements of Driveway Design

The plan view elements involved in the design of driveways include:

Driveway Design Elements

- Width
- Driveway Length
- Return Radius
- Lateral Offset
- Approach Angle
- Approach Flare

Figure 6-16 illustrates the physical relationships between these elements. Table 6-17 gives the effective driveway width for various speeds and driveway geometries.

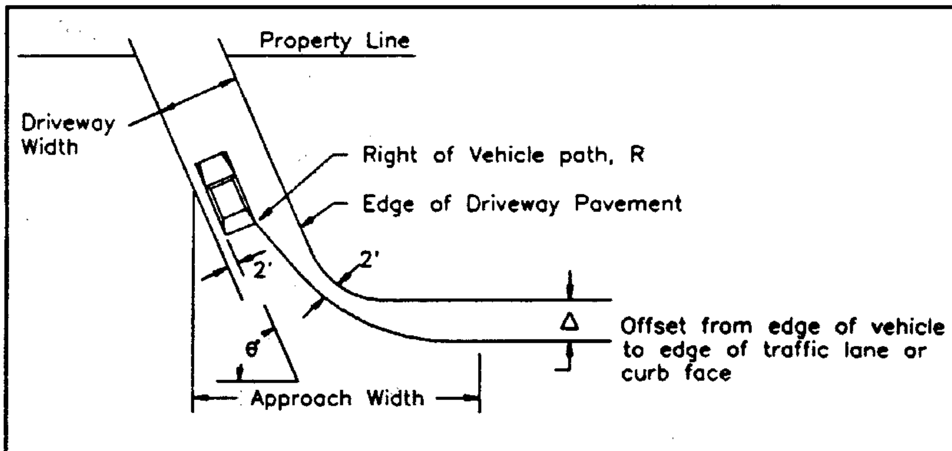


FIGURE 6-16: DRIVEWAY ELEMENTS

Source: Reference Adapted from (1), p. 213

(Continued)

DRIVEWAY DESIGN (Continued)

Elements of Driveway Design (Continued)

TABLE 6-17.1: DRIVEWAY LANE WIDTHS AS A FUNCTION OF DRIVEWAY OFFSET AND RETURN RADIUS

FOR A 90 DEGREE DRIVEWAY ANGLE—α

Turning Speed = 6.6 mph — Driveway Length = 33 feet

Driveway Offset (feet) (Δ)	Driveway Return Radius (feet) (r)					
	0	5	10	15	20	25
0	--	--	23	20	17	14
2	--	24	20	17	14	--
4	24	21	17	14	--	--
6	21	18	15	14	--	--
8	19	16	14	--	--	--
10	17	17	14	--	--	--

Turning Speed = 10 mph — Driveway Length = 51 feet

Driveway Offset (feet) (Δ)	Driveway Return Radius (feet) (r)					
	0	5	10	15	20	25
0	--	--	--	23	20	16
2	--	--	24	21	18	14
4	--	--	23	20	17	14
6	--	25	21	18	15	14
8	25	22	19	16	14	--
10	23	20	17	15	14	--

Turning Speed = 15 mph — Driveway Length = 74 feet

Driveway Offset (feet) (Δ)	Driveway Return Radius (feet) (r)						
	10	15	20	25	30	35	40
0	--	--	--	--	23	20	17
2	--	--	--	24	20	17	14
4	--	--	24	21	17	14	--
6	--	25	21	18	15	14	--
8	25	22	19	16	14	--	--
10	23	20	17	15	14	--	--

Source: Reference (9), p. 63, Adapted from (1)

(Continued)

DRIVEWAY DESIGN (Continued)

Elements of Driveway Design (Continued)

TABLE 6-17.2: DRIVEWAY LANE WIDTHS AS A FUNCTION OF DRIVEWAY OFFSET AND RETURN RADIUS

FOR A 60 DEGREE DRIVEWAY ANGLE—α

Turning Speed = 15 mph | Driveway Length = 74 feet

Driveway Offset (feet) (Δ)	Driveway Return Radius (feet) (r) 0	5	10	15	20	25	30	35
0	--	25	23	21	19	17	15	14
2	24	22	20	18	17	15	14	--
4	20	18	17	16	14	--	--	--
6	18	16	15	14	--	--	--	--
8	16	15	14	--	--	--	--	--
10	14	--	--	--	--	--	--	--

Turning Speed = 20 mph | Driveway Length = 137 feet

Driveway Offset (feet) (Δ)	Driveway Return Radius (feet) (r) 0	5	10	15	20	25	30	35	40
2	--	--	--	--	--	--	--	--	24
4	--	--	--	--	--	25	23	22	20
6	--	--	--	25	23	22	20	19	18
8	--	25	24	22	21	20	18	17	16
10	24	23	22	20	19	18	16	15	14

FOR A 45 DEGREE DRIVEWAY ANGLE—α

Turning Speed = 20 mph | Driveway Length = 73 feet

Driveway Offset (feet) (Δ)	Driveway Return Radius (feet) (r) 0	5	10	15	20	25	30	35	40
0	--	--	--	24	23	22	21	20	18
2	25	24	23	21	20	19	18	17	16
4	21	20	19	18	17	16	15	15	14
6	18	17	17	16	15	14	--	--	--
8	16	15	15	14	--	--	--	--	--
10	15	14	--	--	--	--	--	--	--

Turning Speed = 25 mph | Driveway Length = 121 feet

Driveway Offset (feet) (Δ)	Driveway Return Radius (feet) (r) 0	5	10	15	20	25	30	35	40
4	--	--	--	--	--	--	--	--	25
6	--	--	--	--	25	24	23	22	21
8	--	25	24	23	22	21	21	20	19
10	23	22	22	22	20	19	19	18	17

Source: Reference (*9*), p. 64, Adapted from (*1*)

(Continued)

DRIVEWAY DESIGN (Continued)

Elements of Driveway Design (Continued)

TABLE 6-17.3: DRIVEWAY LANE WIDTHS AS A FUNCTION OF DRIVEWAY OFFSET AND RETURN RADIUS

FOR A 30 DEGREE DRIVEWAY ANGLE—α

Turning Speed = 25 mph | Driveway Length = 115 feet

Driveway Offset (feet) (Δ)	Driveway Return Radius (feet) (r)								
	0	5	10	15	20	25	30	35	40
0	23	23	22	21	20	20	19	19	18
2	20	20	19	19	18	18	17	17	17
4	17	16	16	16	15	15	15	14	--
6	15	15	14	--	--	--	--	--	--
8	14	--	--	--	--	--	--	--	--
10	14	--	--	--	--	--	--	--	--

Turning Speed = 30 mph | Driveway Length = 172 feet

Driveway Offset (feet) (Δ)	Driveway Return Radius (feet) (r)				
	0	10	20	30	40
0	--	--	--	--	--
2	--	--	--	25	24
4	23	23	22	21	20
6	20	20	19	18	17
8	18	18	17	16	16
10	16	16	15	15	14

Source: Reference (*9*), p. 63, Adapted from (*1*)

Driveway Profile

The vertical alignment must provide a smooth transition between the driveway and the roadway to which access is provided. In all cases, the profile must be sufficient to provide sufficient clearance between the surface and the vehicle. Access drives on major streets must permit the driveway maneuver to be made smoothly and comfortably at a forward speed of at least 10 mph.

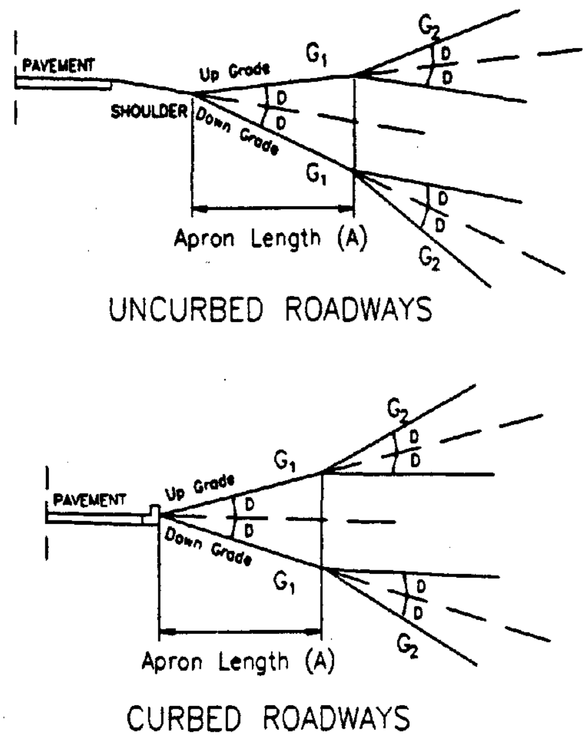
Suggested apron lengths and maximum grade changes are given in Figure 6-17. With the dimensions shown, normal construction practice will provide an appropriate profile. For grade changes greater than those shown, vertical curves at least 20 feet long should be used. the apron length should also be increased where steep grades (G_2) are encountered. Maximum driveway grades (G_2) within a distance of twice the apron length (2A) of the curb, or edge of pavement on uncurbed roadways should not exceed 5% on driveways intersecting major arterials, 8% on minor arterials and major collectors, and 15% on minor collectors and local facilities.

(Continued)

DRIVEWAY DESIGN (Continued)

Driveway Profile (Continued)

Shoulder slopes commonly vary from 4% (1/2 in/foot) to 6% (3/4 in/foot). The shoulder slope should be maintained for the full width, including return radii, of the driveway.



Recommended Design Values			
Roadway Classification	Apron Length (A)	Grade Change (D) Desirable	Grade Change (D) Maximum
Major Arterial	≥25 ft	≤3%	5%
Minor Arterial	≥20 ft	≤4%	5%
Collector	≥15 ft	≤5%	6%
Local	≥10 ft	≤6%	8%

FIGURE 6-17: VERTICAL GEOMETRICS FOR DRIVEWAYS

SIGHT DISTANCE

Introduction

Sight distances greater than the safe stopping sight distance must be maintained on all roadways and access drives. Intersection sight distance must be provided at all signalized and unsignalized intersections, including driveways.

Minimum sight distances should be exceeded, especially on major roadways.

Sight Distance for Vehicles on Main Roadway

Access drives, other features or turning movements should not be permitted where the sight distance is not adequate to allow a motorist to maneuver to come to a safe stop. Table 6-18 gives minimum sight distances for vehicles traveling along the main roadway.

(Continued)

SIGHT DISTANCE (Continued)

Sight Distance for Vehicles on Main Roadway (Continued)

TABLE 6-18: MINIMUM SIGHT DISTANCE FOR VEHICLES TRAVELING ALONG MAIN ROADWAY[(1) (2)]

Speed (mph)	Sight Distance (feet)	
	Minimum Stop[(3)]	Desirable Stop[(4)]
20	120	160
25	150	205
30	200	270
35	250	350
40	325	435
45	400	530
50	475	635
55	550	745
60	650	870
65	725	1,000
70	850	1,140

(1) For determining the sight distance, the driver's eye height above the road surface is 3.5 feet and the driver on the main roadway should be able to see that portion of a vehicle, at an access, which is 2.5 feet above the driveway surface. The front bumper of the driveway vehicle is assumed to be 5.0 feet back from the edge of the traveled way. The driver's eye of the vehicle on the main roadway is assumed to be centerline lane for purposes of determining sight distance.

(2) These lengths should be adjusted for any downgrade of 3.0% or greater and may be decreased for upgrades of 3.0% or greater by multiplying the length given in the table by the factors given below:

3.0% to 4.9% upgrade	3.0% to 4.9% downgrade
0.9	1.2
5.0% to 7.0% upgrade	**5.0% to 7.0% downgrade**
0.8	1.35

(3) Based upon AASHTO minimum stopping distance.

(4) Based upon a 2.5 second perception-reaction time and 6.0 fps^2 average deceleration, rounded to nearest 5 feet.

(Continued)

SIGHT DISTANCE (Continued)

Crossing Sight Distance	In addition to the sight distance necessary for vehicles traveling on the main roadway to see vehicles, or objects, in and adjacent to the traveled way, it is also necessary to provide adequate sight distance for vehicles on cross roads and driveways to enter or cross the roadway. Table 6-19 gives sight distances for vehicles to cross a roadway. Since the sight distance for the crossing maneuver is linear with respect to speed it is common practice to present the sight distances in tabular form as in Table 6-18 rather than to use the AASHTO graph directly.

(Continued)

SIGHT DISTANCE (Continued)

Crossing Sight Distance (Continued)

TABLE 6-19: SIGHT DISTANCE ALONG A ROADWAY FOR A VEHICLE STOPPED ON A CROSSROAD TO CROSS THE ROADWAY(1) (2) (3)

Design Vehicle Crossing Roadway(4)	Minimum Sight Distance Left and Right in Feet per 10 mph of Speed on Roadway to be Crossed		
	Two Lane	Four Lane Undivided	Six Lane Undivided on Four Lane with 24' Median
P	100	110	125
SU	140	150	170
WB-50	180	200	220

(1) Based upon AASHTO crossing sight distance; Reference (2), Figure IX-39, p. 761.

(2) Use sight distances which are 20% larger are recommended as design minimums. Such distances allow for a more adequate perception reaction time (3.5 seconds as opposed to 2.0 seconds).

(3) The sight distance shall be measured using a driver's eye height 3.5 feet to a point on the oncoming vehicle which is 2.5 feet above the roadway surface. The driver's eye of the entering vehicle shall be assumed to be at least 10.0 feet back from the edge of the pavement.

(4) The design vehicle shall be the largest vehicle normally expected to use the access at least once per day.

(Continued)

SIGHT DISTANCE (Continued)

Sight Distance to Enter Roadway	Sight distance must be sufficient for drivers to be able to safely enter the through traffic lanes of a roadway by making a left or right turn. AASHTO sight distances (2, p. 762) should be considered to be absolute minimum sight distances for all conditions. Minimum intersection sight distance for left and right turns onto a 2-lane highway are given in Table 6-20. Logic suggests that a larger sight distance should be used for the left turn maneuver than for the right turn because the driver of the vehicle entering the highway must evaluate gaps in traffic approaching from the right as well as the left. The left turn sight distances given in Table 6-20 assumes a perception reaction time which is 1.5 seconds longer than that for a right turn.

(Continued)

SIGHT DISTANCE (Continued)

Sight Distance to Enter Roadway (Continued)

TABLE 6-20: INTERSECTION SIGHT DISTANCES TO ENTER A HIGHWAY AT AN AT-GRADE INTERSECTION

Design Speed (mph)	Minimum Sight Distance For P-Vehicle Entering Roadway	
	Right Turn[2]	Left Turn[3]
20	225	275
25	300	350
30	375	450
35	475	550
40	575	675
45	700	800
50	850	950
55	1000	1125
60	1150	1275

(1) Sight distance shall be measured assuming the driver's eye of the vehicle entering the roadway is 3.5 feet above the driveway surface and 10.0 feet back from the edge of the through traffic lane to the oncoming vehicle at a height of 2.5 feet above the pavement surface.

(2) Source: Reference (2) Figure IX-40, page 762. Sight distance for P-Vehicle to turn right into a two lane highway and attain 85% of design speed without being overtaken by a vehicle approaching from the left reducing speed to 85% of the design speed.

(3) Adapted from Reference (2), Figure IX-40, p. 762 and by adding the distance traveled by an oncoming vehicle in 1.5 seconds, calculated as (1.47)(V)(1.5) and rounded to the nearest 25 feet, to the sight distance for the right turn. The sight distance for a P-vehicle to turn left into a two lane highway and attain 85% of design speed without being overtaken by a vehicle approaching from the right reducing speed to 85% of the design speed.

FRONTAGE ROADS

Frontage Road Functions

Frontage Road Functions

- **Segregate Local Traffic From High Speed Through Traffic**
- **Intercept Driveways and Reduce Frequency of Access**

As an access control measure, frontage roads provide two main functions:

(1) They segregate local traffic from the high speed through lanes. Traffic can circulate between the various commercial establishments without interfering with through traffic.

(2) Frontage roads intercept the access drives serving the roadside properties and thereby reduce the number of conflict points. The resulting spacing between the intersections with the main roadway facilitates the design of auxiliary lanes for deceleration and acceleration.

However, the intersection of frontage roads, especially continuous frontage roads, with the crossroad can result in overlapping intersections and produce a complex pattern of conflict points as illustrated in Figure 6-18. Such intersections have very low capacities and the traffic volumes generated by commercial development on the frontage roads commonly result in severe congestion, long delays, and high accident experience.

(Continued)

FRONTAGE ROADS (Continued)

Frontage Road Functions (Continued)

Making the frontage roads one-way reduces the number of conflict points. However, severe traffic problems will still be encountered, even with moderate frontage road and cross road volumes. These problems can be minimized by incorporation of horizontal curves in the frontage road design to increase the separation between the intersections of the crossroad-frontage road and crossroad-main roadway as illustrated in Figure 6-19.

A separation of at least 150 feet is necessary to reduce the interference of the frontage road intersections on the crossroad-main highway intersection. A separation of 250 feet or greater creates a buildable site suitable for a service station, fast food restaurant, or convenience stores. An example of such an alignment is shown in Figure 6-20.

(Continued)

FRONTAGE ROADS (Continued)

Frontage Road Functions (Continued)

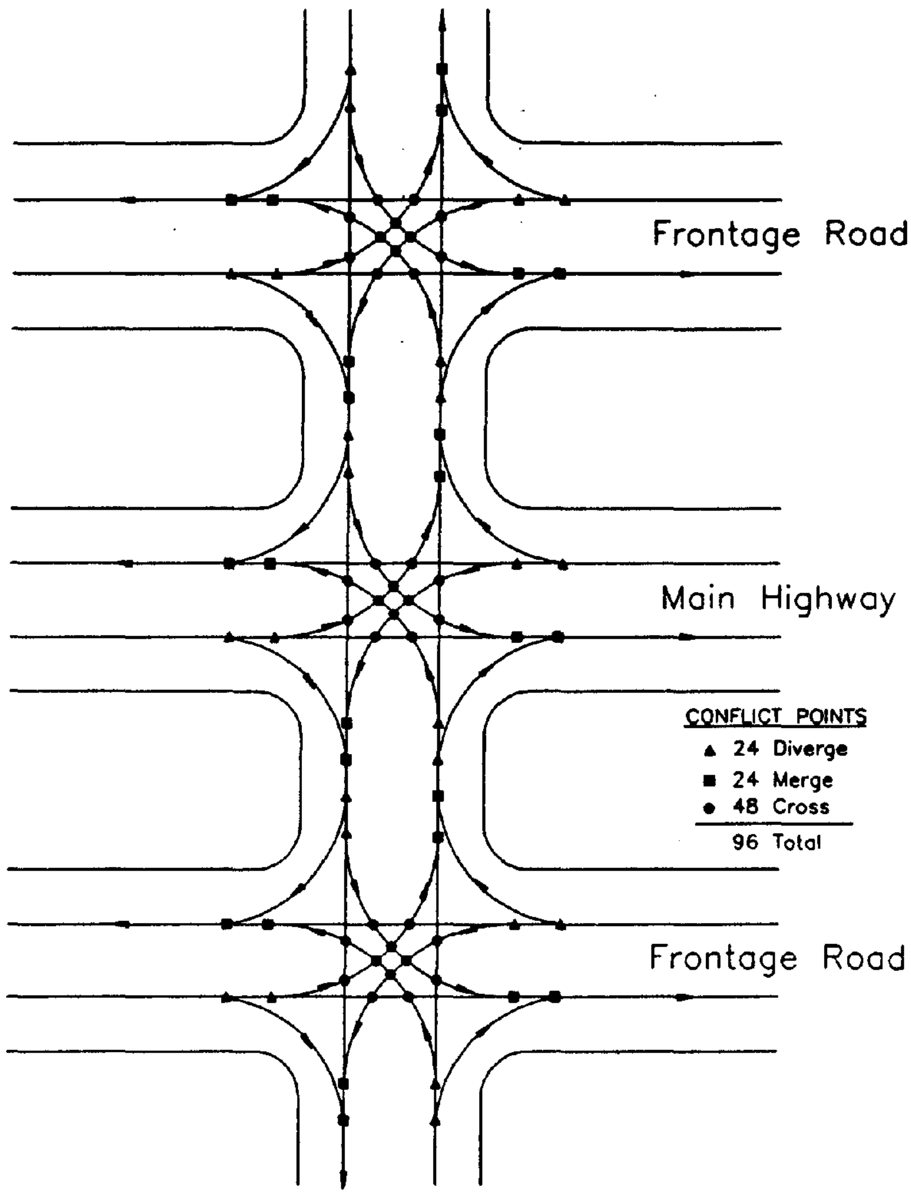


FIGURE 6-18: CONFLICT POINTS RESULTING WITH FRONTAGE ROADS

(Continued)

FRONTAGE ROADS (Continued)

Frontage Road Functions (Continued)

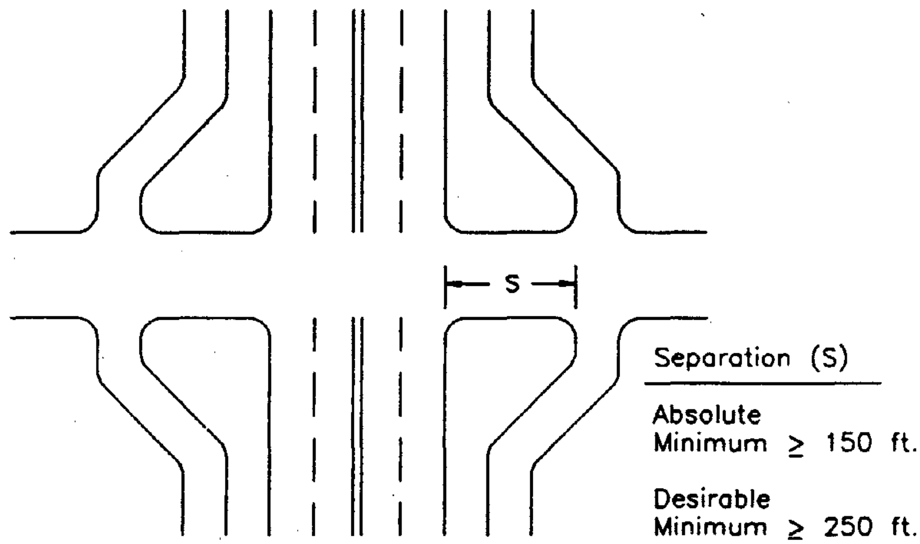


FIGURE 6-19: FRONTAGE ROAD ALIGNMENT TO INCREASE INTERSECTION SPACING ON CROSS ROAD

FRONTAGE ROADS (Continued)

Frontage Road
Functions
(Continued)

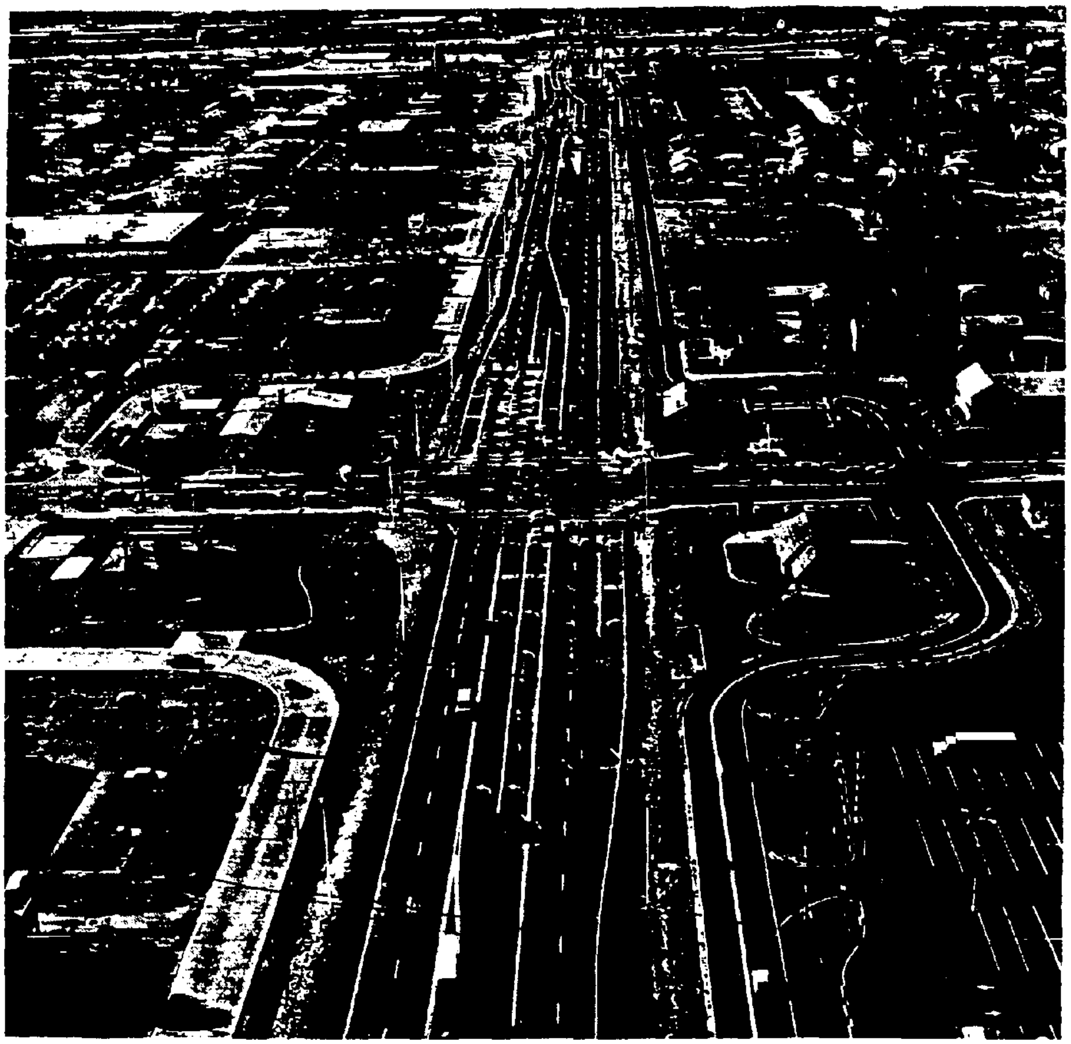


FIGURE 6-20: ARTERIAL STREET WITH TWO-WAY FRONTAGE ROAD ALIGNED TO PROVIDE SEPARATION BETWEEN MAIN HIGHWAY AND FRONTAGE ROAD INTERSECTIONS

REFERENCES

1. J. A. Azzeh, et. al., "Evaluation of Techniques for the Control of Direct Access to Arterial Highways", Report FHWA-RD-76-85, United States Department of Transportation, August 1975.

2. A Policy on the Geometric Design of Highways and Streets, American Association of State Highway and Transportation Officials, 1990.

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6. "Planning and Design Guide At-Grade Intersections", Jack E. Leisch & Associates, Evanston, Illinois, April 15, 1988.

7. "Aspects of Traffic Control Devices", Highway Research Board, Report 211 Highway Research Record, Washington, D.C., 1967.

8. Transportation Engineering Design Standards, Traffic Engineering Division Department of Public Works, Lakewood, Colorado, June 1985.

9. "Access Management for Streets and Highways", Federal Highway Administration, Report FHWA-IP-82-3, June 1982.

APPENDIX 6-A

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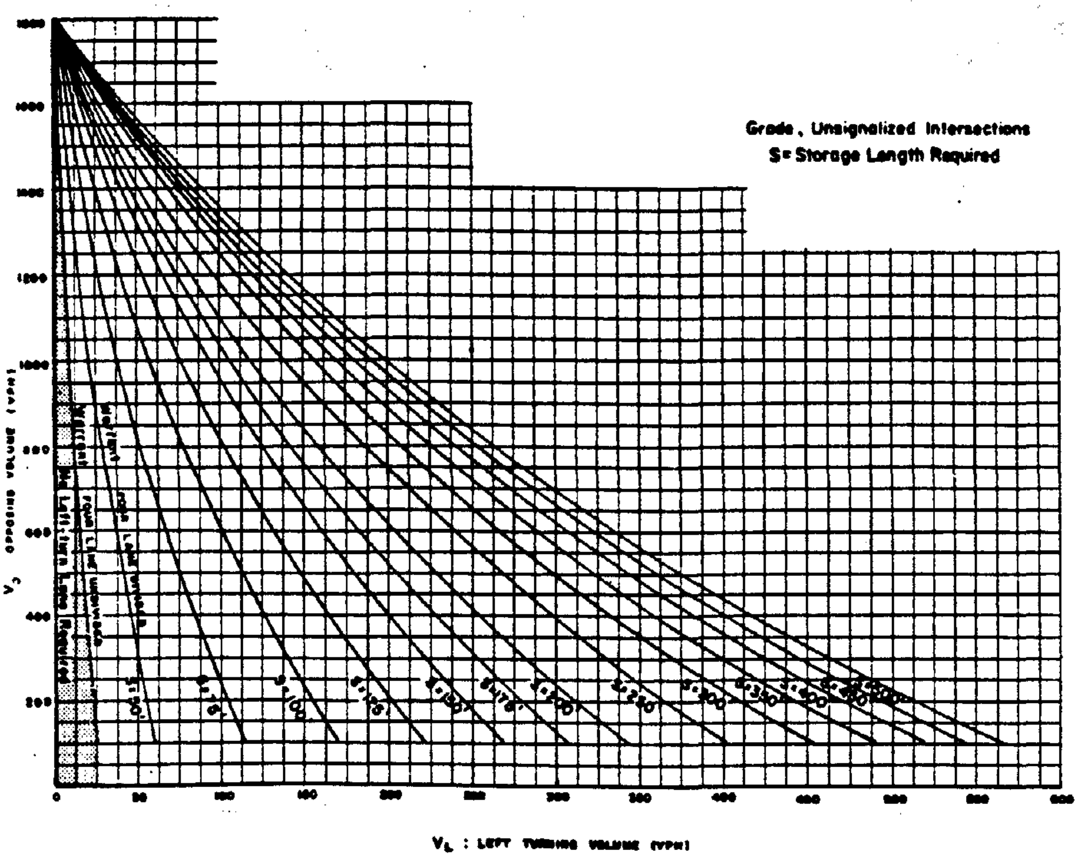

Figure 1. Warrant for left-turn storage lanes on four-lane highways.

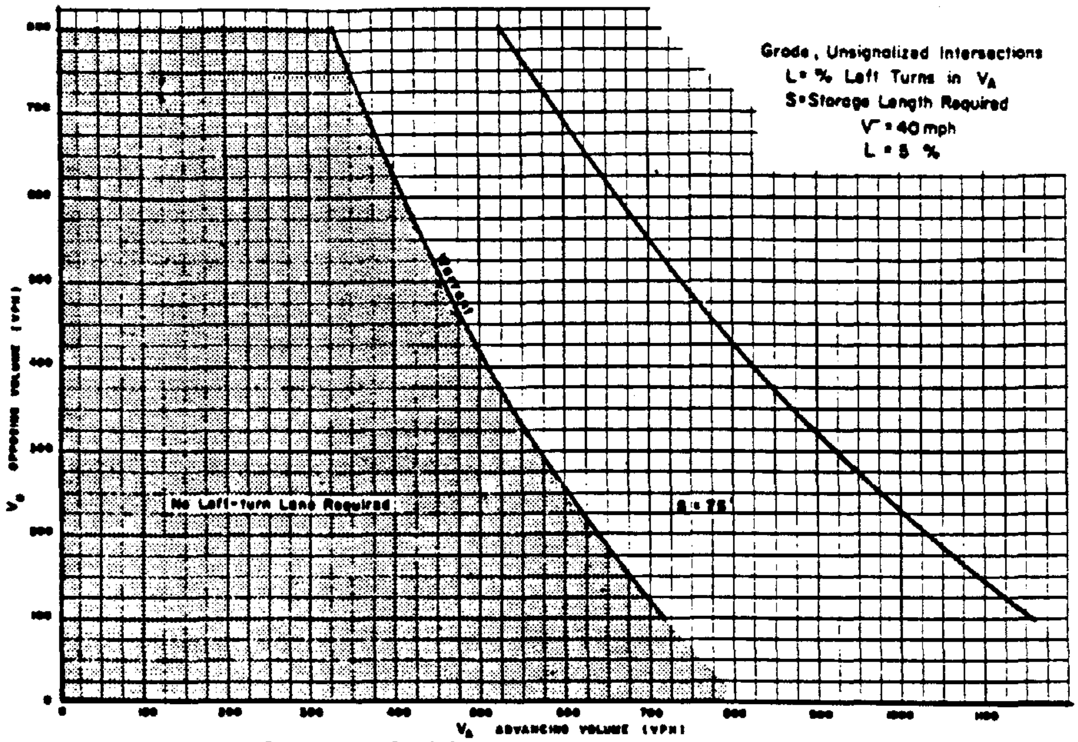

Figure 2. Warrant for left-turn storage lanes on two-lane highways.

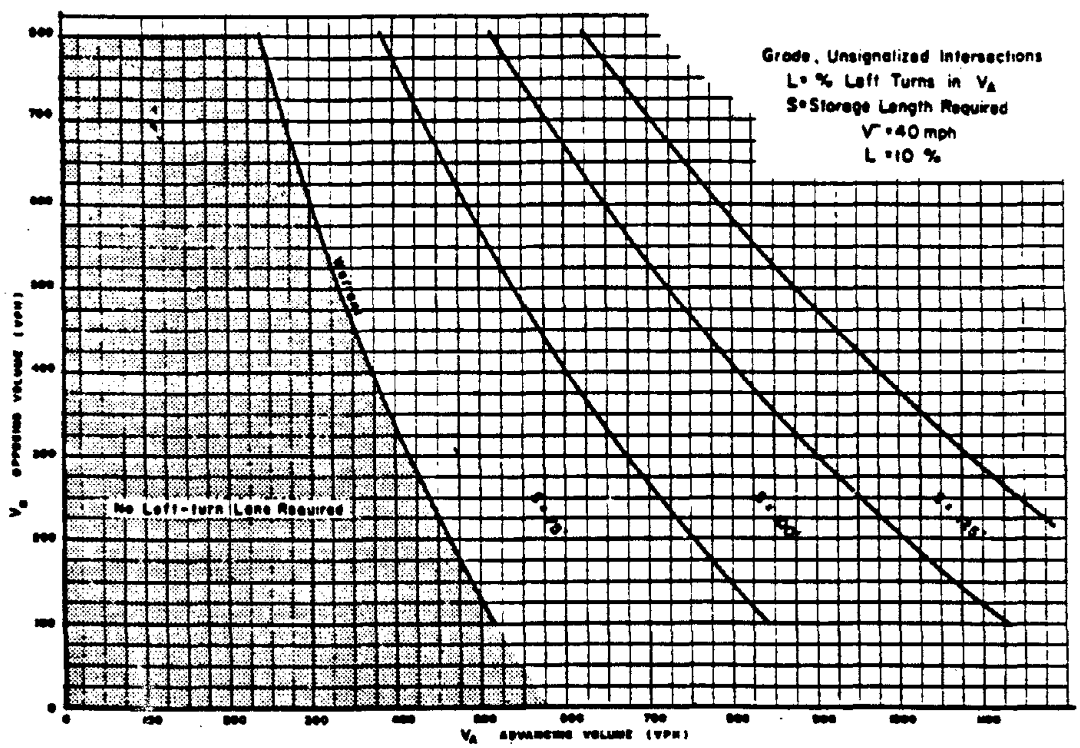

Figure 3. Warrant for left-turn storage lanes on two-lane highways.

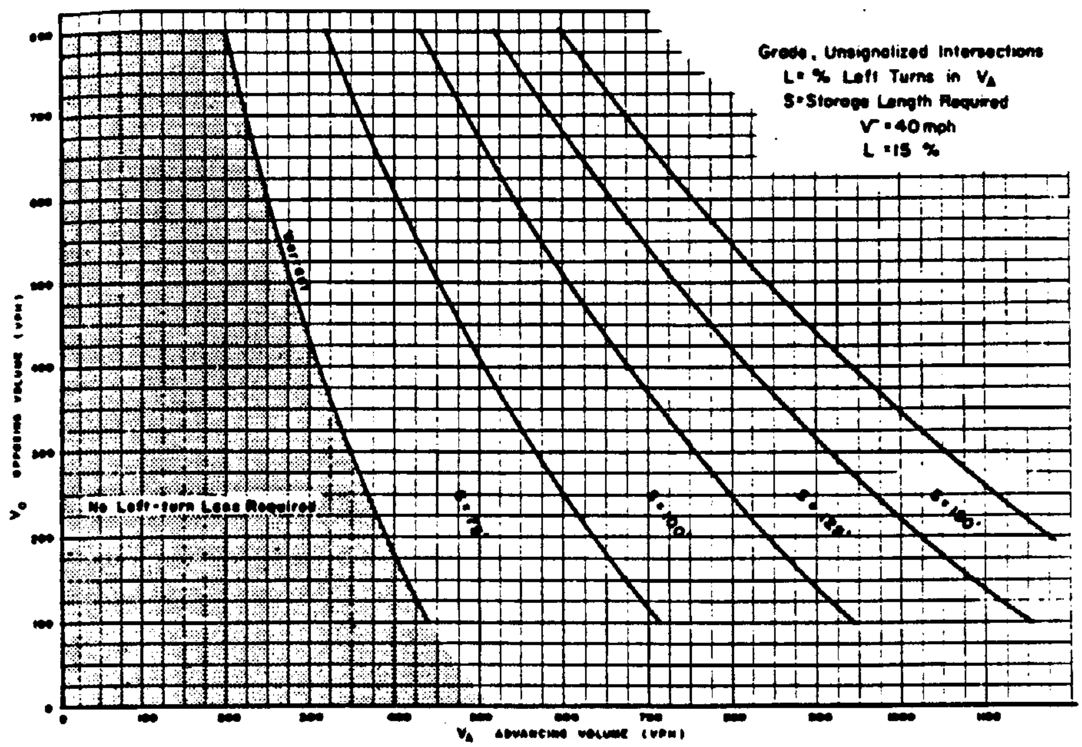

Figure 4. Warrant for left-turn storage lanes on two-lane highways.

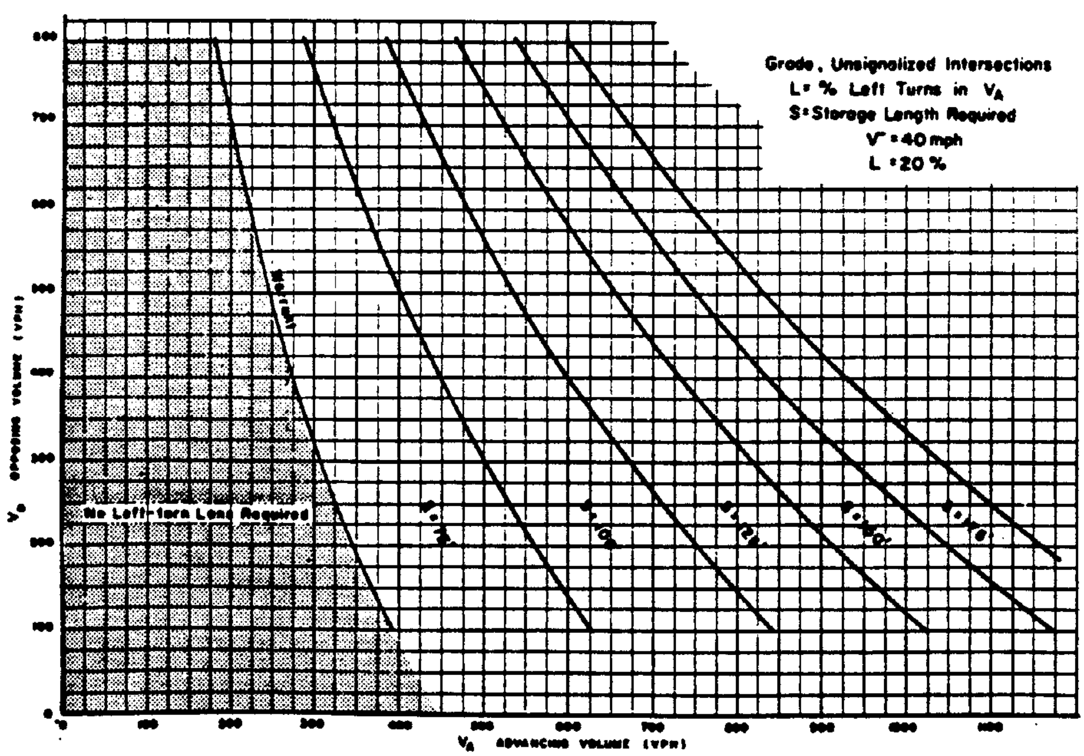

Figure 5. Warrant for left-turn storage lanes on two-lane highways.

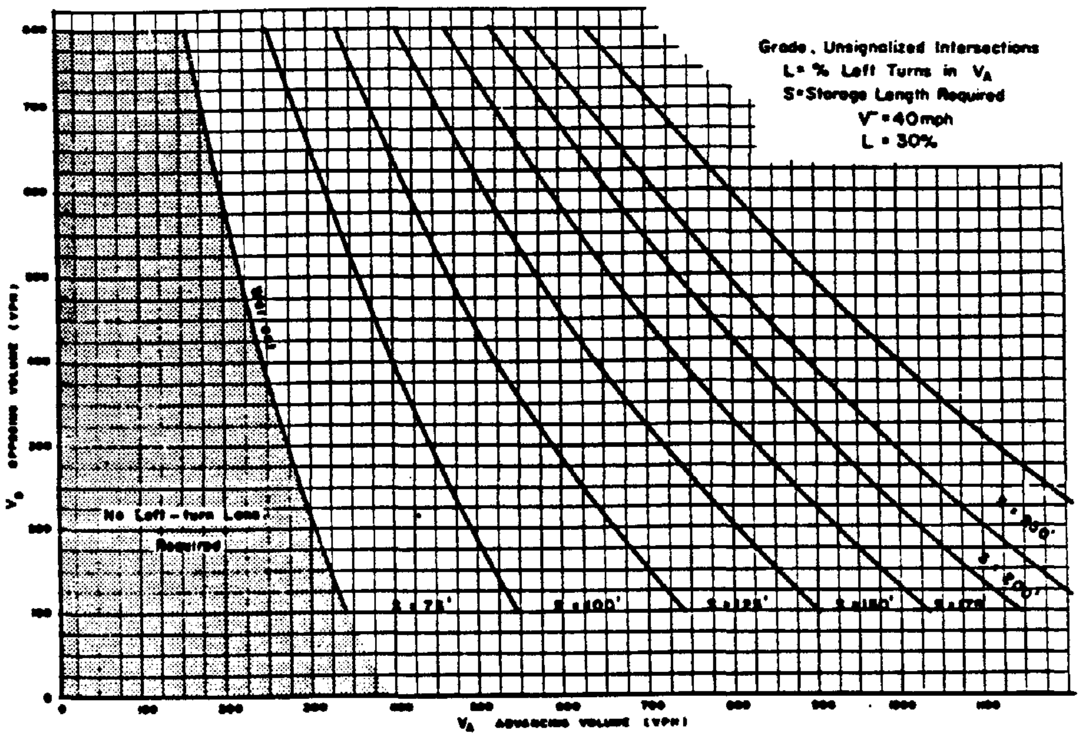

Figure 6. Warrant for left-turn storage lanes on two-lane highways.

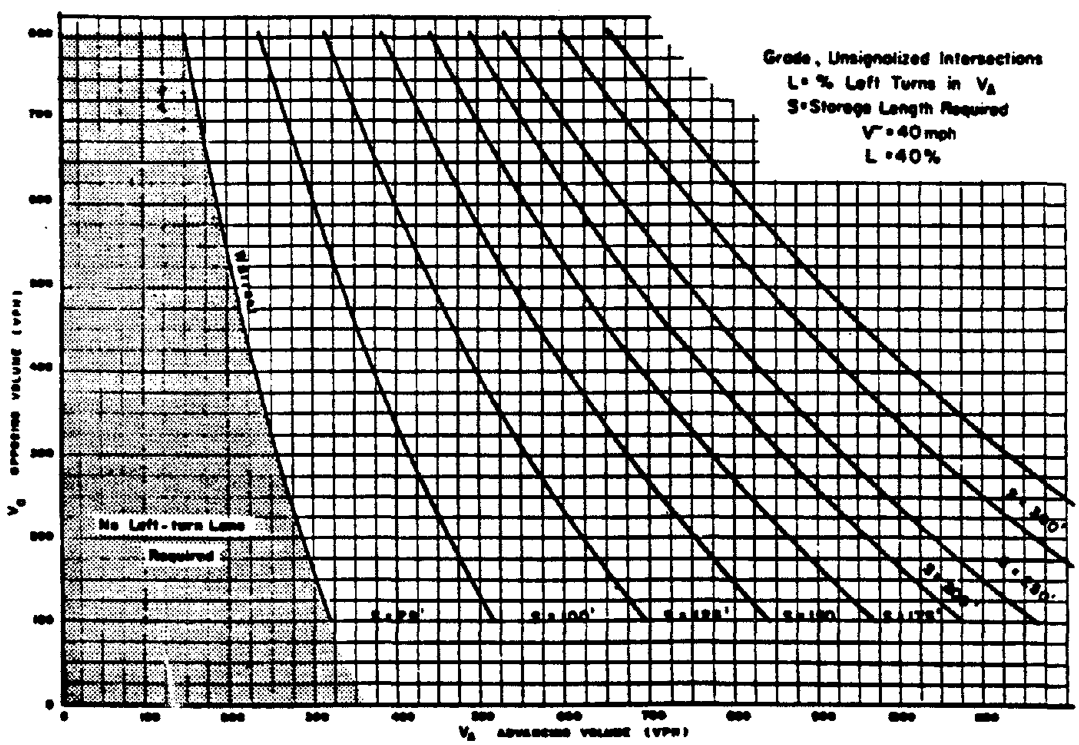

Figure 7. Warrant for left-turn storage lanes on two-lane highways.

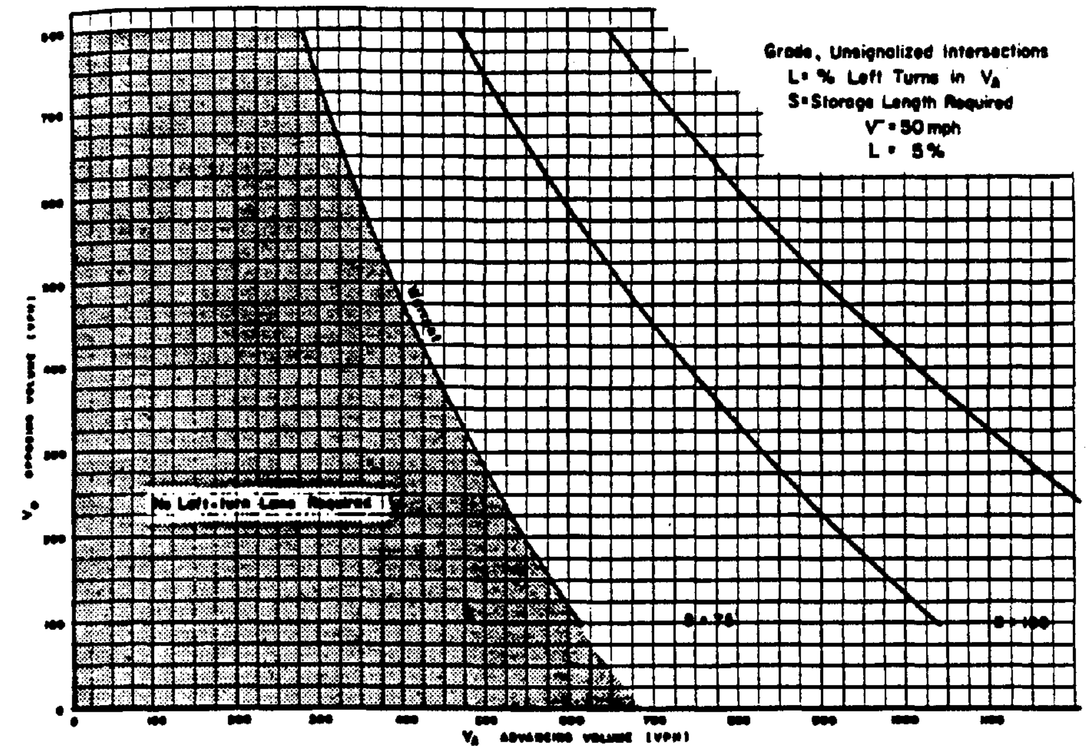

Figure 8. Warrant for left-turn storage lanes on two-lane highways.

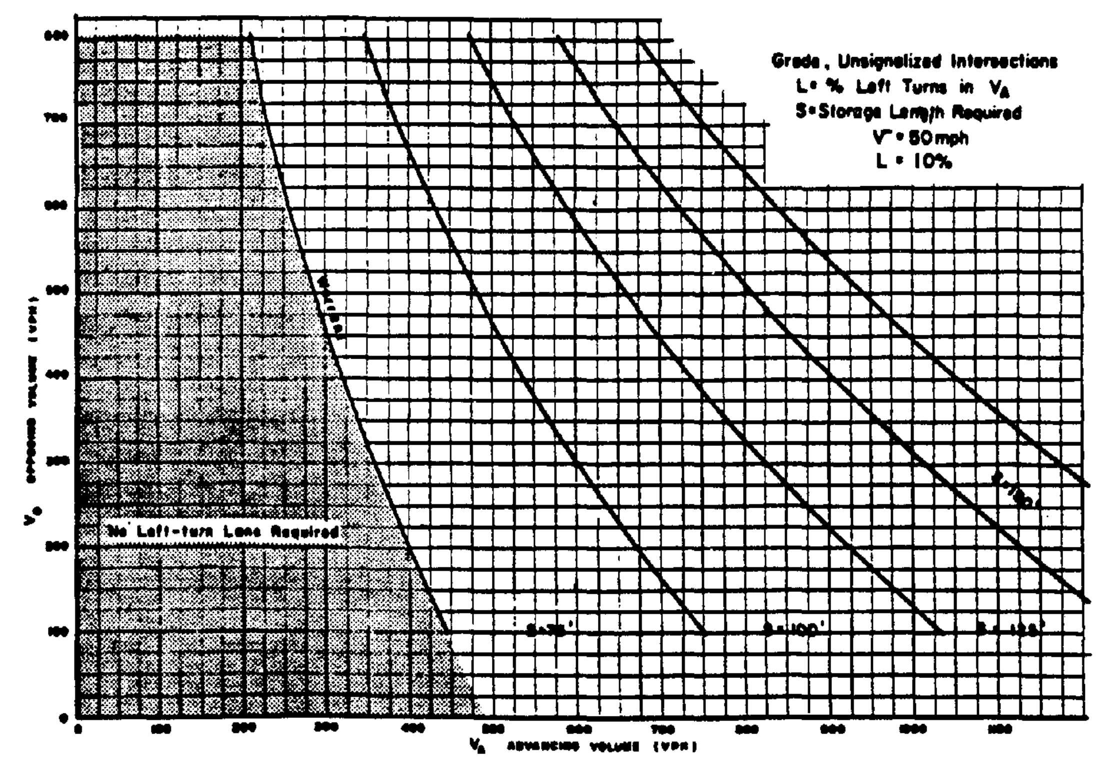

Figure 9. Warrant for left-turn storage lanes on two-lane highways.

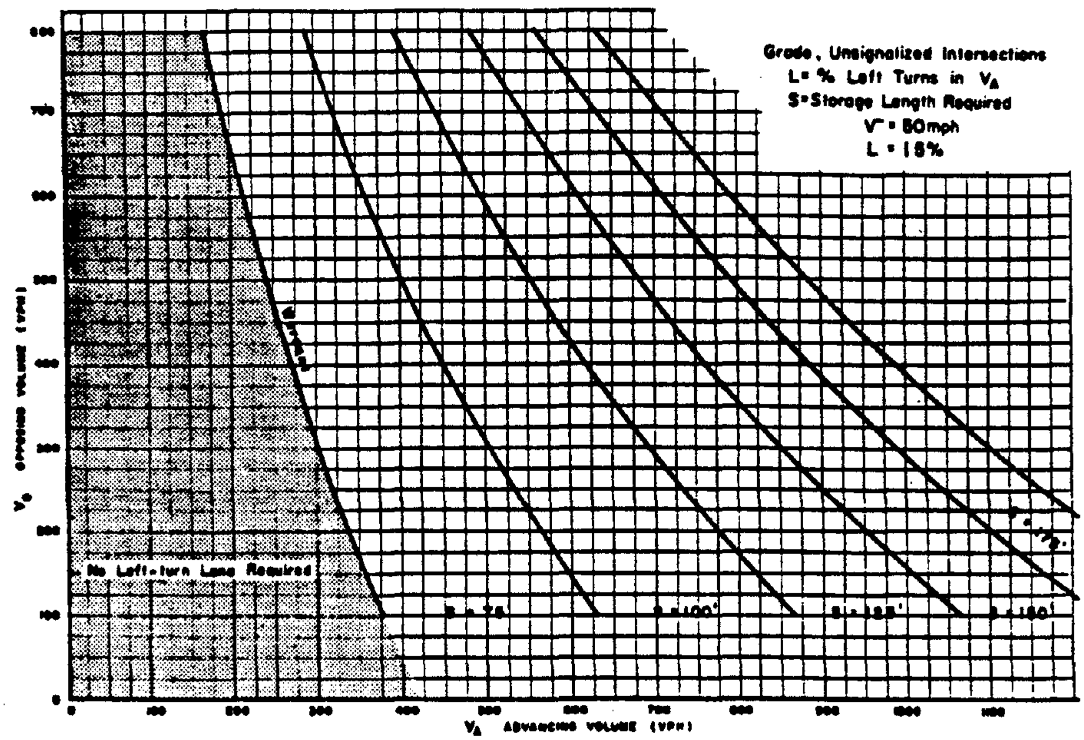

Figure 10. Warrant for left-turn storage lanes on two-lane highways.

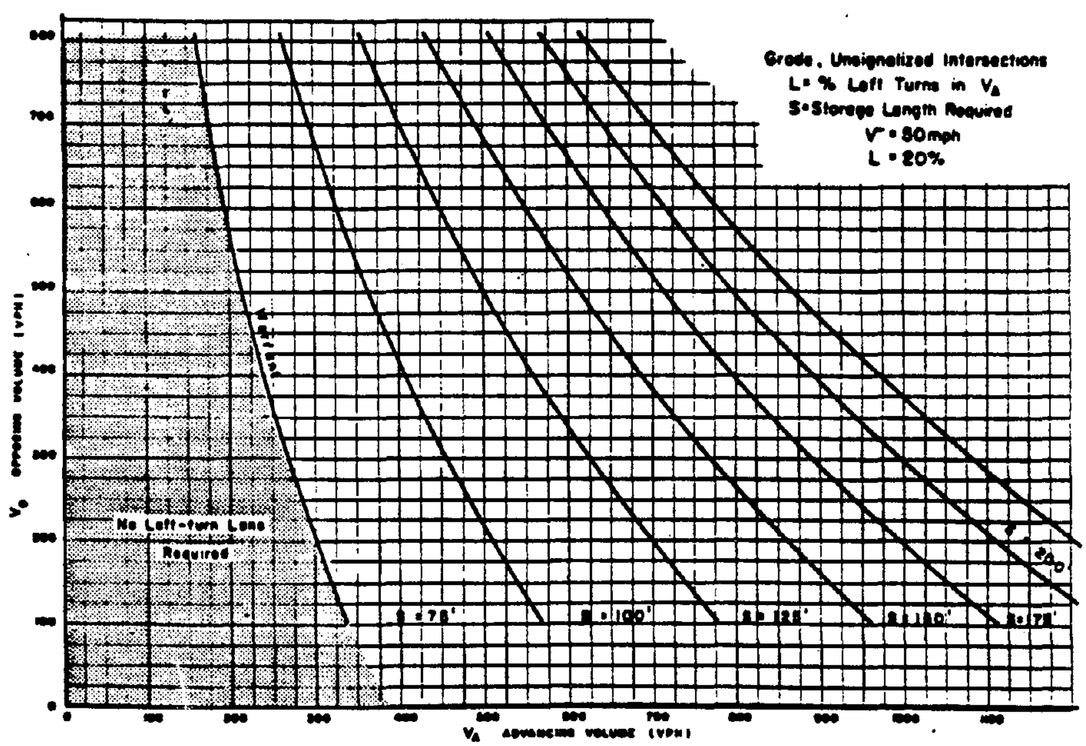

Figure 11. Warrant for left-turn storage lanes on two-lane highways.

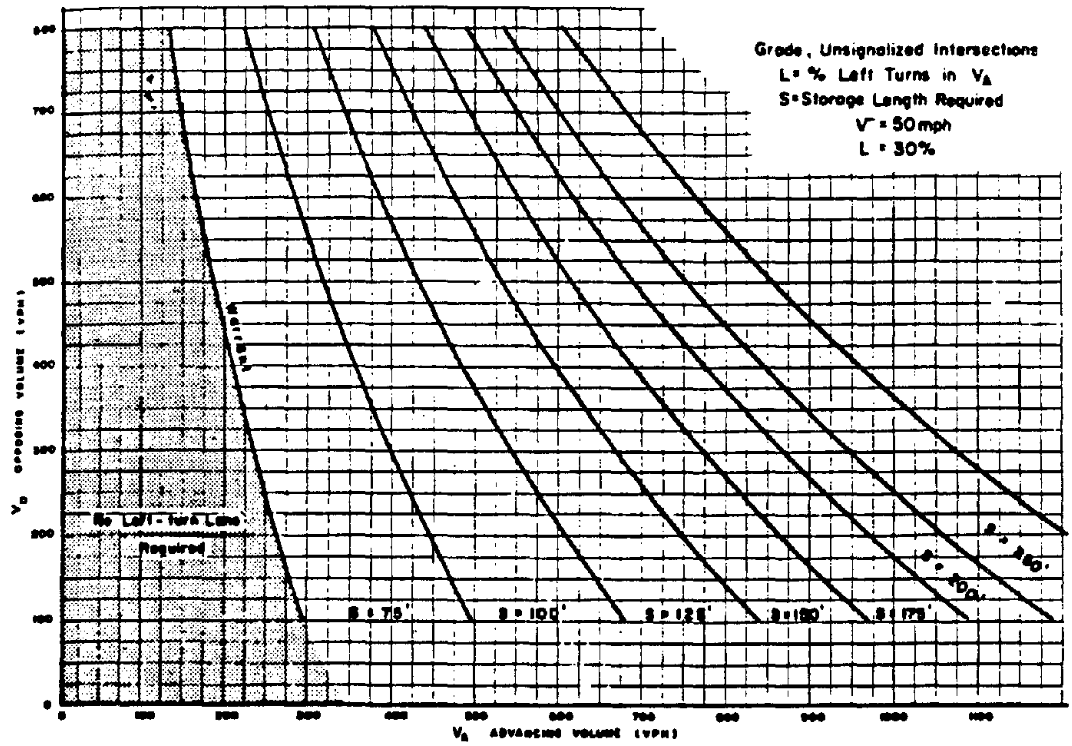

Figure 12. Warrant for left-turn storage lanes on two-lane highways.

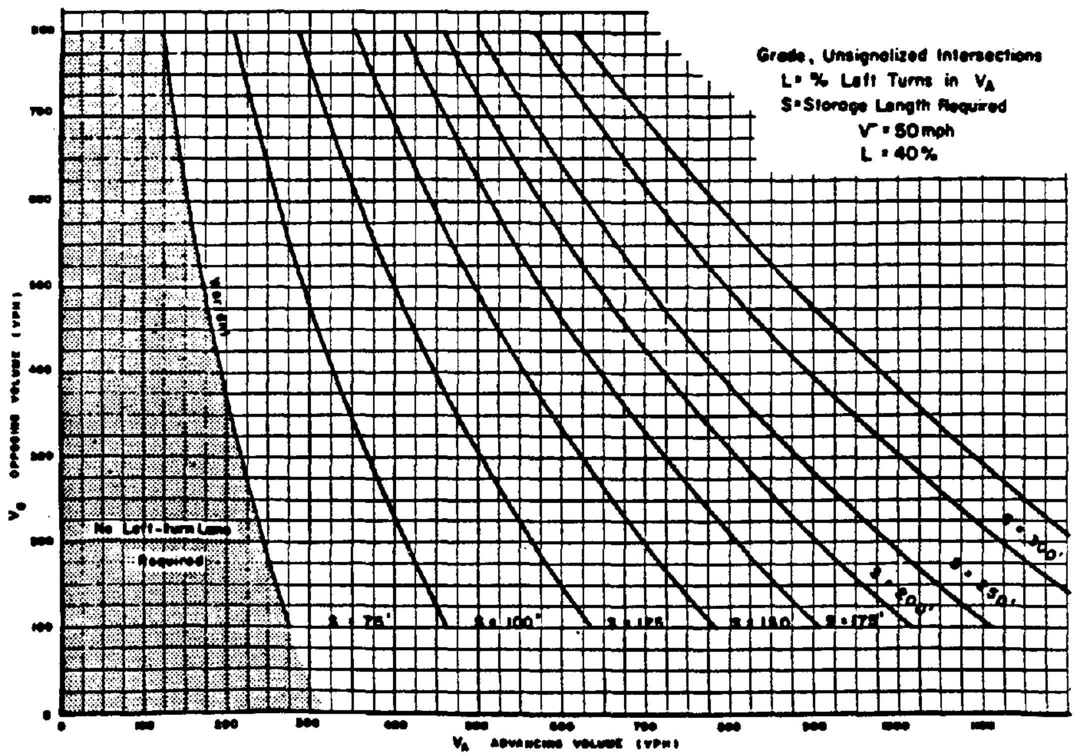

Figure 13. Warrant for left-turn storage lanes on two-lane highways.

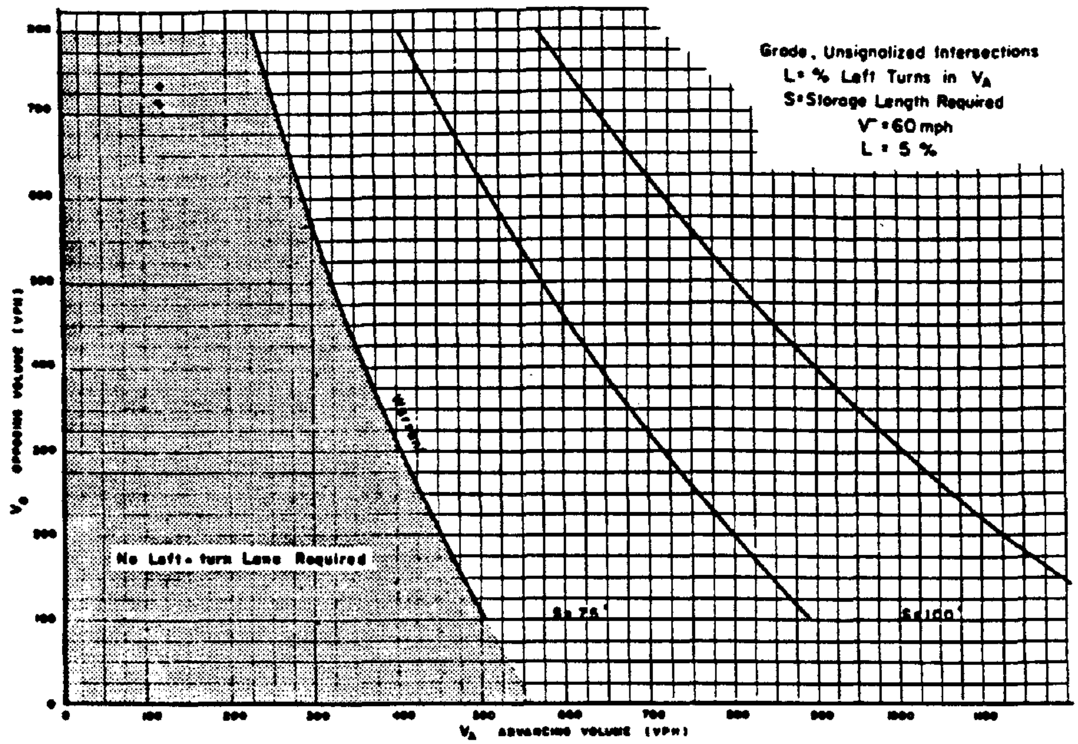

Figure 14. Warrant for left-turn storage lanes on two-lane highways.

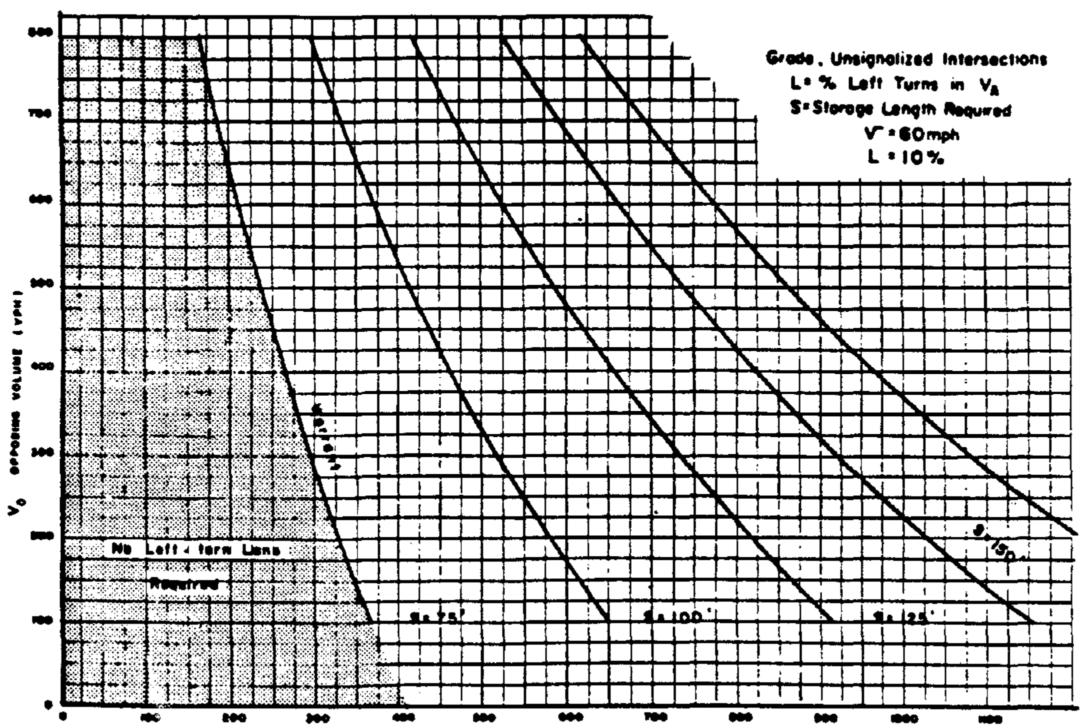

Figure 15. Warrant for left-turn storage lanes on two-lane highways.

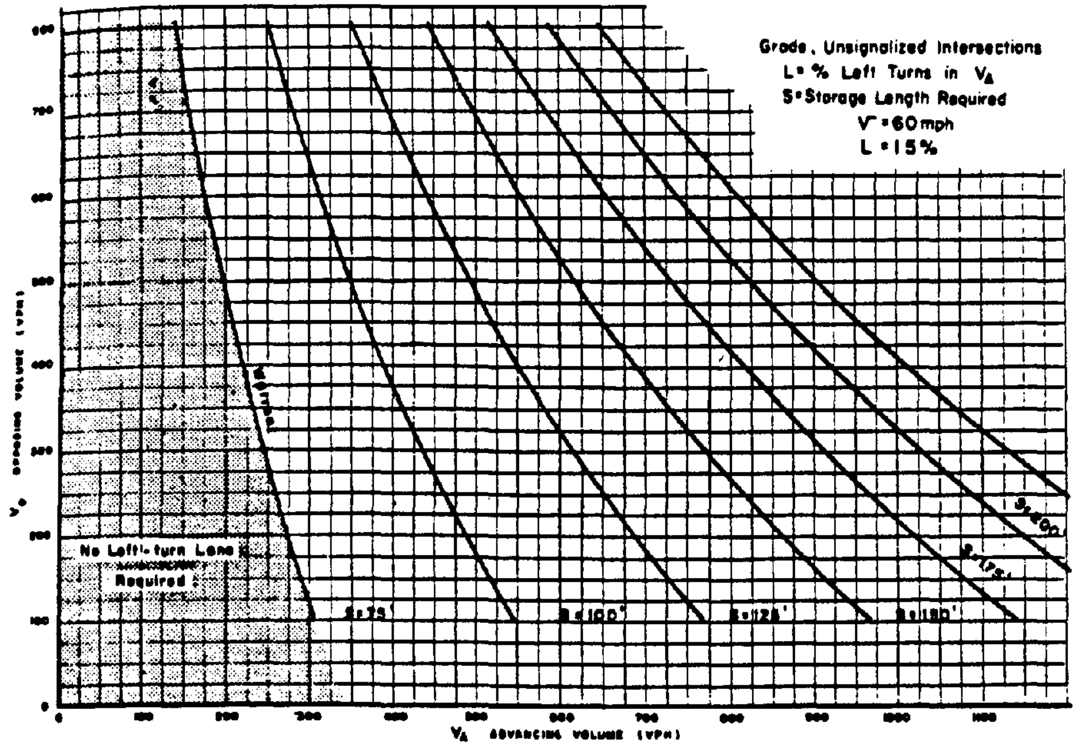

Figure 16. Warrant for left-turn storage lanes on two-lane highways.

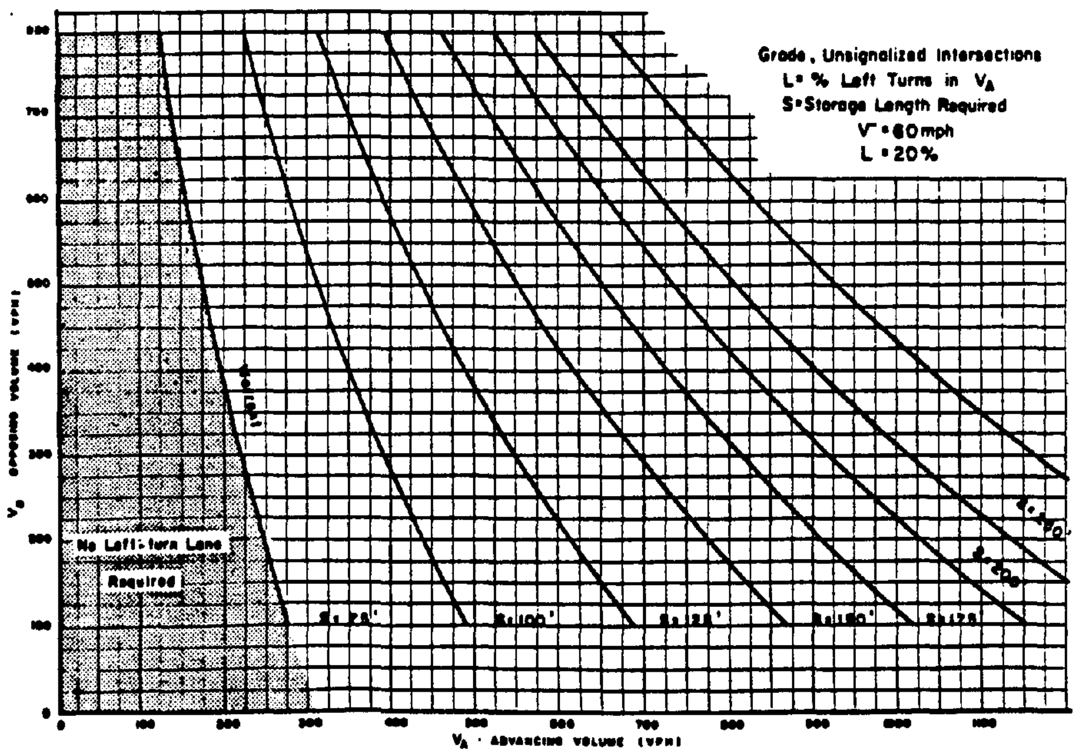

Figure 17. Warrant for left-turn storage lanes on two-lane highways.

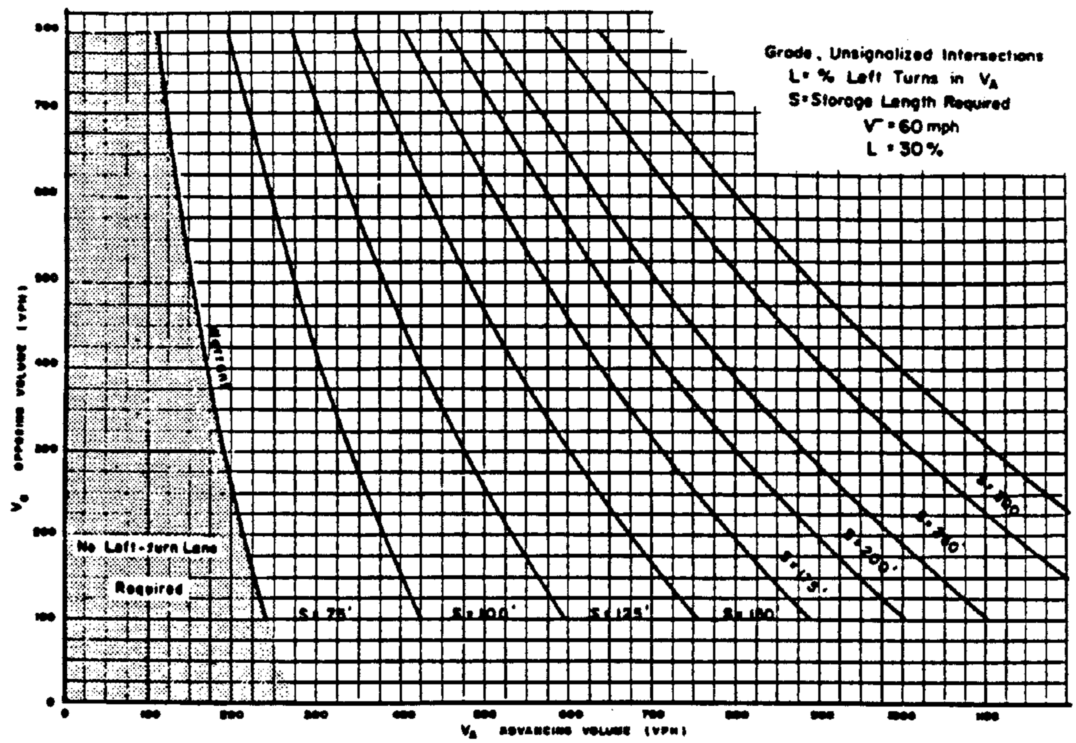

Figure 18. Warrant for left-turn storage lanes on two-lane highways.

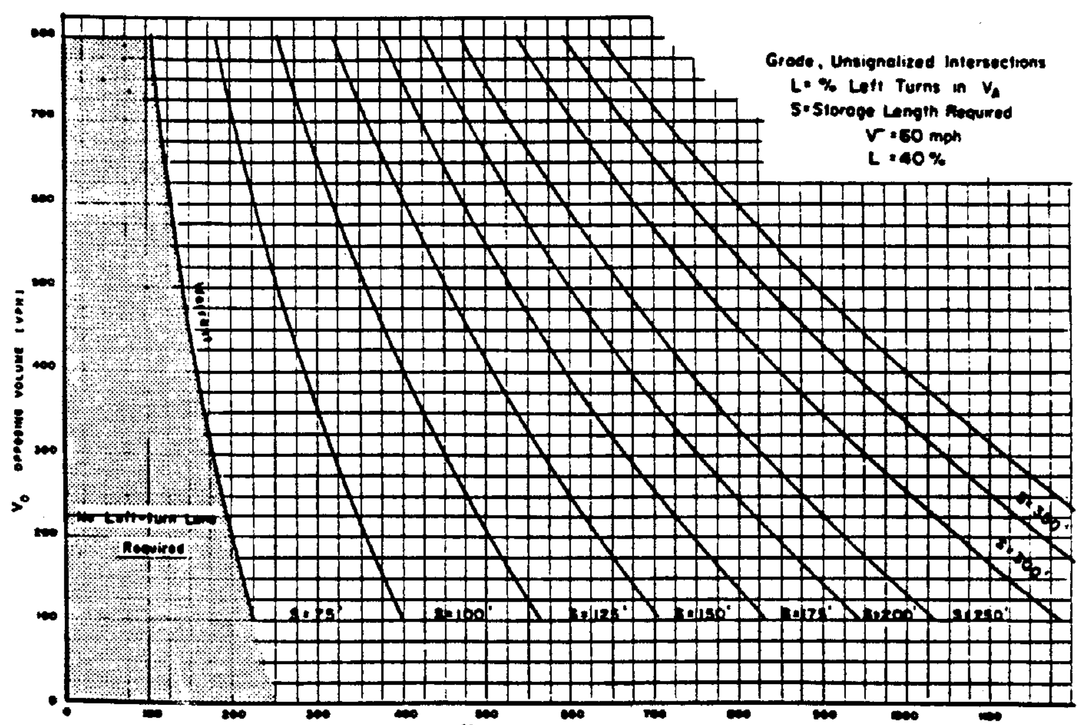

Figure 19. Warrant for left-turn storage lanes on two-lane highways.

CHAPTER 7

SITE PLANS

INTRODUCTION

Land Use - Transportation Cycle

CHAPTER 7

SITE PLANS

Improved urban street systems result in increased travel demand and, in turn, further demand for street improvements. This cycle, the Transportation - Land Use Cycle, is illustrated in Figure 7-1.

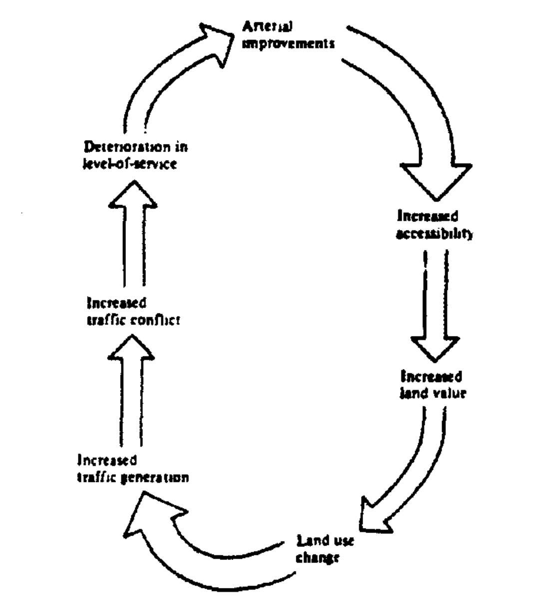

FIGURE 7-1: TRANSPORTATION - LAND USE CYCLE

Source: Reference (*1*), p. 2

Management of the Land Use - Transportation Cycle

Municipalities have extensive powers which can be applied to manage the land use - transportation cycle. These include the zoning ordinance, subdivision regulation, and various other growth management techniques and procedures. Counties in most states and townships in the northeast U.S. have similar powers.

THE SITE DESIGN

Introduction

Access, site circulation, parking, and building footprint and location are all highly related. Failure to recognize these interrelationships results in poor site circulation, improperly located parking, and access location and design which interferes with safe traffic movement on the public street system in vicinity of the development.

The Common Design Process

The design process which begins with the building and ends with access, as illustrated in Figure 7-2 commonly results in poor design.

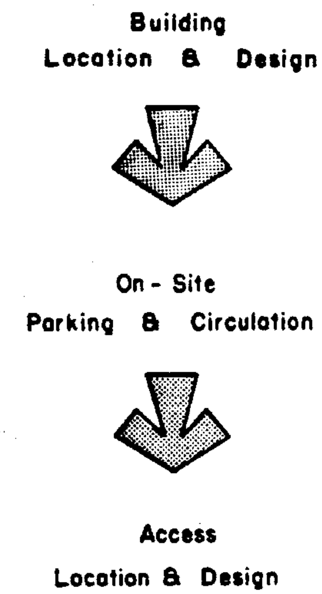

FIGURE 7-2: ILLUSTRATION OF THE COMMON SITE DESIGN PROCESS

Source: Reference (*1*), p. 17

Poor site design will result in traffic accidents on the site as well as on the public street. Because of traffic flow and accident problems, the development will be less financially successful than it could have been. Once the traffic problems become apparent, the developer/owner pressures the responsible public agency to "solve" the site design problem through traffic controls, speed limits, and/or physical changes in the street cross-section.

(Continued)

THE SITE DESIGN (Continued)

A Recommended Design Process

Site circulation design can be improved and negative impact on through adjacent public streets minimized where access and site circulation considerations are included in the feasibility and initial design stages. A recommended design process is illustrated in Figure 7-3.

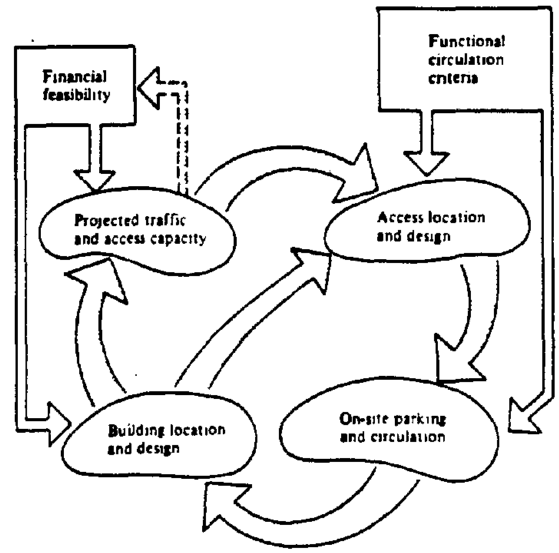

FIGURE 7-3: RECOMMENDED SITE DESIGN PROCESS

Source: Reference (1), p. 18

Preliminary Access/ Circulation Analysis

A preliminary access/circulation analysis should be conducted in conjunction with the financial feasibility study. This investigation should analyze the suitability of potential access and circulation constraints on site development. Development of the site design should follow an evolutionary process. It is preferable to first identify the region in which access would be the most desirable (and undesirable) from the perspective of the adjacent public street. Next, the building footprint should be tentatively located. The process should then follow an iterative procedure as suggested by the above figure.

(Continued)

THE SITE DESIGN (Continued)

Comparison Of Access and Public Streets

The functional hierarchy which applied to the public street system also applies to on-site circulation. Therefore, the functional design criteria that applies to public streets and highways applies to access and site circulation as well. The parallel between public and site circulation elements is illustrated in Table 7-1.

TABLE 7-1: FUNCTIONAL COMPARISON OF SITE ACCESS AND PUBLIC STREETS

Public Street	Site Circulation
Local Street	The aisles between parking stalls; the driveway of a neighborhood shopping development.
Minor Collector	Circulation at end of parking rows; access drive to a convenience shopping development (< 100,000 sq. ft).
Major Collector	Circulation road connecting parking areas of a large development; access drive of a medium-size development (200,000 - 500,000 sq.wt. shopping center).
Minor Arterial	Access drive of a medium size development (500,000 - 750,000 sq. ft. shopping center); ring road for a very large development (shopping center of 1,000,000 sq. ft. or more).
Major Arterial	Access drive of a very large development (shopping center of 1,000,000 sq. ft. or more).

Source: Reference (_1_), p. 85

REVIEW OF PROPOSED DEVELOPMENT

Introduction

Traffic and circulation analysis of a proposed development should consist of the following related studies.

1. Traffic impact analysis (TIA) estimates the traffic which the development can be expected to generate; evaluates the impact of this traffic on the public street system; and, identifies the off-site improvements that may be needed as a result of the development. The TIA should be required by ordinance.

2. A site plan review includes the access location and design, on-site circulation (pedestrian as well as vehicular), and parking. This review should also consider a variety of other site plan details including drainage, landscaping, utility locations and fire protection, loading docks, and solid waste collection.

Traffic Impact Analysis

A traffic impact analysis should be performed in each of the following situation.

Justification For Traffic Impact Analysis

1. Trip Generation
2. Rezoning
3. Change in Land Use
4. Change in Vehicle Type(s)
5. Increase in Traffic Generation
6. Change in Directional Distribution of the Traffic
7. TIA is Out of Date

(Continued)

REVIEW OF PROPOSED DEVELOPMENT (Continued)

Traffic Impact Analysis (Continued)

1. All development which can be expected to generate more than a specified number of trips (say, 100 trips per hour during the peak hour of the street or the peak hour of the generator). When the property is already zoned for the proposed use, an approved TIA should be required between submittal of the final plat in the event of subdivision and before issuance of a building permit or curb cut permit in the case of all development other than single-family-detached or duplex residential development.

2. For all applications for rezoning.

3. Any change in the land use.

4. Any change which would result in a change in the mix of vehicle types.

5. Increase in the traffic generation by more than some stated amount (say, 15%).

6. A change in the directional distribution in the site traffic by more than some specified amount (say, 20%).

7. When the original TIA is out of date (say, more than two years old).

Use of the TIA

The traffic impact analysis has two basic uses. These are: (1) the assessment of exactions -- either impact fees or physical street improvements, and (2) the design of site access and circulation. In the first case, the issue is one of fair and equal treatment. That is, the dollar amount of the fee, or the cost of off-site improvements, should be in proportion to the impact of the development. When the impact fee is several hundred, or thousands, of dollars per trip, precision in trip generation is an issue.

(Continued)

REVIEW OF PROPOSED DEVELOPMENT (Continued)

Use of the TIA (Continued)	However, in the second case (site access and circulation design) the real questions are: Does the site have sufficient access and site circulation capacity? Is it a good design? Precision in estimation of trip generation, or the forecasting of turn movements at the individual driveways and nearby intersections are not the issue. The real issues are: Will the design work if the site traffic volumes are different than forecast? How much flexibility is there in the design?

REVIEW OF PROPOSED DEVELOPMENT

Site Plan Review

The traffic impact analysis provides an evaluation of the volume of traffic that a proposed development may be expected to generate, the projected traffic volume at individual access points, and the impact on critical intersections within the area of influence of the proposed development. The volume of traffic which can be accommodated at an access point without significant interference with the public street is a function of the access location and design. As previously stated, the access location and design must also relate to the on-site circulation and parking, and hence, to the locations and shape of the building(s) to be developed on the site. Hence, a site plan is essential for all development on the site other than single family detached and duplex residential units. In the case of single family and duplex development, the front building line, the side and rear lot requirements, and the local streets as plotted establish the "site plan." For all other types of development, the relationship of the circulation and access to the public street system cannot be determined from the subdivision plat.

Therefore, a site plan should be required for all proposed projects other than single family detached and duplex residential development.

The approved site plan should be basis for the issuance for the building, curb cut, utility connection permits, and any other development. It should be prepared at a scale of one inch equals 20, 25, or 30 feet; one inch equals 40 feet is the smallest scale at which it is practical to determine sight distances and evaluate maneuver areas. All design elements should be dimensioned. The site plan should also show the right-of-way and geometry of all adjacent public streets.

Basic Site Plan Features

- Access Location and Design
- On-Site Circulation and Parking
- Other Items

(Continued)

REVIEW OF PROPOSED DEVELOPMENT (Continued)

Site Plan Review (Continued)

Items which should be checked during the site plan review include the access location and design; on-site circulation and parking; and other items. The various items that should be shown on a site plan are listed in Table 7-2 (*1*).

TABLE 7-2: SITE PLAN ELEMENTS

Access Location and Design

- Spacing to adjacent public and private access
- Angle
- Curb return radii
- Throat cross-section
- Channelization, medial and marginal
- Length, width, and taper of turn bays
- Sign location
- Sight distances
- Visibility of access drive
- Profiles

On-Site Circulation and Parking

- Vehicular conflict points
- Vehicular - pedestrian conflicts
- Sight distances
- Channelization
- Delineation of internal circulation roadways
- Widths of internal circulation roadways
- Potential for high speeds adjacent to building
- Potential for high speed, random vehicular movements in parking area
- Convenience of parking with respect to building entrances
- Parking dimensions
- Location of curbs/wheel stops relative to front of parking stalls
- Building entrances and pedestrian circulation between the entrances and the parking areas
- Sidewalk widths
- Fire lanes
- Delivery/truck docks
- Access to solid waste containers
- Visibility of obstructions such as curbed end islands, barriers, and light posts
- Delineation of edge of development from adjacent streets

Other Items

- Existing and proposed utilities, including fire hydrant locations
- Surface drainage
- Location and type of landscaping
- Location of light poles
- Location of any on-site items such as any kiosks and U.S. Postal Service drop boxes
- Fences and/or landscaping to screen development from adjacent property
- Location and angle of exterior lighting when development is adjacent to residential development or where lighting might interfere with driver's vision

Source: Reference (*1*), pp. 19-20

(Continued)

REVIEW OF PROPOSED DEVELOPMENT(Continued)

Site Plan Review (Continued)

During construction and following development, the project should be inspected to ensure that the site plan is followed. A change should require the submission, review, and approval of a revised site plan. The Certificate of Occupancy should be issued when the final inspection shows that the project has been completed in accordance with the approved site plan, assuming, of course, that the structure(s) also meets the building code.

Because of the complexity and details which need to be shown on a site plan, different aspects of the plan need to be illustrated on separate sheets. Typically, five sheets, identified in Table 7-3 should be used.

TABLE 7-3: LIST OF SITE PLAN SHEETS

Sheet	Elements Illustrated
1	Basic geometry of the site access, circulation, parking and building footprint.
2	Detailed drawings of access, circulation, and parking elements.
3	Landscaping details.
4	Location of existing and proposed utilities.
5	Finished grades and contours.

Source: Reference (2), p. 33

APPLICATION OF QUEUEING ANALYSIS

Applications

Drive-through facilities, parking lot entrances and exist, loading and unloading docks, passenger drop off and pick up, and similar operations can be evaluated using queuing analysis.

Queue Length

The tedious calculations involved in solving the queuing equations can be avoided using the computer program written for IBM compatible microcomputers. The solution for the maximum expected queue length is also easily obtained using the following equation and the table of Q_M values given on the following page.

$$M = \frac{\ln P(x>m) - \ln Q_M}{\ln \rho} - 1$$

Where: M = queue length exceeded P percent of the time

P(x > m) = probability that the queue will exceed M

N = number of service position

Q = service rate per service position

q = demand rate (vehicles per hour)

ρ = q/NQ = utilization factor

Q_M = tabulated values of the relationship between queue length, number of service positions, and the utilization factor (see Table 7-4).

(Continued)

APPLICATION OF QUEUEING ANALYSIS (Continued)

Queue Length (Continued)

TABLE 7-4: TABLE OF Q_M VALUES

ρ	N = 1	2	3	4	6	8	10
0.0	0.0000	0.0000	0.0000	0.0000	0.0000		
0.1	.1000	.0182	.0037	.0008	.0000	0.0000	0.0000
.2	.2000	.0666	.0247	.0096	.0015	.0002	.0000
.3	.3000	.1385	.0700	.0370	.0111	.0036	.0011
.4	.4000	.2266	.1411	.0907	.0400	.0185	.0088
.5	.5000	.3333	.2368	.1739	.0991	.0591	.0360
.6	.6000	.4501	.3548	.2670	.1965	.1395	.1013
.7	.7000	.5766	.4923	.4286	.3359	.2706	.2218
.8	.8000	.7111	.6472	.5964	.5178	.4576	.4093
.9	.9000	.8526	.8172	.7878	.7401	.7014	.6687
1.0	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

$\rho = q/NQ$
q = arrival rate, total
N = number of channels (service positions)
Q = service rate per channel

Example

Use of the equation and the table of Q_M values is illustrated using the following data for a drive-through bank facility.

- average service time = 2.7 minutes
- 5 drive-through windows
- design demand = 100 vehicles in a one-hour period
- acceptable probability that the queue length will exceed the storage capacity = 0.05
- queue storage = 24 vehicles

(Continued)

APPLICATION OF QUEUEING ANALYSIS (Continued)

Example (Continued)

$N = 5$

$g = 100$ vph

$Q = $ (60 min per hour)/(2.7 min average service time)

$= 22.2$

$\rho = 100/[(5)(22.2)] = 0.901$

$P(x > m) = 0.05$

$Q_M = 0.7663$ by interpolation

$$M = \frac{\ln 0.05 - \ln 0.7663}{\ln 0.901} - 1$$

$$= \frac{-2.996 - (-0.266)}{-0.104} - 1$$

$= 26.3 - 1 = 25.3$; say 25 vehicles

The solution indicates that 5 percent of the time there will be more than 25 vehicles waiting in the queue. Therefore, the line of waiting customers can be expected to back up into the street for about three minutes each hour, if demand and service times are as expected.

Solutions to the problem are:

1. Redesign the site to achieve more queue storage;
2. Decrease the service time by decreasing the teller to service position ratio; or
3. Increasing the number of service positions.

(Continued)

APPLICATION OF QUEUEING ANALYSIS (Continued)

Waiting Time

Waiting time is often of more concern to management personnel than queue length. Waiting time and total time in the system can be calculated using the figure shown below.

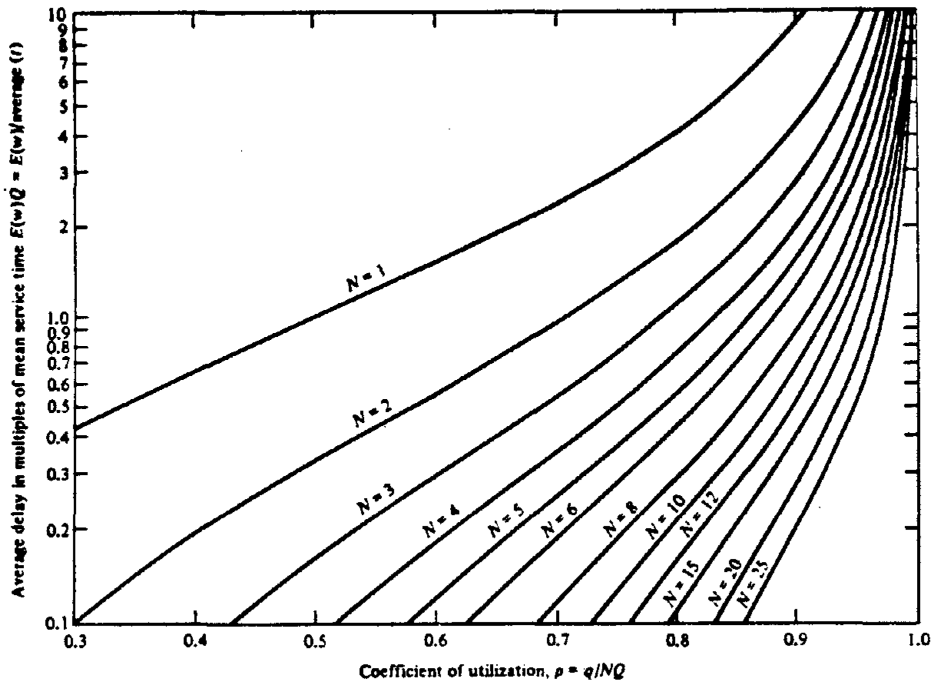

FIGURE 7-4: AVERAGE WAITING TIME [E(w) VALUES]

Source: Reference (*1*), p. 229

Total Time

The total time in the system is the sum of the waiting time and the service time. Continuing with the same example, the average total time in the system is:

- average total time in system = 4.1 + 2.7 = 6.8 minutes

(Continued)

APPLICATION OF QUEUEING ANALYSIS (Continued)

Case Study

The following case study is an example of the effective application of queuing analysis in a public hearing for a conditional use permit between the Planning and Zoning Comission of College Station, Texas. An existing single-family residence was situated on a 2.5 acre tract fronting on the major north-south arterial in the urbanizing fringe of a metropolitan area of 100,000 population. The 85th percentile speed exceeded 50 mph.

Several requests for rezoning from single-family residential to general commercial had received negative recommendations from the Planning and Zoning Commission and denied by the City Council. The fact that changing conditions in the vicinity of the site were making the property less desirable as a single-family residence was generally recognized. When an application was submitted for a Conditional Use Permit to establish a private school using the existing residence for classrooms, six of the seven members of the Planning and Zoning Commission favorably disposed to the request.

The applicant provided the following information prior to the public hearing.

1. The completed application for a conditional use permit to operatea Montessori School using the existing structure.

2. A site plan showing the existing structures, access, and the proposed site circulation and parking.

The following information was presented at the public hearing by the applicant:

1. At least 40 students would be enrolled before any change would be made in the site circulation or structure.

2. Eighty percent of the students were expected to be picked up within a 20 minute period.

(Continued)

APPLICATION OF QUEUEING ANALYSIS (Continued)

Case Study (Continued)

3. A strong parent-school relationship was intended, so that average pick-up time of at least 2 minutes and visits of 5 minutes or longer would not be unusual.

The following were agreed upon at the public hearing:

1. The probability of vehicles backing up onto the main lane of the major arterial should be negligible, less than 1%.

2. The site plan, with no change in the circulation pattern, would provide for four service positions and three storage positions.

Based upon these conditions, the following analysis was performed using queuing analysis:

$M = 3$

$N = 4$

Q = (60 min per hour)/(2 minutes per service) = 30 vph

q = (40 students)(80% in 20 minutes)(60/20) = 96 vph

$\rho = 96/[(4)(30)] = 0.8000$

$P(x > m)$ = 0.01 (a 1% chance of vehicles backing up onto the arterial)

Q_M = 0.5964, from Table 7-4

(Continued)

APPLICATION OF QUEUEING ANALYSIS (Continued)

Case Study
(Continued)

$$3 = \frac{\ln P(x>3) - \ln 0.5964}{\ln 0.8000} - 1$$

$$3 = \frac{\ln P(x>3) - (-0.5168)}{-0.2231} - 1$$

Then,

$$\ln P(x > m) = (4)(-0.2231) - 0.5168 = -1.4092$$

and

$$P(x > m) = e^{-1.4092} = 0.244 \text{ or } 24\%$$

Thus, probability that the queue could back up onto the arterial is calculated to be 24%. This is considerably greater than the acceptable probability of less than 1%, and the application was denied. All proposals by the Planning and Zoning Commission for site circulation improvements and/or limitations in the number of students were rejected by the applicant. The site was subsequently rezoned to the Administrative and Professional District and is now being used as dentist's office.

REFERENCES

1. Vergil G. Stover and Frank J. Koepke, Transportation and Land Development, Institute of Transportation Engineers, Prentice-Hall, Inc., 1987.

2. Vergil G. Stover, Texas Transportation Institute, Texas Engineering Extension Service, Land Development Short Course Notes.

APPENDIX 7-A
QUEUEING ANALYSIS

EXCERPTED FROM

TRAFFIC FLOW THEORY
SPECIAL REPORT 165
TRANSPORTATION RESEARCH BOARD

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Chapter 8
QUEUEING MODELS*

8.1 INTRODUCTION

A desirable goal for transportation engineers is to design and operate facilities that minimize delay to the users. Delay resulting from congestion is a common phenomenon associated with many types of transportation problems. Vehicles wait in line on access ramps for an opportunity to enter a freeway; pedestrians queue up on a crosswalk in anticipation of a gap in road traffic or at a turnstile in a transit station; left-turn slots must be sufficiently long to store the maximum number of vehicles that can be expected to wait for a left-turn signal.

How long a user must wait, or what is the number of units waiting in line, or the proportion of time that a facility might be inactive (an empty parking stall, for instance)? Queueing models, employing the methods of probability and statistics, provide a means by which it is possible to predict some of these delay characteristics.

Queueing theory was first developed early in the twentieth century to deal with problems of telephone switching. Following World War II queueing was accepted for use in a wide range of situations. Adam [2] considered the problem of pedestrian delay at an unsignalized intersection in 1936. Tanner [3] expanded on the pedestrian problem in 1951, and in 1954 Edie [4] evaluated delays at toll booths by applying queueing models to an analysis of their operation. In the same year Moskowitz [5] reported on an empirical study of vehicles waiting for a gap in traffic.

The purpose of this chapter is to present some of the results of studies of probability models of traffic delay. Section 8.2 introduces some elements of queueing or waiting-line theory. The examples used in section 8.2 are concerned with delay problems that occur when all users pass through a single-channel control point, such as a left-turn slot or a single exit lane for a garage.

In section 8.3 the analysis is extended to consider several channels of service; for example, several parallel toll booths or the different stalls of a parking facility. In this section the case of a user who does not get served is also considered; for example, the person seeking a parking space but who then continues on to another destination when none is found.

Much urban traffic engineering is related to the operation of urban intersections. An understanding of delay at these intersections is necessary to obtain the greatest efficiency from existing and planned transportation systems. The analysis of delays at intersections is considered in section 8.5, beginning with an analysis of unsignalized intersections. Queueing models for more complex intersection control, such as pedestrian control or traffic-signal control, are also considered in this section.

A final application of queueing theory, the treatment of delay on roadways, is included in section 8.6. Except for the detailed development of the formulas given in section 8.2, this chapter avoids detailed mathematical development, but does present the theorists' assumptions and some results of interest. The model for service through a single channel is developed in detail because it demonstrates the relationship between probability theory and the behavior of waiting lines. Readers interested in further theoretical development of queueing models should consult textbooks such as Haight,[6] Prabhu,[7] Cox and Smith,[8] or Newell.[9]

8.2 FUNDAMENTALS OF QUEUEING THEORY

Queueing theory draws heavily on probability theory. To mathematically predict the characteristics of a queueing system, it is necessary to specify the following system characteristics and parameters:

A. Arrival pattern characteristics: (1) average rate of arrival and (2) statistical distribution of time between arrivals;

B. Service facility characteristics: (1)

* In preparing this chapter, the authors have drawn freely on the material of Cleveland and Capelle.[1] References to that material are acknowledged at this time. Specific references are noted only for the illustrations used in this text.

service time average rates and distribution and (2) number of customers that can be served simultaneously, or number of channels available;

C. Queue discipline characteristics, such as the means by which the next customer to be served is selected; for example, "first come first served," or "most profitable customer first."

To facilitate reference to these characteristics, a short notation in the form a/b/c has come into use. In this notation a letter denoting the type of arrival pattern is substituted for a; a letter denoting the type of service is substituted for b; a number designating the number of service channels is substituted for c. Symbols in the first two places are as follows:

M = exponentially distributed (i.e., random) interarrival or service time;
D = deterministic or constant interarrival or service time;
G = general distribution of service times;
GI = general distribution of interarrival times;
E_k = Erlang distribution of interarrival or service times with Erlang parameter k.

Thus, M/G/1 designates a queue with random arrivals, general service distribution, and one server.

In some discussions it may be desirable to indicate queue length limitations and queue discipline. For such purposes the notation, M/M/1:(L/Disc) is used, where L is replaced by the maximum allowable length and Disc is replaced by a symbol for the appropriate queue discipline. The following are common disciplines:

FIFO = first in–first out (i.e., service in order of arrival);
SIRO = service in random order;
LIFO = last in–first out.

Thus, $E_k/D/2$ (∞/FIFO) denotes a system with Erlangian arrivals, constant service, two service channels, infinite queue length (i.e., no limitation on queue length), and first come–first served discipline.

8.2.1. System State for M/M/1

The fundamental quantities characterizing a waiting line are the *states* of the system. The system is said to be in state n if it contains exactly n items (this includes all items being served as well as those waiting to be served). The value of n may be either 0 or some positive integer.

If the average arrival rate is called λ, the average interval between arrivals is $1/\lambda$. If the service rate of the system is μ, the average service time is $1/\mu$. The ratio $\rho=\lambda/\mu$, sometimes called the traffic intensity or utilization factor, determines the nature of the various states. If $\rho<1$ (that is, $\lambda<\mu$) and a sufficiently long time elapses, each state will be recurrent. This means that there is a finite probability of the queue being in any state n. If, on the other hand, $\rho\geq 1$, every state is transient and the queue length (the number in the system) will become longer and longer without limit. A fundamental theorem states that the queue will be in equilibrium only if $\rho<1$.

An understanding of the characteristics of queueing systems can be obtained from simple cases. Consider the case of a single-channel queueing system with a mean random Poisson arrival rate of λ customers per unit of time and where service times are independent and distributed exponentially with a mean rate μ. Let $P_n(t)$ be the probability that the queueing system has n items at time t. Consider the situation at time $t+\Delta t$ where Δt is so short that only one customer can enter or leave the system during this time.

Thus, for the period Δt, the following probabilities can be stated:

$\lambda\Delta t$ = probability that one unit enters the system;
$1-\lambda\Delta t$ = probability that no unit enters the system;
$\mu\Delta t$ = probability that one unit leaves the system;
$1-\mu\Delta t$ = probability that no unit leaves the system.

There are three ways in which the system can reach state n at time $(t+\Delta t)$ (when $n>0$):

1. The system was in state n at t and no customers arrived or departed in Δt. (The probability of simultaneous arrival and departure in Δt is considered to be zero.)
2. The system was in state $n-1$ at t and one customer arrived in Δt.
3. The system was in state $n+1$ at t and one customer departed in Δt.

The probability of the system being in state n at $(t+\Delta t)$ is

$$P_n(t+\Delta t)=P_n(t)[(1-\lambda\Delta t)(1-\mu\Delta t)]+P_{n-1}(t)[(\lambda\Delta t)(1-\mu\Delta t)]+P_{n+1}(t)[(1-\lambda\Delta t)(\mu\Delta t)] \quad (\text{for } n\geq 1) \qquad (8.1)$$

Expanding and collecting terms,

$$P_n(t+\Delta t)-P_n(t)=-P_n(t)\ (\mu+\lambda)\Delta t+P_{n-1}(t)\lambda\Delta t+P_{n+1}(t)\mu\Delta t+\mu\lambda(\Delta t)^2\,[P_n(t)-P_{n-1}(t)-P_{n+1}(t)]$$

Neglecting terms with second-order infinitesimals and dividing by Δt,

$$\frac{P_n(t+\Delta t)-P_n(t)}{\Delta t}=\lambda P_{n-1}(t)-(\mu+\lambda)\ P_n(t)+\mu P_{n+1}(t)$$

Letting $\Delta t\rightarrow 0$,

$$\frac{dP_n(t)}{dt}=\lambda P_{n-1}(t)-(\mu+\lambda)\ P_n(t)+\mu P_{n+1}(t) \qquad (8.2)$$

where $n=1,2,3\ldots$.

The probability of the system being in state 0 at time $(t+\Delta t)$ can come about in two ways: (1) There are no units in line at time t *and* none arrives in interval Δt; *or* (2) there is one unit in line at time t *and* one unit departs in interval Δt *and* none arrives in interval Δt. Expressing these relationships in terms of probabilities,

$$P_0(t+\Delta t)=P_0(t)\ (1-\lambda\Delta t)+P_1(t)[(\mu\Delta t)(1-\lambda\Delta t)]$$

Expanding, collecting terms (neglecting terms with second-order infinitesimals), and dividing by Δt,

$$\frac{P_0(t+\Delta t)-P_0(t)}{\Delta t}=\mu P_1(t)-\lambda P_0(t)$$

Letting $\Delta t\rightarrow 0$

$$\frac{dP_0(t)}{dt}=\mu P_1(t)-\lambda P_0(t) \qquad (8.3)$$

When dealing with the steady state of the system (that is, when the probabilities of being in a given state do not change with time), the following results,

$$\frac{dP_n(t)}{dt}=0 \qquad \text{for all } n \text{ at time } t. \qquad (8.4)$$

From Eqs. 8.2, 8.3, and 8.4, it is then possible to set up systems of differential–difference equations for various steady states. The resulting equations are of the form

$$\mu P_{n+1}+\lambda P_{n-1}=(\lambda+\mu)P_n \qquad \text{for } n>0$$

and

$$\mu P_1=\lambda P_0 \qquad \text{for } n=0 \qquad (8.5)$$

in which P_n is the value of $P_n(t)$ as $t\rightarrow\infty$.

The first few equations are as follows:

$$\lambda P_0=\mu P_1 \qquad (8.6)$$

$$\lambda P_0+\mu P_2=(\lambda+\mu)P_1 \qquad (8.7)$$

$$\lambda P_1+\mu P_3=(\lambda+\mu)P_2 \qquad (8.8)$$

Recalling that $\rho=\lambda/\mu$ and noting (from Eq. 8.6) that $P_1=\rho P_0$ and substituting in Eqs. 8.7 and 8.8,

$$P_2=(\rho+1)P_1-\rho P_0=\rho^2P_0 \qquad (8.9)$$

$$P_3=(\rho+1)P_2-\rho P_1=\rho^3P_0 \qquad (8.10)$$

$$\vdots$$

$$P_n=\rho^nP_0 \qquad \text{for } n\geq 0 \qquad (8.11)$$

Because the sum of all probabilities is 1,

$$\sum_{n=0}^{n=\infty}P_n=1$$

$$1=P_0+\rho P_0+\rho^2P_0+\ldots$$

$$=P_0(1+\rho+\rho^2+\rho^3+\ldots)$$

$$=P_0\left(\frac{1}{1-\rho}\right) \qquad \text{for } \rho<1$$

and

$$P_0=1-\rho \qquad \text{for } \rho<1 \qquad (8.12)$$

Therefore, Eq. 8.11 may be written as $P_n=\rho^n(1-\rho)$.

The traffic intensity, ρ, can then be seen to express the fraction of time that the system is busy (P_0 is the probability that the system is empty and $1-P_0$ is the probability that it is occupied).

8.2.2 Average and Variance of Number of Units (Customers) in System (M/M/1)

The average number of customers in the system is

$$\begin{aligned}E(n) &= \sum_{n=0}^{n=\infty} nP_n \\ &= 0+P_1+2P_2+3P_3+\ldots \\ &= P_0(\rho+2\rho^2+3\rho^3+\ldots) \\ &= (1-\rho)\left[\frac{\rho}{(1-\rho)^2}\right] \quad \text{for } \rho<1 \\ &= \frac{\rho}{1-\rho} \quad \text{for } \rho<1 \qquad (8.13)\end{aligned}$$

The upper curve of Figure 8.1 illustrates this relationship. It will be noted that when the traffic intensity ρ exceeds about 0.8, the congestion (number in system) increases rapidly.

The variance of the number in the system is

$$\text{Var}(n) = \sum_{n=0}^{n=\infty}[n-E(n)]^2P_n = \frac{\rho}{(1-\rho)^2} \qquad (8.14)$$

This relationship is plotted in Figure 8.2. The derivation of this expression may be found in a standard text on queueing theory.

8.2.3 Delay Time in the System (M/M/1)

Consider the total time a customer spends in the system (v) to be made up of two components: a time to wait before service, w (queueing time) plus a time in service, s (service time). The average number in the system, $E(n)$, is the product of the average time in the system, $E(v)$, multiplied by the arrival rate, λ, such that

$$E(n) = \lambda E(v)$$

$$E(v) = E(n)/\lambda$$

Substituting Eq. 8.13 for $E(n)$ and recalling that $\rho=\lambda/\mu$, this becomes

$$\begin{aligned}E(v) &= \left(\frac{\rho}{1-\rho}\right)\left(\frac{1}{\lambda}\right) \\ &= \left(\frac{\lambda}{\mu-\lambda}\right)\left(\frac{1}{\lambda}\right) = \frac{1}{\mu-\lambda} \qquad (8.15)\end{aligned}$$

the average time an arrival spends in the system. The expected time to wait before service (that is, the time spent waiting in a queue) is

$$E(w) = E(v) - E(s) \qquad (8.16)$$

where $E(s)$ is the average service time $(1/\mu)$; thus, Eq. 8.16 may be rewritten as

$$E(w) = \frac{1}{\mu-\lambda} - 1/\mu = \frac{\lambda}{\mu(\mu-\lambda)} \qquad (8.17)$$

The average number of customers waiting to be served (the average queue length), $E(m)$, is the product of the average waiting time, $E(w)$, multiplied by the arrival rate, λ:

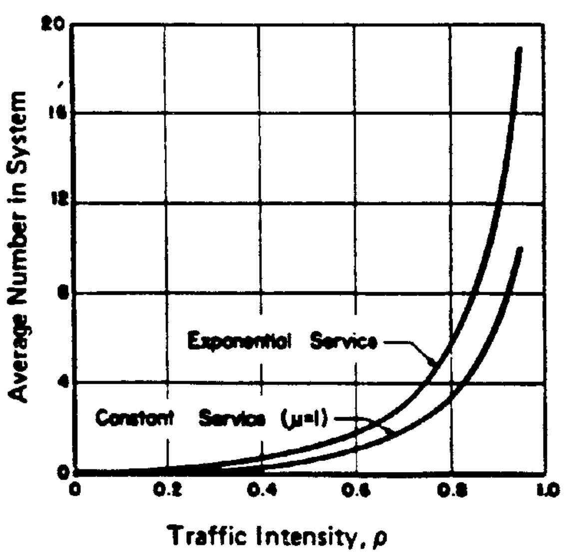

Figure 8.1 Average number in system as a function of traffic intensity.[1]

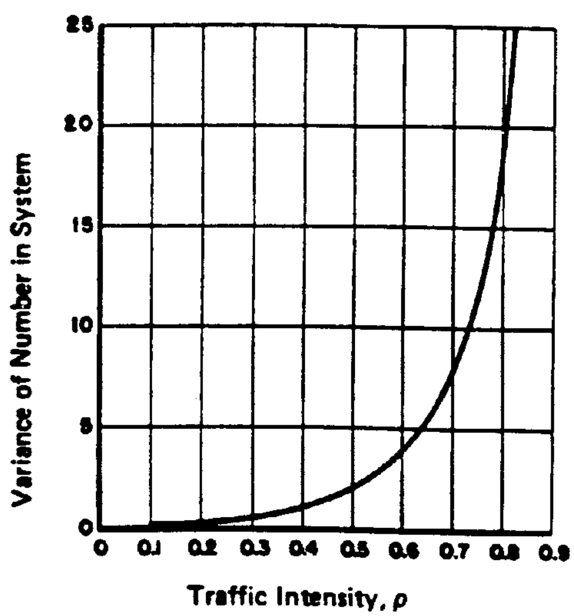

Figure 8.2 Variance of number in system as a function of traffic intensity.[1]

$$E(m)=\left[\frac{\lambda}{\mu(\mu-\lambda)}\right]\lambda=\frac{\lambda^2}{\mu(\mu-\lambda)} \quad (8.18)$$

Eq. 8.18 considers the average queue length over all time, including the periods when the queue is empty. Of interest is the average queue length, given that the queue length is greater than zero. This is defined as

$$E(m|m>0)=\frac{\text{average queue length}}{\text{prob. of nonempty queue}}=\frac{E(m)}{P(m>0)} \quad (8.19)$$

A zero queue length will occur if the system is in state zero or state one so that by Eqs. 8.11 and 8.12 the probability of a nonempty queue is

$$\begin{aligned} P(m>0) &= 1-(P_0+P_1) \\ &= 1-[(1-\rho)+\rho(1-\rho)] \\ &= 1-1+\rho-\rho+\rho^2=\rho^2=\frac{\mu^2}{\lambda^2} \quad (8.20) \end{aligned}$$

Substituting Eqs. 8.18 and 8.20 in Eq. 8.19 gives

$$E(m|m>0)=\left(\frac{\lambda^2}{\mu(\mu-\lambda)}\right)\left(\frac{\mu^2}{\lambda^2}\right)=\left(\frac{\mu}{\mu-\lambda}\right) \quad (8.21)$$

8.2.4 Example of Application of Queueing Formulas (M/M/1)

The exit from a parking garage is through a single gate where a variable fee is collected and change is made for drivers. Vehicles arrive at the gate at random at a rate, λ, of 120 vehicles/hr. The time to collect fees is exponentially distributed, with a mean duration ($1/\mu$) of 15 sec. What are the characteristics of the operation when $\lambda=120$ arrivals/hr, $\mu=4$ services/min=240 services/hr, and $\rho=\lambda/\mu=120/240=0.5$

(a) The probability of an idle booth (Eq. 8.12) is $1-0.5=0.5$.

(b) The probability that n vehicles will be in the system (Eq. 8.11) is

	$P_{x=n}$	$P_{x\leq n}$
$P_0=$	0.5	0.5
$P_1=$	0.25	0.75
$P_2=$	0.125	0.875
$P_3=$	0.0625	0.9375
$P_4=$	0.03125	0.96875
$P_5=$	0.015625	0.984375

If the garage operator wanted to be certain with 0.95 probability that departing vehicles would not interfere with other operations, he would need to provide space for about three vehicles, one in service, two in queue. Similarly, if he wished to be certain at the 0.99 probability level, he would have to provide space for 5 or 6 vehicles, one in service, the others in queue.

(c) The average number in the system (Eq. 8.13) is $E(n)=120/(240-120)=1$.

(d) The average number waiting in a queue (Eq. 8.18) is $E(m)=(120\times120)/[240(120)]=0.5$.

(e) The average length of a nonempty queue (Eq. 8.20) is $E(m|m>0)=240/120=2$.

(f) The average time in the system (Eq. 8.15) is $E(v)=1/120$ hr=0.5 min.

(g) The average time waiting in a queue (Eq. 8.17) is $E(w)=120/[240(120)]=1/240$ hr=0.25 min.

8.3 THE CASE OF MULTIPLE CHANNELS WITH EXPONENTIAL ARRIVALS AND EXPONENTIAL SERVICE TIMES (M/M/N)

A parking lot (or the face of a block with on-street parking) may be considered as an example of a system with parallel service channels where the N parking slots represent the service channels. An arriving vehicle will occupy an empty slot if one is available; if not, it joins the waiting queue. The arrivals into the system are assumed to be random with rate λ and the service time per service channel (duration of parking) is also random with mean $1/\mu$. Again, ρ is defined as λ/μ. Further, ρ/N is defined as the utilization factor for the entire facility, representing the mean proportion of busy channels (full parking spaces). For the multiple-channel case the value of ρ may be greater than one but the following formulas apply only for the case where the utilization factor $\rho/N<1$.

8.3.1 Synopsis of Equations for Queues with Multiple Channels

Probability of n units in system

$$P_n=\frac{\rho^n}{n!}P_0 \qquad \text{for } n\leq N \quad (8.22)$$

$$P_n=\frac{\rho^n}{N^{n-N}N!}P_0 \qquad \text{for } n\geq N \quad (8.23)$$

Probability of no units in system

$$P_0 = \frac{1}{\sum_{n=0}^{N-1} \frac{\rho^n}{n!} + \frac{\rho^N}{N!(1-\rho/N)}} \quad (8.24)$$

Average queue length

$$E(m) = \frac{P_0 \rho^{N+1}}{N!N}\left[\frac{1}{(1-\rho/N)^2}\right] \quad (8.25)$$

Average length of nonempty queues

$$E(m|m>0) = \frac{1}{1-\rho/N} \quad (8.26)$$

Average number of units in system

$$E(n) = \rho + E(m) \quad (8.27)$$

Average time an arrival spends in the system

$$E(v) = E(n)/\lambda \quad (8.28)$$

Average waiting time in queue

$$E(w) = E(v) - 1/u \quad (8.29)$$

Average waiting time for an arrival who waits

$$E(w|w>0) = \frac{1}{\lambda}\frac{1}{1-\rho/N} \quad (8.30)$$

Probability of waiting for an empty space

$$P_{n>N} = P_0 \frac{\rho^{N+1}}{N!N(1-\rho/N)} \quad (8.31)$$

8.3.2 Example

The branch office of a customer repair service operates a fleet of vehicles that return to the office for picking up spare parts and assignments. The repair vehicles arrive at random during the day at a rate λ of four vehicles/hr. The stay at the parking lot is exponentially distributed, with a mean duration of 0.5 hr ($u=2$). There are five stalls ($=N$) in the lot set aside for the vehicles. What are the characteristics of the lot operation?

Solution

$N=5$ stalls, $\lambda=4$ arrivals/hr, $u=2$ services/hr, $\rho=\lambda/u=4/2=2$, and the utilization factor $=\rho/N=2/5=0.4$.

(a) P_0 = probability of empty lot (Eq. 8.24)

$$= \frac{1}{1+\frac{2}{1!}+\frac{2^2}{2!}+\frac{2^3}{3!}+\frac{2^4}{4!}+\frac{2^5}{5!(0.6)}}$$

$$= \frac{1}{7.44444} = 0.134328.$$

(b) The probability that n vehicles will park (Eq. 8.22)* is

$P_0 = 0.134328$
$P_1 = (2/1)(0.134328) = 0.268656$
$P_2 = (2/2)(0.268656) = 0.268656$
$P_3 = (2/3)(0.268656) = 0.179104$
$P_4 = (2/4)(0.179104) = 0.089552$
$P_5 = (2/5)(0.089552) = 0.035821$

(c) The probability that a vehicle will have to wait on arrival (Eq. 8.31) is $P(n>5) = 0.134328\frac{2^6}{5!5(0.6)} = 0.023880$, which is the same as $1-(P_0+P_1+P_2+P_3+P_4+P_5)$.

(d) The average number of vehicles waiting for an empty slot (Eq. 8.25) is $E(m) = 0.134328\frac{2^6}{5!5(0.6)^2} = 0.0398$ vehicles.

(e) The average number of waiting vehicles when the lot is full (Eq. 8.26) is $E(m|m>0) = 1/0.6 = 1.67$ vehicles.

(f) The average number of vehicles parked and waiting (Eq. 8.27) is $E(n) = 2+0.0398 = 2.0398$ vehicles.

(g) The average time a vehicle spends parking and waiting (Eq. 8.28) is $E(v) = 2.0398/4 = 0.50995$ hr.

(h) The average time spent in waiting for an empty slot (Eq. 8.29) is $E(w) = 0.50995 - 1/2 = 0.00995$ hr.

(i) The average time a waiting vehicle waits for an empty slot (Eq. 8.30) is $E(w|w>0) = \frac{1}{4}\frac{1}{0.6} = 0.417$ hr.

8.3.3 System with Infinite Stalls: An Example of the M/M/∞ Case

As the number of stalls becomes very large ($N\to\infty$), Eq. 8.24 gives

$$\lim_{N\to\infty} P_0 = \frac{1}{e^\rho} = e^{-\rho} \quad (8.32)$$

and the expected number of parked vehicles is

$$E(n) = \sum_{n=0}^{\infty} nP(n) = \rho P_0\left(1+\rho+\frac{\rho^2}{2!}+\ldots\right) = \rho \quad (8.33)$$

* Computation can be simplified by observing that $P_n = (\rho/n)P_{n-1}$.

8.3.4 The System with Loss

A more realistic type of operation for a parking lot occurs when vehicles unable to park go away instead of waiting in line; that is,

$$P_n = 0 \qquad \text{for } n > N$$

For this model the probability that n vehicles will be parked is

$$P_n = \frac{\rho^n/n!}{\sum_{i=0}^{N} \rho^i/i!} \qquad \text{for } n = 0,1,2,\ldots,N \tag{8.34}$$

The probability of an empty lot is

$$P_0 = \frac{1}{\sum_{i=0}^{N} \rho^i/i!} \tag{8.35}$$

and the probability that a car cannot park is the probability that there are N slots occupied, so that

$$P_N = \frac{\rho^N/N!}{\sum_{i=0}^{N} \rho^i/i!} \tag{8.36}$$

Eq. 8.36 is called Erlang's Loss Formula, $L_N(\rho)$, the probability that an incoming unit is "lost" to the system.

Finally, the average number of vehicles in the parking lot may be developed as follows:

$$E(n) = \sum_{n=0}^{N} n\,P_n$$

$$= \frac{\sum_{n=0}^{N} n \frac{\rho^n}{n!}}{\sum_{n=0}^{N} \frac{\rho^n}{n!}}$$

$$= \frac{\left[\frac{1\rho}{1} + \frac{2\rho^2}{2\cdot 1} + \frac{3\rho^3}{3\cdot 2!} + \frac{4\rho^4}{4\cdot 3!} + \cdots + \frac{N\rho^N}{N\cdot(N-1)!}\right]}{\sum_{n=0}^{N} \frac{\rho^n}{n!}}$$

$$= \frac{\rho\left[1 + \rho + \frac{\rho^2}{2!} + \frac{\rho^3}{3!} + \cdots + \frac{\rho^{N-1}}{(N-1)!}\right]}{\sum_{n=0}^{N} \frac{\rho^n}{n!}}$$

$$E(n) = \rho\,\frac{\sum_{n=0}^{N-1} \frac{\rho^n}{n!}}{\sum_{n=0}^{N} \frac{\rho^n}{n!}} \tag{8.36}$$

If Eq. 8.36 is multiplied by $e^{-\rho}/e^{-\rho}$, the expression becomes

$$E(n) = \rho\,\frac{\sum_{n=0}^{N-1} \frac{e^{-\rho}\rho^n}{n!}}{\sum_{n=0}^{N} \frac{e^{-\rho}\rho^n}{n!}} \tag{8.37}$$

in which case it is possible to use tabulations of the Poisson distribution function to get the desired answer.

A more elegant discussion of the relationship between the Poisson distribution and the queueing formulas developed here is given by Kometani and Kato [10] and by Haight and Jacobson.[11]

8.3.5 Example of a Queueing System Operating with Loss

Assume the same data given in example 8.3.2, except that vehicles do not wait for an empty space. Again, $N=5$, $\lambda=4$ arrivals/hr, $u=2$ service/hr, $\rho=\lambda/u=4/2=2$, and utilization factor $=\rho/N=2/5=0.4$.

The probability of an empty slot (Eq. 8.35) is

$$P_0 = \frac{1}{1 + \frac{2}{1} + \frac{2^2}{2} + \frac{2^3}{3!} + \frac{2^4}{4!} + \frac{2^5}{5!}} = \frac{1}{7.2667}$$

$= 0.137614$

$P_1 = (2/1)P_0 = 0.275228$
$P_2 = (2/2)P_1 = 0.275228$
$P_3 = (2/3)P_2 = 0.183485$
$P_4 = (2/4)P_3 = 0.091743$
$P_5 = (2/5)P_4 = 0.036697$ (probability that a car cannot park)

The average number of vehicles parked (Eq. 8.37) is $E(n) = 2\,\frac{0.947}{0.983} = 1.93$.

8.4 SYSTEM M/D/1 BUSY PERIOD

In this section the number of units, n, that will be served before the system will again become empty is considered, given r units in the system at a given time. For example, there may be five vehicles (r) in a queue at the start of the green interval on a traffic signal. It is desired to find the number n of vehicles that will pass through the intersection before the queue is dissipated; i.e., the system is again empty. The solution to this particular problem has been accomplished by assuming the M/D/1 queueing model; that is, random arrivals into the single queue with a uniform service time for each of the "customers."

In this system vehicles arrive randomly at a rate λ, there is one server, and each vehicle is "served" for exactly B units of time, so that r vehicles in line will require rB units of time for service. The distribution of the number of units served, n, before the system again becomes empty in a busy period starting with an accumulation of r units is given by the Borel–Tanner distribution:

$$P(n|r) = \frac{r}{n} \frac{e^{-\lambda nB}(\lambda nB)^{n-r}}{(n-r)!} \qquad (8.38)$$
$$n = r, r+1, \ldots$$

The development of Eq. 8.38 may be found in Prabhu.[7] This equation can be rewritten by noting that $\rho = \lambda B$

$$P(n|r) = \frac{r}{n} \frac{e^{-n\rho} n\rho^{n-r}}{(n-r)!} \qquad (8.39)$$
$$n = r, (r+1), (r+2), \ldots .$$

Tabulated values for a limited range of n and r, given $\rho = 0.2$, are presented in Table 8.1.

For example, if there are three units in a queue, including the one being served, the probability that no more units will arrive during the service for these three is 0.549, but the probability that exactly five will be served before the queue empties again is 0.110. Haight[12] used the Borel–Tanner distribution to analyze delay at a signalized intersection (see section 8.5.3), whereas Tanner[13, 14] has applied the Borel–Tanner distribution to a model for delays to vehicles on two-way, two-lane roads.

TABLE 8.1 State Probabilities for Borel–Tanner Distribution ($\rho = 0.2$)

n \ r →	1	2	3	4	5
1	0.819				
2	0.134	0.670			
3	0.033	0.220	0.549		
4	0.010	0.072	0.270	0.449	
5	0.003	0.025	0.110	0.294	0.368
6	0.001	0.009	0.043	0.145	0.301
7	*	0.003	0.017	0.064	0.172
8	*	0.001	0.007	0.028	0.086
9	*	*	0.003	0.012	0.040
10	*	*	0.001	0.005	0.018
11	*	*	*	0.002	0.008
12	*	*	*	*	0.003

* Probability $(n|r)$ less than 0.001.

CHAPTER 8

EVALUATION OF IMPROVEMENTS

CHAPTER 8 - EVALUATION OF IMPROVEMENTS

INTRODUCTION

Implementation Constraints

CHAPTER 8

EVALUATION OF IMPROVEMENTS

Implementation of access control techniques on an existing roadway may be constrained by existing physical situations. Major constraints include small property frontages, major intersection spacing, median design or the absence of a median, right-of-way width, building setbacks, and existing driveway spacings and corner clearance. Table 8-1 summarizes the major physical constraints which might influence the implementation of various techniques on an existing roadway.

Evaluation Of Improvements

- **Accident Reduction**
- **Construction Cost**
- **Maintenance Costs**
- **Capacity**
- **Traffic Delays**
- **Impact On Adjacent Properties**

Other considerations involved in the evaluation of possible access improvements on existing roadways include the following: potential accident reduction, cost of constructing the improvement, maintenance costs, capacity, traffic delays, and the impact on adjacent properties.

IMPLEMENTATION ON EXISTING ROADWAYS

Background

The access management techniques included in Categories A, B, C, and D in Chapter 4 were identified in research reported by the Midwest Research Institute in 1975 (*1*, *2*, *3*). "The scope of research was limited to control of direct access to commercial properties on two-lane and multi-lane highways with unlimited access, where traffic volumes are high enough to produce a hazardous situation. The emphasis was on the control of direct access on existing urban and suburban routes under state highway department jurisdiction." (*1*)

Operational Evaluation Parameters

- Level Of Development
- Highway Volume
- Commercial Driveway Volume

A major effort of this research was to evaluate the potential benefit/cost ratio of the various techniques based upon the following three operational parameters: (1) level of development, (2) highway volume, and (3) commercial driveway volume.

Each of the operational parameters was grouped according to "low", "medium", and "high" as indicated in Table 8-1.

(Continued)

IMPLEMENTATION ON EXISTING ROADWAYS (Continued)

Background (Continued)

TABLE 8-1: OPERATIONAL EVALUATION PARAMETERS

Level of Development	Number of Commercial Driveways per Mile	Average
Low	0-30	15
Medium	31-60	45
High	>60	75
Highway Volume	**ADT Range**	**ADT Average**
Low	0-5,000	3,000
Medium	5,001-15,000	10,000
High	> 15,000	20,000
Commercial Driveway Volume	**ADT Range**	**ADT Average**
Low	0-500	250
Medium	501-1,500	1,000
High	> 1,500	2,000

Source: Reference (*1*), pp. 100-101

Because of limited data on high volume roadways, the "high" level for the parameter for roadway (average annual daily traffic or ADT) is > 15,000 vpd. This is obviously an inappropriate value for urban/suburban conditions. However, the value levels given in Table 8-1 may not be inappropriate for rural conditions.

The research used reduced accidents as a measure of benefits. Costs used in calculating the benefit/cost ratios for the various alternatives included such elements as construction cost, effect on businesses, and maintenance costs. In this regard, it might be noted that current (1992) dollar values for traffic accidents are substantially higher than the dollar amounts used in the mid-1970's. While construction and other costs have also increased, the escalation is probably less than for accidents.

(Continued)

IMPLEMENTATION ON EXISTING ROADWAYS (Continued)

Background (Continued)

It is also pertinent to note that the evaluation/implementation guidelines presented in these reports are for modification of existing highways. This is reflected by the following statement:

"Consideration for implementation include: (1) comprehensive policy development; and (2) the selection of techniques to counteract operational problems on existing highways."

Most of the access management techniques should be included in the design of major roadways on new locations and in the major reconstruction of existing roadways. Such practices include the incorporation of long and uniform signal spacings, provision of left-turn and right-turn deceleration lanes at all intersections (including medial or marginal driveway access) limiting medial access at unsignalized locations to designate a movement(s) only, with the elimination of crossing movements at all unsignalized locations, and insuring that all driveways are suitably located and designed.

Application Of Techniques

Situations will vary in different locations and among the various public agencies administering the program, however, the general elements involved in the approach to an access-related problem usually include:

Application Of Techniques

- **Definition Of Problem**
- **Inventory Of Operational And Physical Characteristics Of Facility And Surrounding Area**
- **Identification Of Alternative Solutions Using Warrants**
- **Evaluation Of Alternative Solutions**
- **Selection Of Alternative To Be Implemented**

(Continued)

IMPLEMENTATION ON EXISTING ROADWAYS (Continued)

Application Of Techniques (Continued)

These steps are further defined in the following recommended procedure.

Step 1: Definition of problem. This step implies recognition that operational or safety conditions are not within parameters acceptable to the affected community. These obviously vary with the roadway character, urban or rural setting, type and volume of traffic, and community values. Many jurisdictions set theoretical accident rates and/or delay levels (or levels of service) beyond which they institute investigation.

Step 2: As a minimum, identify the operational and physical characteristics of the roadway segment to be studied including:

- Highway volume
- Driveway volume
- Level of development

These should be classified as high, medium, or low as per Table 8-1. The roadway segment should be physically identified as:

- Multi-lane divided
- Multi-lane undivided
- Two-lane

Step 3: Select the alternative techniques that <u>may</u> be applicable to the problem(s). This is accomplished through the use of Table 8-2.

- Select the segment of Table 8-2 (A, B, or C) which corresponds to the highway volume (high, medium, low).
- Find the horizontal section of that table that corresponds to the physical definition of the roadway (multi-lane divided, two-way, etc.).

(Continued)

IMPLEMENTATION ON EXISTING ROADWAYS (Continued)

Application Of Techniques (Continued)

- Enter that portion of the table within the column that describes the operational parameters of the roadway segment (level of development or driveway volume-high, medium, low). The techniques listed in this square are those which may be applicable to this particular situation.
- Evaluate each of these techniques.
- Select the technique (or group of techniques) which provides the greatest cost-effective solution in achieving the community's goals.

(Continued)

IMPLEMENTATION ON EXISTING ROADWAYS (Continued)

Application Of Techniques (Continued)

TABLE 8-2-A: APPLICATIONS OF TECHNIQUES

HIGH HIGHWAY VOLUME
(MORE THAN 15,000)

OPERATIONAL PARAMETERS

LOW				MEDIUM				HIGH			
Multilane Divided											
A	B	C	D	A	B	C	D	A	B	C	D
9	2	2	5	1	1	2	3	2	2	2	1
11	3	3	6	2	2	3	5	4	3	3	3
12	5	4	7	5	3	4	6	5	4	4	5
13	6	5	14	8	4	5	7	8	5	5	7
14	8	6	16	9	5	6	14	9	6	6	9
15	9	7	17	11	6	7	16	11	8	7	10
18	10	8	18	12	8	8	17	14	9	8	11
19	11	9	20	13	9	9	18	17	10	9	12
20	12	10		14	10	10	20	18	11	10	13
		11		15	11	11		20	12	11	14
		12		17	12	12				12	16
				18							17
				19							18
				20							20
Multilane Undivided											
A	B	C	D	A	B	C	D	A	B	C	D
11	2	2	4	1	1	2	3	2	2	2	1
14	3	3	16	2	2	3	4	3	3	3	
15	5	4	17	3	3	4	14	4	4	4	3
18	6	5	18	8	4	5	16	8	5	5	4
19	8	6	20	11	5	6	17	11	6	6	9
20	9	7		12	6	7	18	12	7	7	11
	10	8		14	7	8	20	14	8	8	12
	11	9		15	8	9		16	9	9	13
	12	10		16	9	10		17	10	10	14
		11		17	10	11		18	11	11	16
		12		18	11	12		20	12	12	17
				19	12						18
				20							20
Two-Lane											
A	B	C	D	A	B	C	D	A	B	C	D
11	2	2	4	3	1	2	3	3	2	2	3
14	3	3	14	8	2	3	4	4	3	3	4
15	5	4	16	11	3	4	14	8	4	4	9
18	6	5	17	12	4	5	16	11	5	5	11
19	8	6	18	14	5	6	17	12	6	6	12
20	9	7	20	15	6	7	18	14		7	14
	10	8		16	8	8	20	16	8	8	15
	11	9		17	9	9		17	9	9	16
	12	10		18	10	10		18	10	10	17
		11		19	11	11		20	11	11	18
		12		20	12	12			12	12	20

Source: Reference (4), p. 89

(Continued)

IMPLEMENTATION ON EXISTING ROADWAYS (Continued)

Application Of Techniques (Continued)

TABLE 8-2-B: APPLICATIONS OF TECHNIQUES

MEDIUM HIGHWAY VOLUME
(5,000 - 15,000)

OPERATIONAL PARAMETERS

Multilane Divided

LOW A	LOW B	LOW C	LOW D	MEDIUM A	MEDIUM B	MEDIUM C	MEDIUM D	HIGH A	HIGH B	HIGH C	HIGH D
9	2	2	5	1	1	2	3	2	2	2	1
11	3	3	6	2	2	3	5	4	3	3	3
12	5	4	7	5	3	4	6	5	4	4	5
13	6	5	14	8	4	5	7	8	5	5	7
14	8	6	16	9	5	6	14	9	6	6	13
15	9	7	17	11	6	7	16	11	8	7	14
18	10	8	18	12	8	8	17	14	9	8	16
19	11	9	20	13	9	9	18	17	10	9	17
20	12	10		14	10	10	20	18	11	10	18
		11		15	11	11		20	12	11	20
		12		17	12	12				12	
				18							
				19							
				20							

Multilane Undivided

LOW A	LOW B	LOW C	LOW D	MEDIUM A	MEDIUM B	MEDIUM C	MEDIUM D	HIGH A	HIGH B	HIGH C	HIGH D
10	5	2	4	1	1	2	3	2	4	2	1
11	6	3	14	2	4	3	4	3	5	3	3
12	8	4	16	3	5	4	14	4	6	4	5
14	9	5	17	8	6	5	16	8	8	5	7
15	10	6	18	10	8	6	17	10	9	6	13
18	11	7	20	11	9	7	18	11	10	7	14
19	12	8		12	10	8	20	14	11	8	16
20		9		14	11	9		16	12	9	17
		10		16	12	10		17		10	18
		11		17		11		18		11	20
		12		18		12		20		12	
				19							
				20							

Two-Lane

LOW A	LOW B	LOW C	LOW D	MEDIUM A	MEDIUM B	MEDIUM C	MEDIUM D	HIGH A	HIGH B	HIGH C	HIGH D
10	5	2	4	3	1	2	3	3	4	2	3
11	6	3	14	8	4	3	4	4	5	3	4
12	8	4	16	10	5	4	14	8	6	4	14
14	9	5	17	11	6	5	16	10	8	5	16
15	10	6	18	12	8	6	17	11	9	6	17
18	11	7	20	14	9	7	18	14	10	7	18
19	12	8		15	10	8	20	16	11	8	20
20		9		16	11	9		17	12	9	
		10		17	12	10		18		10	
		11		18		11		20		11	
		12		19		12				12	
				20							

Source: Reference (4), p. 88

(Continued)

IMPLEMENTATION ON EXISTING ROADWAYS (Continued)

Application Of Techniques (Continued)

TABLE 8-2-C: APPLICATIONS OF TECHNIQUES

LOW HIGHWAY VOLUME
(LESS THAN 5,000)

OPERATIONAL PARAMETERS

LOW (a)				MEDIUM (b)				HIGH (c)			
Multilane Divided											
A(d)	B	C	D	A	B	C	D	A	B	C	D
(e)	8	2	14		8	2	14		8	2	14
	9	3	18		9	3	18		9	3	18
	10	4			10	4			10	4	
	11	5			11	5			11	5	
	12	6			12	6			12	6	
		7				7				7	
		8				8				8	
		9				9				9	
		10				10				10	
Multilane Undivided											
A	B	C	D	A	B	C	D	A	B	C	D
10	8	2	14	10	8	2	14	4	8	2	14
	9	3	18		9	3	18	10	9	3	18
	10	4			10	4	19		10	4	
	11	5			11	5			11	5	
	12	6			12	6			12	6	
		7				7				7	
		8				8				8	
		9				9				9	
		10				10				10	
Two-Lane											
A	B	C	D	A	B	C	D	A	B	C	D
10	8	2	14	10	8	2	14	4	8	2	14
	9	3	18		9	3	18	10	9	3	18
	10	4			10	4			10	4	
	11	5			11	5			11	5	
	12	6			12	6			12	6	
		7				7				7	
		8				8				8	
		9				9				9	
		10				10				10	

(a) Low = <30 driveways per mile
(b) Medium = 30 - 60 driveways per mile
(c) High = >60 driveways per mile
(d) Category of techniques
A= Limit number of conflict points
B= Separate conflict points
C= Limit deceleration requirement
D= Remove turning vehicle from through lane
(e) Numbers in each column identify individual treatments in each category

Source: Reference (4), p. 87

(Continued)

IMPLEMENTATION ON EXISTING ROADWAYS (Continued)

Application of Techniques (Continued)

TABLE 8-3: GENERAL PHYSICAL CONSTRAINTS TO IMPLEMENTATION ON EXISTING ROADWAY

	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-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					●					
B-1				●		●				
B-2				●		●				
B-3				●						
B-4	●									
B-5	●									
B-6					●				●	
B-8	●									
B-9	●									
B-10	●									
B-11	●									
B-12					●					
C-2	●									
C-3	●									
C-4					●					●
C-5				●	●	●	●			
C-7				●	●	●				
C-8										●
C-9	●									
C-10	●									
C-11		●		●		●				
C-12										●
D-1		●			●			●		
D-3		●			●					
D-4		●			●					
D-5			●						●	
D-6			●							
D-7					●					
D-9		●			●					
D-10		●						●		
D-11										●
D-12										●
D-13				●	●					
D-14					●					
D-16		●		●	●	●	●			
D-17				●	●	●				
D-18										●
D-20										●

Source: Reference (1), p. 68

(Continued)

IMPLEMENTATION ON EXISTING ROADWAYS (Continued)

Application of Techniques (Continued)

TABLE 8-4: PREDICTION OF DELAY AND ACCIDENT REDUCTION

Techniques with Quantified Benefits

			Annual Accident Reduction and/or (Annual Hours of Delay Reduction)								
			Highway Volume								
			Low			Medium			High		
		Operational Parameter (a)	Operational Parameter Level			Operational Parameter Level			Operational Parameter Level		
Technique	Option		Low	Medium	High	Low	Medium	High	Low	Medium	High
A-1	*	2	-2.7	1.8	6.3	-4.0	4.7	13.6	-5.0	8.1	21.3
A-2	*	2	2.2	5.8	10.7	6.1	11.2(2628)	20.7(6059)	6.3	17.2(6933)	31.2(17066)
A-3	*	2	---	---	---	---	9.9(30403)	13.6(36300)	---	14.9(73000)	20.4(91250)
A-4	1	3	0.12(-358)	0.28(-358)	0.43(-358)	0.20(-3975)	0.49(-3975)	0.76(-3975)	0.28(-15735)	0.67(-15735)	1.02(-15735)
	2	3	0.17(-358)	0.42(-358)	0.65(-358)	0.30(-3975)	0.74(-3975)	1.14(-3975)	0.42(-15735)	1.00(-15735)	1.53(-15735)
A-5	1	1	0.08	0.19	0.29	0.14	0.33	0.51	0.19	0.45	0.69
	2	1	0.05	0.13	0.19	0.09	0.22	0.34	0.12	0.30	0.46
	3	1	0.13	0.31	0.49	0.23	0.55	0.85	0.31	0.75	1.15
A-8		1	---	---	---	---	0.4	0.6	---	0.4	0.6
A-10		1	0.40	0.90	1.60	0.7	1.7	2.6	1.0	2.3	3.6
A-11		1	-0.38	-0.60	-0.60	-1.0	-1.0	-0.8	-1.4	-1.4	-1.2
A-12		1	0.02	0.07	0.11	0.03	0.12	0.18	0.06	0.16	0.26
A-13		1	0.09	0.21	0.32	0.15	0.37	0.57	0.21	0.50	0.77
A-14		1	0.28	0.70	1.08	0.50	1.27	1.88	0.68	1.66	2.56
A-15		1	0.34	0.84	1.30	0.60	1.46	2.26	0.82	2.00	3.06
A-16	1	1	0.05	0.13	0.19	0.09	0.22	0.34	0.12	0.30	0.46
	2	1	0.08	0.19	0.29	0.14	0.33	0.51	0.19	0.45	0.69
	3	1	0.13	0.31	0.49	0.23	0.55	0.85	0.31	0.75	1.15
A-17	1	1	0.010	0.025	0.039	0.018	0.044	0.068	0.025	0.060	0.092
	2	1	0.008	0.019	0.029	0.014	0.033	0.051	0.019	0.045	0.069
	3	1	0.013	0.032	0.049	0.023	0.055	0.085	0.031	0.075	0.115
A-19		1	0.08	0.19	0.29	0.014	0.033	0.051	0.019	0.045	0.069
A-20		1	---	---	---	---	0.4	0.6	---	0.4	0.6

* Note: All benefits expressed as benefits per installation except those marked "*" indicating benefits per mile of improvement.

a. 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

FUNCTIONAL OBJECTIVE B -- SEPARATE BASIC CONFLICT AREAS

Techniques with Quantified Benefits

			Annual Accident Reduction and/or (Annual Hours of Delay Reduction)								
			Highway Volume								
			Low			Medium			High		
		Operational Parameter (a)	Operational Parameter Level			Operational Parameter Level			Operational Parameter Level		
Technique	Option		Low	Medium	High	Low	Medium	High	Low	Medium	High
B-5		2	0.25	0.25	0.25	0.49	0.49	0.49	0.73	0.73	0.73
B-6		1 (c)	0.10	0.33	---	0.17	0.50	---	0.20	0.70	---
B-9		1	0.26	---	---	0.43	---	---	0.62	---	---
B-10		2	0.25	0.25	0.25	0.49	0.49	0.49	0.73	0.73	0.73
B-12		1	---	---	---	0.19	0.47	0.73	0.36	0.87	1.33

* Note: All benefits expressed as benefits per arterial driveway eliminated, or collector driveway added.

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

Source: Reference (4), pp. 72-73

(Continued)

IMPLEMENTATION ON EXISTING ROADWAYS (Continued)

Application of Techniques (Continued)

TABLE 8-4: PREDICTION OF DELAY AND ACCIDENT REDUCTION (Continued)

FUNCTIONAL OBJECTIVE C -- LIMIT MAXIMUM DECELERATION REQUIREMENTS

Techniques with Quantified Benefits

			Annual Accident Reduction and/or (Annual Hours of Delay Reduction)								
			Highway Volume								
			Low			Medium			High		
		Operational Parameter (a)	Operational Parameter Level			Operational Parameter Level			Operational Parameter Level		
Technique	Option		Low	Medium	High	Low	Medium	High	Low	Medium	High
C-2		1	0.016	0.038	0.058	0.027(23)	0.066(91)	0.102(182)	0.037(30)	0.090(122)	0.138(243)
C-3	1	1	0.05	0.13	0.20	0.09	0.23	0.36	0.13	0.32	0.48
	2	1	0.02	0.06	0.09	0.04	0.11	0.16	0.06	0.14	0.22
	3	1	0.04	0.11	0.16	0.08	0.18	0.29	0.10	0.25	0.39
C-4		2	1.9	3.0	4.2	3.8	6.0	8.2	5.7	9.0	12.3
C-7		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-8		1	(25.3)	(101.4)	(202.8)	(50.6)	(202.8)	(405.6)	(75.9)	(304.2)	(608.4)
C-9		1	(25.3)	(101.4)	(202.8)	(50.6)	(202.8)	(405.6)	(75.9)	(304.2)	(608.4)
C-10		1	(25.3)	(101.4)	(202.8)	(50.6)	(202.8)	(405.6)	(75.9)	(304.2)	(608.4)
C-11		1	0.02	0.05	0.07	0.03	0.08	0.13	0.05	0.11	0.17
C-12		1	---	---	---	---	0.4	0.4	---	0.4	0.4

* Note: All benefits expressed as benefits per driveway except for C-4, which is in benefits per mile of parking removed.

a. Operational Parameter Code
1. Driveway volume
2. Level of development (commercial driveways per mile)

FUNCTIONAL OBJECTIVE D -- REMOVE TURNING VEHICLES OR QUEUES FROM SECTIONS OF THE THROUGH LANES

Techniques with Quantified Benefits

			Annual Accident Reduction and/or (Annual Hours of Delay Reduction)								
			Highway Volume								
			Low			Medium			High		
		Operational Parameter (a)	Operational Parameter Level			Operational Parameter Level			Operational Parameter Level		
Technique	Option		Low	Medium	High	Low	Medium	High	Low	Medium	High
D-1	*	2	4.4	7.1	9.7	8.8	13.9(2628)	19.0(6039)	13.3	20.9(6935)	28.4(17066)
D-2	*	2	4.4	7.1	9.7	8.8	13.9(2628)	19.0(6039)	13.3	20.9(6935)	28.4(17066)
D-3		2	1.7	3.5	6.4	3.2	7.1(2628)	13.3(6039)	5.1	11.4(6935)	21.0(17066
D-4		1	0.13	0.32	0.49	0.23	0.35(263)	0.83(606)	0.31	0.73(694)	1.15(1705)
D-5		1	---	0.13	0.19	---	0.22	0.34	1.2	3.0	4.5
D-6		1	0.02	0.04	0.07	0.03	0.07	0.11	0.04	0.10	0.16
D-7		1	0.026	0.063	0.097	0.045	0.11(263)	0.17(343)	0.062	0.15(694)	0.23(973)
D-8		1	0.01	0.03	0.04	0.02	0.04	0.07	0.03	0.06	0.09
D-9	*	2	---	1.4	2.1	---	1.8	3.6	---	3.3	6.9
D-14		1 (c)	---	---	---	---	-0.13	-0.03	---	-0.03	-0.03
D-16		1	0.02	0.03	0.07	0.03(23)	0.08(91)	0.13(183)	0.03(32)	0.11(122)	0.17(243)

* Note: All benefits are expressed as benefits per installation except those marked "*", indicating benefits per mile of improvement.

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

Source: Reference (*4*), pp. 73-74

BENEFIT ANALYSIS

Benefits

Benefits Of Access Improvements

- **Reduced Accident Costs**
- **Reduced Vehicle Operating Costs**
- **Reduced Time Costs**

The benefits associated with improved access design and management are associated principally with accidents, vehicle operating costs, and the value of reduced travel time.

Accident Costs

Accident costs increase with increased severity of the accident. Current average costs are as follows:

TABLE 8-5: AVERAGE ACCIDENT COSTS FOR ECONOMIC ANALYSIS

Severity	Cost
Fatal	$1,500,000
Injury	$11,000
Property Damage Only	$3,000

More detailed accident cost information is contained in the FHWA Technical Advisory, which is included in Appendix A of this chapter. The Appendix also includes a paper which discusses the proper and improper use of accident cost information in economic evaluations.

(Continued)

BENEFIT ANALYSIS (Continued)

Vehicle Operating Costs

Vehicles leaving and entering the roadway may require through traffic to decelerate or even come to a stop. This traffic friction increases vehicle operating costs.

Vehicle Operating Cost Categories

- **Fuel Consumption**
- **Maintenance**
- **Oil Consumption**
- **Tire Wear**
- **Depreciation**

On roadways which experience high traffic volumes the friction with driveway traffic results in large numbers of vehicles decelerating and then accelerating. This significantly increases fuel consumption (and brake wear) and greatly increases vehicular emissions. This relationship between acceleration - deceleration (commonly referred to as acceleration noise) and emissions will become of increased concern as cities attempt to achieve air quality standards mandated by federal legislation.

Deceleration And Acceleration Greatly Increase Vehicular Emissions

(Continued)

BENEFIT ANALYSIS (Continued)

Benefit/Cost	The benefit/cost ratio is perhaps the method most widely used by state and local highway agencies. All project variables need to be estimable in monetary units. While a dollar value can be placed on time, its inclusion as a benefit is controversial. This is due to the fact that the cumulative vehicle-hours or person-hours per year may be very large. The time saving to any individual amounts to minutes or fractions of a minute. Therefore, the value of the time saved is often omitted from the analysis.
Cost/Effectiveness	The cost/effectiveness method requires that only costs be reduced to monetary value. A dollar value need not be placed on benefits. Therefore, if delay reduction is the measure of effectiveness (MOE) the technique which produces largest MOE/cost ratio is the most effective.

COST EVALUATION

Cost Elements

Costs associated with the implementation of access changes or an existing roadway include the following:

Associated Costs

- Land Acquisition
- Project Design
- Construction
- Maintenance
- Negative Impact On Businesses And Affected Properties

All costs (as well as benefits) are commonly analyzed using an appropriate recovery life of the improvement and an appropriate opportunity cost (interest rate).

Relative Costs

Construction and maintenance costs vary considerably due to geographical location, method of construction, contract amount, time of year, and inflation. Therefore, Table 8-6 was developed showing relative unit costs. A technique which has a relative cost index of 50 is expected to cost 50 times that of a technique having an index of 1, and 5 times that of one having an index of 10, etc. These relative cost indices might be used to and in the preliminary evolution of alternatives. However, specific cost estimates must be made for construction budgeting and wherever a location specific cost/benefit analysis is desired.

(Continued)

COST EVALUATION (Continued)

Relative Costs (Continued)

TABLE 8-6: RELATIVE IMPLEMENTATION COSTS OF ACCESS MANAGEMENT TECHNIQUES

Functional Objective A -- Limit Number of Conflict Points

Technique	Construction Option	Relative Cost Index
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	370
	2. Basic construction plus additional pavement widening	608
	3. Basic construction plus additional pavement widening and right-of-way acquisition	798
A-2: Install Raised Median Divider With Left-Turn Deceleration Lanes	1. Basic construction - raised median with openings on existing paved median	195
	2. Basic construction plus additional pavement widening	738
	3. Basic construction plus additional pavement widening and right-of-way acquisition	1,180
A-3: Install One-Way Operations on the Highway	1. Signing and striping	15
A-4: Install Traffic Signal at High-Volume Driveways	1. Two-phase pretimed signal installation	30
	2. Three-phrase semi-actuated signal installation	60
A-5: Channelize Median Openings to Prevent Left-Turn Ingress and/or Egress Maneuvers	1. Channelizing island to prevent left-turn egress maneuvers	2
	2. Channelizing island to prevent left-turn egress	2
	3. Close median opening to prevent all left-turn maneuvers	2
A-8: Install Physical Barrier to Prevent Uncontrolled Access Along Property Frontages	1. Barrier curb	184
A-9: Install Median Channelization to Control Merge of Left-Turn Egress Vehicles	1. Channelizing island on existing median	1
A-10: Offset Opposing Driveways	1. Close and relocate driveway	9
A-11: Locate Driveway Opposite a Three-Leg Intersection or Driveway and Install Traffic Signals Where Warranted	1. Two-phase pretimed signal installation	30
	2. Signal installation plus closing and relocating driveway	39
A-12: 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	6
	2. Close two-way driveway and construct two one-way driveways	5

Source: Reference (4), p. 76

(Continued)

COST EVALUATION (Continued)

Relative Costs (Continued)

TABLE 8-6: RELATIVE IMPLEMENTATION COSTS OF ACCESS MANAGEMENT TECHNIQUES (Continued)

Technique	Construction Option	Relative Cost Index
A-13: Install Two Two-Way Driveways with Limited Turns in Lieu of One Standard Two-Way Driveway	1. Construct one driveway and channelize both driveways	8
	2. Close one driveway and construct two channelized driveways	16
A-14: Install Two One-Way Driveways in Lieu of Two Two-Way Driveways	1. Signing	1
A-15: Install Two Two-Way Driveways with Limited Turns in Lieu of Two Standard Two-Way Driveways	1. Channelize two angled driveways	2
	2. Close two driveways and construct two angled limited-turn driveways and medial turning bays	34
	3. Channelize two t-driveways	2
A-16: Install Driveway Channelizing Island to Prevent Left-Turn Maneuvers	1. Driveway widening and channelization to prevent left-turn egress vehicles	4
	2. Driveway widening and channelization to prevent left-turn egress vehicles	4
	3. Driveway widening and channelization to prevent both left-turn ingress and egress vehicles	7
A-17: Install Driveway Channelizing Island to Prevent Driveway Encroachments Conflicts	1. Medial channelizing island and driveway widening	2
	2. Driveway curbing (one side)	1
	3. Medial channelizing island, driveway widening, and driveway curbing (one side)	3
A-18: Install Channelizing Island to Prevent Right-Turn Deceleration Lane Vehicles from Returning to the Through Lanes	1. Channelizing island	3
	2. Channelizing island and deceleration lane widening	8
	3. Channelizing island, deceleration lane widening, and additional right-of-way acquisition	10
A-19: Install Channelizing Island to Control the Merge Area of Right-Turn Egress Vehicles	1. Channelizing island and driveway widening	4
A-20: Regulate the Maximum Width of Driveways	1. Curbing	1

Source: Reference (4), p. 77

(Continued)

COST EVALUATION (Continued)

Relative Costs (Continued)

TABLE 8-6: RELATIVE IMPLEMENTATION COSTS OF ACCESS MANAGEMENT TECHNIQUES (Continued)

Functional Objective B -- Separate Basic Conflict Areas

Technique	Construction Option	Relative Cost Index
B-1: Regulate Minimum Spacing of Driveways	1. Close one driveway	2
	2. Close and relocate one driveway	8
B-2: Regulate Minimum Corner Clearance	1. Close one driveway	2
	2. Close and relocate one driveway	8
B-3: Regulate Minimum Property Clearance	1. Close one driveway	2
	2. Close and relocate one driveway	8
B-4: Optimize Driveway Spacing in the Permit Authorization Stage	1. Implemented during the permit authorization stage	NC[2]
B-5: Regulate Maximum Number of Driveways per Property Frontage	1. Close one driveway	2
B-6: Consolidate Access for Adjacent Properties	1. Close two driveways and construct one driveway on property line	11
	2. Close one driveway and construct one driveway on property line	8
B-8: Buy Abutting Properties	1. Basic construction - costs are highly site-specific	NC[1]
B-9: Deny Access to Small Frontage	1. Basic construction - costs are highly variable and dependent on land value	NC[1]
	2. Construct connection between properties	2
	3. Close one driveway and construct one driveway on property line	8
B-10: Consolidate Existing Access Whenever Separate Parcels are Assembled Under One Purpose, Plan, Entity, or Usage	1. Close one driveway	2
B-11: 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	NC[2]
B-12: Require Access on Collector Street (when available) in Lieu of Additional Driveway on Highway	1. Construct one driveway	6

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

Source: Reference (*4*), p. 78

(Continued)

COST EVALUATION (Continued)

Relative Costs (Continued)

TABLE 8-6: RELATIVE IMPLEMENTATION COSTS OF ACCESS MANAGEMENT TECHNIQUES (Continued)

Functional Objective C -- Limit Maximum Deceleration Requirements

Technique	Construction Option	Relative Cost Index
C-2: Restrict Parking on the Roadway Next to Driveways to Increase Driveway Turning Speeds	1. Signing	<1
C-3: Install Visual Cues of the Driveway	1. Suspended red-yellow flashing beacon	6
	2. Advance warning sign and flashing beacon	1
	3. Driveway illumination	4
C-4: Improve Sight Distance by Preventing Parking on the Traveled Way, Either Totally or Partially	1. Signing	10
C-5: Regulate Minimum Sight Distance	1. Close and relocate one driveway	8
C-6: Optimize Sight Distance in the Permit Authorization Stage	1. Implemented during the permit authorization stage	NC[1]
C-7: Increase the Effective Approach Width of the Driveway	1. Increase return radii on both sides of driveway	1
C-8: Improve the Vertical Geometrics of the Driveway	1. Partial driveway reconstruction	2
	2. Mountable curb removal	1
C-9: Require Driveway Paving	1. Driveway paving	6
C-10: Regulate Driveway Construction (performance bond) and Maintenance	1. Implemented during the permit authorization stage	NC[1]
C-11: Install Right-Turn Acceleration Lane	1. Acceleration lane	10
	2. Acceleration lane and additional right-of-way acquisition	
C-12: Install Channelizing Islands to Prevent Driveway Vehicles from Backing onto the Highway	1. Channelizing islands	19

1. No incremental cost.

Source: Reference (4), p. 79

(Continued)

COST EVALUATION (Continued)

Relative Costs (Continued)

TABLE 8-6: RELATIVE IMPLEMENTATION COSTS OF ACCESS MANAGEMENT TECHNIQUES (Continued)

Functional Objective D -- Remove Turning Volumes or Queues from Sections of the Through Lanes

Technique	Construction Option	Relative Cost Index
D-1: Install Two-Way Left-Turn Lane	1. Basic construction - median striping on existing median	16
	2. Basic construction plus additional pavement widening	560
	3. Basic construction plus additional pavement widening and right-of-way acquisition	1,000
D-3: Install Alternating Left-Turn Lane	1. Basic construction - median striping on existing median	20
	2. Basic construction plus additional pavement widening	564
	3. Basic construction plus additional pavement widening and right-of-way acquisition	1,006
D-4: Install Isolated Median and Deceleration Lane to Shadow and Store Left-Turning Vehicles	1. Basic construction - median installation and highway widening	73
	2. Basic construction plus right-of-way acquisition	117
D-5: Install Left-Turn Deceleration Lane in Lieu of Right-Angle Crossover	1. Deceleration lane installation	15
D-6: Install Medial Storage for Left-Turn Egress Vehicles	1. Channelizing island and existing median alteration	10
D-7: Increase Storage Capacity of Existing Left-Turn Deceleration Lane	1. Storage increase for a continuous curbed median	13
	2. Storage increase for an isolated curbed median	28
	3. Storage increase for an isolated curbed median plus additional right-of-way acquisition	39
	4. Highway widening for two-lane left-turn bay at an isolated curbed median	71
	5. Highway widening plus additional right-of-way acquisition for two-lane left-turn bay at an isolated curbed median	130
D-9: Install Continuous Right-Turn Lane	1. Basic construction - continuous right-turn lane	99
	2. Basic construction plus additional right-of-way acquisition	194

Source: Reference (4), p. 80

(Continued)

COST EVALUATION (Continued)

Relative Costs (Continued)

TABLE 8-6: RELATIVE IMPLEMENTATION COSTS OF ACCESS MANAGEMENT TECHNIQUES (Continued)

Technique		Construction Option	Relative Cost Index
D-10: Construct a Local Service Road	1.	Frontage road	NC[1]
D-11: Construct a Bypass Road	1.	Bypass road	NC[1]
D-12: Reroute Through Traffic	1.	Basic construction - costs are highly variable and location-dependent	NC[1]
D-13: Install Supplementary One-Way Right-Turn Driveways to Divided Highway (non-capacity warrant)	1.	Construct one one-way supplementary driveway	6
D-14: Install Supplementary Access on Collector Street When Available (non-capacity warrant)	1.	Construct one supplementary driveway at no cost to the highway agency	NC[2]
D-16: Install Right-Turn Decleration Lane	1.	Deceleration lane	9
	2.	Deceleration lane and additional right-of-way acquisition	16
D-17: Install Additional Exit Lane on Driveway	1.	Additional driveway lane construction	8
D-18: Encourage Connections Between Adjacent Properties (even when each has highway access)	1.	Connection between properties	2
D-20: Require Adequate Internal Design and Circulation Plan	1.	Basic construction - costs are highly variable and location-dependent	NC[1]

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

Source: Reference (4), p. 81

(Continued)

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4. "Access Management for Streets and Highways", Federal Highway Administration, Report FHWA-IP-82-3, June 1982.

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6. R. Winfrey and C. Zellner, "Summary and Evaluation of Economic Consequences of Highway Improvements", NCHRP-122, HRB, Washington, D.C. 1971.

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APPENDIX 8-A

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Technical Advisory

U.S. Department of Transportation
Federal Highway Administration

Subject

MOTOR VEHICLE ACCIDENT COSTS

Classification Code	Date
T 7570.1	June 30, 1988

1. PURPOSE. To provide information on recent developments in estimating motor vehicle accident costs and to encourage States to use these accident costs for economic analyses of highway projects and programs.

2. BACKGROUND AND DISCUSSION

a. When new roads, streets, and highways are constructed or existing ones are reconstructed, safety improvements result from the use of American Association of State Highway and Transportation Officials Standards. However accident costs are frequently used in economic analyses to assist in determining what improvements should and should not be implemented when older roads, streets, and highways are refurbished and improved. When used this way, accident costs can have a profound influence upon the identification, prioritization, and selection of additional cost-effective enhancements.

b. The National Highway Traffic Safety Administration and the National Safety Council (NSC) routinely publish estimates of economic costs that result from motor vehicle accidents. In the NSC's 1987 Accident Facts publication, page 65, an important difference in the use of accident costs was recognized. The NSC states that its cost figures ". . .are appropriate for measuring the economic loss to a community resulting from past motor vehicle accidents. They should not be used, however, in computing the dollar value of future benefits due to traffic safety measures because they do not include the value of a person's natural desire to live longer or protect the quality of one's life. That is, the economic loss estimates do not include what people are willing to pay for improved safety. . . ."

c. In 1986, a Federal Highway Administration research contract entitled "Alternative Approaches to Accident Cost Concepts"

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(see paragraph 5a) established fatal, injury, and property damage costs for use in highway improvement economic analyses which reflect the amount individuals are willing to pay to reduce the number and severity of accidents. This report contains an extensive literature review and critique of accident cost methodologies and related studies. Component as well as total accident costs resulted from that effort.

d. The Office of the Secretary of Transportation in 1986, adopted a minimum amount of $1 million to be associated with the value of a human life (see paragraph 5b) to be used in the Department's regulatory analyses or rulemaking activities.

3. DEFINITIONS

a. Component Motor Vehicle Accident Costs-categorized into direct costs and indirect costs.

(1) Direct Costs are the costs of goods and services consumed as a result of those accidents. Direct costs include expenditures on property damages, emergency medical services, medical care, legal and court services, and funeral and burial.

(2) Indirect Costs include costs of consumption of resources, loss of potential productivity, and costs or value of psychosocial deterioration.

b. Willingness to Pay Cost includes both direct and indirect costs and reflects the value which individuals are willing to pay to reduce the number or severity of accidents or to ensure continued health and safety.

4. RECOMMENDED ACCIDENT COSTS

a. The motor vehicle accident cost figures shown in Table 1 are recommended for use by State and local highway and safety agencies. These costs should be updated at least every two years.

b. In performing economic analyses on highway safety projects, often there are insufficient numbers of accidents to provide an accurate assessment of the cost-effectiveness of the improvement. To avoid disproportionate attention to locations where a fatality occurred and thus improve decisions regarding safety improvements, States should use a combined fatal-plus-injury cost (also property damage only (PDO) if available). This may be done on a statewide basis, by functional system, by land use (rural/urban), by accident type, or some other combination depending upon the data available within the State's accident records system. The differences in combined costs reflect the variations in accident severity. 1/ As an example, the average cost for fatal and injury accidents on each system and groups of systems may be calculated using the formula:

Cost ($)/Fatal Plus Injury Accident =

$$\frac{(\text{Fatalities} \times \text{Fatality Cost}) + (\text{Injuries} \times \text{Injury Cost})}{\text{Fatal Accidents} + \text{Injury Accidents}}$$

TABLE 1

FHWA Recommended Values for
Cost per Accident and per Incident 2/ by Accident Severity
Willingness-to-Pay Approach 3/

Severity by Most Severe Injury	Cost Per Accident $	Cost Per Incident $
FATAL	1,700,000	1,500,000
Injury (Overall)	14,000	11,000
ABC Injury Scale:		
A Injury - Incapacitating injury	47,000	39,000
B Injury - Nonincapacitating Evident Injury	19,000	12,000
C Injury - Possible Injury	8,500	6,000
Property Damage Only (PDO)	3,000	2,000

1/ See attached paper entitled "Accident Costs -- Are We Using Them Correctly?" by A. Graham Bailey, Region 1 Traffic Operations and Safety Engineer, which describes a rational method to develop the fatal-plus-injury accident/incident costs.

2/ Per incident means per individual or per vehicle for PDO.

3/ Calculations are based on the FHWA contract findings in the "Alternative Approaches to Accident Cost Concepts." A 5 percent discount rate was used. Figures are expressed in 1986 dollars.

5. **REFERENCES**

a. Ted R. Miller, Kenneth A. Reinert, and Brooke E. Whiting, "Alternative Approaches to Accident Cost Concepts," Report No. FHWA/RD-83-079, Federal Highway Administration, Washington, D.C., January 1984 (PB No. 84 196658).

b. Memorandum from Jim J. Marquez, General Counsel, to Regulation Council Members concerning "Value of a Life," April 10, 1986.

c. Brenda C. Kragh, Ted R. Miller, and Kenneth A. Reinert, Accident Costs for Highway Safety Decisionmaking," Public Roads, Washington, D.C., June 1986.

Marshall Jacks, Jr.
Associate Administrator for
Safety and Operations

Attachment

In performing economic analyses on completed highway safety projects, it is rare to encounter a location or segment where there are sufficient numbers of fatal accidents to allow a statistically significant evaluation of the effect of the improvement on the change in number of fatal accidents. If the before-and-after frequencies of fatal accidents are used in the traditional benefit/cost calculations along with the newly recommended fatality cost of $1.5 million, the results can be quite misleading. To illustrate this problem, consider a safety-improvement project which was included in a State's recent annual HSIP report.

Project Evaluation

Project Cost	$728,000
Service Life	10 years
Interest Rate	5%
Capital Recovery Factor	.12950

	Before	After
Traffic (ADT)	9500	9300
Evaluation Period (Months)	36	36
Fatal Accidents	0	1
Fatalities	0	1
Injury Accidents	46	20
Injuries	57	26
P.D.O. Accidents	43	16
Total Accidents	89	37

Using a value of $1,500,000 per fatality, $11,000 per injury, and $3,000 per P.D.O. accident, the Benefit/Cost ratio was calculated using FHWA's recommended evaluation procedure 1/ (simplified to assume no salvage value and no net change in operational costs). This Benefit/Cost ratio for this project was - 3.87, suggesting that the improvement had a negative value. This is an unreasonable conclusion considering that the improvement resulted in more than a 50% reduction in injury, P.D.O., and total accidents. The fact that there was one fatal accident following project implementation, and the high cost assigned to each fatality, created this misleading result. Similar misleading results could show a project to be cost-effective even though there may have been a large increase in the number of injury and P.D.O. accidents.

A Solution

How to overcome this problem and develop a methodology which could better predict or evaluate the cost-effectiveness of a safety improvement necessitated a larger data base to offset the effect of large weighting of few and random occurrences.

FHWA's annual publication Highway Safety Performance - Fatal and Injury Accident Rates on Public Roads in the United States includes accident data from the States. The data included in this report shows the number of persons injured or killed in accidents for each type of highway. If it can be assumed that fatal accidents are random events which on a system basis can be expressed as a percentage of the combination of fatal and injury accidents occurring on that particular system each year, then it would also be possible to combine and average the cost of the fatal and injury accidents. Using the data contained in

1/ Office of Highway Safety Series - Highway Safety Evaluation (An Abbreviated Step-by-Step Procedure) FHWA - 1984

ACCIDENT COSTS — ARE WE USING THEM CORRECTLY?

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Introduction

The proper use of current accident costs is one of the most useful tools we have to measure the effectiveness of a particular safety improvement. The selection of the appropriate accident costs and the proper use of these costs can have a profound influence upon the economic analysis in the prioritization and subsequent analysis of highway safety projects. It can also be extremely useful as a tool in deciding whether an incremental safety enhancement would be cost effective on 3R-type projects.

There has been widespread reluctance on the part of many individuals and agencies to agree upon and assign a value to a human life. This is an emotionally charged issue which is often addressed in an indirect or relative way. The effectiveness of safety improvements is sometimes expressed as cost-per-accident reduced or cost-per-injury reduced. This avoids the need to assign a specific value to a human life. Nevertheless, after the cost for a proposed safety improvement has been estimated, the decision must be made whether to commit the funds to implement the improvement. This requires relating the cost of the proposed improvement with the expected benefit (accidents reduced or lives saved). Directly or indirectly, we are making a judgment on the value of human life.

Which Accident Costs to Use

For many years, there have been different accident costs developed by different governmental agencies and by the National Safety Council. Recent estimates of the value of a life range from $220,000 to $3,500,000. Without discussing the merits of specific accident costs, this paper will focus on the appropriate use of whatever accident costs are selected by the user. For the purpose of illustration, the following accident costs which have been recently developed and recommended by FHWA will be used.

Fatality	-	**$1,500,000**
Injury	-	**11,000**
Property Damage Only Accident	-	**2,000**

It is important to recognize that the first two of the above costs refer to each person killed or injured. The costs must therefore be adjusted to reflect the costs per accident.

The Problem

With the development and general acceptance of a significantly higher value for each fatality, it has become increasingly important to be sure that our economic analysis uses these costs in a way which would not ignore or underestimate the need to address high accident locations involving a significant number of injuries, even where no fatalities are evident.

the Annual Report, the average cost for fatal and injury accidents on each system and groups of systems may be calculated using the formula:

$$\text{Cost (\$)/Accident} = \frac{(\text{Fatalities x Fatality Cost}) + (\text{Injuries x Injury Cost})}{\text{Fatal Accidents} + \text{Injury Accidents}}$$

For example, take the fatal and injury accidents on one State's Urban Primary System. The 1985 accident data reported by that State indicates the following:

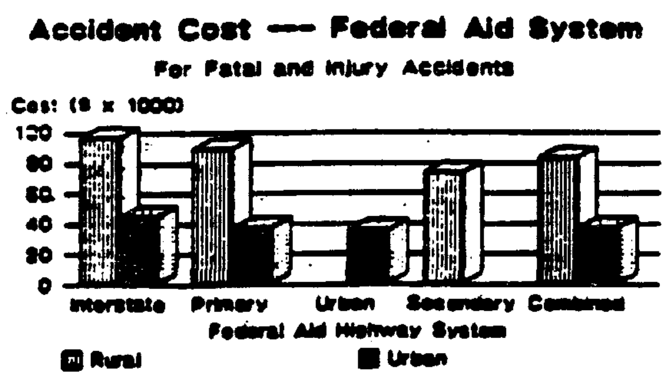
55	Fatalities	53	Fatal Accidents
1834	Injuries	1781	Injury Accidents

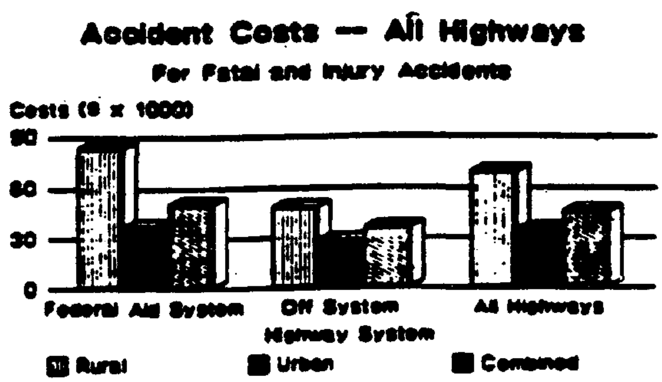
Using this data in the above formula:

$$\text{Cost (\$)} = \frac{(55 \times \$1,500,000) + (1834 \times \$11,000)}{53 + 1781} = \$35,569$$

Thus, the average cost of a fatal/injury accident on that State's Urban Primary System is $35,569, or say $35,600, using current data.

The following charts depict the combined fatal/injury accident cost on a nationwide basis using 1985 fatal and injury accident data reported in the 1987 Annual Report. These charts show accident costs for the various Federal-aid highway system and costs for all highways.





The information shown on the above charts illustrates a consistent and important point. Accidents in urbrn highways involve more injuries per fatality than accidents on rural highways. This is probably due to generally lower operating speeds in urban areas. As a result the fatal/injury accident costs are consistently lower on urban highways than on rural highways.

Actual values for these accident costs using both 1985 and 1984 accident data are shown in Appendix A. The relationship between the various system costs from one year to the next remains unchanged.

The Use of Combined Accident Costs

To illustrate how these average combined fatal/injury accident costs can assist in the economic analysis of a safety project, let's re-examine the example presented earlier:

	Before	After
Fatal Accidents	0	1
Fatalities	0	1
Injury Accidents	46	20
Injuries	57	26
Property Damage Accidents	43	16
Total Accidents	89	37

As discussed earlier, using the accident costs of $1,500,000 per fatality, $11,000 per injury, and $3,000 per P.D.O. accident, the economic analysis yielded a Benefit/Cost ratio of -3.87.

Using the same methodology but substituting the average nationwide Federal-aid system costs of $50,100 for both fatal and injury accidents, the calculated Benefit/Cost ratio becomes 5.38. Since the safety improvement project was on a segment of the rural primary system, a more appropriate fatal/injury accident cost would be $83,900, which is the rounded nationwide average for this system. Using this cost would yield a Benefit/Cost ratio of 8.82.

These higher Benefit/Cost values are consistent with an objective, common-sense look at the results of the safety project which was extremely effective in reducing the number and severity of accidents. An addition or reduction of a single fatality should not have been the determining factor by which to judge the cost-effectiveness of the project.

The use of combined average fatal/injury costs, such as described, has the potential for improving the prioritization process for selecting safety improvements as well as improving the reliability and credibility of their post-implementation evaluation.

As accident data improves, the ability to develop more reliable accident costs will be enhanced. There is little doubt, for example, that the average severity of injury accidents differs between highway systems. To account for this would require additional injury severity data. It may also be possible to isolate specific accident types (for example, accidents involving fixed objects) and develop average societal costs attributable to that classification of accident.

Future refinements are certainly possible as additional or improved data becomes available.

Attachment

ACCIDENT COSTS FOR FATAL/INJURY ACCIDENTS

Using 1985 and 1984 Accident Data

NATIONWIDE COSTS BASED ON 1985 ACCIDENT DATA
ACCIDENT COSTS: FATALITY $1,500,000 , INJURY $11,000

		FTL ACC	FATLS	INJ ACC	INJS	ALL ACCS	COST/ACC
INTERSTATE	RURAL	1,833	2,153	38,317	60,779	40,150	$97,088
	URBAN	1,857	2,031	103,967	156,488	105,824	$45,055
PRIMARY	RURAL	8,321	9,856	197,480	328,708	205,801	$89,406
	URBAN	3,975	4,347	312,088	480,581	316,063	$37,356
URBAN	ARTERIAL	8,302	8,897	665,386	995,940	673,688	$36,065
SECONDARY	RURAL	5,664	6,476	163,405	254,826	169,069	$74,035
COMBND FED-AID	RURAL	15,818	18,485	399,202	644,313	415,020	$83,887
SYSTEMS	URBAN	14,134	15,275	1,081,441	1,632,609	1,095,575	$37,306
	ALL FA HWYS	29,952	33,760	1,480,643	2,276,922	1,510,595	$50,104
NON-FED-AID	RURAL	5,505	6,053	274,536	407,536	280,041	$48,430
SYSTEM	URBAN	3,711	3,982	463,321	655,942	467,032	$28,239
	ALL NON-FA	9,216	10,035	737,857	1,063,478	747,073	$35,807
ALL HIGHWAYS	RURAL	21,323	24,538	673,738	1,051,849	695,061	$69,602
	URBAN	17,845	19,257	1,544,762	2,288,551	1,562,607	$34,596
	ALL HWYS	39,168	43,795	2,218,500	3,340,400	2,257,668	$45,373

NATIONWIDE COSTS BASED ON 1984 ACCIDENT DATA
ACCIDENT COSTS: FATALITY $1,500,000 , INJURY $11,000

		FTL ACC	FATLS	INJ ACC	INJS	ALL ACCS	COST/ACC
INTERSTATE	RURAL	1,872	2,178	36,534	58,421	38,406	$101,797
	URBAN	1,719	1,929	91,765	136,945	93,484	$47,066
PRIMARY	RURAL	8,640	10,266	196,408	326,882	205,048	$92,635
	URBAN	3,580	3,987	253,111	386,774	256,691	$39,873
URBAN	ARTERIAL	7,963	8,560	625,776	923,140	633,739	$36,288
SECONDARY	RURAL	5,259	6,017	146,211	227,177	151,470	$76,084
COMBND FED-AID	RURAL	15,771	18,461	379,153	612,480	394,924	$87,178
SYSTEMS	URBAN	13,262	14,476	970,652	1,446,859	983,914	$38,245
	ALL FA HWYS	29,033	32,937	1,349,805	2,059,339	1,378,838	$52,260
NON-FED-AID	RURAL	5,309	5,832	233,538	343,068	238,847	$52,426
SYSTEM	URBAN	3,624	3,827	422,095	598,713	425,719	$28,954
	ALL NON-FA	8,933	9,659	655,633	941,781	664,566	$37,390
ALL HIGHWAYS	RURAL	21,080	24,293	612,691	955,548	633,771	$74,081
	URBAN	16,886	18,303	1,392,747	2,045,572	1,409,633	$35,439
	ALL HWYS	37,966	42,596	2,005,438	3,001,120	2,043,404	$47,424

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