NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM REPORT 93

GUIDELINES FOR MEDIAL AND MARGINAL ACCESS CONTROL ON MAJOR ROADWAYS

HIGHWAY RESEARCH BOARD
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GUIDELINES FOR MEDIAL AND MARGINAL ACCESS CONTROL ON MAJOR ROADWAYS

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WITH THE BUREAU OF PUBLIC ROADS

SUBJECT CLASSIFICATION.
- TRANSPORTATION ADMINISTRATION
- TRANSPORTATION ECONOMICS
- HIGHWAY DESIGN
- TRAFFIC CONTROL AND OPERATIONS
- URBAN COMMUNITY VALUES

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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

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FOREWORD

By Staff

Highway Research Board

This report will be of interest primarily to highway administrators, those concerned with traffic control and operations and transportation economics, state and municipal transportation planners, highway design engineers, and highway maintenance personnel. It discusses the importance of providing the proper degree of medial and marginal access control to meet the projected growth of the urban-suburban population, as well as the development (use and layout) of land adjacent to arterials. Recommendations are made concerning policies and procedures relative to the design and treatment of access—including driveways, intersections, and median openings—to the roadways.

A need exists for guides in selecting the degree of access control for a specific project and for selecting the type, location, and width of medians and median openings and the design and frequency of entrances to be associated with the degree of access control. Current practice represents wide variation in judgment, and indicates the need for better understanding of the functions and use of medial and marginal access control.

The scope of this research by the Texas Transportation Institute includes the full range of medial and marginal control, in cases of both full and partial control of access. The objectives were to develop guidelines to enable the highway administrator to determine the appropriate degree of access control, and to provide him with the physical means of accomplishing such control. Standards developed cover such items as cross-section design, intersection spacing, location and frequency of medial and marginal openings, and design of these openings.

In the development of the guidelines, the research also considered accident frequency and type, legal considerations, traffic patterns, services to the highway user, motor vehicle operating costs, travel time and costs, land use, and convenience of access to abutting property. Consideration also was given to property values and provision for future needs for access control under changing traffic characteristics, user requirements, or land use. Brief discussions cover traffic noise, property values, the economic impact (land value and sales volumes) of highway improvements (medians) on non-users.

Procedures are recommended for review of requests for driveway permits in urban areas and on state-maintained roads. The policies of a number of cities and states in designating the degree of access control for particular facilities are discussed, and general procedures relative to the treatment of access are recommended.

Additional research is recommended on the effects of geometric driveway configuration on driver operations, and on the relationship between hazard and specific elements of roadway design. Also, further research is recommended into specific economic aspects of access in relation to the land market and land development, and the intensity of business activity.

CONTENTS

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Grateful thanks are extended to the several individuals who participated in the study through the supplying of data and valuable suggestions. These individuals, and the agencies with which they are associated, are listed in Appendix H. The assistance provided by all 50 state highway departments in providing information on their current practices and procedures is also acknowledged and greatly appreciated.

The invaluable assistance provided by the several individuals who kindly gave of their time in the review of the draft of this report is also appreciated. These include: Paul C. Box, Paul C Box and Associates, James O. Granum, Automotive Safety Foundation; Jack Anderson, Minnesota Highway Department; D. F. Haist, Bureau of Planning, Wisconsin Department of Transportation; G W Skiles, City of Los Angels; Paul H. Fowler, Automobile Club of Southern California; Clark Bennett, National Highway Safety Bureau; and members of I.T E Committee 5N. The comments and suggestions provided were of considerable help to the authors in preparing the final report.

GUIDELINES FOR MEDIAL AND MARGINAL ACCESS CONTROL ON MAJOR ROADWAYS

SUMMARY

Major transportation arteries have a service life that is much longer than the geometric design life of the traveled way. Substantial rural as well as urban arterial mileage has been successively upgraded on the original alignment to accommodate increased volumes, higher levels of service, and even different types of vehicular travel.

Unless the existing urban areas are either abandoned or instantaneously redeveloped in total, the existing and planned arterials will continue to be important facilities for decades to come. Further, the increasing criticism of traffic congestion dictates that appropriate action be taken to preserve the traffic-carrying capability of these arterials.

Access control is of principal importance in insuring that an arterial, once constructed and opened to traffic, will continue to have a high traffic movement capability in future years. The potential offered by the implementation of improved access control is pointed up by the fact that in the next 30 years the urban population of the United States is expected to increase by more than 100 million persons. To accommodate this growth it will be necessary to nearly double the nation's urban development—including transportation facilities. Hence, there is an opportunity to implement new practices on thousands of miles of arterial roadways.

Balance Between Land Use and Transportation is Essential

If this growth is to be accommodated efficiently, it is essential that a balance be obtained between transportation and the intensity of land-use activities.

The term "balanced transportation" has been used by some special interest groups to mean rapid transit. This is more properly the "mix of transportation." "Balanced transportation" should mean a balance between land-use intensity and transportation—whatever the mode or modes.

Experience with traditional zoning indicates that the exercise of the police power, as it has been applied, has little hope for preserving the traffic-carrying capability of major roadways. The administration of zoning controls is such that the continuity necessary for a regional arterial system is not readily obtained. Also, the relatively short-time horizon for zoning is in considerable variance with the very long-time horizon for a major transportation artery. Land adjacent to arterials has been observed to pass through a number of changes and different land uses during the useful life of a major roadway.

Moreover, it often is not the use to which the adjacent land is put but the site layout which is the real concern. With proper location and design of the access points and internal circulation system, a parcel might be zoned and used for commercial development without deleterious effects on traffic flow. On-site development controls (such as subdivision ordinances for residential developments) are suggested as the means of protecting the traffic-carrying capability of major roadways.

The agency responsible for planning and maintaining the arterial must exercise leadership in planning for development or redevelopment of property adjacent to the roadways.

It is believed that a concentrated effort to upgrade access control and land development practices will be effective. Fortunately, the better developers of residential, commercial, and industrial developments show an increasing awareness that their interests are served by the preservation of the traffic-carrying capability of the arterial system in general and the arterial on which their developments front in particular.

Recommended Procedure and Policy Guidelines

The street and highway networks of local areas, urban regions, states, and the nation should adequately provide for the conflicting functions of land access (local traffic) and longer trips (through traffic). Sections of the more important roadways providing similar services should be of similar design and have similar treatment of access.

Specifically, it is recommended that:

- Access control policies and standards imposed on a roadway should be related to the functional classification of the facility.
- Each administrative agency should develop and adopt for its jurisdiction a master highway plan of existing and proposed facilities, indicating the functional classification of each facility A policy on the degree of access control to be exercised on each functional class should be adopted simultaneously.
- Standards should be developed and adopted for each functional class and applied uniformly on all facilities within each class.
- Policy and standards relating to intersections with other public streets and roads should be based on intersection spacing criteria and not on the location or existence of cross streets.
- Driveway permits should be issued for a given land use and a specific development plan. A change in the land use or a change in the development would render the driveway permit void and require a request for a new permit based on the anticipated new development plan.
- Guidelines for the location of direct access points on arterials should be developed on the basis of desired traffic operation on the arterial system rather than on the basis of land ownership patterns.
- Building and driveway (curb cut) permits should be issued jointly and should be based on an acceptable site development plan.
- Local and state traffic and planning staffs should work directly with the developer in arriving at a mutually agreeable plan for the development or redevelopment of a site and the provision of access.
- Each jurisdiction should undertake a detailed study of the existing legislation and court interpretations and then initiate the appropriate steps to obtain legislation to implement improved access control procedures and guidelines as necessary.

Suggested Guidelines for Access Control Standards

Standards for the location, design, and construction of access points should result in minimum interference to through traffic. Specific recommendations include:

• Intersection spacings of 1,600 to 2,000 ft on urban primary arterials and 1,200 to 1,600 ft on urban secondary arterials.

• Frequency of direct access driveways:

FUNCTIONAL CLASS	URBAN	RURAL
Primary arterial	Major generators under specific conditions	2 per mile per side, farm residences and field drives only
Secondary arterial	1 per 200 ft of frontage	6 per mile per side
Collector	2 per 100 ft of frontage	No restriction on number
Local	No control	No control

• Separate right- and left-turn lanes should be provided on all intersections on urban primary arterials.

• Separate right- and left-turn lanes should be provided at all intersections on rural primary and secondary arterials.

• Driveway standards should insure that direct-access points are designed and constructed in a manner that will encourage proper use by the driver; specifically,

Long open (uncurbed) sections should be avoided.

Driveways to and parking areas on commercial properties should be paved.

Both the curb and gutter section should be removed when a curb cut is made.

A performance bond or deposit should be required to insure that the driveway is properly located and constructed in accord with approved design and construction standards.

• The driveway as well as the circulation/parking area in the vicinity of the curb cut should be properly maintained by the property owner, or such maintenance should be performed, at the property owner's expense, by the agency having jurisdiction over the street. If the area is not maintained, the driveway permit should be revoked.

• Medians should be provided on all primary arterials, both urban and rural.

• Minimum median width should be 14 ft at signalized locations. At unsignalized locations where left turns onto the arterial are permitted, the minimum median width should be 30 ft; at locations where left turns from the arterial only are permitted, the minimum median width may be 14 ft.

• Median openings that allow crossing traffic as well as left turns onto the arterial should be provided at public street intersections only. An exception may be at access points to large traffic generators where the access point conforms in all respect to the standards for the location (spacing) and design of intersections.

• All median openings should be of the "bullet-nose" design.

• Medians should be designed and constructed so as to prevent crossing except at designated points.

• The two-way left-turn lane should be restricted to use on urban secondary arterials and to existing primary arterials where there are frequent low-volume driveways and intersections; the minimum width should be 12 ft, and preferably 14 ft. Protected left-turn lanes should be provided at locations that have high left-turn volumes.

• Spiralized or three-centered compound curves should be used for the curb return at all intersections on primary and secondary arterials, both urban and rural.

CHAPTER ONE

INTRODUCTION AND RESEARCH APPROACH

Any complete street and highway system must provide the functions of both land access and traffic movement. Although limited demand for both types of service might be accommodated simultaneously on the same facility, increased demand in one type of service must be accompanied by reduced capacity for providing the other service, if efficient operation is to be maintained Typically, however, increased demands for through service are paralleled by increased demands for local service, with the result that neither can be provided effectively by the same roadway.

The continuing growth in economic activity and population is expected to result in increased traffic demands on major roadways in both urban and rural areas. In the rapidly developing urban fringe this increase is truly phenomenal. Because land access and through traffic movement are operationally incompatible, it has become increasingly necessary to separate these functions. That is, it is necessary to design, construct, maintain, and operate facilities that are exclusively or primarily for the movement of traffic, through the elimination or control of direct access points.

Failure to exercise adequate access and land development controls leads to an early functional obsolescence of major arterials. The sequence of events frequently has been observed as follows:

1. Construction of the new arterial changes the accessibility of the adjacent land and gives rise to increased land values.

2. Strip development along the arterial generates an increasing amount of local (land access) traffic. Owing to traffic growth and increased conflict between through and local traffic, congestion reaches intolerable proportions and the facility becomes functionally obsolete.

3. Because of the prohibitive cost of acquiring additional right-of-way and/or access rights along the existing facility, a new facility must be constructed on new location.

URGENCY OF THE PROBLEM

The urgency in the application of access controls on a systematic basis is pointed out by the forecast growth in population and projected urbanization. The population of the United States is expected to increase from the present population of nearly 205 million to 252 million in 1985. By the year 2000 the population is expected to exceed 300 million—a 50 percent increase in a scant 30 years.

Further concentration of the population in urban areas is also anticipated. In 1960, 60 percent of the nation's population resided in metropolitan areas; by 1985 the proportion is expected to exceed 70 percent; and by the year 2000 between 75 and 80 percent will live in urban places.

Furthermore, it is of importance to note that most of this urban population growth will take place in the suburban areas (*3*). Between 1960 and 1985 the growth in the suburban ring of Standard Metropolitan Statistical Areas (SMSA's) is expected to be 105 percent; total growth in the central cities and outside SMSA's is expected to be only about 12 percent. To accommodate this increase in population, extensive land area will have to be converted to urban use, and vast quantities of increased public services and utilities, including new arterial streets, will be required.

If suburban growth is to continue at a density of 2,600 persons per square mile, which was the average population density of suburban areas in 1960 (*15*), some 22,000 square miles of new development will be required by 1985 to accommodate the 58 million additional urban residents. By the year 2000 approximately twice that area would be converted to urban use. Approximately one-half of the total urban development in the nation, as well as redevelopment of sizable existing urban areas under the urban renewal and model cities programs, must be provided in the 30 remaining years of this century.

Decisions made in the immediate future will materially affect the form of our urban areas, including the type, nature, and future efficiency of each urban area's transportation system. Inasmuch as history has shown that major arteries of transportation have had extremely long life, access controls implemented on major arterials in the next very few years will determine the ability to serve traffic well into the next century, and perhaps beyond.

The over-all effect of such decisions can, of course, be expected to differ in the various regions of the nation, because different regions are expected to show varying absolute and relative increases in metropolitan population growth. As given in Table 1, western cities as a group are expected to experience the greatest relative increases in population; therefore, they will be adding greater proportions of their street systems in the years ahead.

It might also be observed that the public has registered ever-increasing expectations in both the quality and quantity of goods and services it desires, including transportation A case in point is Los Angeles. This urban area is often cited as the example of intolerable freeway congestion and the failure of auto-oriented transportation. Studies conducted by the Automobile Club of Southern California (7), however, indicate that although the metropolitan area has grown by phenomenal proportions, travel times in the peak hour have improved somewhat or have remained nearly constant. Off-peak travel times have decreased substantially. Similar effects, although not nearly so well documented, have been experienced in other urban areas. Nevertheless, criticism and complaint by the general public (as well as by vested interest groups) have greatly increased since the mid-1950's.

The point is: access controls that provide for levels-of-service that are acceptable in the 1960's may not guarantee acceptable levels-of-service a few years from now. How many members of the motoring public would be willing to return to the conditions acceptable a short 15 to 20 years ago?

TABLE 1

FORECAST OF METROPOLITAN POPULATION, BY REGION

REGION	POPULATION (THOUSANDS) 1960	1985	% CHANGE (1960-1985)
United States	112,884	178,138	57.8
Northeast	35,350	47,328	33.9
North Central	30,963	44,642	44.2
South	26,436	46,156	74.6
West	20,135	40,012	98.7

Source Hodge and Hauser (3)

PURPOSE AND SCOPE

As stated in the research Problem Statement:

> A need exists for guides in selecting the degree of access control for a specific project and for selecting the type, location, and width of median and median opening and the design and frequency of entrances to be associated with the degree of access control. Current practice represents wide variation in judgment, and indicates the need for better understanding of the functions and use of medial and marginal access control

The scope of this research as set forth in the contract is:

> The scope of the research should include the full range median and marginal control other than full control. The research should consider, but not be limited to. accident frequency and severity; cost of physical construction and right-of-way to accomplish access control; legal consideration; traffic patterns, service to the highway user, motor vehicle operating costs; travel time and costs; land use, convenience of access to abutting property; property values and provision for future needs for access control and for changing traffic characteristics, user requirements or land use.

Full control is considered in the study, however, in that it is the limiting condition for establishing a policy and standard for partial access control. The study considers the problems of access control at the policy or macroscopic level, as well as at the design and operations, or microscopic, level. The policy level problems include. the degree of access (frequency of direct access points) and the type of access (direct access drives, service roads, and access to major roadways via public roads).

At the design and traffic operations level, the specific questions of curb return radius, width of curb opening, horizontal and vertical alignment of the access drive, and the relationship between the arrangement of on-site improvements to the location and design of the direct access points are considered.

The research also considers both the user and nonuser implications concerning the type, degree, and design of access control. The highway user considerations include: motor-vehicle operating costs, accident frequency and costs, right-of-way requirements and costs, construction costs, traffic control, capacity, convenience to the motorists, and potential future changes in traffic characteristics.

The non-user interests in access control include: convenience of access to abutting property, property values and development, zoning and on-site development controls, trends in development patterns of major generators, safety, convenience, and integrity of adjacent development, and changing characteristics of abutting land uses.

Study Objectives

The general objectives of the research, as stated in the project contract, are:

1. Develop guidelines to enable the highway administrator to determine the appropriate degree of access control and the spacing, design, and location of access facilities and control measures and devices to accomplish the access control for the optimum benefit of the highway user.

2. Develop specific, quantitative guides for access control requirements and the physical means to accomplish such control, including geometric design of highway cross sections, entrances, medians and median openings, and the

optimal frequency and location of such medial and marginal openings.

Specifically, this research included:

1. Definition of the functions and uses of access control to the benefit of the highway user.
2. A review and evaluation of research related to this problem as described previously.
3. Development of specific guidelines for access control policies.
4. Review and evaluation of related representative current practices, their trends, effects, and acceptance.

RESEARCH APPROACH

Because of the interrelationships between transportation and land use, the research plan was developed to include the economic, political, social, and legal considerations that might affect the application and implementation of the access control guidelines.

Guidelines were to be directed at a general or national application rather than to be designed around the specific enabling legislation, court interpretation, and current practice in each, or any, of the individual states. Detailed review of these considerations for each individual state is outside the scope of this research.

The basic approach in the development of the guidelines was to identify the alternatives that might be reasonably considered and to then evaluate the consequences and relative merits of each. In many cases the absence of data in the necessary form or the inability to obtain quantitative measures necessitated a qualitative, rather than a quantitative, evaluation. Insofar as possible, the supporting information is appended to indicate the basis for the recommendations presented.

Information Sources

In the formulation of the research approach and in the preparation of the proposal it was decided that primary reliance for information should be placed on the literature, research reports, and other secondary sources. This was done with full knowledge that much of the information was not necessarily in a form that might be most directly usable for the specific purposes of the research. Furthermore, various sources were known to involve information that was not directly comparable.

Nevertheless, it was believed that a wealth of information did exist which could and should be used, even though some interpretation might need to be exercised in its application. This reliance on secondary sources was further motivated by the fact that extensive primary data collection was not possible within the time and funding limitations.

Primary data sources included the several highway departments, as well as individuals in other public and private agencies. The information obtained from most highway departments included:

1. The current organizational chart of the highway department, together with an identification as to where the responsibility for decisions on access control was located.
2. A copy of any written policy on access control and/or any departmental directives concerning practices and procedures followed in designating access control on facilities other than freeways.
3. A copy of the current design manual.
4. A copy of any regulations or policies and standards for direct access drives.
5. A copy of the legislative acts and/or interpretation of these acts under which the state highway department was presently designating access-controlled facilities.

Contacts were made with representatives of selected highway departments, counties, and cities. Selected private developers and other agenices having a major interest in access control were also contacted. These included: national oil companies, national motel chains, and regional shopping center developers. Because these agencies have widespread operations with centralized control, they provided a convenient means of obtaining an indication of the developer's viewpoint of access control. A great deal of unpublished information, as well as valuable reaction to various proposals concerning access limitations and design, was also obtained.

DEFINITIONS

This research is concerned with a problem that is of interest to many individuals, as well as to public and private agencies. Because terminology may differ slightly between different individuals or agencies, certain terms used in this report are defined as follows:

Full Control of Access is defined as no direct access driveways to abutting property and no at-grade intersections Traffic can enter and leave the through lanes only at designated on and off ramps at interchange areas. All crossing streets and highways, as well as railroads, are grade separated. Opposing traffic is separated by a median and/or barrier with two or more traffic lanes in each direction.

Partial Control of Access permits intersections with other streets and highways, as well as with railroads, to be at-grade; interchanges may be provided at intersections with some major roadways. Direct access driveways may or may not be permitted to abutting property. Where permitted, they are controlled with respect to spacing, location, design, and usage.

Primary Arterials are those streets and highways for which the principal function is movement. These facilities connect the largest and most important traffic generators or centers of development. They serve long-distance trips and characteristically carry high traffic volumes. Although these facilities might account for only 10 percent of the total street or highway mileage, they accommodate about 50 percent of the vehicle-miles of travel. This class includes facilities having full control of access.

Rural primary arterial highways connect the largest population and economic centers of the region.

Urban primary arterials connect the major centers of activity within the urbanized area. They provide accessibility to large concentrations of commercial and industrial development such as the central business district, large suburban commercial and office centers, major industrial areas, and residential developments of community size. Urban primary arterial streets are generally spaced at about 1-mile intervals in areas developed at average suburban densities in recent decades (2,600 to 3,500 persons per square mile); in areas of more intense development, spacings are at closer intervals.

Secondary Arterials have a predominant function of movement, although they also provide for some access. This class of street or highway distributes traffic to and from facilities in the primary class.

Rural secondary arterials serve the urban centers not served by principal arterial highways.

Urban secondary arterials serve areas of less traffic generation than those served by the primary arterials; such areas include neighborhood and community shopping centers, smaller industrial areas, and residential neighborhoods.

Collector Streets and Highways serve, equally, the functions of movement and access. They connect with the secondary arterials and with some primary arterials.

Collector streets in residential areas should serve as collector-distributors and concentrate traffic entering and leaving a neighborhood prior to intersecting with streets of a higher functional classification. To discourage their use by traffic not destined on originating within the neighborhood, they should not provide a direct connection through the neighborhood. They will provide direct access to churches, neighborhood shopping centers, neighborhood parks, and elementary schools.

Local Streets and Roads include all facilities not in one of the higher functional classifications. Their purpose is to provide direct access to individual abutting properties. They should provide traffic movement from the abutting property to a convenient collector when one end of the trip is outside of the immediate local area or neighborhood.

Guidelines are intended to provide a basis for implementing a stated procedure or meeting an objective. Guidelines are flexible and good engineering judgment is expected to be exercised in their use. *Standards,* on the other hand, are prescribed policy or practice from which deviation is not permitted without approval by the issuing agency or individual.

Urban Area is that area which can be expected to be in urban land use by some target date or design year. Hence, it includes that area which may be converted to urban land use within some future time period, in addition to that land which is presently devoted to urban uses.

CHAPTER TWO

FINDINGS

This chapter reviews the findings and conclusions on which the guidelines in Chapter Three are based. Additional detail and further discussion of individual topics appear in the appendices.

It is not possible to approach the planning and design of major roadways in isolation from the problems and influences of the adjacent properties and the community; nor is it reasonable to spend vast sums of public monies for streets and highways based exclusively on the needs and dictates of the present. Access control, then, should be exercised to preserve the traffic-carrying capacity and safety of public highways and thereby preserve the public investment. This control may be effected by acquiring rights of access from abutting property owners, by selectively limiting the number of approaches to a highway, by requiring that specific design criteria for access points be met, by limiting the use of an approach to particular types of vehicles, by limiting use of the driveway to a specific type of land use, or by a combination of these.

The public benefit that will result from the judicious exercise of such controls is evidenced by the fact that in the next 30 years the U.S. population residing in urban places is expected to increase from about 150 million to over 250 million. To accommodate this growth of approximately 100 million persons,* thousands of miles of new arterial streets will be required. Substantial improvements and additions to the intercity highway system will also be necessitated by the increasing propensity to travel on the part of the nation's population. If functional obsolescence of these new and improved roadways is to be avoided, coordinated and consistent access control practices will be needed.

PERMANENCE OF MAJOR TRANSPORTATION ROUTES

The history of overland transportation abounds with examples of facilities that have been successively upgraded to provide improved service to the traveler. The Michigan Road (between Michigan City and Madison) in Indiana, the Cumberland Road between Vandalia, Ill., and Cumberland, Md., and portions of the Old Spanish Trail through Texas are examples of old highways which have been adapted to changing needs and standards of service.

* Forecasts of the total U S population by the U S Bureau of the Census range up to 361 million, depending on the birth rate assumptions. The number of persons residing outside of urban areas is expected to remain nearly constant at just over 50 million. Hence, the growth in population residing in urban places might be as large as 160 million

The Michigan Road, which is now approaching 150 years of use, might be cited as an example An Act of the Congress dated January 29, 1830, providing for the opening of a part of the Michigan Road stipulated that. "all parts of the road, 100 feet wide, were to be cleaned off, leaving no stump more than one foot above the level of the earth; and grubbed 30 feet wide in the center of the road as the United States Road (Cumberland Road) was grubbed through Indiana" (*10*).

Continued use of this alignment by portions of U.S. 31 and U S 421 indicates the permanence of the route as well as the extent to which successive upgrading has been accomplished on an existing alignment. In fact, the obsolescence of such transportation facilities generally does not result from the excess demand of increasing traffic. Rather, it is an economic obsolescence that occurs because it is less expensive to abandon the old facility and to use an entirely new right-of-way when expansion of capacity and prohibition of access are necessary This is frequently the situation with the Interstate System where a new fully controlled access highway connects the same major terminal points as an existing route and is within the same general travel corridor as the old route. Indeed, it is often within a distance of the few hundred yards of the old facility.

The permanence of major urban arterials is also suggested by comparison of the present arterial system with an old street and highway map for almost any city All urban areas have substantial arterial street systems which have been in continuous service since the earliest days of the central city. Washington Avenue and Liberty Street in Houston, Texas, are but two examples of such permanence. These arterials are two of the five roads radiating from the original City of Houston (*21*). Their existence extends back to the earliest days of the city and they have continuously served as important transportation arteries since the 1840's Except for the recent addition of the freeway, urban street layout and design has changed remarkably little since the appearance of the automobile.

The more recent attention given to the potential of converting unneeded railroad right-of-way in several cities to the use of rail rapid transit or exclusive busways is a further example of the continued use of right-of-way under greatly changing conditions over long periods of time. The absence of unrestricted access rights along the right-of-way is the essential element that makes their conversion economically and practically feasible. Thus, it is believed that the investment in access control not only will prevent deterioration in the traffic-carrying capability of an arterial but also will provide for future flexibility in the use of the right-of-way by surface transportation.

It is expected that there will be a perpetual need for (and use of) the travel corridors, unless there is a wholesale abandonment of existing urban areas and the relocation of activities elsewhere; therefore, it is also expected that the controlled access streets and highways now being planned and constructed may be efficiently used by the motor vehicle as it may evolve over the years or perhaps by some other yet undeveloped mode of surface transportation.

SUMMARY OF CURRENT ACCESS CONTROL PRACTICE

Washington and Wisconsin appear to be making the most significant advances in developing and implementing access controls on a system-wide basis. Based on a study conducted by the Automotive Safety Foundation (ASF) (*1*), Washington recently adopted access control policies related to the functional classes in use in that state. This ASF study is the first "systems" evaluation of an entire state highway network for the purposes of developing access control guidelines.

Another significant aspect of current practice in the state of Washington is that driveway permits on the state highway system are issued under the condition that the property served by the driveway remain in residential use. This practice of limiting the driveway to a given land use/development is considered by the researchers to be a most significant and important element in the long-range control for the public benefit

Wisconsin has developed guidelines for the type and frequency of access related to the classification of the facility and design year ADT. These guidelines provide for higher type access control and less frequent spacings on higher class facilities.

Both Madison, Wis., and Indianapolis, Ind., have had considerable success in obtaining the financial participation of developers in the reconstruction of existing roadways which provide accessibility to new shopping center developments. This participation includes street improvements some distance from the development. Other cities require the developer to share in reconstruction and traffic control adjacent to a new development. New Orleans, for example, requires the developer to pay for the redesign, the installation of traffic signals, and one-half the cost of the street construction. Participation is not necessarily limited to the improvements in the immediate vicinity of the development, although this has been the general practice.

New Orleans has also recently passed an ordinance and implemented a procedure under which the developer must obtain approval of the driveway location prior to the issuance of a building permit. In Indianapolis, a developer must (after January 1969) submit a layout of the location of all proposed improvements including buildings, parking, and access points, with a request for a driveway permit. A similar practice has been followed in Madison since 1962.

Further description of these procedures as well as a review of certain design practices appear in Appendix G; a detailed discussion of driveways appears in Appendix F Summaries relating to driveways and medians are given in later sections of this chapter.

DEVELOPMENT TRENDS

Various trends indicated that changes are taking place in private development which are compatible with improved access control.* The larger and more progressive developers are becoming increasingly aware that maintenance of

* *The Community Builder's Handbook* published by the Urban Land Institute is an outstanding dissertation on the improved practices proposed and followed by many of the better developers in the U S

the traffic-carrying capability of the arterial street is in their long-run interest. Further, the accelerating application of improved site layouts and larger scale developments lend themselves to a smaller number of more adequately designed access points.

Trends in residential development are perhaps the most obvious in the general adoption of the concept of the "limited-access subdivision." Such design of residential areas eliminates direct access of individual residences to the arterial street. Also, the use of long block lengths and street layouts to discourage through traffic results in a preference for a limited number of collector streets intersecting the arterial bordering the subdivision. Spacings of 1,000 ft for other limited access subdivision designs and ¼ mile with more recent developments are common. See Figure 1.

Market changes are also taking place in the service station industry which result in a normal reduction in the frequency of access points. Minimum station sites have increased from 100 by 100 ft to 200 by 200 ft at present; at least some oil companies are considering a site 250 by 250 ft to be a minimum for station developments undertaken in the near future. Standard designs still use two driveways on each frontage, but a few stations have been developed which have a single driveway. If the "car care center" which several oil companies are now market-testing proves to be successful, fundamental changes in site, size, and layout can be expected.

Based on oil company forecasts, a threefold increase is expected in the number of vehicles entering and leaving an average station by 1985. Although there will be fewer access points for a given length of frontage with the larger station sites, this means that there will be a much larger number of vehicles using each access point. Changes in market structure and site requirements also mean that some marginal stations will be forced out of business, regardless of changes that may be made in medial or marginal access control.

Substantial change has also taken place in the motel industry (Fig. 2). The small motel which was dependent on "drive-in" traffic has given way to the large chains with their sophisticated reservation systems. These large motels are more concerned with accessibility, so that their clientele can conveniently find and reach the vicinity of the motel complex and be less dependent on direct access. Such motel developments rarely use more than two access points, and a single access point is not uncommon. Again, the result is a smaller number of driveways, each with a much larger traffic volume.

Figure 1. Examples of treatment of margin of limited-access subdivision bordering an arterial street. Access to the existing road (upper) was restricted by the developer of the residential area on the right-hand side. The houses along the left side have direct access. The arterial (lower) was planned and constructed in conjunction with the abutting development. Access points are at ¼-mile intervals; the median is of sufficient width to provide protected left-turn bays at access points to the subdivision.

Figure 2. Examples of change in the motel industry. The "Mom and Pop" operation (upper) which formerly dominated the motel scene relied on drive-in clients and thus required convenient and easy-to-find access points. In contrast (lower), the advertising potential of the greater size of the physical plant, the strategic location, and better signing reduce the relative importance to the motel operation of the location of the direct-access points. Here direct access is provided via the secondary street rather than the freeway or the major intersecting street. However, the proximity to the freeway does provide for good regional accessibility.

Growth in shopping center development has been nothing short of phenomenal as this marketing institution has established itself as the dominant organization in retail sales (Fig. 3). Centers having as much as 1 million sq ft of gross leasable area frequently operate successfully with only two or three main entrances/exits. These access points are, however, of a high type of design. Further, the entire site layout, including the location and arrangement of buildings, parking, internal circulation, and access points, are designed as a unit capable of conveniently accommodating large traffic volumes. Continued growth in the number and size of shopping centers will result in fewer but much higher volume access points.

Also, large shopping center developers, perhaps more than anyone else, are aware that the continued traffic-carrying capability of the arterial streets is essential to the long-run success of their development. These developers have shown an increased willingness to work with local officials in the location and design of the access points. Some also have indicated a willingness to contribute, in a substantial way, to the reconstruction of arterial roadways, even when the improvements are some distance from their development. For example, a developer of a shopping center in Madison, Wis., contributed $250,000 toward reconstruction of the arterial leading to his proposed development. The number, location, and design of the access points were worked out with local and state traffic engineering personnel. The developer of a proposed center in Indianapolis, Ind., signed an agreement to participate in reconstruction and other improvements to the extent of an estimated $1 million.

Figure 4 shows strip development along an uncontrolled section of a major highway.

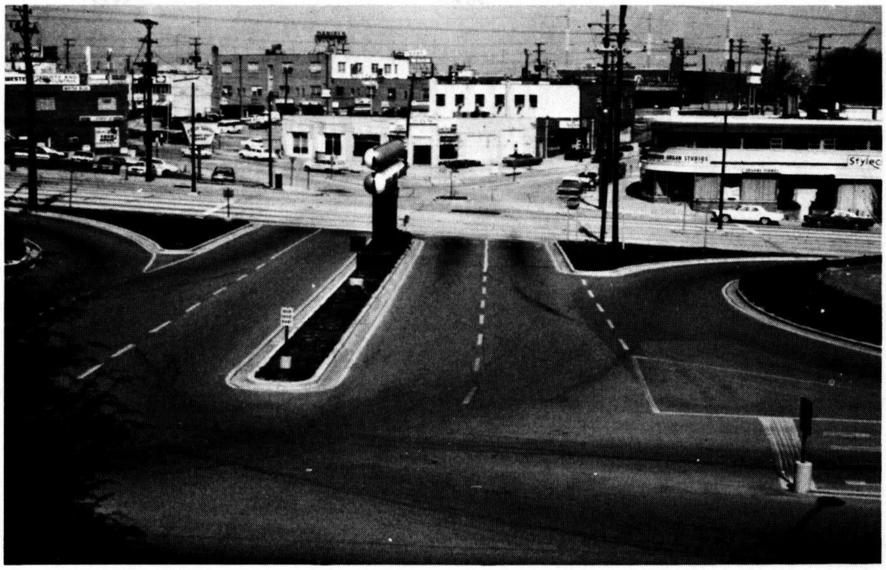


Figure 3. A well-designed access point to a regional shopping center. This access point to the Wheaton Plaza Shopping Center has separate right-turn lanes for entering and exiting vehicles; a median strip separates the entering and exiting roadways. This center contains 1 million sq ft of gross leasable area, two separate office buildings, and has only two such major entrances.

OFF-HIGHWAY CONTROLS UNDER THE POLICE POWER

Planning in the United States has its roots in the earliest days of the American Colonies; Williamsburg, Va. (laid out in 1699), is perhaps the best-known example of colonial town planning. By the 1800's, planning had sunk to an all-time low. Streets were typically laid out in a rigid gridiron with little regard to topography or open space, and speculation largely controlled the urban land market.

The near absence of planning did not present serious problems in the early 1800's, as the scale of urban development was very small. In 1840, the U.S. Census indicated only 12 cities with over 25,000 population and only three with populations over 100,000. The rapid urbanization and high density development of the mid-1800's led to the first attempts to regulate site development in the last third of the century. These ordinances restricted the percentage of the lot that might be covered by a residential structure.

Planning of the 1920's did not attempt to change the point of view that land is a speculative commodity; it simply imposed some "rules of the game." This philosophy, in large measure, continues to the present. In the past 40 years, planning has continued to undergo substantial change in attempting to adapt to the expanding problems of the large complex urban areas. The concept of employing planning to guide development in an orderly manner to optimize the use of land began to emerge in the 1930's. With the even greater pressures that will be generated by a rapidly increasing population and continued urbanization, it will be necessary to further extend the concept of planning and greatly improve the efficiency of its application. More effective use of zoning and development controls under the police power will be necessary.

Figure 4. Strip development along an uncontrolled section of a major highway. A bypass or new arterial that is constructed without access control frequently becomes a new location for strip commercial development. The result is a facility such as shown, which effectively serves neither the through traffic nor the local establishments. A new bypass recently was constructed to serve the through traffic at this location.

Zoning *

The Standard State Zoning Enabling Act of 1926 and the enabling acts of the majority of the states include traffic considerations. This relationship between zoning and trans-

* Because this research was nation-wide in character, it was not feasible to review numerous individual city ordinances. Rather, *The Law of Zoning and Planning* prepared by the most notable authority in the field, Arden H. Rathkopf, was used as the primary source of current zoning law.

portation was early recognized in decisions upholding ordinances that require off-street parking for certain land uses. Some courts have also recognized the purpose "to lessen congestion in the streets" in the denial of zoning changes. Such favorable action by the courts appears to be most frequent when traffic problems that may be expected to result from the intended land use have been clearly defined. To obtain broader consideration of transportation criteria in zoning, legislation is necessary in most jurisdictions. Nevertheless, zoning, as it has been traditionally applied, has three major shortcomings with respect to preservation of the traffic-carrying capability of major roadways. *

1 The criteria considered by the courts in determining the legal validity of zoning measures
2. The local administration of zoning ordinances.
3. The difference in the time horizon of land development and that of a major roadway.

Stanhagen (*14*), in his excellent review of the use of transportation criteria in zoning, states: "The criteria currently considered and relied upon by the courts in determining the legal validity of zoning measures do not seem broad enough to permit all zoning measures that are capable of promoting traffic and transportation objectives."

Stanhagen also suggests that legislative action, including an expanded statement of purpose in zoning, might lead to application of the law in a manner more responsive to transportation requirements. He further suggests that in those states where a clearer and more specific statement of purpose does not accomplish the desired result, a constitutional amendment directing the courts to consider such zoning laws liberally may be desirable.

The administration of zoning is properly a concern of local government; however, the fact that major roadways (both urban and rural) cross several local jurisdictions, each having a separate administrative structure for zoning, poses substantial problems in achieving continuity over any substantial length of roadway.

Further, local governing bodies or boards of zoning appeals are frequently more sensitive to the interests of individual property owners and developers than to the long-range public benefit. Variances are "routinely" allowed in many jurisdictions, contrary to the recommendations of their professional traffic engineering and planning staffs. This, in part, results from the nearly total lack of understanding by most local officials of the relationship between land use and transportation.

Unfortunately, many professional planners—especially those in small urban areas—share this lack of understanding concerning the traffic-generating characteristics of different land uses, different development patterns, and the effect on arterial streets. The recommendation for strip commercial zoning by some planners reflects this lack of knowledge. Further, coordinating the actions of the several jurisdictions through which a major roadway passes presents significant administrative problems. In some urban areas, the recent development of an effective Council of Governments (COG) has begun to alleviate this problem; continued improvement in the effectiveness of COG's presents considerable hope for the future.

However, there are numerous local jurisdictions (rural counties as well as some cities) that do not have zoning and in which the prospect for adoption of a zoning ordinance in the near future is dim at best. Obviously, some alternative is necessary in these cases to obtain compatibility between the capacity of the roadway and adjacent development It would seem that exercise of access design policy and standards might be a more feasible means of insuring the traffic-carrying capability of major roadways, even if legislative action is needed to achieve implementation.

The fact that the time horizon for land development is considerably shorter than that for a major roadway presents additional problems in the use of zoning alone to protect the highway. Whereas the economic life of some developments (such as service stations and drive-in restaurants) may be roughly 10 to 20 years, the economic life for the right-of-way of a major roadway is (or should be) essentially infinite.

Local jurisdictions often are moved by the prospect of immediate development for increasing the tax base by a modest amount, rather than by the longer-range development potential of the land adjacent to a new arterial. (Interestingly enough, this acceptance of immediate development frequently precludes more substantial, but later, development that would add significantly more to the tax base.) In many instances the immediate development is of a type that requires limited capital investment, uses small tracts of land, and desires a large number of access points. Generally, the development is unplanned and scattered, so that the possibility of requiring the developer to provide a frontage road or other access and internal circulation roads that might serve several individual businesses is limited.

A fourth shortcoming is that zoning-enabling legislation and ordinances have not kept pace with new concepts in urban development This problem is less serious than the three previously mentioned, for two reasons. (1) the needed changes do not run counter to the vested interests of developers; and (2) there is more awareness of the need for change and more "pressure" for such change. Designers and developers often are prepared to take a more creative approach to the environmental design of large-scale development consisting of several planned units on a single parcel of land than is permitted under the strict application of conventional zoning ordinances.

The Urban Land Institute has prepared a model state enabling act * and suggested ordinances that are designed to facilitate the use of new concepts in large-scale development. These and other changes are desirable so as to encourage larger-scale residential, commercial, or industrial development. These changes also should allow increased variation in the type of units that may be incorporated

* One of the strongest proposals that has been made as a result of the failure of traditional zoning to cope with the problems of rapidly growing urban areas has been made by Prof John W Reps In his paper presented at the 1967 annual meeting of the American Society of Planning Officials he states, "I suggest that virtually all land to be urbanized should come into public ownership and then be made available for development as needed, where required, and under conditions that will assure building only in conformity with public development plans"

* Legal Aspects of Planned Residential Development," *Technical Bulletin 52*, Urban Land Institute

within a large-scale development (e.g., mixture of low- and high-density residences) as well as mixture of land uses (e.g., residential and commercial) where the market for such development exists.

Finally, and perhaps most important, it must be recognized that zoning and planning are not interchangeable terms, although planning necessarily includes the use of zoning, the reverse is not true. Planning involves ordering of individual activities so as to serve the public good through the systematic development of an area. Zoning involves regulation of the use of property. Although the use of a property might be controlled so as to prevent extremely high trip generation, the solution to the problem equally involves the design by which access is provided to the street system. This includes not only the location of the access points but also the arrangement of the internal circulation system and location of the buildings.

An example may be given in relation to residential development. Zoning might be used to limit, in a very general way, the total number of trips generated in a geographical area by zoning the property for single-family dwelling units rather than high-rise apartments. The problem on the arterial street is only partially solved, unless subdivision standards are also employed to avoid direct access to each residence and provide for adequate local street layout and development.

As another example, a property adjacent to an arterial might be appropriately zoned commercial if the site layout is properly designed. Indeed, to have accessibility (as differentiated from access) to its potential market, commercial development must be located adjacent to the more important roadways. This suggests that on-site development controls such as subdivision standards for residential areas and comparable standards for commercial and industrial developments must be employed if the best interests of the public are to be served.

On-Site Development Controls

Building controls are in force in nearly all urban jurisdictions, and a building permit is required prior to beginning construction. Further, building codes cover a variety of design and construction items (e.g., allowable design limit for various construction materials, electrical wiring, plumbing).

Use is commonly made of other on-site development controls such as setbacks, minimum lot size, density (dwelling units per acre), height and bulk limits, and provision of adequate parking. In certain jurisdictions, architectural and aesthetic controls also are imposed and all proposed developments must be reviewed for compliance to the criteria set forth to preserve the character of the area. Limitation against the erection of permanent structures in areas delineated and zoned as floodplains is an even more severe (but accepted) control over on-site improvements. These restrictions are exercised under the "general welfare" provisions of the police power.

Subdivision regulations are a more recent method of control than is zoning and are presently accepted as appropriate and necessary by local government. These regulations control and guide the subdivider in the layout of the development of a parcel of land and provide for minimum design and engineering standards. Local ordinances also specify the procedures for submission of plans, plat preparation and recording, public hearings, and street dedication.

The subdivision standards implemented by subdivision ordinance generally include criteria on horizontal and vertical alignment of streets, maximum block length, street width, use of cul-de-sacs, intersection design, pavement standards, and other considerations relative to the design of residential areas.

Some subdivision ordinances specify that a performance bond be posted or that money be placed in escrow to assure completion of the subdivision in conformance with the adopted standards. Assurance that the improvements in the subdivision are properly installed might also be accomplished through the use of an occupancy permit procedure. This has the advantage of eliminating the expense involved with either the bond or escrow account.

These requirements, especially the subdivision control, establish a precedent for regulations controlling land development; however, it should be recognized that many subdivision ordinances and standards are badly in need of updating.

Restrictions related to traffic problems might be just as appropriately imposed with respect to other types of development. Certain jurisdictions, notably Madison, Wis., have begun to initiate requirements concerning the total development plan of a site prior to issuance of a building permit. Elements of the site development plan that are considered include: location of all structures, the layout of internal (on-site) circulation, and the location and design of access points. Consideration of the proposed development as a whole, rather than just the access points, should greatly facilitate the development of adjacent land in a manner compatible with the intended function of the roadway. Often relocation of a building or relocation of the access points and redesign of the circulation pattern will maximize the potential of the land parcel as well as minimize any adverse effects on the arterial.

The difference in access and internal circulation that is possible with different site layouts is exemplified by the two banks shown in Figures 5 and 6. Both occupy sites of approximately the same size, front on the same street, and have buildings of about the same floor area. Access to the one shown in Figure 5 is via the local streets. The driveway at the front of the building is to accent the front and is very seldom used; a planter of a different design might accomplish the same objective (it was reported that eliminating the drive and replacing it with a planted area is being considered). The long curb cut in the vicinity of the drive-in windows poses no traffic problem at present because of the extremely low volume on the adjacent local street. However, plans are in progress to relocate the drive-in windows and greatly reduce the length of this opening.

The firm that designed the bank shown in Figure 5 attempts to avoid direct access to the arterial, and a larger number of developments by the firm's clients share this feature. This demonstrates that competent professionals can be, and are, successful in showing clients that their best interests are not served by obtaining a large number of direct access points. Agencies responsible for the adminis-

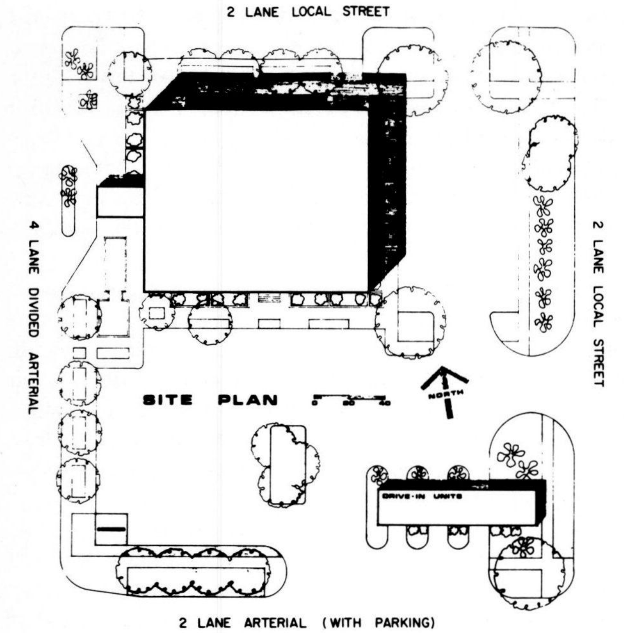


Figure 5. Example of a bank not having direct access to the arterial street.

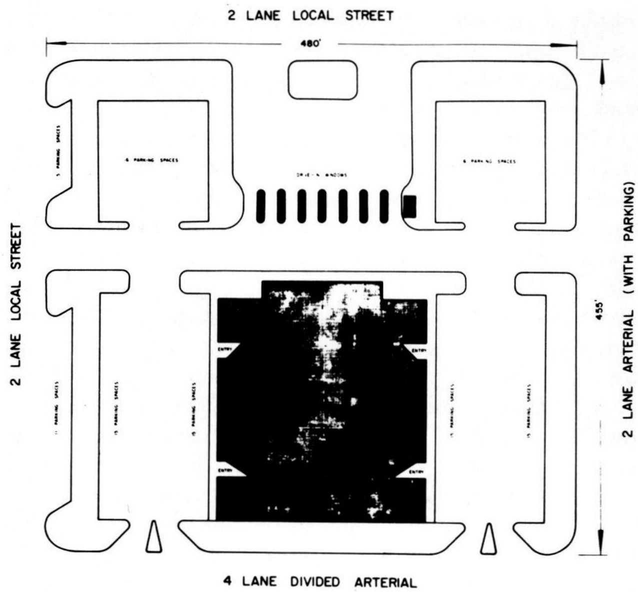


Figure 6. Example of a bank having poor access and internal circulation design.

tration of access control might use similar examples to considerable benefit in dealing with requests for curb cuts to arterial streets; if many highly successful establishments do not need this direct access, others should not.

Review of the entire site development plan means that the staff must work closely with the developer in any modifications. This, of course, will require more time on the part of the professional staff of the governmental unit having jurisdiction over the street or highway. The experience to date (again, notably in Madison, Wis.) indicates that the first few attempts are the most troublesome and time-consuming; however, once the value to the developer has been made clear and the new procedure has become established, the problems and time needed in working with the developers are greatly reduced.

Development controls are administered locally by the same body that administers zoning. Problems might be expected in those jurisdictions where there is no competent professional staff or where the "short range politics of the day" results in approval of plans and construction of improvements which obviously will cause future difficulties. Also, because such development controls will be exercised by the several units of local government, leadership will be needed to yield reasonably uniform and consistent treatment along an arterial roadway system.

To help do this, the highway departments will need to develop policies and standards, on a functional basis, that will serve the long-run public interest. The highway personnel should then work closely with the professional staffs of those local jurisdictions in obtaining development patterns along each roadway that are compatible with the function of the particular street or highway.

INTERSECTION SPACING

A detailed discussion of the analysis leading to the conclusions on intersection spacing is given in Appendix D. The vehicle operating and time costs used in the analysis are presented in Appendix A.

Some authorities have suggested that spacings of less than 1,000 ft are not capable of providing acceptable speeds of progression with reasonable cycle lengths.* Desirable speeds of progression on arterial streets require intersection spacings which are significantly longer than those commonly found in present street networks.

Although it may be necessary to operate arterials at lower speeds during peak hours (even at long intersection spacings), the majority of the traffic on arterials will move during the periods of lower volumes when speeds of 35 to 45 mph are common. If this large portion of the daily traffic is to be accommodated efficiently, intersection spacings must facilitate progression. Speeds of at least 25 mph and up to 40 mph should be provided for on secondary arterials; on primary arterials, desirable speeds might range from 30 to 45 or even 55 mph.

It is further necessary to accommodate fluctuation in volume, both hourly variations as well as changes in traffic volumes over a period of years. This necessitates maximum flexibility, because traffic forecasts are not of sufficient accuracy to provide information for detailed design. Further, the spacing of signalized intersections, once established, is not easily changed, and the existence of the arterial and the intersections will continue well beyond the normal traffic forecast period of 20 years.

Intersection spacings, then, should provide for the maximum range in cycle length and speed progression and tim-

* Herbert J. Klar, "Traffic Signalization," Chap. 11, *Traffic Engineers Handbook*, 3d ed. (1965) p. 396.

ing plan. The spacing also should provide for the lowest reasonable total road user cost.

The total road user cost for vehicles on an arterial will decrease with increased intersection spacing; however, the cost decreases at a decreasing rate and further reduction in cost is negligible beyond some particular intersection spacing. As shown in Figure 7,* the estimated total daily road user costs approach a constant value at signalized intersection spacings of approximately 1,000 ft at a volume of 4,000 vehicles per lane per day and 16,000 ft at 6,000 vehicles per lane per day. (Interpolation may be used to estimate the costs at volumes of 5,000 and 7,000 vehicles per lane per day.) The cost continues to decrease somewhat for spacing beyond 2,000 ft at daily lane volumes of 8,000 vehicles; however, such volumes are extremely high and are considered to be the limiting volume condition.

It might also be observed that the range in total user cost at different speeds of progression decreases with increasing intersection spacing, especially at the lower traffic volumes. A narrow range indicates that there is little penalty, in terms of user cost, incurred by using different timing plans to accommodate difficult traffic conditions (i.e., longer cycle lengths will lower speeds of progression in periods of higher traffic volume).

Considerations of signal timing and user costs indicate that spacings of signalized intersections should be at least 1,600 ft on primary arterials. Spacings much longer than 2,000 ft are probably not appropriate, in general, for the following reasons:

1. On an arterial having intersections at-grade, traffic volumes are not likely to be high enough to produce further reduction in user costs.
2. For a given number of turning vehicles, the longer the intersection spacing, the larger the volume of turns that must be accommodated at any intersection and, hence, less green time may be available for through movement with any cycle length and multiphase operation.
3. The average spacing between parallel arterials would become excessive or the opportunity for intersecting streets of lower functional classes would be unacceptable. For example, with two intermediate intersections with secondary arterials or collectors at a 2,000-ft spacing, the primary arterials would have to be spaced at 6,000 ft.

Considering that traffic volumes on secondary arterials generally will be lower than on primary arterials (or that a lower level-of-service may be acceptable), it is recommended that intersection spacing on secondary arterials be 1,200 to 1,600 ft.

Economic Implications of Intersection Spacing

Conclusions relating to the economics of intersection spacing in regard to vehicle operating costs and time savings are presented previously. The analysis does not attempt to distinguish between the outlays required for different spacings and signal systems. It may be supposed, however, that the fewer intersections and signal devices due to increased spacing might result in lower costs. On the other hand, greater spacing may require more expensive designs for each intersection.

In regard to road user services, the recommended intersection spacings should have no important effects. Some fewer shopping options may be available, but there should still be ample ones to meet motorists' needs. One might expect that circuity of travel should not be an important result unless fully controlled access is used.

However, there are viewpoints other than those of the road user and of the public expense. Because the spacings recommended are longer than those ordinarily found today, there are economic implications for nonusers. These include owners and occupants of abutting as well as nonabutting lands in the area or corridor.

Abutting property owners and occupants may be affected if fewer corner locations (than would otherwise be available) resulted. The fewer corners that would exist would have a tendency to be more valuable. Midblock locations may show less value (than otherwise) if their increased numbers are not offset by an increase in demand for such sites; however, to the extent that greater intersection spacing increases the long-run capacity of the arterial, the land and its improvements might enjoy a more stable and longer economic life in the selected uses. All in all, the cumula-

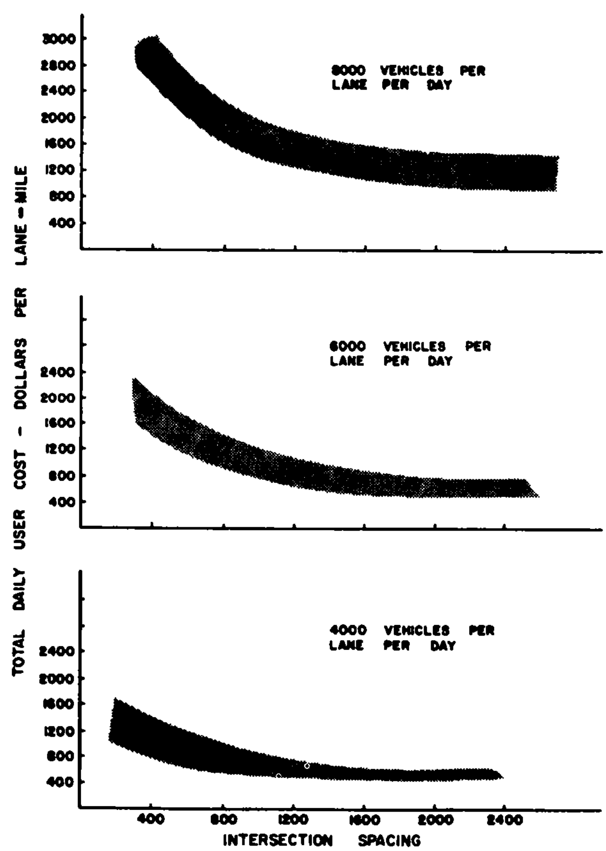


Figure 7. Envelope of total daily user cost per lane.

* This figure is a simplified version of Figure D-9 The cost at particular combinations of speed and signalized intersection spacing protrude outside this envelope curve This suggests that some care should be exercised so as to avoid using certain spacings Fortunately, these points generally do not occur at spacings of even 100 ft, however, in some cases where a desired spacing cannot be achieved because of local conditions, a shorter rather than a longer spacing (or vice versa) should be used.

tive value of all abutting property probably would be largely unaffected by the longer (or for that matter, shorter) intersection spacing. The location of high-value (priced) parcels would, however, be affected.

Nonabutting owners and occupants will be benefitted to the degree that the service by the arterial is improved and its high level-of-service life lengthened. Other things being equal, the preservation of general accessibility of nonabutting properties enhances their long-term value.

Further, the longer spacings recommended in this section are by no means adverse to current trends in business activity. There is a strong indication that service stations, for example, will become much larger and relatively fewer, even with present transport technology. Such potential advances as steam-powered automobiles (or other far-reaching innovations) would fundamentally affect the pattern of automotive services in a manner that cannot be practically predicted. Yet, the same basic street and highway system would (indeed, must) serve these future vehicles

Large shopping centers should have little difficulty in adjusting to greater intersection spacing Smaller centers may be forced to locate where street patterns allow good circulation. Other retail business outlets seem likely to continue to aggregate in "unplanned" shopping complexes. These activities must seek locations where good circulation is or can be provided.

It is possible that, in some instances, land development (subdivision) costs in adjacent areas will be increased by greater intersection spacing, however, such spacing is also in keeping with current superblock concepts of city planners and progressive developers.

There are no known empirical data which bear on these postulated effects of intersection spacing. It seems likely, however, that in most instances the recommended policies will not be a critical or limiting factor in land use or land values. Their predominant effect will be to bring about a reorientation of economic activity from the erstwhile pattern in a traffic corridor. The major trade-offs will be between short-run abutter interests and long-run interests of some abutters, nonabutters in general, and the road user.

Legal Aspects of Intersection Spacing

A longer spacing for intersections, whether accomplished by street closings or denial of petitions for new openings, has a bearing on both access and accessibility of land. The taking or denial of direct access through intersection control falls in the same legal framework as that described subsequently for driveways. The impairment of general accessibility is a somewhat more complex subject and it is likely to be the major point of any legal controversy over intersection closing and spacing.

The national experience with the System of Interstate and Defense Highways has shown that under one rule of law or another, the states have authority to exercise full control of access to highways. One aspect of such control is the elimination of and, similarly, the refusal to permit, intersections. In 1963, specific statutory authority to close intersections was held by 41 states, and four states had other specific legal provisions for such control. The consent of the state to open new intersections was a specific statutory requirement in 37 states (*11*). It is not known to what extent this described authority is restricted only to roads designated as limited-access roads. In other words, intersection elimination or denial on highways in general is not necessarily authorized by statutory authority.

It would appear, however, that most states have a general regulatory authority to restrict access between roads even when neither is designated as limited access. Certainly, the precise placement and the design of intersections can be used to promote safety and more efficient traffic operations. More severe restriction, however, may require additional legislation in most states. If frontage roads are constructed (as on primary arterials), there should be no difficulty in legal authority regarding access.

In summary, as Netherton states: ". . . It may be said that on principle the right of access is not destroyed or compensably damaged by changes in the highway which require more circuitous travel in its use" (*11*, p. 160). To hold otherwise would, in effect, concede to abutters the right "to perpetuate the original physical design and structure of the adjacent highway" (*11*, p. 161).

MEDIAL CONTROLS

The traffic engineer has generally had more effective control over design features and traffic operational controls within the limits of the traveled way than at the margins. Nevertheless, uniform guidelines for the installation of median barriers, spacing of median crossovers, and the design of median openings have not been developed. Further, the literature lacks detailed data that might be used in a completely quantified justification for all elements of medial control. However, current practice and the available literature,* together with the experience of practicing traffic engineers (evaluation of implemented designs and/or controls, which are by and large unreported), do provide a basis for recommendations.

Median Width and Design

Where medians are provided, they should be of sufficient width to "shadow" any left-turn or crossing vehicles. Priest (*19*) has shown the value of having a median of sufficient width to "shadow" a vehicle on a major roadway. Accident frequency was shown to increase significantly with narrower medians at higher values of an exposure index (a measure based on arterial ADT, cross street ADT, and the exposure time of a crossing vehicle).

When a median is installed, it should be designed and constructed so that vehicles cannot easily or comfortably cross it. The location shown in Figure 8 has a "rounded" median strip that is about 2 in. high at the center. Such a median can be crossed easily without discomfort; consequently, there is a high volume of left turns into and out

* The 1963 report, *Traffic Control and Roadway Elements Their Relationship to Highway Safety*, prepared by the Automotive Safety Foundation, is still the most complete summary on the subject of medians under one cover A revision of this document is now being prepared and issued in sections, the section dealing with medians is expected to be available in the summer of 1970.

Figure 8. A median divider that is comfortably and frequently crossed. This median had been in place about 1 yr when the photographs were taken; deterioration of the light-colored median surface indicates that turning vehicles maneuver across a substantial section (more than 150 ft) of the median. The lower photograph shows the extent to which crossing vehicles encroach on the traffic lanes while waiting for oncoming traffic.

of a driveway to a small community shopping center just off the left center of the photograph. It is literally impossible to prevent left turns across such a median with any realistic degree of police enforcement.

Median Openings

All median openings should be designed to provide a natural path for the maneuvers to be made at that location. Evidence that drivers prefer and take a noncircular path, when possible, is demonstrated at numerous locations such as those shown in Figure 9. This strongly suggests that where left turns are from and to the divided roadway, a "bullet-nose" design should be employed. This design is superior to the circular end treatment of a median in that the more natural path facilitates the maneuver at a higher speed with less or no encroachment on the adjacent lane.

Where median crossings are provided, the two parallel roadways should be approximately the same elevation—particularly if the median crossing is to accommodate substantial volume of traffic or is likely to be signalized. Maximum differences in roadway elevations for different median widths are given in Table 2. It may be noted that these maximum differences are not especially large even though a vehicle stopped on the crossover (with the front bumper 1 ft from the outside edge of the traffic lane) would be on a grade of 5 percent. With the vehicle "sitting" at a more desirable grade, the differences in elevation would, of course, be substantially less.

Where the median is of sufficient width, greater application of the New Orleans "U-turn" practice for accommodating left turns might be considered. Under this procedure, "left-turning" vehicles pass straight through the intersection, make a U-turn through a median opening, and then make a right turn at the intersection to travel in the desired direction.

The absolute minimum median width for this type of operation is 24 ft (equal to the turning radius of the design passenger car) to allow the vehicle to begin the turn from the inside traffic lane. If this U-turning vehicle is not to interfere seriously with through traffic, a turn bay should be provided in the same manner as for a conventional left turn. The minimum median width for application of this technique with an arterial on new location is therefore 36 ft.

Two-Way Left-Turn Lanes

Where it is necessary to accommodate left turns to and from adjacent driveways, the two-way left-turn lane might be employed. In recent years this operational technique has been used with success at various locations throughout the

Figure 9. Circular end treatment of median openings. On this newly opened facility near Indianapolis (upper), the paths of vehicles turning left from the right-hand roadway to a local gravel road to the left of the photograph follow a natural spiral using a portion of the median outside the portland-cement-paved median crossing. In this instance the median has an asphalt surface so that erosion of the median surface will not be a problem (unless, of course, the repeated wheel loads cause breakup of the asphalt surface). Median crossings on Airline Highway (lower) have circular end treatment at median openings. Left-turning vehicles entering the northbound roadway follow a natural path across the grassed median; although the gravel surface is rough, it is the preferred path.

United States. Where there are numerous driveways along one or both sides of the street, with a relatively low volume using each driveway, it appears to be a very useful technique. Where it is necessary to operate a separate left-turn phase on minor movements at an intersection, a left-turn lane may be delineated by striping or, preferably, by a low, rounded, painted asphalt strip.

However, the two-way left-turn lane should not be contemplated for arterials on new location. Rather, access control, together with planning and zoning controls, should be employed to obtain development patterns that would not involve frequent direct access driveways.

Spacing of Median Openings

Median openings at locations other than signalized intersections on divided roadways, in both urban and rural areas, should be provided only when there is sufficient room to completely "shadow" the longest vehicle expected to use the opening. This will generally mean that the median be at least 20 ft wide—preferably 25 ft or wider—where left turns to and from the divided roadway are to be accommodated and/or where there is traffic passing directly across the divided roadway. This will allow a vehicle to cross the nearside roadway and then stop in the median before entering or continuing across the farside roadway. If trucks commonly use the median opening, substantially greater median width (at least 60 ft) will be necessary.

In some unique situations where there are only left turns from the arterial to an intersecting street and right turns back onto the arterial, an opening on a median width of 14 ft would be permissible. Any such opening must be designed so that left turns onto the arterial, as well as crossings, are physically prevented. Wherever left turns are to be permitted through a median opening, a protected turn lane must be constructed in the median. This will enable turning vehicles to complete the turning maneuver with a minimum of interference to traffic in the through lanes. The length of the protected turn lane must, of course, be sufficient to allow an acceptable deceleration and to store all turning vehicles. The storage length is, of course, a variable depending on the number of vehicles expected. Thus, median openings might be provided at spacings no shorter than the sum of the length of the turn lane (including the taper) plus an acceptable distance between the median opening and the beginning of the taper of the next downstream turn lane.

Accepting a 10-mph differential between through and turning traffic at the beginning of the taper and a deceleration rate of 8 ft/sec/sec yields the values shown in Table 3 for minimum distance between median openings for urban areas.

This would indicate that on an arterial street operating at 45 mph in off-peak periods and where the maximum queue length of waiting left-turn vehicles is only two cars, the spacing of median openings should be no less than 670 ft; at 55 mph the distance would be 910 ft. Therefore, with the intersection spacing desirable on primary arterials, one intermediate median opening is the maximum that should be used. Where U-turns are to be accommodated through a median opening, two openings would, of course, be required; however, there would be only one opening serving traffic from each direction. There should be no direct access driveways in the vicinity of a U-turn median opening.

TABLE 2

MAXIMUM DIFFERENCE IN ELEVATION OF DIVIDED ROADWAYS [a]

MEDIAN WIDTH (FT)	MAX. DIFFERENCE IN CENTERLINE ELEVATION (FT) [b]	RADIUS OF CONNECTING VERTICAL CURVES (FT)
20	0.9	100
25	1 2	125
30	1.5	200
40	2.0	200
50	3.0	200
60	4.0	200

[a] Maximum allowable effective grade of 5 0 percent, plus or minus, for a vehicle stopped on the median crossover, front bumper assumed to be approximately 1 ft from the outside edge of the traffic lane. Maximum grade at steepest point on the crossover not to exceed 10 percent

[b] To nearest 0 1 ft.

DIRECT ACCESS DRIVEWAYS

Control of direct access may be viewed at two levels. At the macroscopic level, concern is centered mainly around the frequency and the magnitude of the interference resulting to through vehicles from vehicles using driveways. Control at this level deals with the frequency or spacing of access points and the requirements for their operation. At the microscopic level, access control is concerned with specific design elements of access points. These include turning radius, profile, angle, and width.

Providing control over direct access to a major roadway for the optimum benefit of the road user requires that the frequency and severity of interference to main stream traffic incurred from vehicles using the access points be minimized. Although much work remains in quantifying the effects of access conditions on the level-of-service provided to through traffic, a number of general conclusions can be drawn regarding the effects of driveways on the interference to vehicles in the through lanes.

Traffic Considerations

Frequency of Access Points

It has been suggested that the number of driveways, rather than the absolute volume of access traffic, poses the greater threat to the safety and traffic-carrying capacity of the roadway (*9*). Major and Buckley (*8*, pp. 206-228), furthermore, have indicated that considering the delay to entering vehicles and the ability of the traffic stream to absorb vehicles exiting from driveways, additional driveways at close spacings provide no additional benefit and may increase traffic hazard. For high-volume traffic generators, however, driveways spaced at distances of greater than 1.5 times the acceleration distance of the normal vehicle will reduce delay to vehicles entering the traffic stream and will improve the traffic-absorption characteristics of the stream.

Frick (*4*), in his comparison of traffic operations for two major streets (MacArthur Boulevard and Stevenson Drive) in Springfield, Ill., has reported more uniform speeds and smoother flows for Stevenson, the street with greater restriction of direct access. The more frequent midblock turning maneuvers on MacArthur, together with more frequent signalized intersections, were considered to be largely responsible for the higher rate of rear-end accidents on MacArthur (640 per 100 MVM) than on Stevenson (181 per 100 MVM).

It would, therefore, appear that at least for major roadways where service to through traffic is the prime consideration, the fewer the number of driveways used to provide

TABLE 3

MINIMUM DISTANCES BETWEEN MEDIAN OPENINGS

ARTERIAL SPEED (MPH)	MINIMUM DISTANCE (FT) ABSOLUTE MINIMUM [a]		DESIRABLE MINIMUM [b]
25	140	Plus 25 ft per car to be "stored"	390
30	190		370
35	240		460
40	300		530
45	360		670
50	430		780
55	510		910

[a] 8 0 ft/sec² deceleration rate with 10 mph deceleration in through traffic lane.

[b] 6 5 ft/sec² deceleration rate with no deceleration in through traffic lane.

access to abutting property, the better will be the operation. Exceptions include very large traffic generators where several driveways are needed to furnish sufficient capacity. The use of separate entrance and exit driveways in lieu of a single two-way driveway may also be frequently desirable.

Operation of Traffic at Access Points

For any given driveway, the interference to through traffic caused by ingress and egress maneuvers will depend on the speeds of both the through vehicles and the turning vehicles, the turning paths, and the volumes of through traffic. Driveway alignment and width sufficient to prevent encroachment of turning vehicles on adjacent lanes of the roadway must be provided if interference to more than one lane is to be avoided. In addition, the site layout should be carefully integrated with driveway location and design to provide for adequate sight distances, ample on-site circulation facilities to discourage the use of the adjoining street by circulating vehicles, enough storage to accommodate queues at service units (i.e., drive-up bank tellers, mail boxes), and sufficient restraint to prevent unparking by backing into the street or haphazard parking which may block or restrict ingress or egress movements. Driveway profile, together with other geometric elements of the driveway, should permit and encourage the driver to use the driveway at the highest speed consistent with roadway characteristics and the land use served.

To quantify the effects of driveway entrance speed * on the interference incurred by through traffic, driveway entrance maneuvers along freeway frontage roads were studied by use of aerial time-lapse photographs. The analysis was then extended by simulation of a variety of traffic and access conditions. This analysis is discussed in greater detail in Appendix F. Interference was measured in terms of the delay incurred by individual vehicles while decelerating (and later accelerating to the original speed) to conform to the speed reduction imposed by the turning vehicle.

On the basis of the simulation analysis, the curves in Figure 10 show the ratio of total delay to vehicles in the traffic stream to the number of driveway entrance maneuvers for varying entrance speeds and through volumes. These curves indicate that for volumes and speeds (45 mph) typical of major urban roadways, the interference decreases rapidly as driveway entrance speed is increased to 10 mph. For the increase from 10 to 15 mph some additional reduction in interference is obtained, but, with further increases, the change in level of interference is negligible. It would appear, therefore, that design entry speeds for driveways along major urban roadways should be at least 10 to 15 mph.

For higher operating speeds characteristic of the through lanes on rural and certain urban roadways, the interference resulting from driveway maneuvers can be expected to be greater. However, the accident potential can also be expected to increase in relative importance for higher speeds. Solomon (*13*) has shown a correlation between the incidence of rear-end, two-car accidents and speed differentials on rural highways which indicates a significant increase in accident potential with speed differentials above 10 mph. Although driveways that provide for entrance speeds within this 10-mph differential may frequently be impractical, there does appear considerable justification for using a design entrance speed as high as practical (more than 15 mph) for rural and other high-speed urban roadways. In many instances, however, high-speed entrances in rural areas can be provided simply by the use of deceleration lanes or paved shoulders.

* The driveway entrance maneuver refers to the movement of a vehicle from the through lane onto the driveway of an abutting property. The entrance speed is taken as the component of the speed of the turning vehicle in the direction of the roadway at the instant the vehicle clears the roadway.

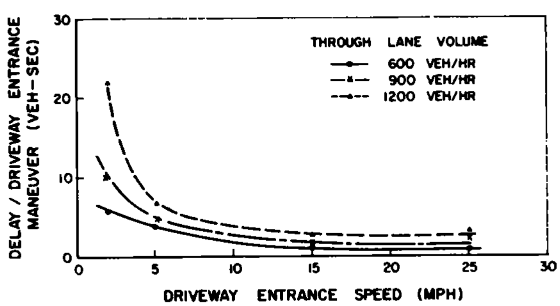


Figure 10. Relationship between delay and driveway entrance speed.

Driveway Accidents

An alternative approach to the development of driveway design standards is the correlation of design elements with accident rates. Box, in his study of accidents in Skokie, Ill., has reported that 11 percent of the city's total accidents were accounted for by accidents at driveways. Of these accidents, approximately two-thirds involved left turns into or out of driveways.

For major roadways, with which this discussion is principally concerned, however, safety is only one measure of the relative merits of a particular set of access control policies and standards. Indeed, conflicts and interference resulting from poor or inadequate control of access may have reduced the efficiency and even the safety of the roadway to an unsatisfactory level long before the poor operation is reflected in statistically significant accident rates. Furthermore, potential conflicts which account for much of the accident hazard are also those conflicts to which other inefficiencies of the traffic stream can be attributed so that, if these inefficiencies are corrected, many of the accident hazards will be also.

It would therefore appear that, at least for major roadways where the efficient movement of traffic is a primary consideration, reliance on accident rates to provide sound criteria for control of access is not likely to yield completely satisfactory results. Use of accident data is further complicated by the dearth of information providing the necessary correlations between design elements and potential hazards.

This is not to say that accidents should be ignored. Certainly, in many cases (i.e., residential subdivisions, low-volume rural highways) safety is the main concern; however, for major roadways, design criteria are more appropriately assessed on the basis of efficient movement of through traffic, complemented by findings relative to the safety of operation.

Existing Access Control Practices

A brief survey of current driveway location, design, and construction practices provides evidence that, in many cases, the flow of through traffic along major roadways suffers from poor access controls. Several examples are shown in the figures herein. The urgency of the problem is emphasized by the fact that most of these driveways have been constructed within recent years and that, throughout the U.S., driveways with these same defects are still being built.

One of the critical problems with regard to open frontage along commercial developments (Figs. 11 and 12) is the continuum of access points and the large number of conflicting maneuvers which results, not only between roadway vehicles and driveway vehicles but also between vehicles circulating within the facility. The severity of sight restrictions caused by vehicles parked too close to the edge of the through lanes is shown in Figure 12.

Restrictive driveway widths, return radii, and angles require short turning radii and restrict the speeds at which vehicles can enter or leave the traffic stream. Figures 13 and 14 show evidence of encroachment by turning vehicles on unpaved areas adjacent to the roadways. Such encroachment results when the desired turning speeds cannot be accommodated within the geometric limits of the driveway. Greater disruption to the flow of through traffic would be expected along curbed roadways as a result of greater encroachment by the turning vehicle on the adjacent traffic lane, lower turning speeds, or both.

Abrupt changes in grade also force vehicles to enter or leave driveways at low speeds. The driveway profile shown in Figure 15 is so severe that the vehicle is forced to cross the curb line at an angle to avoid dragging the rear bumper. The severity of the profile at the shopping center entrance in Figure 16 is evident from the jounce of the vehicle shown entering the driveway. By depressing the back edge of the sidewalk (which had recently been reconstructed) to a level

Figure 11. Open frontage along a commercial development.

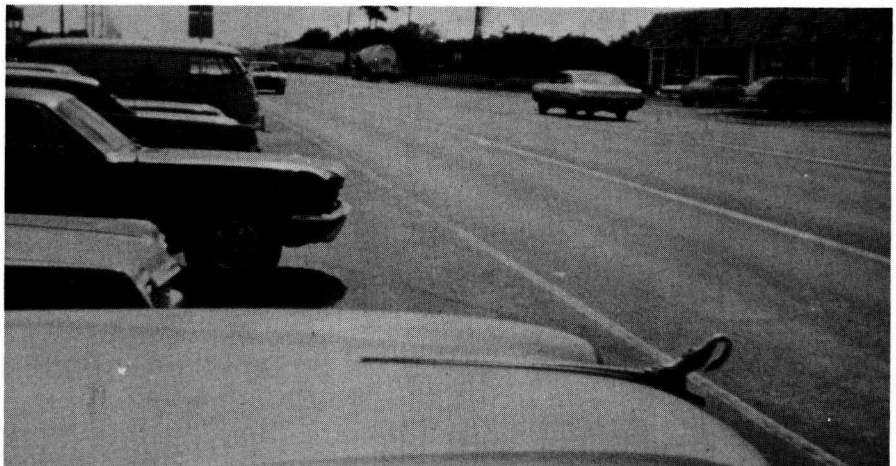


Figure 12. Restricted sight distance due to improper parking at commercial development with open frontage.

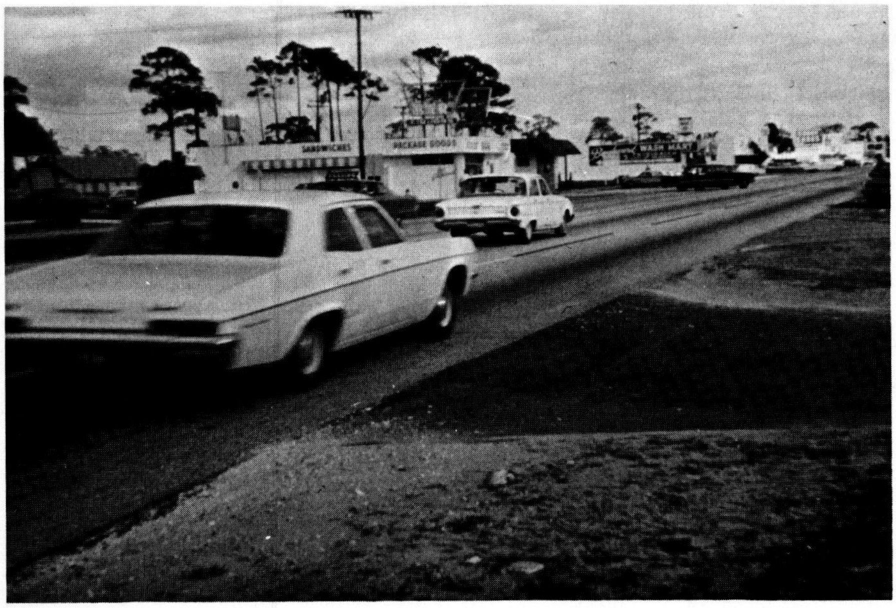


Figure 13. Encroachment on unpaved area adjacent to driveway to apartment development along primary arterial.

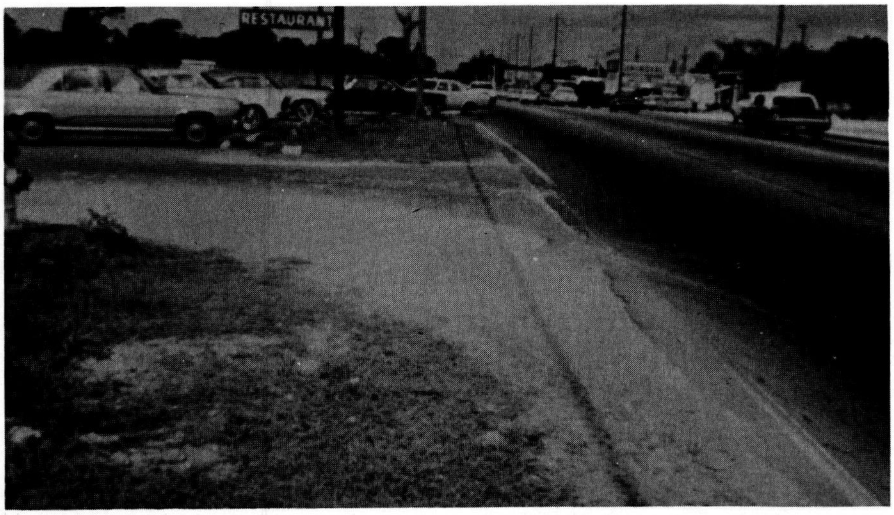


Figure 14. Encroachment on unpaved area adjacent to driveway to restaurant along primary arterial.

equal to or below that of the original driveway surface, a much more satisfactory profile could have been provided for this driveway.

Unpaved and poorly maintained driveways may also lead to excessive interference to through traffic. As shown in Figure 17, unpaved commercial driveways tend to become very rough, requiring extremely low speeds for vehicles entering or leaving the roadway. Potholes and spalling (Figs. 18 and 19) result from poor construction and maintenance practices and also force poor driveway operation.

Another category of problems that has a marked effect on the operational efficiency of the driveway is related to the driveway spacing, corner clearance, and site layout. Except where driveway volumes are very low, driveways in close proximity should be located far enough apart so that simultaneous ingress and egress movements can be accommodated without conflicting with each other. Corner clearances should be great enough so that vehicles entering or leaving the driveways do not conflict with other vehicles which may turn at the corner after the driveway vehicle begins the maneuver. Corner clearances also should be sufficient so that queueing at the intersection does not cause excessive blocking of the driveway.

Figures 20, 21, and 22 show a dry cleaning-drug store

Figure 15. Extreme driveway profile along residential street.

Figure 16. Adverse driveway profile at major entrance to regional shopping center.

Figure 17. Unpaved commercial driveway.

Figure 18. Potholes along curb line of poorly maintained driveway.

Figure 19. Spalling at driveway due to poor construction practices in making the curb cut.

establishment at the intersection of a major arterial and a two-lane collector street. Although adequate parking facilities are provided in the rear, the shallow parking lot in the front and the wide curb opening encourage unparking vehicles to back into the street. As shown in Figure 20, even under moderate through-traffic volumes, queueing at the intersection results in partial blocking of the driveway due to the limited corner clearance.

Along the collector street, the exit to the drive-in service window has a corner clearance of approximately 25 ft. Vehicles making left-turn exits from the driveway (Fig. 21) must cross the left-turn lane (because right turns at the intersection are the principal movement). Even for vehicles making right-turn exits from the driveway, the likelihood that the driveway vehicle will interfere with vehicles turning at the intersection is high because of the limited corner clearance. These problems are further compounded by the haphazard circulation on the site and by the very restrictive turning radii.

A problem common of many drive-in restaurants is shown in Figure 23 where access to the drive-in facilities is provided by one driveway on each side of the restaurant. Vehicles making multiple passes through and around the restaurant while looking for a place to park must reenter the through lanes to complete the circuit. In the same city the same restaurant chain provides a more satisfactory treatment for the restaurant in Figure 24 with only one access point for the drive-in facilities which are located completely behind the building.

Failure to provide continuation of driveways into the parking lots of major traffic generators, such as regional shopping centers, is another frequent problem area in driveway design. Figure 25 shows the haphazard maneuvers, congestion, and potential conflicts both within the parking lot and at the street, which result where traffic converges on and diverges from a point very near the opening of the driveway into the street. By extending the driveway into the parking lot (Fig. 26) a much more orderly flow of traffic within the parking lot is encouraged, and, if congestion does occur, it has been moved well away from the roadway, providing for free ingress and egress movements with a minimum of disruption to the flow of through traffic.

In rural areas along roadways with narrow, fenced rights-of-way, gates should be set back from the roadway far enough to store vehicles between the shoulder and the gate. Designs such as that shown in Figure 27 provide for such temporary storage. In the design of such entrances, however, care must be taken to insure that the fence does not restrict sight distance.

Economic and Legal Considerations

Economic Implications of Driveway Control

The purpose of driveway policies and standards is to maintain a high level of through traffic service and at the same time honor, in an acceptable fashion, the rights of abutting properties to have direct access. Three major groups which may have conflicting interests can be identified; these are: (1) road users with their several trip purposes and service needs, (2) nonusers who own, occupy, or otherwise use the lands served by the roadway, and (3) the public, as represented by many organizations and levels of government. An individual may be a member of all of these groups, although for a given time or in a specific situation his interest or activity may cause him to identify most strongly with only one viewpoint.

Road Users.—The road user is interested in travel time, safety, comfort, convenience (including driving ease and freedom from impedances and hazards), and vehicle operating costs. He is also interested in motorist services and

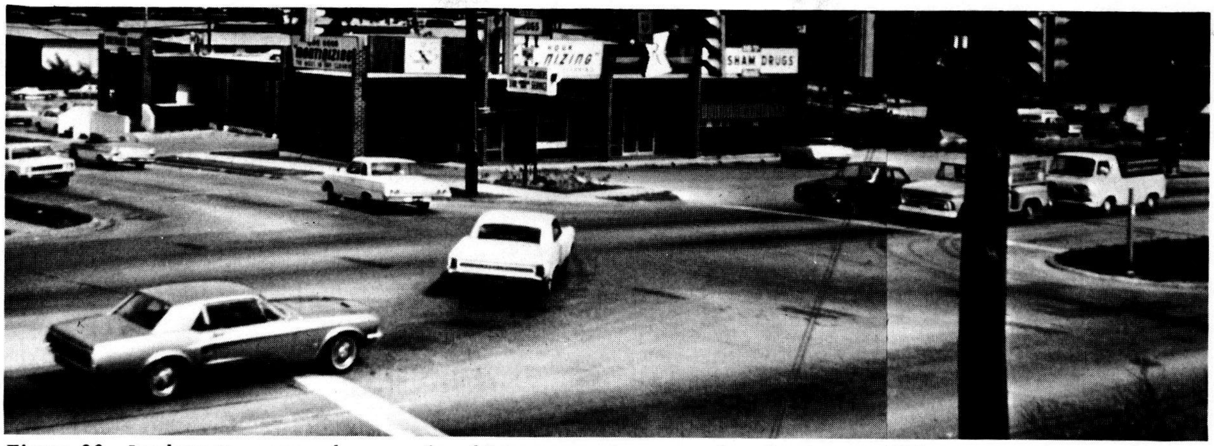


Figure 20. Inadequate corner clearance for driveways to drug store-dry cleaning establishment.

Figure 21. Inadequate corner clearance for exit driveway.

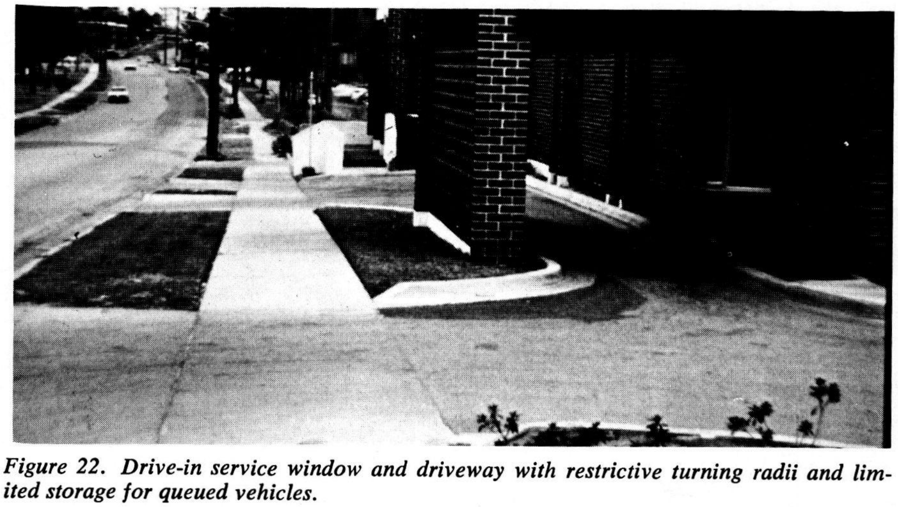


Figure 22. Drive-in service window and driveway with restrictive turning radii and limited storage for queued vehicles.

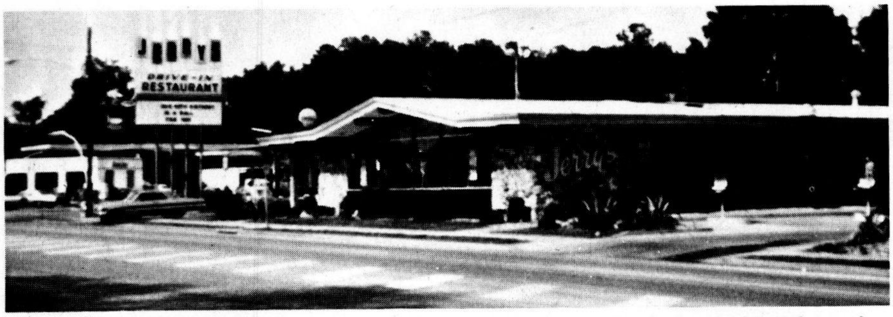


Figure 23. Drive-in restaurant with two access points using the main roadway lanes for circulation around the site.

Figure 24. Drive-in restaurant with one access point to drive-in facilities and complete circulation system provided on the site.

Figure 25. Congestion at access point of regional shopping center resulting from concentration of converging and diverging maneuvers near the roadway.

Figure 26. Extension of driveway into the parking lot of regional shopping center to promote orderly on-site circulation and free ingress/egress maneuvers.

Figure 27. Driveway along rural highway with narrow right-of-way.

perhaps is indirectly involved in an evaluation of each of these qualities of service. The values of travel time, operating costs, and safety, to some degree, have been quantified and are noted in Appendix A. Comfort and convenience, no less real, have not been successfully quantified but, nevertheless, must be considered. In fact, mounting criticism of traffic congestion suggests that comfort and convenience need to be given primary consideration.

For any given volume of traffic, it is obvious that the road user can benefit from fewer driveways and from driveways designed to minimize marginal friction and accident hazard. It is also likely that the road user seeking to obtain a motorist service will benefit from faster exit and reentry speeds and from a lower accident probability. As a generalization, the road user stands to be disadvantaged from driveway controls only when they cause a severe rationing of offerings of his immediate needs as a motorist. Such needs appear to vary with trip length and purpose.

Nonusers.—There are many subgroups of nonusers who have a recognizable interest in driveway numbers, spacing, and design. Shoppers in general, as one such group, have needs for accessibility and direct access to establishments and offices where goods and services are available. No case has come to attention, however, in which shoppers have been vociferous in demanding more access points. The shopper, as such, is far more likely to criticize the quality of direct access (narrow driveway openings, short radii, bad profile, and poor sight distance) than to make an outcry for a larger number of driveways and a greater choice of shopping outlets along a particular roadway.

Perhaps the least acknowledged of the nonuser's interests is the protection of the integrity of a roadway and, thus, the preservation of the accessibility features of his locale. Indeed, from his viewpoint as a resident of the area, the locational quality of his homesite tends to be preserved to the extent that driveway control reduces costs for any trip purpose to and from his residence.

Another nonuser subgroup consists of property owners; these may be further subdivided into owners of abutting properties and owners of other lands in the corridor. The owners of nonabutting lands have the same interest credited to the residents and road user relating to accessibility. That is, a roadway that continues to provide good through service sustains regional or area accessibility and the locational and functional utility of lands and, thus, the value of the nonabutting lands.

Of course, it is possible that owners of certain nonabutting lands may have a speculative interest dependent for realization on the access given to abutting lands. Here the owner's expectation would be for frontage so valuable that the pressure for assembly of nonabutting tracts with abutting parcels would lead to windfalls to nonabutting owners. But, it seems probable that any such windfalls that might rarely be lost due to driveway control would be far more than offset by the preservation of general area accessibility.

There is yet another aspect of driveway spacing that may be of great importance for nonabutting commercial properties. A policy that encourages new businesses in continuous strip development may, under certain conditions, lead to destructive competition. Such could occur in an area that is highly built up, is fairly stable in land use and population, and has a sufficiency of goods and services readily available. New businesses that locate on parcels abutting the new arterial, in order to gain direct access to through traffic, might take enough of the limited local market to make already established businesses submarginal. If the local market (and the market in general) did not benefit from lower prices or improved goods and services, destructive competition will have occurred. If, at the same time, the excessive number of new businesses has penalized the traffic operation of the roadway, extra public costs will have been incurred. If it is desired to effectively control abutting land uses, however, some other control measures besides driveway spacing must be employed.

Owners of abutting properties, along with businessmen wishing to operate upon such properties, represent the group with the most concentrated economic stake in driveway policies. The underlying factor for this position is the desire for the best possible access to high volumes of potential customers (traffic). But, despite the obvious high regard for highway access (presumably direct access), retailing enterprises show awareness of other locational attributes.

Direct access also is prized because it may permit the use of the street for a part of site circulation. This reduces the amount of land needed for a particular use and decreases the investment required for improvements. These savings are partially transferred to the value of abutting land as measured in the land market.

Thus, direct access is sought because of land value expectations. Retail firms seek such locational position in order to gain advantage over, if possible, but at least to meet similarly located competition. Their anxiety translated to demand undergirds the land price structure.

Public Interest —Governmental agencies that participate in the construction, maintenance, and operation of roadways should be interested in the flow of costs and benefits of any particular project over a long period of time Still, other governmental units are more concerned with the growth dynamics of the particular locality or region. This latter viewpoint encompasses the tax base (and the economic base) of the jurisdiction and also the ease and efficiency of providing a variety of public services (e.g., fire protection).

The policies and standards recommended in Chapter Three for direct access driveways would seem to indicate no additional public costs. Even if initial costs might prove to be higher on occasion, maintenance costs apparently would be smaller. Vastly more important in this case, annualized capital costs of the roadway should be substantially reduced simply because the economic life (functional life) of the project should be greatly lengthened. At the same time, the flow of benefits from the roadway should be increased to users, certainly to nonabutting nonusers and to the public sector; furthermore, such benefits also should flow over a longer project life. From the public view, therefore, the economic implications of more restrictive driveway controls seem to be a high probability of increased benefits at somewhat lower fully accounted costs.

Direct Access Driveways.—The limitation of number of driveways is not necessarily an economic imposition on abutting properties. The result may simply be the forcing of a more orderly use of the access available. In other instances, fewer driveways may require internal circulation of traffic as a substitute for the highway as a place for traffic storage and maneuvering. Here, additional paving may be needed on the site, and perhaps additional land. For some types of development, it would simply necessitate a different site layout than that which is now prevalent.

Any of these latter effects will carry some costs to be borne by property owners rather than by the general and traveling public. The economics simply involves a transfer from the public to the private sector or, perhaps more accurately, the absence of transferring costs from the private to the public sector. The failure of the developer to insure such costs may make the property submarginal for the existing or for the intended use, or may accelerate its obsolescence. Amounts obviously would vary from site to site and alternatives would be different between improved and unimproved sites.

As far as land-use economics is concerned, any fairly intensive land use should be rather insensitive to small annualized capital costs resulting from adjustments to fewer access points. Very extensive land uses should feel little, if any, impact; their internal traffic will simply be forced into a different and perhaps more orderly behavior.

There are land uses, however, which are moderately intensive and which may be ruled out by fewer driveway access points. A particular case might be a very shallow site suitable for a gasoline service station with open frontage; such a shallow site would be of doubtful value for a service station if it were allotted only one driveway or even two specific access points on each street. Although such parcels are not rare, they do not represent the general case. Any special treatment or allowance for them is therefore a trade-off of benefits to a few persons for disadvantages to numerous highway users.

In cases where larger sites are needed because of the adoption of a policy of fewer access points, assembly of tracts of less than adequate size and shape would be necessitated. (For areas along new locations, less disassembly would likely occur.) The economics of land assembly can be generalized to only a limited degree. Several possible positions for initial owners or businessmen can be described. First, suppose that all abutting lands have previously had improvements added to them. Businesses that are dependent on on-street parking or use of the street for internal circulation may face the necessity of providing these conveniences on their sites or lose business volume, if driveway limitations are imposed. In some instances, the capital outlay required to accomplish the adjustment may be more than the particular land use can pay. Also, there will be some sites that are not of sufficient size to accommodate the improvements needed to sustain the existing use. These sites may have to be converted to other uses. (Lease contracts may prevent even this change, in which case the business must operate at a loss or renegotiate or "buy up" the lease. In addition to this cost, the property owner may be penalized on future leases.) An alternative for existing uses is that they pool their parking accommodations. This may require some capital outlay. Also, it may be difficult to arrange because of improvement placements, types of businesses, or other factors that can work against cooperation. There will be some instances, according to the age of the highway, the age of improvements, the existence of alternative routes and locations, and the dynamics of the community and neighborhood, where obsolescence of adjacent properties has already started to take place. For some such properties, the remainder of economic life may be shortened by imposed access control. For others, obsolescence may be arrested and even offset as a result of improved traffic operations.

Where new marginal access policies and standards are adopted for a highway on new location or for an existing highway with open or sparsely improved adjacent lands, the nonuser consequences are likely to take a somewhat different pattern. Adaptability of the land is not inhibited by sunk and depreciable capital improvements. Furthermore, ownerships are likely to be somewhat larger, because disassembly or subdivision of land is a direct result of actual or anticipated intensity of use. Athough it is true that speculative activities (waiting for "ripening") may have kept the land bare, this is a probable event for a long-established highway only if there has been little demand for nonagricultural uses. One would expect then, in this latter situation, that land values were anticipating a long waiting period and there was little imminence of use. Access restrictions should have few, if any, short-range effects on nonusers, and long-range effects would as likely be positive as negative. Note, however, that access standards are still very important in such a situation. There is some reasonable probability that at least one site out of many could move into nonagricultural (or nonidle) use at any time. Also, there is a chance, especially on a statewide basis, that, out of all localities with rather low probabilities of immediate development, one or more can become ripe for intensive build-up almost overnight. These latter circumstances present an almost perfect gamble from the standpoint of public policy; a series of miniscule bets where the chances of only one avoided mistake can pay many times the total wager in highway user dividends.

Impact Studies.—Literature on economic impacts of new highways, with few exceptions, attributes sizable land value increments to such improvements. Benefits have been found universally for highways ranging from full freeways to low-volume farm-to-market roads. What has been demonstrated is that highways improve accessibility and decrease transportation costs for particular areas not previously so well-served. One should remember that city streets also do this; in fact, one of the major treatments given a land inventory by a developer is the addition of city streets. Of course, the purpose of economic impact studies was not principally to confirm the phenomenon of the capitalization of transportation cost savings. Rather, the somewhat over-simplified justification for such studies was to develop general information for public relations. Despite the apparent attention given to detailed variations in highway design and land uses, economic impact studies have stopped short of developing coefficients for differences in direct access.

Summary.—In the absence of contrary evidence, the economics, both public and private, favor restrictive controls over the frequency, location, and design of direct-access driveways. It would seem that nonusers, as a group, have more to gain than to lose over the long run from service by a protected capacity highway. Further, owners and users of abutting lands may also benefit on balance under a firm access policy. Certainty of the highway's integrity, optimized site use, and some added knowledge of the bounds of future competition may lead to greater selectivity of land uses, longer-lived activities, and, thus, a lower risk element.

Legal Aspects of Driveway Control

Generally, driveway control is to be attained by driveway spacing, location, design, and regulation of operation. These devices are exercised within the highway right-of-way for the most part. They may be reinforced with land use, planning, and zoning, including traffic zoning. These latter powers of control are discussed earlier in this chapter.

The restriction of the number of direct-access driveways taken alone should face no legal obstacles. It is the allocation of a limited number among abutting properties through spacing and locating that will give rise to controversy regarding authority and equity under the law. The location standards recommended in this report have to do with (1) sight distance, (2) distance from other driveways, and (3) distance from intersections.

The requirement that driveway locations have good visibility to and from the roadway imposes different kinds of restrictions according to the pattern of abutting land ownership. A small tract with very poor sight distance may be denied direct access altogether. In this case, the legal authority would be based on public necessity or welfare (*5*, p. 202). Compensation will be required unless other "sufficient and suitable" access is available or is provided (*5*, p. 175).

If the particular land area having poor sight distance is a part of a much larger frontage in a way that access points might be moved to improve sight distance, denial of access at a particular point may be made under the police power without compensation.

The matter of existing land use may bear on how the law relates to denial of access at a particular point. What constitutes "sufficient and suitable" access varies among land uses.

Whether or not there was a taking of real property also seems to be a factor as to the law which applies when access is to be taken or acquired. In practice, the taking of a part of a parcel involving direct access results in some difficulty in distinguishing between access and accessibility, between special and general benefits, and between specific and general damages. This is more particularly a problem in valuation. Nevertheless, it seems to be the case that what might be accomplished under the police power in old locations with no property taking might require compensation in new ones.

Distances between driveways can be established under the police power as long as the access given and remaining for abutters is "sufficient and suitable." However, there are numerous occasions for which access may not be "sufficient and suitable." One of these conditions would prevail when an abutter has less than the recommended minimum frontage for the granting of a direct-access driveway. Here, eminent domain and compensation might be in order unless some device was at hand to bring about a pooling of access with other abutters.

The setting of minimum distances of driveways from intersections similarly would not be barred legally if "sufficient and suitable" access was not denied. Again, however, it seems likely that certain ownership patterns and land uses might have less than adequate access under such a policy, in which event the police power would not suffice.

Driveway Design.—The proposed driveway designs should be of benefit to both public and private interests. The only legal implication that can be seen here is for those sites which, due to size and/or topography, cannot accommodate the recommended design. Here, either access must be denied or design requirements must be excepted.

Driveway Closing.—The imposition of direct-access control will frequently require the closing of selected driveways, especially on old locations. It is conceded that any driveway closing which completely removes access to any public thoroughfare results in compensable damage to the property owner and can be accomplished only under the power of eminent domain (and its corollary the "power of the purse"). The justification for such an act rests on the proof of public necessity and convenience.

Any other circumstance than the complete destruction of access introduces numerous additional questions which bear on that power of government which is applicable and on the balance between the public good to be accomplished and the private costs that might be imposed (*11*, p. 157). Whereas complete taking of access undoubtedly requires compensation, apparently there are a variety of conditions under which access may be partially restricted or denied. If the access that remains to an abutting property is "sufficient and suitable" for its use and if the public position is obviously enhanced (through increased safety or improved traffic operations, for example), the regulatory or police power of government suffices as authority to close driveways (*5*, p. 157). On the other hand, if the impairment of access is very severe, compensation may be required, although the potential public good is well-demonstrated. This is notably the case if there is special injury to an abutter's property (*11*, p. 176).

The severity of access impairment depends on the size and shape of the parcel and, apparently to some degree, the nature and intensity of its current use. If obvious and sizable damages are caused by the driveway restriction, alternative designs and solutions may possibly be expected of the public. Compensation may very well be required if alternatives in access treatment are not feasible.

The "rule of reason" seemingly has much to do with whether access restriction is valid under the law and whether compensation is required. What is "reasonable and proper" depends on abutter's customary rights in general and on local situations, including the attitudes of public authorities and the public (*11*, p. 173).

Circuity of travel brought about by access restriction or denial usually of itself is not compensable and it will not stand against the validity of public action (*11*, p. 209); however, it may be a factor in deciding whether an abutter has been left with access that is "sufficient and suitable" for the use of his particular property.

Opening of New Driveways.—Pressures for the opening of new driveways will pose a difficult problem in the administration of the recommended driveway policies.

It seems reasonable that on new arterial locations most unimproved sites will not have detailed plans and, thus, that the exact placement of driveway access points cannot be anticipated. If curb openings are originally given, there is a chance that their placement will prove unsatisfactory.

As land improvement becomes imminent and any direct access that is due is to be granted, care must be exercised not only to minimize hazards and traffic disruption but also to avoid conflict with possible future openings for adjacent tracts. Careless awards of access could raise the later impasse that spacing standards would have to be violated or that access to one or more adjacent parcels would have to be denied. Although there is precedent for refusing driveway openings under land use controls, abutters may have legitimate claims on access (*11*, pp. 172-174) unless access rights were previously acquired by the public.

Attempts might be made to circumvent driveway spacing standards through parcelation of land. Sell-offs of land could give rise to demands by new abutters for access driveways. The new owner may petition for direct access rather than seek a pooling of access with adjacent owners. Unless appropriate legislation for driveway controls has been passed the new owner may be successful in his demands, according to what the court holds to be reasonable.

Coordination of Access and Off-Highway Controls

If land is to be developed and used in the most efficient manner, a high degree of coordination between the design of the transportation system and the design of the urban form is necessary. The transportation planner, the highway engineer, the urban planner, and other interested professionals, as well as the elected officials and the general public, must recognize that urban form and the provision of economical transportation are mutually dependent parts of a single problem. A decision with respect to one carries with it a limitation in the rational decision that may be made with respect to the other.

This mutual dependence of transportation and land development is shown schematically in Figure 28. The figure attempts to show, for example, that high-rise residential development dictates consideration of the mass transit modes as the primary means of transportation. That is, one cannot have large high-rise residential complexes and expect to adequately or efficiently serve the development by autos on arterial streets.

Conversely, the selection of autos on arterial streets as the mode of transportation limits the residential development that may be efficiently served to those types which result in lower density. Similarly, dependence on automobiles operating on arterial streets limits the density of commercial and industrial developments that can be reasonably served.

Optimum use of land and protection of the arterial street system necessarily involves the coordination of access controls, zoning, and land development regulations. Histori-

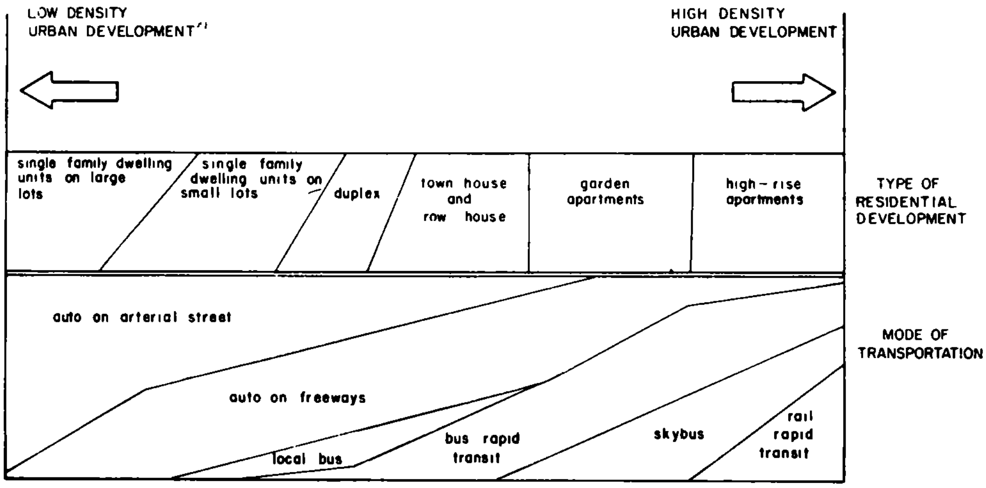


Figure 28. Mutual dependence of land use and transportation

cally these functions have been exercised by different agencies and different levels of government. In the past, the necessary channels of communication to effect this coordination have been established in only infrequent instances.

The following recommendations identify steps that will be generally necessary to effectively obtain land development patterns compatible with the function of the roadway on which the properties front. Actual implementation would, of course, differ from place to place, depending on the organization of the state highway agency and the organization and effectiveness of the local governmental units.

Access Controls

In the implementation of the access control guidelines recommended for major roadways, each highway department should accomplish the following:

1. In cooperation with the state attorney general's office, review the recommended guidelines and compare them with the practices permissible under existing legislation and court interpretation.
2. Identify any deficiencies in the existing law and assist in drafting the necessary legislation.
3. Modify existing, or adopt new, policy relating to access control on highways under state administrative jurisdiction.
4. Modify existing, or adopt new, standards that are to be followed in carrying out the access control policy.
5. Develop a master state highway plan based on functional classification.
6. Inform local governments and interested segments of the public of the new policy and standards and the basis for their application.
7. Develop workable channels of communications with each unit of local government and procedures for coordination of access, zoning, and development controls on the part of the professional staffs of the state and local governments.

Zoning and Development Controls

The following might be most efficiently accomplished at the state level by the state planning agency in cooperation with the state attorney general's office:

1. Review enabling legislation giving local government the authority to enact zoning ordinances and subdivision regulations together with local and state court decisions concerning their application.

Particular attention should be paid to the traffic criteria used by the courts in rendering decisions concerning zoning cases.

2. Draft appropriate material for consideration and action by the state legislature to expand on the statement of purpose in the zoning enabling act and to more specifically state the transportation objectives that should be considered in the application of zoning.

Local governments will then need to accomplish the following:

1. Adopt zoning ordinances in keeping with the revised enabling legislation.
2. Update their subdivision ordinances in order to incorporate the latest and most advanced professional practice.

CHAPTER THREE

RECOMMENDED POLICY, PROCEDURES, AND STANDARDS

The increasing traffic volumes resulting from a rapidly growing population and increased propensity to travel are limiting the ability of a given roadway to provide the conflicting functions of land access and traffic movement. For a roadway to efficiently serve through traffic at higher levels of use, local access must be limited. On the other hand, a roadway that is to provide safe and convenient access must be free of traffic not having an origin or destination at a property along the roadway.

To insure that both local access and through traffic needs of a region are efficiently satisfied, it is necessary that, on a systemwide basis, each roadway be classified according to its intended function in providing these two services. Control of access should then be exercised on each roadway so that the degree of access permitted is consistent with the function of that roadway. Roadways within the same functional classification should have a high degree of consistency and continuity in access control, as well as other design features, throughout a street or highway system.

Using the roadway classification defined in Chapter One, the following sections provide specific recommendations concerning access control for each functional class. Some states appear to have the authority to implement most or all of the policy recommendations. In other instances the authority is questionable and legislative clarification is desirable or necessary; new legislation is essential in some states.

A review of the specific points of statutory law and court interpretation of each state, together with particular legislative changes or clarification needed in each case, is outside the scope of this project. It is suggested, therefore, that each state highway department, together with the attorney general's office of that state, review the recommendations contained herein to identify those elements that can be implemented directly and to draft documents for legislative action which will enable full implementation of the recommended policies and standards.

GUIDELINES FOR DEGREE OF ACCESS CONTROL

Publication of an official highway or street map showing the functional classification of each existing and proposed facility, together with the access control policies that apply to each functional class, is recommended. Public information of this nature would permit property owners and developers to weigh the alternative investment opportunities, knowing the amount and nature of access allowed along a given roadway. This would eliminate the making of access control decisions on a project-by-project or case-by-case bases and, therefore, avoid much of the pressure now exerted by developers to obtain more favorable access treatment.

Where access is permitted, the issuance of driveway permits should be dependent on the approval of the site development plan so that a balance might be obtained between the adjacent development and the roadway. Any permit that is issued should describe the conditions of legal use, including the type of land-use and specific development to be served.

Recommended Guidelines for Urban Areas

Access control and design criteria for primary and secondary urban arterials should be based on the desired level-of-service Under the traffic demand in the off-peak periods, vehicular speeds are reasonably high on urban arterials through the U.S.—speeds of 40 to 45 mph are common. Urban arterials also carry the majority of their total 24-hr traffic volume during the off-peak hours. With progressive movement through a coordinated signal system, the average headways of vehicles within platoons will be approximately the same in peak and off-peak periods. At the higher off-peak speeds, the interference between a turning vehicle and following vehicles will be more severe. Hence, the access design (as well as other geometric features) should be such as to accommodate vehicles operating at these off-peak speeds.

A summary of guidelines for urban facilities is given in Table 4. Additional comments relative to the proposed guidelines are presented as follows for each functional class.

Primary Arterials

Minimum spacings in the range of 1,600 to 2,000 ft are recommended for signalized intersections on primary arterial streets. Along any single arterial, all intersections should be at the same spacing. All movements might be allowed at these signalized intersections. The traffic signals should be incorporated in a coordinated signal system.

Right turns from an arterial to an intersecting street should be accommodated by a separate right-turn lane. Left turns from a four-lane primary arterial should be permitted only where the median width is sufficient to provide for a protected left-turn lane.

Access points with a primary arterial might be provided at unsignalized locations where specific limited movements are to be accommodated under the following conditions:

1. Where the median width is not sufficient to provide a protected left-turn lane, right turns (only) to and from the intersecting facility might be allowed. Where the median width is less than 14 ft, the right turns at the intermediate intersections might be accommodated as shown in Figure 29. At any such location where the right-turn volume is less than 500 vpd, a direct taper as represented in this figure might be used. At volumes over 500 vpd, a right-turn lane is suggested.

TABLE 4

SUMMARY OF ACCESS CONTROL GUIDELINES FOR URBAN HIGHWAYS AND STREETS

ITEM			PRIMARY ARTERIAL	SECONDARY ARTERIAL		COLLECTOR		LOCAL
NUMBER OF TRAFFIC LANES			4 OR MORE	4 OR MORE	2	4 OR MORE	2	(DESIGN STANDARDS TO INSURE REASONABLE DRIVEWAY DESIGN AND CONSTRUCTION FOR THE PROTECTION OF THE HOME BUYER)
MINIMUM SPACING OF SIGNALIZED INTERSECTIONS			1600 TO 2000 ft	1200 TO 1600 FT		VARIABLE		
DIRECT ACCESS DRIVEWAYS	RESIDENTIAL		PROHIBIT	SPECIAL CASES ONLY		ONE PER PROPERTY		
	COMMERCIAL AND INDUSTRIAL		MAJOR GENERATORS UNDER SPECIAL CONDITIONS – SEE TEXT	SPECIAL TURN LANES	ONE PER 200 FT FRONTAGE	TWO PER 100 ft FRONTAGE		
ACCESS POINTS WITH OTHER PUBLIC STREETS	EXPECTED ADT ON INTERSECTING ROADWAY	UNDER 500	RIGHT TURNS, LEFT TURNS ONLY WHERE MEDIAN WIDTH PERMITS PROTECTED TURN LANE	RIGHT TURNS, LEFT TURNS WHERE MEDIAN WIDTH PERMITS PROTECTED TURN LANE	RIGHT TURN LANES, LEFT TURN FROM TRAFFIC LANE	DIRECT TAPER FOR RIGHT TURNS, LEFT TURNS FROM TRAFFIC LANES		
		500 TO 2000	RIGHT TURNS, LEFT TURNS ONLY WHERE MEDIAN WIDTH PERMITS PROTECTED TURN LANE		RIGHT TURN LANES, LEFT TURN FROM TRAFFIC LANE	RIGHT TURN LANES, LEFT TURNS FROM TRAFFIC LANES		
		OVER 2000	RIGHT TURNS ONLY UNLESS CONFORMS TO SIGNALIZED SPACING		RIGHT AND LEFT TURN LANES	RIGHT TURN LANES, LEFT TURN LANES WHERE PRACTICAL		
GRADE SEPARATIONS	PROVIDE	RAILROAD	ALL CROSSINGS	CROSSING PROTECTION – SEE TEXT				
		HIGHWAY	ESTIMATED PEAK HOUR VOLUMES WITHIN 30 YRS. ≥ CALCULATED INTERSECTION SPACING	NOT APPLICABLE				
	PLAN FOR	RAILWAY	ALL CROSSINGS	MAIN LANE CROSSINGS		CROSSING PROTECTION —SEE TEXT		NO ACCESS CONTROL
		HIGHWAY	ESTIMATED PEAK HOUR VOLUMES WITHIN 30 YRS > CALCULATED INTERSECTION CAPACITY	NOT APPLICABLE				
MEDIAN WIDTH(1)	ABS MINIMUM		14 FT	14 FT	NOT APPLICABLE ON 2-LANE SECTION	NONE	NOT APPLICABLE ON 2-LANE SECTION	
	DESIRABLE MIN		16 FT	16 FT				
MINIMUM SPACING OF MEDIAN OPENINGS			500 FEET PLUS 25 FT/CAR	300 FEET PLUS 25 FT/CAR		NONE		

(1) SEE TEXT FOR WIDTHS AT LOCATIONS WHERE TURNS ARE TO BE MADE AN INTERSECTING STREET OR DRIVE ONTO THE ARTERIAL AT AN UNSIGNALIZED LOCATION

(2) 2-WAY CONTINUOUS TURN LANE LIMITED TO EXISTING ROADWAYS

2. Where the median width is sufficiently wide and a protected left-turn lane is provided, left turns from the arterial to the intersecting facility may also be permitted. This will require a median width of 16 ft (14 ft absolute minimum). A minimum distance of 500 ft plus 25 ft for each car that must be stored in the protected turn pocket is recommended for primary arterials. As indicated in Chapter Two, this spacing requires very high deceleration, and longer spacings are desirable. Such spacings may mean that left turns from the arterial will not be permissible at all intersecting streets. (For example, if four cars are to be stored, a spacing of 600 ft is minimum; therefore, the spacing of intersecting streets would have to be greater than 600 ft if left turns were to be permitted to each.)

3. Where the median is of sufficient width to "shadow" a left-turning vehicle, allowing it to cross the nearside traffic lanes and wait in a protected median opening prior to completing the left-turn maneuver, left turns to the arterial from an intersecting facility might also be permitted. Median widths of over 30 ft will be required in this case. Where

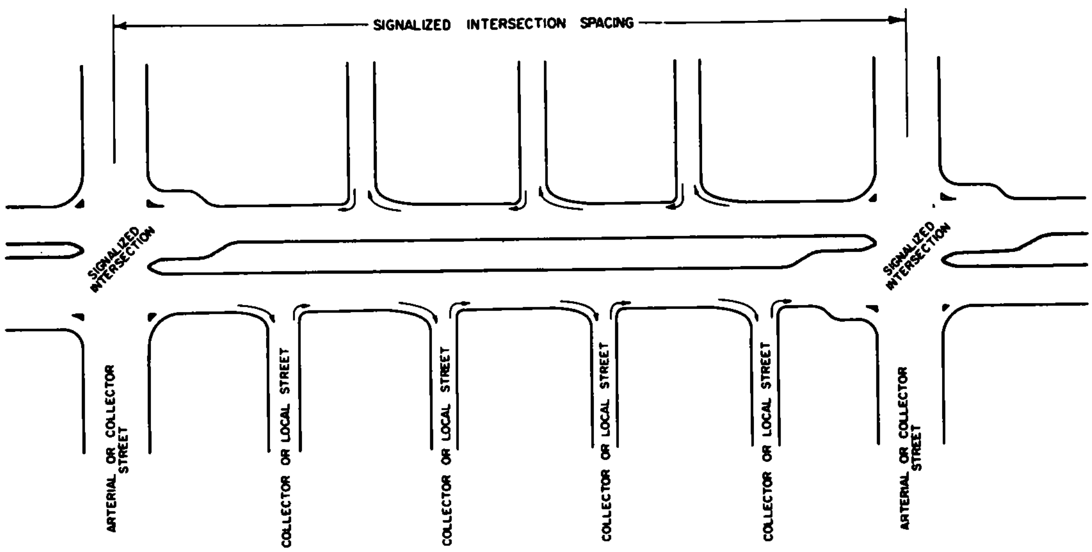


Figure 29 Provision for right turns only with narrow median

left-turning volumes are extremely low, turns both to and from the arterial might be permitted at the same point in a manner shown in Figure 30 Where there is more substantial volume, left turns from the arterial and those onto it should be at separate points, as shown in Figure 31.

The design of the access point should be such that only the intended movements are possible. Provision for left turns at such intermediate, unsignalized access points should be restricted to locations where the traffic volume on the intersecting roadway is low (less than 2000 vpd). In any case, an unsignalized intersection with an urban primary arterial should be designed to prevent crossing movements. Hence, it is further recommended that any intermediate intersections be "T-intersections." That is, intersections that do not conform to the signalized intersection spacing should not be located directly opposite each other along an urban primary arterial (see Fig. 32): This will minimize "pressure" that might develop for the later provision of a median opening to accommodate cross traffic.

Direct access to adjacent property along urban primary arterials should be provided for major generators only. Such access points should conform, in all respects, to the guidelines for provision and design of intermediate intersections. Any direct access to a major generator which provides for movement in all directions should not be permitted unless such access point complies in all respects with the design criteria for signalized intersections—including the guidelines for intersection spacing. At all access points, both driveways and intersections, return radii should be sufficient to permit vehicles to enter the arterial without encroaching on the inside traffic lane

Grade separations should be provided at all railroad crossings with urban primary arterials. These streets comprise the most important traffic facilities in an urban area; although they may account for only 5 to 10 percent of the street mileage they might carry over one-half of the vehicle-miles of travel.

Grade separations with intersecting streets are recommended when the estimated traffic volumes within 5 yr are greater than or equal to the calculated capacity using the procedures discussed in Chapter Six of the *1965 Highway Capacity Manual* (or similar procedures). The lower values (0.70 to 0.80) of the peak-hour factor should be used in these calculations Grade separations should be planned at all intersections where the estimated volumes within 30 yr after completion of construction are greater than the calculated capacity; larger values (0.85 to 0 90) for the peak-hour factor might be used for these longer-range estimates

Recommended minimum median widths for different conditions of traffic operation are given in Table 5. Where left turns are permitted at signalized intersections, minimum width should be 16 ft. This will provide for a 12-ft turn lane and a 4-ft divider. The same width, 16 ft, is recommended where left turns are permitted from the arterial to an intersecting street or private access point but where crossing movements and left turns onto the arterial are prohibited.

At locations (other than signalized intersections) where either left turns onto the arterial or crossing of the arterial are to be permitted, the median width should be 30 ft where automobiles only are to be accommodated. If trucks are expected, the median should be at least 10 ft wider than the length of the longest truck expected to use the opening.

The number of median openings should be held to a minimum on urban primary arterials. Their use should be restricted principally to those intersections which conform to the adopted uniform spacing for signalized intersections. Median openings might be provided at intermediate (un-

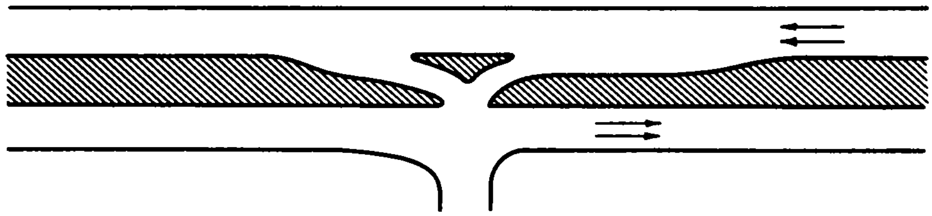


Figure 30. Left turns to and from the arterial at the same point.

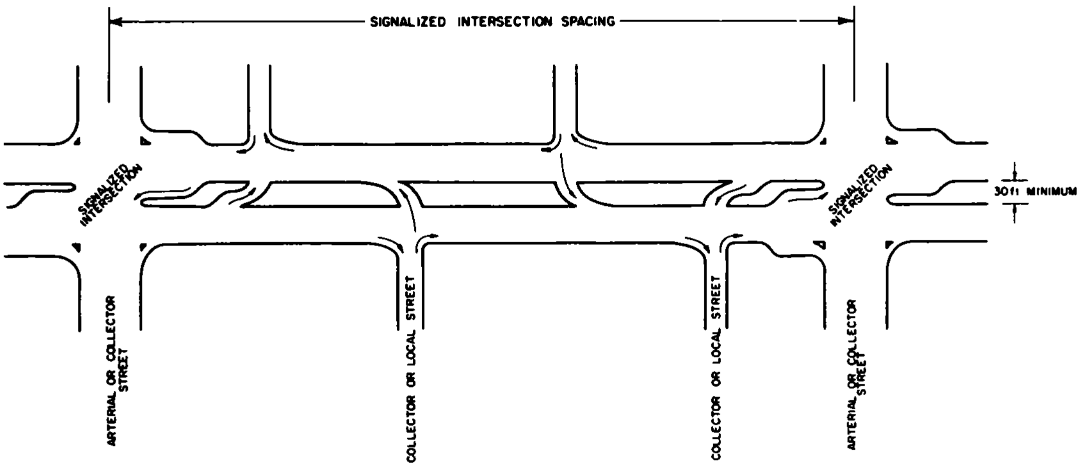


Figure 31. Separation of left turns to and from a major street.

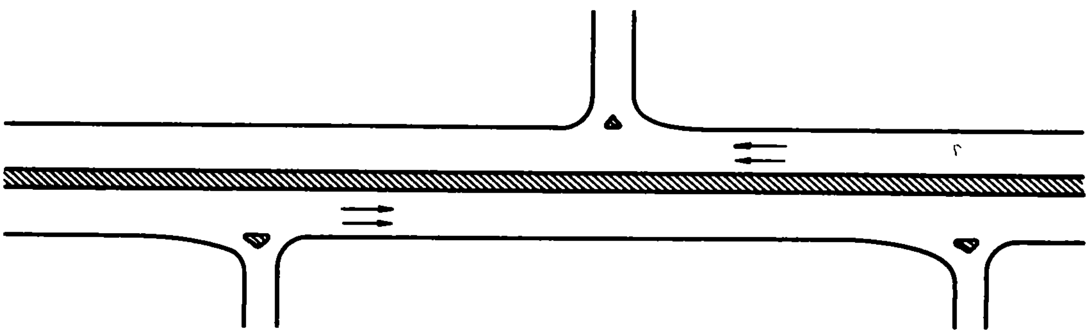


Figure 32 "T" intersections are recommended at intermediate unsignalized locations.

signalized) locations so as to accommodate the following only:

1. Left turns from the arterial to an intersecting street or other access point.
2. Left turns to the arterial from an intersecting street or other access point.
3. U-turns, after the New Orleans practice.

Median openings permitting traffic to continue directly across both directions of travel on a primary arterial should be provided only at intersections which conform to the selected spacing for signalized intersections. Recommended minimum spacings for median openings are:

RUNNING SPEED (MPH)	MEDIAN OPENING SPACING (FT)	
40	300	Plus 25 ft for each car to be stored in the turn lane at the maximum expected queue length.
45	350	
50	425	
55	500	

Use of a barrier curb is recommended on all sections of median to prevent crossings of the median at other than designated points.

Use of the continuous two-way left-turn lane is not

TABLE 5

RECOMMENDED MEDIAN WIDTHS ON URBAN PRIMARY ARTERIALS

	MEDIAN WIDTH (FT)			
	AUTOMOBILES ONLY		WITH TRUCKS[a]	
CONDITION	ABSOLUTE MINIMUM	DESIRABLE MINIMUM	ABSOLUTE MINIMUM	DESIRABLE MINIMUM
Signalized intersections:				
All movements permitted[b]	14	16	14	16
Unsignalized locations:				
Left turns (only) from a divided arterial to an intersecting roadway[b]	14	16	14	14
Cross-street traffic crossing or making left turns onto a divided arterial[c]	25	30	65	70

[a] 60-ft tractor-trailer or other combinations

[b] Minimum 12-ft turn lane, 2-ft divider, desirable 12-ft turn lane, 4-ft divider.

[c] Minimum 5-ft total clearance, desirable 5-ft clearance at front and rear of vehicle

recommended for application on primary arterials on new location. It is, however, suggested as a valuable operational technique for application on existing sections of arterials. Where median openings are provided, the centerlines of the two parallel roadways should be at the same elevation; the maximum grade on the intersecting roadway should be only sufficient to provide longitudinal drainage where necessary.

Secondary Arterials

Recommended spacing of signalized intersections on urban secondary arterials is 1,200 to 1,600 ft; a single uniform spacing within this range should, of course, be used along any individual secondary arterial street. The direct taper or separate turn lane should be used at all intersections with a secondary arterial, the direct taper being used at intersecting streets having lower turn volumes.

Direct access to residential property should be granted only where alternative access cannot be provided at a reasonable cost. Where such access is provided, a direct taper should be used to allow the vehicle to clear the through lane before completing the right turn.

It is recommended that direct access to commercial and industrial properties be allowed under limited conditions. On four-lane facilities, a special right-turn lane (Fig. 33) is recommended. This will permit the turning vehicles to leave the through traffic lane prior to decelerating to the speed at which the right turn will be completed. Driveway spacings and designs under this condition should be in conformance with a section of this chapter entitled "Guidelines for the Provision of Direct Access Driveways." Left turns should be permitted only where protected left-turn lanes are provided, or where a two-way, continuous left-turn lane is used—the latter being employed where driveway volumes are relatively light and no serious accident potential is present.

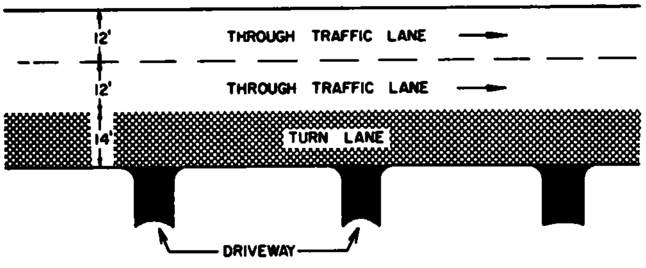


Figure 33. Special lane to accommodate right turns.

On two-lane urban secondary arterials it is recommended that driveways be limited to one per 200 ft of frontage. A direct taper or other high-speed driveway design is recommended so that right-turning vehicles can clear the through lane without undue interference to through traffic. Where a median is used, the centerlines of the two parallel roadways should be at the same elevation in the vicinity of any median opening.

It is recommended that grade separations with railroads be provided where the vehicular traffic volume, number of trains, and duration of crossing closures justify. At present, there are no acceptable or acknowledged criteria for providing rail-highway grade separations. However, research still in progress by the research agency suggests that the arterial street ADT needs to be about 17,000 vehicles before a grade separation will be justifiable, based on accident and time costs alone. This same research has developed procedures for the evaluation of grade-crossing protection. Interim recommendations for the provision of rail-highway grade-crossing protection are given in Table 6.

Recommended minimum median widths are the same as for primary arterials except that the absolute minimum where left turns are allowed from the arterial is 12 ft. This

TABLE 6

INTERIM RECOMMENDATION FOR PRIORITY IN THE PROVISION OF RAIL GRADE-CROSSING PROTECTION

It is recommended that a priority index based on the ratio of annual benefits to annual costs (Priority Index = EAB/TAC) be used as a priority index for the provision of grade-crossing protection The calculation benefits and costs are described by the following equation:

BENEFITS:

EAB = Estimated annual benefits
= $ER \times CAC \times EAR$

in which

EAB = expected annual accident cost reduction,
ER = relative effectiveness rating for an increment of protection;
CAC = composite accident cost, and
EAR = expected annual accident rate for a given crossing location.

COSTS:

TAC = Total annual costs
= $(CRF \times IC) + MC$

in which.

TAC = total annual cost of an increment of protection,
CRF = capital recovery factor
$r(1+r)^m/(1+r)^m-1$

and:

r = interest rate;
m = useful life of device;
IC = total installation cost of improvement; and
MC = annual maintenance cost.

This procedure [a] essentially provides a framework for the construction of a ranking system or priority index for traffic intersections according to their relative attractiveness as investment alternatives. Given this framework a rail-highway grade-crossing protection program can be implemented that will make most effective use of the funds available.

If the funds allocated for the safety program are determined solely on an institutional (legislative or executive) basis, then the problem is one of protecting crossings in descending order or ranking until these funds are exhausted. If the total budget for the program is to be determined on an economic basis, however, the decision criterion should be to protect all intersections in decending order of ranking until the incremental benefit (marginal reduction in accident cost) equals the incremental cost of added protection (marginal cost). This will insure that net benefits are maximized. This latter method requires that the cost of accidents include value of future earnings and other indirect costs incurred in both benefit and cost computations.

[a] The complete procedure for establishing priorities for the installation of rail-highway grade-crossing protective devices is described in "Establishing Priorities for the Installation of Traffic Control Devices The Rail-Highway Intersection Example," *Proc HRB Western Summer Meeting* (1969).

would provide a 10-ft turn lane and a 2-ft divider. Construction on new location should, of course, conform to the desirable minimum of 16 ft rather than the absolute minimum.

Collectors

Access control on collector streets should be exercised primarily to insure that access points conform to the adopted standards for location, design, construction, and maintenance.

Because the function of collectors is to provide land access and to move traffic, one or more access points might be provided to each abutting property. As a general practice, however, developers of larger parcels should be encouraged to so design the site layout as to voluntarily limit the number of access points. This might be done by appealing to their self-interests (such as increased value resulting from superior design) rather than through a specific restriction on the maximum number of access points.

The recommended spacing, design, and construction standards that should guide the provision of direct access to collector streets are developed in Appendix F and summarized in the section of this chapter entitled "Guidelines for the Provision of Direct Access Driveways."

Interim recommendations for the provision of rail-highway grade crossing protection are the same as those for secondary arterials given in Table 6.

Recommended Guidelines for Rural Areas

Access control recommendations for arterials in rural areas are based on the premise that major corridors of intercity travel will increase in importance. The trend for continued concentration of population in an area adjacent to existing urbanized areas with the resulting conversion of roadways in the urban fringe from rural to suburban/urban facilities is expected to continue. Further, increased propensity to travel can be expected as the population becomes more affluent and increasingly accustomed to greater mobility.

Guidelines for rural facilities are summarized in Table 7. The actual spacing of intersections with public roads in rural areas should, of course, be a function of the intensity of development. Minimum spacings, as recommended for urban areas, should, however, be the limiting condition. In areas which are presently rural in character but which might come under urban influence within 30 years, intersection spacings should be multiples of the urban spacings. This will allow for the provision of intermediate intersections with public roads should the area develop in the future.

TABLE 7

SUMMARY OF ACCESS CONTROL GUIDELINES FOR RURAL HIGHWAYS

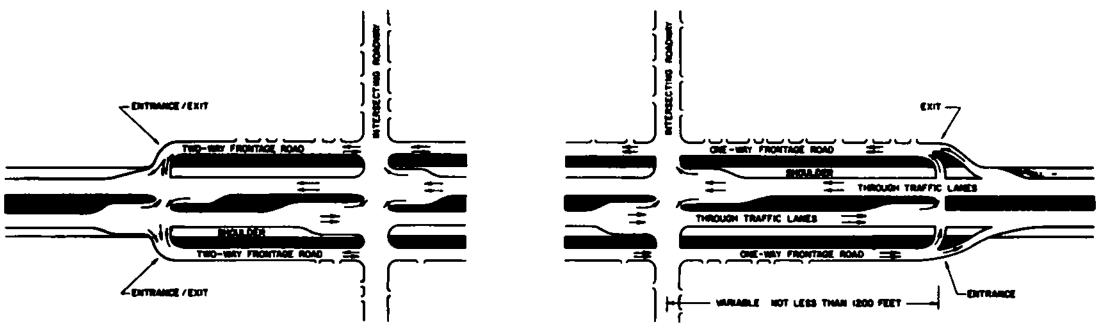
ITEM			FUNCTION CLASSIFICATION: PRIMARY ARTERIAL		SECONDARY ARTERIAL		COLLECTOR	LOCAL
NUMBER OF TRAFFIC LANES			4 OR MORE	2	4 OR MORE	2		NO ACCESS CONTROL
INTERSECTIONS WITH PUBLIC ROADS			CROSSROAD ADT < 2000, MINIMUM SPACING ONE PER MILE		CROSSROAD ADT < 2000, MINIMUM SPACING ONE-HALF MILE		ALL PUBLIC ROADS	
MAXIMUM NUMBER			2 PER SIDE PER MILE, FARM RESIDENCES AND FIELD DRIVES ONLY		6 PER SIDE PER MILE INCLUDING FIELD DRIVES		10 PER SIDE PER MILE	
ACCESS POINTS WITH PRIVATE PROPERTY	TOTAL TRAFFIC ENTERING AND LEAVING	UNDER 50 ADT	NO INDIVIDUAL DRIVEWAYS ACCESS VIA FRONTAGE ROAD		DIRECT TAPER		DIRECT TAPER	
		50 TO 500 ADT			FRONTAGE ROAD			
		OVER 500 ADT			TURN LANES OR FRONTAGE ROAD		TURN LANES	
GRADE SEPARATIONS	PROVIDE	RAILROAD	ALL MAINLINE AND MAJOR SPUR TRACKS		ALL MAINLINE TRACKS		CROSSING PROTECTION - SEE TEXT	
		HIGHWAY	CROSSROAD ADT OVER 2,000 WITHIN 5 YEARS		CROSSROAD ADT OVER 5,000 WITHIN 5 YEARS		NOT APPLICABLE	
	PLAN FOR	RAILROAD	ALL CROSSINGS			CROSSING PROTECTION - SEE TEXT		
		HIGHWAY	CROSSROAD ADT OVER 2,000 WITHIN 30 YEARS		CROSSROAD ADT OVER 5,000 WITHIN 30 YEARS		NOT APPLICABLE	
MEDIAN WIDTH		MINIMUM	30 FT	NOT APPLICABLE ON 2-LANE SECTION	20 FT	NOT APPLICABLE ON 2-LANE SECTION	NOT APPLICABLE	
		DESIRABLE	50 FT		30 FT			
LOCATION OF MEDIAN OPENINGS			AT PUBLIC ROADS, TERMINALS OF FRONTAGE ROADS AND FARM DRIVES		AT PUBLIC ROADS AND ACCESS DRIVEWAYS			

Primary Arterials

Intersections with rural primary arterials on new location should be limited to public roads having a functional classification of collector or higher. Direct access from abutting property to the through lanes of rural primary arterials should be prohibited. The only exception should be the provision of access to rural farm residences and field drives when access to a lower classification of roadway cannot be economically provided. Where such access to farm residences or field drives is provided, the wording of the driveway permit should limit the use of the driveway to that specific purpose and land use. Use of the driveway for any other purpose or land use should be expressly prohibited and the permit revoked and the access point closed in the event of violation. The number of any such access points should be limited to no more than two per mile per side.

On divided highways, such access points on opposite sides of the roadway should be located directly opposite each other so that service can be provided by a single median crossover. When necessary, one or both of the driveways should be relocated to comply with this guideline. In any case, adjacent median openings should not be located within 500 ft of each other. If a lesser spacing would result, one or both of the driveways should be redesigned so as to position them opposite each other; or, a frontage road should be provided on one (or both) sides with the connections of the frontage road directly opposite driveways (or frontage road connections) on the other side.

Access to commercial, residential, or other nonagricultural land uses should be provided by way of other roadways or through the provision of frontage roads, as shown in Figure 34. Where land adjacent to a new rural arterial is being converted to residential or commercial uses, direct access to each home site or commercial establishment should not be permitted. Rather, access should be by way of a collector roadway that would serve a number of dwell-



TWO-WAY FRONTAGE ROAD ONE-WAY FRONTAGE ROAD

Figure 34 Schematic arrangement of frontage roads to serve commercial development in rural location

ing units or establishments. Further, provision of any intersection with such a collector should be contingent on the developer's submission of an acceptable plan for the ultimate development of the total property.

All intersections and other access points should be designed to enable a vehicle to leave the through traffic lane before beginning the turning maneuver. A right-turn lane, 12 ft wide and different in surface texture from the shoulder, is recommended. This turn lane should be long enough to allow at least one-half of the deceleration to take place off the through traffic lane. Recommended lengths are given in Table 8.

Grade separations are recommended at all railroad crossings with rural primary arterials. Accident costs plus time costs are not likely to be sufficient to justify grade separations in all cases on the basis of a strict benefit-cost ratio. This class of intercity highways, however, is believed to warrant such grade separations by virtue of the importance and increasing demand in level of service.

Grade separations should be planned for all intersections with other rural primary arterials and with other intersecting highways on which traffic is expected to exceed an ADT of 2,000 vehicles within 30 years.

Median width should be sufficient to allow crossing traffic to cross one roadway of a multi-lane divided roadway at a time. A minimum width of 30 ft is recommended; for major at-grade intersections where tractor-trailer combinations are likely to be entering or crossing the arterial, width of 70 ft is recommended. The maximum difference in elevation between the two parallel roadways at a median opening should not exceed 1 ft.

Secondary Arterials

Rural secondary arterials may have at-grade intersections with all classes of public roads; however, the spacings of such intersections should not be less than those for secondary arterials in urban areas. Other direct access should not exceed six points per mile per side.

Direct access may be provided to residential, commercial, or industrial development in addition to agricultural land uses. The driveway, however, should be restricted to a specified land use and site layout. Should a change in land use or development be desired, a permit for continuation of the access point or provision of an alternative point should be required.

When the daily traffic volume using a driveway (total volume entering and leaving) is less than 50 vpd, direct access might be permitted—providing that the total number of driveways per mile per side does not exceed six. At intermediate volumes (between 50 and 500 vpd), it is recommended that access to individual properties be via a frontage road. This frontage road would serve as a collector-distributor roadway with ramp-type connections to the through traffic lanes.

At higher volumes (more than 500 vpd), a driveway might connect directly with the through traffic lanes. Such access points should have separate right-turn lanes. Further, they should not be located within 1,200 ft (preferably, 1,600 ft) of a public road intersection.

If more than six access points, including farm drives and connectors to any frontage roads, may be required, access should be via frontage road. Any development that might be provided with direct access initially should be set back a sufficient distance to provide for a frontage road at a later date.

Driveways on opposite sides of the roadway should be located so that a single median opening will serve access points on both sides whenever possible.

Railroad grade separations are recommended on four-

TABLE 8

RECOMMENDED TURN LENGTHS

RUNNING SPEED (MPH)	LENGTH (FT)[a]		
	TAPER	FULL WIDTH	TOTAL
75	300	675	1075
70	275	550	825
65	250	450	700
60	225	350	575

[a] Assumptions 20-mph speed reduction takes place in through lane, deceleration rate 5 0 ft per sec² Number rounded to nearest 25 ft

lane sections of secondary arterial highways which cross a railroad main line. Crossing protection is recommended at all other rail-highway crossings (Table 5).

Collectors

Direct access from abutting property to the through lanes of collector highways should normally be provided where requested; except, properties having less than 100 ft of frontage on the collector should be limited to one driveway. A permit should be required for all driveways on collector roads to insure that the design and construction of the driveway is in conformance with the adopted standards.

A short direct taper is suggested for driveways with an ADT of less than 50 vehicles. With driveway volumes in excess of 50 vpd, right-turn lanes are recommended.

GUIDELINES FOR THE PROVISION OF DIRECT ACCESS DRIVEWAYS

Driveways

Design Recommendations

The driveway design recommendations summarized in the following discussion are covered in detail in Appendix F. To minimize interference, relatively high turning speeds, minimum encroachment by turning vehicles on adjacent roadway lanes, and minimum conflict between vehicles using adjacent driveways are required. Recognizing the impracticalities of completely eliminating all interference caused by access movements, Table 9 includes entrance speeds and encroachment criteria for the design of driveways for various use and location categories.

These recommendations are based on typical access requirements; * in situations where local variations or constraints take precedence, engineering judgment must be exercised in the application of these recommendations. In areas of high pedestrian activity, for example, efficiency of vehicular movement must be compromised to insure the safety and convenience of the pedestrian movements. High percentages of commercial vehicles will impose different operational requirements on the driveways. The large number of constraints and possible configurations virtually precludes the specification of a set of standard designs that will adequately serve all, or even most, access needs. It is to be emphasized that the provision of an adequate driveway requires the exercise of sound judgment and basic design principles for each driveway.

* A traffic mix consisting of predominantly passenger vehicles is assumed An occasional single- or multiple-unit commercial vehicle may be accommodated Operating speeds in the through lanes are typical of urban areas, therefore, higher turning speeds should be used on rural roadways

Driveway Spacing and Corner Clearance

Guidelines for degree of access in terms of number of access points per mile are given in earlier sections. These guidelines do not consider the interaction between adjacent driveways or between driveways and intersections, and hence are not intended to imply minimum spacings between adjacent driveways. Such interactions include conflicts between vehicles which enter the traffic stream simultaneously from closely spaced driveways, blocking of driveways as a result of queueing at intersections, and sight restrictions resulting where driveways open into the sight triangles of driveways.

Recommended driveway spacings and corner clearances are shown in Figure 35; these recommendations reflect the differences in operating characteristics and desired levels-of-service for the different classes of roadway. In applying these values the sight-distance requirements should be checked using the AASHO procedure as discussed in Appendix F.

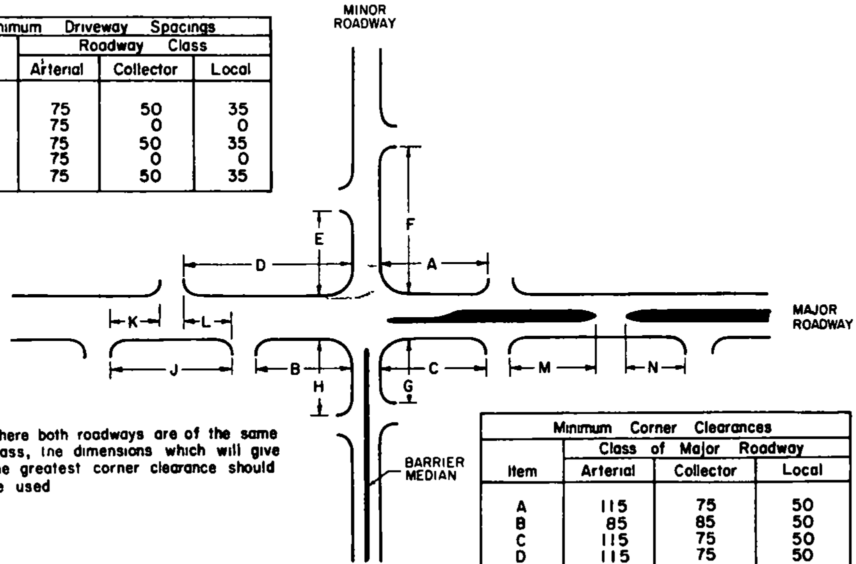
Dimensions shown in Figure 35 are measured from curb line to curb line (or edge of pavement) instead of to the property line. If measurement to the property line is nec-

TABLE 9

DRIVEWAY DESIGN CRITERIA

ROADWAY CLASS	TYPE OF DRIVEWAY	VEHICLE	MINIMUM SPEED AT WHICH VEHICLE LEAVES THROUGH LANES (MPH)	IS ENCROACHMENT ON THROUGH ROADWAY LANES BY VEHICLES USING THE DRIVEWAY PERMITTED?	IS ENCROACHMENT ON ADJACENT DRIVEWAY LANES BY VEHICLES USING THE DRIVEWAY PERMITTED?
Arterial	High volume	Passenger	15	No	No
		Commercial	5–10	No	Yes
	Low volume	Passenger	10	No	Yes
		Commercial	5–10	Yes	Yes
Collector	High volume	Passenger	15	No	No
		Commercial	5–10	Yes	Yes
	Low volume	Passenger	10	No	Yes
		Commercial	5	Yes	Yes
Local	High volume	Passenger	10	Yes	No
		Commercial	5	Yes	Yes
	Low volume	Passenger	5	Yes	Yes

Minimum Driveway Spacings			
	Roadway Class		
Item	Arterial	Collector	Local
J	75	50	35
K	75	0	0
L	75	50	35
M	75	0	0
N	75	50	35



Note Where both roadways are of the same class, the dimensions which will give the greatest corner clearance should be used

Minimum Corner Clearances			
	Class of Major Roadway		
Item	Arterial	Collector	Local
A	115	75	50
B	85	85	50
C	115	75	50
D	115	75	50
E	230	115	50
F	230	175	50
G	50	50	50
H	230	175	50

Figure 35. Recommended corner clearances and driveway spacings.

essary in a particular local jurisdiction, such standards set by the local agency should be stringent enough to ensure that spacings and clearances recommended herein are satisfied.

Horizontal Alignment

The ability to accommodate a turning vehicle at some specified speed within the geometric limits of the driveway and the lane from which the turn is made depends on the combination of driveway angle, driveway width, return radius, and offset or taper. For "T" driveways (Fig. 36), the recommended combinations of lane width offset, and return radius, are given in Table 10. Separate tabulations are included for commercial vehicles and passenger vehicles turning at very low speeds and for passenger vehicles turning at speeds up to 15 mph.

For angle driveways (Fig. 37), values are given in Table 11. This set of values is based on requirements for passenger vehicles turning at 15 mph and varying driveway angles. For other combinations of angle, vehicle type, and turning speed, the appropriate return radius and driveway width can be readily determined using the approach outlined in Appendix F.

Recommended widths for one-way driveways can be taken directly from Table 10 or Table 11; minimum width is 15 ft. For two-way driveways where encroachment on the adjacent driveway lane is undesirable, the total width is sum of the lane widths required for the entrance and exit maneuvers at the respective design speeds. For two-way driveways where such encroachment causes no problem, the total required width is given by the lane width required for the entrance maneuver, except that this width should not be less than 30 ft.

Because angle driveways may permit higher speed ingress or egress movements, one-way angle driveways may be preferred to "T" driveways along roadways with high speeds where access is restricted to only one direction of the through lanes. With access to both directions of traffic, however, the use of one-way angle driveways will require acute angle turns across lanes of opposing traffic. This may result in greater interference to through traffic. Angle driveways are therefore not recommended along roadways where access is permitted to or from both directions of the through lanes.

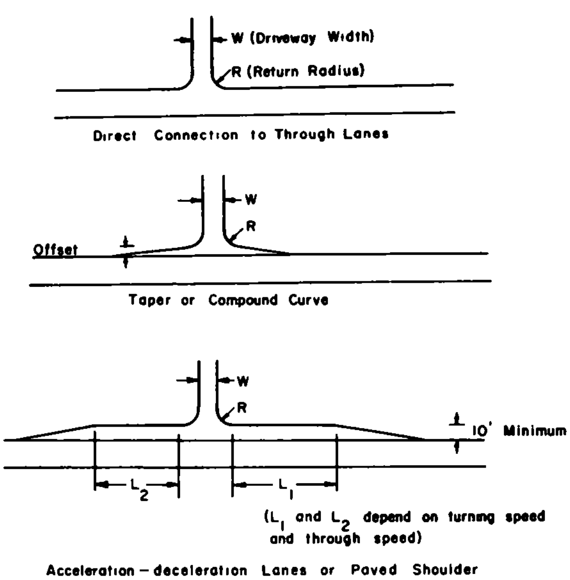


Figure 36. "T" driveways.

TABLE 10

MINIMUM LANE WIDTHS FOR "T" DRIVEWAYS

RADIUS RETURN (FT)	DESIGN CONDITION: PASSENGER VEHICLE @ 0+MPH FOR OFFSET OF 2 FT	4 FT	6 FT	10 FT	14 FT	PASSENGER VEHICLE @ 15 MPH FOR OFFSET OF 2 FT	4 FT	6 FT	10 FT	14 FT	S-U VEHICLE @ 0+MPH FOR OFFSET OF 2 FT	14 FT	WB-50 VEHICLE @ 0+MPH FOR OFFSET OF 2 FT	14 FT
5	23	17	14	11	10	43	34	30	24	19	52	22	—	32
10	20	13	12	10	10	39	31	26	20	16	47	19	50	29
15	14	10	10	10	10	38	26	22	17	15	39	17	45	27
20	10	10	10	10	10	29	22	19	15	15	35	15	40	25
25	10	10	10	10	10	25	18	15	15	15	29	14	36	23
30	10	10	10	10	10	20	15	15	15	15	25	13	31	20
40	10	10	10	10	10	15	15	15	15	15	16	15	24	18

Design vehicles are the standard AASHO design vehicles.

Minimum widths given will permit the designated vehicle to enter or leave the driveway at the indicated speed without encroaching on either the adjacent roadway or driveway lanes

Dimensions given are shown in Figure 36

To apply lane widths to two-lane driveways, a minimum approach width of 30 ft should be used If no encroachment on either driveway lane is to be permitted, the width is the sum of the lane widths required for the design entrance and exit speeds If encroachment on the adjacent driveway lane is permitted, the width is the lane width required for the entrance turn except that the width should not be less than 30 ft

Driveway Profile

A large number of combinations of lengths of vertical tangents, grade differentials, and vertical curves will provide satisfactory driveway profiles. The values shown in Figure 38 are presented as a guide for the design of the driveway profile.

Several other generalizations are also appropriate. For severe grade changes, vertical curves should be used. Intersections of vertical tangents should be at least 10 ft apart (the approximate wheelbase of a passenger vehicle) where possible Except where pedestrian convenience is of special importance, sidewalks depressed to conform to the desired driveway profile are to be preferred. Curbs, gutters, and other fixtures located along the edge of the pavement should also be constructed and maintained so that the resulting irregularities in the driveway profile are minimized.

Construction and Maintenance

Permanent paving is recommended for all driveways except those serving very low-volume traffic generators such as single-family residences, farms, or similar uses. For such driveways along major roadways, paving of that portion of the driveway adjacent to the roadway is highly desirable. Satisfactory driveway operation also requires that the driveway be well maintained and free of potholes, ponding of water, or other problems that would adversely affect the driver's choice of path or speed in using the driveway.

Any driveway that has a gate across it should be designed so that the longest vehicle using it can completely clear the roadway. This problem is encountered principally on farm drives on the lower highway classes. A design of the type shown in Figure 27 is recommended; use of such a design should be a condition for the issuance of the driveway permit and the continued use of the driveway.

TABLE 11

MINIMUM LANE WIDTHS FOR ANGLE DRIVEWAYS

RETURN RADIUS (FT)	DRIVEWAY ANGLE (DEGREES): 30, FOR OFFSET OF 2 FT	6 FT	14 FT	45, FOR OFFSET OF 2 FT	6 FT	14 FT	60, FOR OFFSET OF 2 FT	6 FT	14 FT
5	15	15	15	22	15	15	24	16	15
10	15	15	15	20	15	15	22	15	15
15	15	15	15	19	15	15	21	15	15
20	15	15	15	17	15	15	18	15	15
25	15	15	15	16	15	15	18	15	15

Minimum widths given will permit the AASHO passenger vehicle to enter the driveway at speeds up to 15 mph without encroaching on the adjacent roadway lane

These dimensions are shown in Figure 37

Figure 37. Angle driveways Appropriate combinations of outside return radius, driveway width, and offset are given in Table 11 The inside return radius will have little or no effect on the ability of a one-way driveway to accommodate turning maneuvers. To avoid excessive driveway openings, a radius of 5 ft is suggested

Recommended Procedures for Review of Driveway Requests

Many cities have established review procedures whereby the departments concerned with planning and traffic operations must review and act on requests for driveway permits. The department which actually issues the permit varies from one governmental jurisdiction to another, so the review procedures also differ. The essential element for successful and effective review is that all parties, including the person(s) making the driveway permit requests, are aware of the procedures and requirements. Generalized flow charts indicating how this might be accomplished are shown in Figures 39 to 42.

The following recommended procedure is based on the critical evaluation of procedures presently being used:

Recommended Procedures in Urban Areas

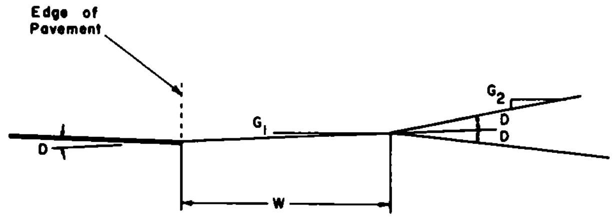
Although the exact procedures for the issuance or denial of a driveway permit will vary from one governmental jurisdiction to another, the following must be accomplished:

1. Inform the individual (developer) making the request for a driveway permit of the requirements and procedures.
2. Obtain review of the request by the traffic engineering and the planning departments.
3. When the permit is granted, obtain a performance deposit to ensure that construction of the driveway(s) will be in accordance with approved design and construction specifications.

The developer can be conveniently informed of the driveway permit requirements and procedures when application is made for a building permit or for a zoning change. Inclusion of a reference to the approvals that must be obtained prior to issuance of a building permit should be made in the building code so as to inform architects and developers who are unfamiliar with the specific requirements of the required approvals. It is recommended that the request for a building permit and a driveway permit be filed, reviewed, and issued jointly.

It is further recommended that a site development plan indicating the building location, internal circulation and parking, and requested access be filed at the time the request is made for the joint building-driveway permit or a change in zoning. At this time the individual should be advised of the procedure that will be followed in acting on the request, as well as the policies and standards for granting approval; it is suggested that the explanatory pamphlet be prepared and used for this purpose. When a change in zoning must be requested first, this information should be distributed at the time this request is filed.

Joint filing of the building and driveway permits will also provide the planning and traffic engineering professional staffs with the necessary information to evaluate the building and driveway locations as part of the total site development plan. In the event of deficiencies or possible improvements in the site plan, more specific and valuable advice can be provided to the developer along with a more satisfactory explanation of recommended changes in his site development plan.



Suggested Maximum Grade Change (D)

	Desirable	Maximum
High Volume Driveway	0%	± 3%
Low Volume Driveway on Arterial or Collector Streets	± 3%	± 6%
Low Volume Driveway on Local Streets	± 6%	Controlled by Vehicle Clearance

Maximum absolute grades, G_1 and G_2, must be compatible with the requirements for drainage and sight distance of the particular site

Figure 38. Suggested driveway profiles.

It is recommended that a performance deposit be collected from the developer at the time the driveway permit is issued. The deposit should be held to ensure that the driveway is located, designed, and constructed in accordance with the approved standard. After inspection, the deposit, less any inspection charge, would be returned to the individual.

Recommended Procedures on State Maintained Roads

The specific procedures for the consideration of driveway permit requests will vary, depending on the organization of the individual highway department and the particular unit within the department having the responsibility for issuance (or denial) of driveway permit requests. They may also differ depending on whether there is county-wide zoning in rural areas.

Restricted Use Driveways

It is recommended that all permits for driveways on any primary or secondary arterials, in urban or rural areas, be issued for service to a specific and limited land use. Conversion of the property to a different land use classification will automatically make any driveway permit null and void; a new permit must be requested and issued for the new or anticipated new land use.

On rural primary arterials, permits for direct access to the through traffic lanes should be issued for farm residences and field driveways only. Temporary permits, which shall expire at a specific future date not to exceed 20 years from the date of issue, may be issued for other land uses, including commercial and industrial. On expiration of the permit, a new permit must be applied for; such renewal may, for a specified period of time, be approved if the driveway traffic does not interfere with the then traffic on the arterial.

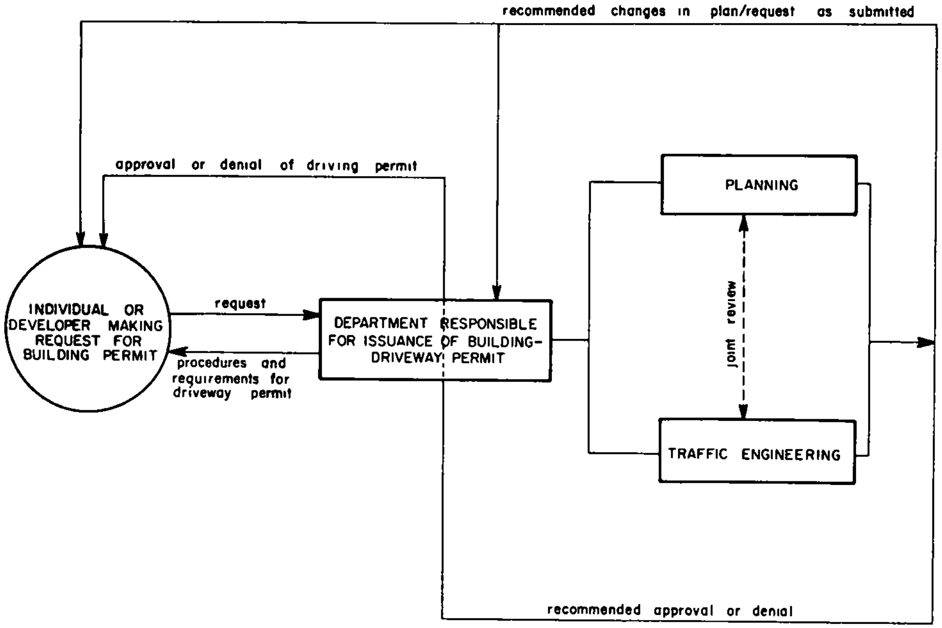


Figure 39. Flow chart for review of access problems when request initiated by building-driveway permit.

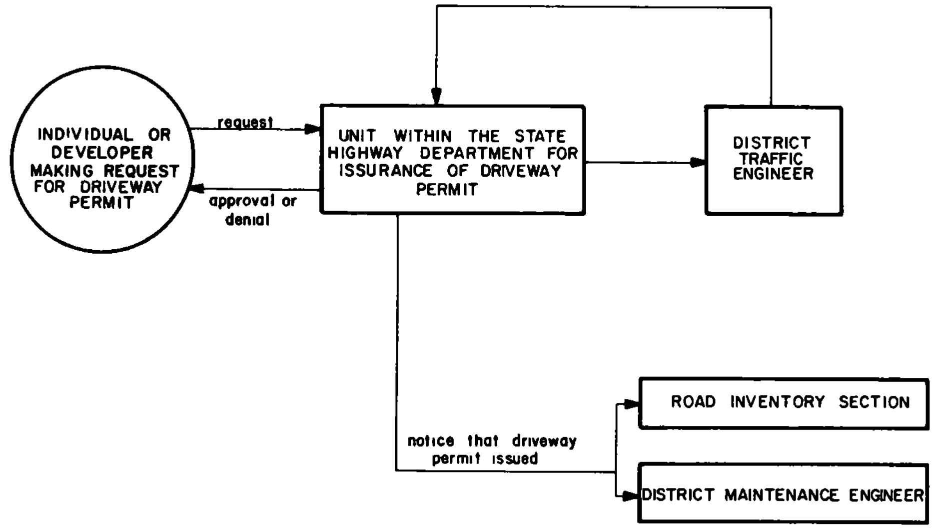


Figure 40. Flow chart for processing requests for driveway permits on state-maintained routes.

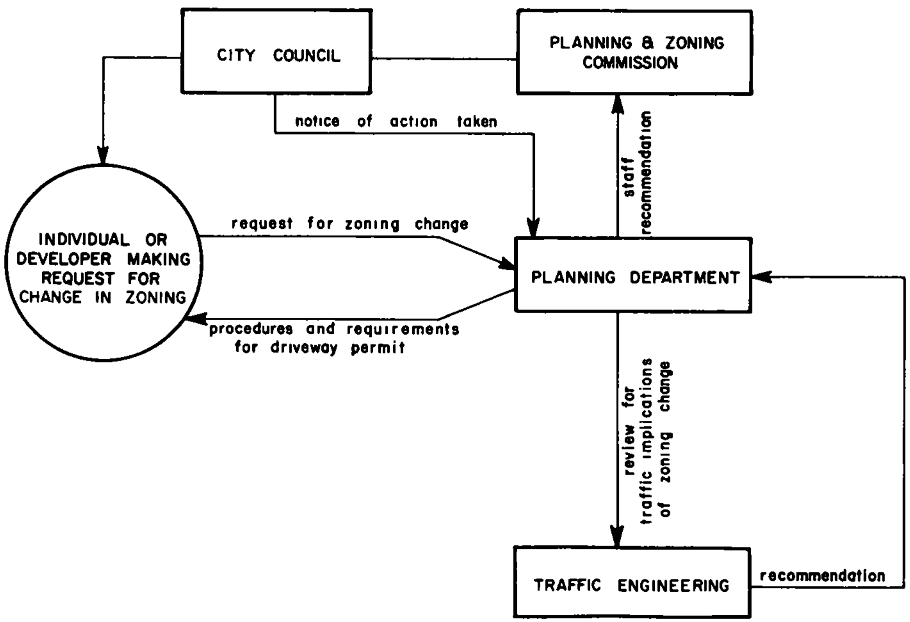


Figure 41 Flow chart for review of access needs when request initiated by request for change in zoning.

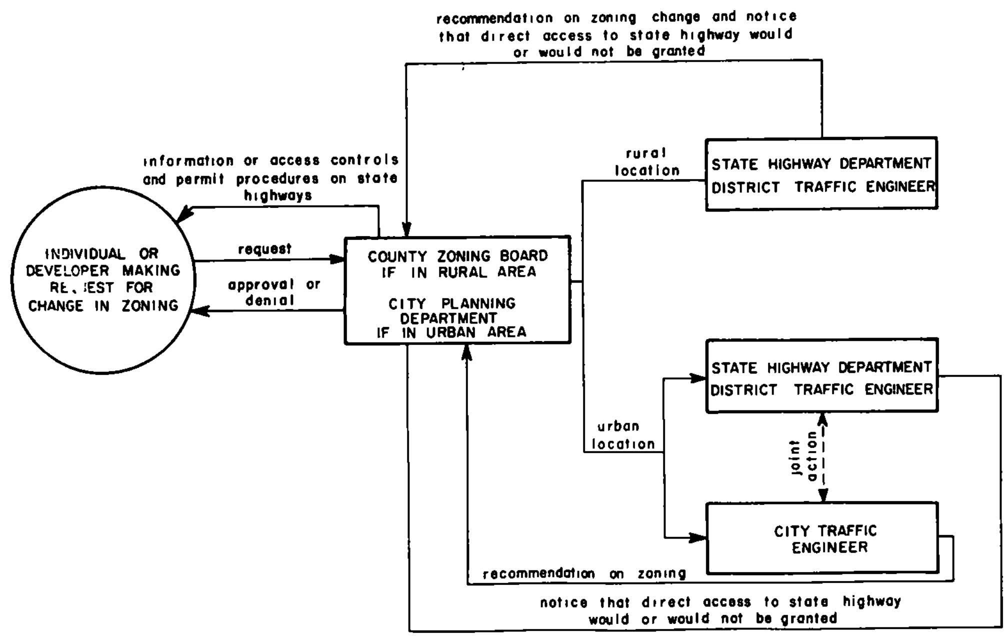


Figure 42. Flow chart for review of access problems with request for zoning change on state-maintained routes.

Recommendations for Existing Roadways

Access control should be instituted on all existing roadways of a collector and higher functional classification. Application of access control should be directed toward the long-run improvement and upgrading of the existing facilities to a condition comparable to that for new roadways of the same functional class.

The design and construction standards, as well as permit procedures, for additional driveways on existing roadways should be the same as those for driveways on new alignment insofar as possible.

Use of the two-way left-turn lane should be limited to existing roadways. Greater use of this operational technique is suggested in the following situations:

1. As an interim measure where widening and reconstruction is to be eventually accomplished.
2. Where there are numerous curb-cuts along one or both sides of the roadway and a limited number of vehicles use any one driveway.

It is recommended that greater use be made of the mapped street powers in those cases where an arterial will need reconstruction and widening before some reasonable future date. These powers are more restrictive than the zoning powers and might be used effectively to discourage erection of buildings, or other permanent structures, in close proximity to the existing facility. Compensation must, of course, be paid for the property when it is taken; however, courts generally have held that compensation need not be paid for improvements within the area to be acquired that are made subsequent to the filing of the official map.

Under certain conditions, the access control design on primary arterials should consider the possible upgrading of the roadway to full-control of access (freeway design). The conditions under which the responsible administrative jurisdiction should provide for this potential are:

1. The highway is located in the urban fringe where the population is presently sparse but has high growth potential.
2. The urban centers connected by the highway are relatively close together and the traffic volume between them might be expected to increase so as to require two or more lanes in each direction within 30 years.

Conversely, contemplation of full-control of access is not recommended as feasible when:

1. Large areas of adjacent land are sparsely populated and have low growth potential.
2. The urban centers connected by the highway are so far apart that traffic volumes will be very low for the foreseeable future.
3. The primary highway is the only road available for many miles and some land access, under controlled conditions, is essential.

CHAPTER FOUR

RECOMMENDED RESEARCH

The analysis of interference caused by driveway entrance maneuvers provides an estimate of the relationship between the degree of local access and the service provided to through traffic. However, extension of this approach to measure the rate at which local access is substituted for capacity for service to through traffic and to more precisely quantify the cost imposed on the traffic stream by medial and marginal access would provide the highway administrator with further valuable information to be used as a basis for designating the degree of access control on a particular facility.

With regard to specific design of roadway elements related to access, the standards suggested here are based on the physical limitations of the driver-vehicle combination. Although roadway elements designed according to these recommendations will accommodate access maneuvers as desired, more information is needed to show what the driver actually will do under a particular set of access conditions.

Specific information of this type includes:

1. The effect of geometric driveway configuration on turning path and speed of the vehicle entering the driveway.
2. The effect of profile and surface roughness of driveways, median openings, or other access points on the speed at which drivers are generally willing to execute their intended maneuver.
3. The effect of spacing between access points and median crossings on the relative frequency of wrong-way movements upstream on multi-lane divided roadways.
4. More specific information on the performance characteristics (i.e., acceleration, deceleration, etc.) of vehicles executing various access maneuvers.

Accident data generally available at present do not provide sufficient information to define the relationship between hazard and specific elements of roadway design. More detailed information relating safety to specific items such as driveway width, driveway spacing, and maneuvering speed would be desirable.

Additional research into the economic aspects of access and accessibility in relation to the land market, land development, intensity of business activity, and relative competitive position of competing establishments are also recommended. This research should be designed to answer specific questions rather than attempt to investigate broad effects of highway improvements such as in the conventional impact study. Specific research topics that are suggested for investigation include:

1. The operation of the land market in respect to properties adjacent to arterials having different degrees of access control.

2. The difference in the land development along arterials having different degrees of access control (i.e., arterials having no direct access vs those with various degrees of limitation on the number and spacing of driveways); more specifically the following elements should be compared:

(a) Distribution of tract size (sq ft) and frontage versus depth along urban arterials.

(b) The type of economic activity conducted on abutting parcels.

(c) The distribution of land values along urban arterials.

(d) The distribution of the type of construction and value of developments on abutting parcels.

(e) The return on investment for different types of business establishments located on abutting parcels.

(f) The percentage of business derived from through traffic and local residents, together with the attitudes of patrons of abutting business establishments and their criteria for selection of the establishment patronized.

(g) The economic linkages between business types found along urban arterials.

3. Identify the nature and extent of economic and functional obsolescence of establishments presently along existing arterials, including:

(a) The extent to which changes in business activity are occurring.

(b) The types of establishment that are going out of business and the types of establishment which are replacing them.

(c) The parcel size (frontage and depth) together with the number and design of driveways for properties that have been redeveloped or for which the business activity has changed.

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APPENDIX A

ROAD USER COSTS

Road user costs have been developed from a variety of sources and are summarized in this appendix. These costs include time costs, vehicle operating costs, and accident costs. Time values and operating costs are presented in a way to make it possible to calculate costs associated with operating at uniform speed, with speed changes (including stops), and with stopped time. The time and operating costs are given for several types of vehicles and weighted-average values are developed using the vehicle proportions in Table A-1. Accident costs are given for rural and urban areas for different types of accidents and for different types of access control. These road user costs are discussed in more detail in the following.

TIME COSTS

Tables A-2 through A-4 give information on time costs. Table A-2 gives values of time per vehicle-hour for different types of vehicles and a weighted-average value of time for commercial vehicles. Table A-3 gives the additional amount of time, in hours, consumed by making speed changes. The values in Table A-2 and A-3 are used to derive the cost of the additional time it takes to make speed changes given in Table A-4. The last column of Table A-4 gives a weighted-average of these time costs for commercial vehicles, the weights used in deriving these data are given in Table A-1.

VEHICLE OPERATING COSTS

Tables A-5 through A-7 give information on vehicle operating costs for different types of vehicles and weighted-average costs for commercial vehicles. These weighted averages are based on the vehicle proportions given in Table A-1. It is assumed that 2-axle, 4-tire, single-unit trucks have operating costs like "commercial delivery trucks." All other single-unit trucks are assumed to have the costs of a 12,000-lb single-unit truck. All other commercial vehicles are matched with either a 2-S2 or a 3-S2 truck-semitrailer combination.

Table A-5 gives the operating costs for traveling at uniform speeds. Table A-6 gives the additional operating costs of making speed changes, including stops. Table A-7 gives the operating costs of idling.

ACCIDENT COSTS

Tables A-8 through A-15 give information on accident costs. Accident cost information has been collected for rural and urban accidents from statewide studies in Massachusetts, Illinois, New Mexico, and Utah, and for the Washington, D. C., area. These accident cost studies cover accident cost variation by type of accident, type of access control, location of accident, and severity of accident.

There is a considerable range in accident costs among the studies. This is especially the case for accidents involving fatalities. The Washington, D. C., study was the only study that included the loss of future earnings in the cost of fatalities; this loss-of-future-earnings cost comprised about 90 percent of the cost of a fatality.

All of the studies included in accident costs, the costs of property damage, ambulance, services of doctors, dentists, and nurses, hospitalization, lost work time, attorney and court fees, and other miscellaneous items.

To make full use of accident cost information it is necessary (1) to have information on how accident rates vary with the conditions for which it is known that accident costs vary, and (2) to have a means for predicting accident rates by types of accident (such as head-on, rear-end, and angle). Unfortunately, the information on accident rates in general is not such that it makes it possible to predict different types of accidents.

The accident costs from the studies reviewed show in general that rural accidents are more costly than urban

TABLE A-1

VEHICLE AND VALUE OF TIME INFORMATION USED IN DERIVING TIME AND OPERATING COSTS

Type of Vehicle	Proportion of Vehicles[1]	Value of Time Used ($ per Vehicle Hour)[2]	Type of Costs Used[3]
Passenger Cars	8619	3.50	P.C.
Single-Unit Trucks			
2-axle, 4-tire	0784	3 81	C D.
2-axle, 6-tire	0337	3 81	S U
3-axle	0032	4.00	S U
Combinations with Semitrailers			
3-axle	0046	4 41	2-S2
4-axle	0084	4 65	2-S2
5-axle	0015	4 77	3-S2
Combinations with Full Trailers			
3-axle	0001	4 80	3-S2
4-axle	0003	4 80	3-S2
5-axle	0006	4 80	3-S2
6-axle or more	0001	4 80	3-S2
Combinations with Trailers & Semitrailers	0005	5 66	3-S2
Buses	0067	15 30	3-S2

[1] These proportions are a simple average of 1964 traffic for the United States on urban roads classified as "federal-aid secondary" and "other roads and streets," as given in United States Congress, Supplementary Report of the Highway Cost Allocation Study, House Document 124, 89th Congress, 1st Session (Washington, D C U S Government Printing Office, 1965), p 55

[2] These values are taken from Table A-2

[3] P C is for passenger cars, C D for 5-kip commercial delivery vehicle, S U for 12-kip single-unit truck, 2-S2 for 40-kip (2-S2) gasoline truck with semi-trailer, and 3-S2 for 50-kip (3-S2) diesel truck with semi-trailer

TABLE A-2

VALUES OF TIME, BY VEHICLE TYPE

Vehicle Type	Value of Time (Dollars Per Vehicle Hour)
Passenger Car[1]	3 50
Single-Unit, 2-Axle Truck	3 81
Single-Unit, 3-Axle Truck	4 00
2-S1 Truck-Semi-trailer	4 41
2-S2 Truck-Semi-trailer	4 65
3-S2 Truck-Semi-trailer	4 77
3-2 Truck-Trailer	4.80
Truck-Semi-trailer-Trailer[2]	5.66
Bus[3]	15 30
All Commercial Vehicles	4.47

[1] This value of time for passenger cars is based on 1 3 persons per vehicle and a value of time of $2.70 per person per hour

[2] This value is a composite of that for a 2-S1-2 ($5 30) and a 3-S2-4 ($6 20), using 6 times the 2-S1-2 value plus .4 times the 3-S2-4 value

[3] This value includes $10 00 per hour (which was arbitrarily assigned) for passengers

NOTE Values in this table are based on information in Stanford Research Institute, The Value of Time for Passenger Cars, Volume I compiled by Dan G Haney and Volume II by Thomas C. Thomas (Menlo Park, California Stanford Research Institute, May, 1967), Thomas E. Lisco, The Value of Commuters' Travel Time A Study in Urban Transportation, Paper Presented at the 47th Annual Meeting of the Highway Research Board, Washington, D.C., January 18, 1968. W. G Adkins, A W. Ward, and W F McFarland, Values of Time Savings of Commercial Vehicles, NCHRP Report 33 (Washington, D.C. Highway Research Board, 1967).

TABLE A-3

ADDITIONAL TIME CONSUMED BY STOPPING AND RETURNING TO INITIAL SPEEDS, BY SPEED AND VEHICLE TYPE

Initial Speed (mph)	Time (Hours Per 1000 Stops)				
		Commercial Vehicles			
	Passenger Car	Commercial Delivery	Single Unit	2-S2 Gasoline	3-S2 Diesel
15	1.36	1 52	2 20	2.30	3 48
20	1 63	1.93	2 93	3.19	4.76
25	1 91	2 36	3 67	4.16	6 10
30	2 21	2 81	4 40	5.22	7 56
35	2 53	3 28	5 13	6.41	9 19
40	2 87	3 78	5 87	7 76	11.09
45	3.26	4 30	6 60	9 35	13 39
50	3 75	4 87	7 33	11 34	16 37
55	4 41	5 48	8.07	13 94	20 72
60	5.35	6 15	8.80	17 47	27.94

Source Robley Winfrey, Motor Vehicle Running Costs for Highway Economy Studies (Arlington, Virginia, November, 1963), pp 20-11, 20-16, 20-21, 20-26, 20-31

TABLE A-4

ADDITIONAL TIME COST OF STOPPING AND RETURNING TO INITIAL SPEED, BY SPEED AND VEHICLE TYPE

Initial Speed (mph)	Cost (Dollars per 1000 Stops) by Vehicle Types					
		Commercial Vehicles				
	Passenger Cars	Commercial Delivery	Single Unit	2-S2 Gasoline	3-S2 Diesel	Weighted Average
15	4.76	5.79	8.43	10.51	41 83	9.50
20	5.71	7.35	11.22	14.58	57.22	12.60
25	6.69	8.99	14.06	19.01	73.32	15.86
30	7.74	10.71	16.85	23.86	90.87	19 27
35	8.86	12.50	19.65	29.29	110.46	22.94
40	10.05	14.40	22.48	35.46	133.30	26.97
45	11.41	16.38	25.28	42.73	160.95	31.50
50	13.13	18.55	28.07	51.82	196.77	36.87
55	15.44	20.88	30.91	63.71	249.05	43.78
60	18.73	23.43	33.70	79.84	335.84	53 64

Note. The values in this table are based on the "additional times consumed" from Table A-3 and the values of time and proportions of vehicles from Table A-1. The values of time which are used are: passenger cars, $3.50; commercial delivery, $3 81, single unit trucks, $3.83; 2-S2 Gasoline trucks, $4.57; 3-S2 diesel trucks, $12.02 (includes buses, with passenger time at $10.00 per hour total, and full trailer combinations).

TABLE A-5

OPERATING COSTS AT UNIFORM SPEEDS ON LEVEL, TANGENT HIGHWAYS WITH PAVEMENT IN GOOD CONDITION, BY SPEED AND VEHICLE TYPE

Uniform Speed (mph)	Cost (Dollars Per 1000 Vehicle Miles) Passenger Cars	Commercial Vehicles Commercial Delivery	Single Unit	2-S2 Gasoline	3-S2 Diesel	Weighted Average
15	39.06	44.15	69.62	120.17	103.41	62 31
20	36.98	41.39	65.90	107.10	95.81	57.99
25	35.80	39.95	64.73	101.19	92.92	56.10
30	35 22	39.32	65.11	99.51	93.01	55.68
35	35.13	39 29	66.60	100.84	95.10	56.34
40	35.44	39 83	68.87	104.55	99 85	57.94
45	36 09	40.88	71.84	110.43	105.80	60.31
50	37.03	42 49	75.59	118.70	113.63	63.56
55	38.13	44.72	80.24	130.18	123 66	67.86
60	39.70	48.11	85.84	145.55	134.60	73.51

Note: Values in this table are based on Robley Winfrey, Motor Vehicle Running Costs for Highway Economy Studies (Arlington, Virginia, November, 1963), pp. 20-2, 20-3, 20-4, 20-5, 20-6, and Paul J. Claffey, Fuel Consumption Rates of Passenger Cars as Affected by Grades, Curvature, Speed and Transmission Ratio, Interim Report on N C.H.R.P. Project 2-5/2 (Potsdam, New York, January, 1968), p. 14. The weights used to derive the weighted average commercial vehicle costs are taken from Table A-1

TABLE A-6

ADDITIONAL OPERATING COST OF STOPPING AND RETURNING TO INITIAL SPEED, BY SPEED AND VEHICLE TYPE

Initial Speed (mph)	Cost (Dollars Per 1000 Stops) Passenger Car	Commercial Vehicles Commercial Delivery	Single Unit	2-S2 Gasoline	3-S2 Diesel	Weighted Average
15	3.26	3.70	8.30	26.88	34.50	9.30
20	4.95	5.64	12.57	41.06	52.51	14.15
25	6.96	8.00	17 65	58.85	74.75	20.11
30	9.36	10.86	23.76	80.92	102.21	27.39
35	12.24	14.33	31.07	107.94	136.05	36.26
40	15.76	18.55	39.92	141.08	178.00	47.12
45	19.99	23.62	50.49	181.23	229.46	60.12
50	25.15	29.67	63.11	229.62	292.31	76.06
55	31.43	36.80	78.00	287.13	368.52	94.91
60	39.09	45.19	95.45	355.49	462.48	117.44

Source: Robley Winfrey, Motor Vehicle Running Costs for Highway Economy Studies (Arlington, Virginia, November, 1963) pp. 20-10, 20-15, 20-20, 20-25, 20-30.

Note: The weights used to derive the weighted average commercial vehicle costs are taken from Table A-1.

TABLE A-7

OPERATING COST OF IDLING

Vehicle Type	Cost (Dollars Per 1000 Vehicle-Hours) By Vehicle Type	Weighted Average
Passenger Car	170.41	170 41
Commercial Delivery	132 54	
Single-Unit Truck	199.93	166 07
2-S2 Gasoline	249.45	
3-S2 Diesel	196 28	

Source. Robley Winfrey, Motor Vehicle Running Costs for Highway Economy Studies (Arlington, Virginia, November, 1963), p. 20-52
Paul J Claffey, Fuel Consumption Rates of Passenger Cars as Affected by Grades, Curvature, Speed and Transmission Ratio, Interim Report on N C H.R.P Project 2-5/2 (Potsdam, New York, January, 1968), p 39

Note The weights used to derive the weighted average commercial vehicle costs are taken from Table A-1

accidents. The most expensive type of accident is the head-on accident; the next most expensive type is the angle and sideswipe. This is shown by the information in Tables A-8 and A-9. Thus, the more expensive types of accidents are directly related to access control, head-on accidents being related to medial access controls and angle accidents being related to marginal access controls.

Tables A-10 through A-15 give accident costs as related to different types of access control.

TABLE A-8

SUMMARY OF URBAN TRAFFIC ACCIDENT COSTS PER INVOLVED PASSENGER CAR, BY TYPE OF COLLISION

Type of Collision	1953 Mass All	1955 New Mexico Urban	1955 Utah Urban	1958 Illinois Urban	1964-6 Wash D C Area
Head-on	$709	$652	$496	$418	$594
Rear-end	482	182	300	385	307
Angle	327	291	363	410	481
Sideswipe (Same Direction)	276	95	137	125	-
Sideswipe (Opposite Direction)	471	88	230	462	-
Turning Movement	232	164	132	236	-
Parking Maneuver	94	46	49	103	-
Backing in Traffic Lane	-	55	295	496	-
All Collisions	381	184	296	269	389

Sources Massachusetts J.E Johnston, "The Economic Cost of Traffic Accidents in Relation to Highway Planning and a Comparison of Accident Costs in Utah and Massachusetts," Public Roads, Vol 31, No 2 (June, 1960), New Mexico New Mexico State Highway Department, The Economic Costs of Motor-Vehicle Accidents, New Mexico Passenger Cars, 1955 (Santa Fe, not dated), Utah State Road Commission of Utah, Cost of Passenger Car Accidents to Motorists in 1955 (Salt Lake City, 1959), Illinois Illinois Division of Highways, Costs of Motor Vehicle Accidents to Illinois Motorists, 1958 (Springfield, 1962), Washington, D C, Area Wilbur Smith and Associates, Motor Vehicle Accident Costs Washington Metropolitan Area (1966)

Note· Costs cover urban traffic accidents, except for Massachusetts values which also include rural accidents, and are "costs per passenger car involvement" except for the Washington, D C values which are for both passenger cars and trucks The Washington, D C, values cover only reported accidents, all other values cover reported and unreported accidents

TABLE A-9

SUMMARY OF RURAL TRAFFIC ACCIDENT COSTS PER INVOLVED PASSENGER CAR, BY TYPE OF COLLISION

Type of Collision	1955 New Mexico Rural	1955 Utah Rural	1958 Illinois Rural
Head-on	$986	$1,586	$1,069
Rear-end	548	429	318
Angle	634	493	310
Sideswipe (Same Direction)	194	1,235	164
Sideswipe (Opposite Direction)	500	370	764
Turning Movement	387	378	313
Parking Maneuver	116	40	169
Backing in Traffic Lane	468	260	103
All Collisions	467	609	340

Sources New Mexico New Mexico State Highway Department, The Economic Costs of Motor-Vehicle Accidents, New Mexico Passenger Cars, 1955 (Santa Fe, not dated), Utah State Road Commission of Utah, Cost of Passenger Car Accidents to Motorists in 1955 (Salt Lake City, 1959), Illinois Illinois Division of Highways, Costs of Motor Vehicle Accidents to Illinois Motorists, 1958 (Springfield, 1962)

Note Costs cover rural traffic accidents and are "costs per passenger car involvement," and cover both reported and unreported accidents

TABLE A-10

AVERAGE ACCIDENT COST PER VEHICLE INVOLVEMENT, BY TYPE OF OPERATION AND DEGREE OF ACCESS CONTROL

Type of Operation	Degree of Access Control: None	Partial	Full	Not Stated	Total
One-Way					$307
Two-Way, Undivided					528
Two-Way, Divided	$490	$1,560	$890	$560	610
Not Stated					339
All Types					527

Source· Wilbur Smith and Associates, Motor Vehicle Accident Costs Washington Metropolitan Area (1966), pp 60, 61

Note Values are for reported accidents only

TABLE A-11

ILLINOIS AVERAGE TRAFFIC ACCIDENT COST INVOLVING VEHICLES OF ILLINOIS REGISTRY, BY ACCIDENT LOCATION

Accident Location	Average Accident Cost: Urban Accidents	Rural Accidents	All Accidents
Intersection	$346	$ 471	$357
Non-Intersection			
One-Way Streets			
One Traffic Lane	111	-	111
Two Traffic Lanes	65	-	65
Three or More Traffic Lanes	109	-	109
Undivided Highways (Two-Way)			
Two Traffic Lanes	173	438	251
Three Traffic Lanes	113	94	104
Four or More Traffic Lanes	249	405	263
Divided Highways			
Four Traffic Lanes	406	1,242	461
Six or More Traffic Lanes	735	3,931	780
Not Specified	74	53	69
All Locations	255	407	282

Source Illinois Division of Highways, Cost of Motor Vehicle Accidents to Illinois Motorists, 1958 (Illinois, December, 1962), pp 13,91

Note Values cover both reported and unreported accidents

TABLE A-12

AVERAGE COST OF MOTOR-VEHICLE TRAFFIC ACCIDENTS IN UTAH ON HIGHWAYS WITH TWO-WAY TRAFFIC INVOLVING PASSENGER CARS OF UTAH REGISTRY, BY TYPE OF HIGHWAY AND LOCATION, 1955

Type of Highway	Accident Location					
	Urban			Rural		
	Inter-Sectional	Non-Inter-Sectional	All Urban	Inter-Sectional	Non-Inter-Sectional	All Rural
Two-Lane, Undivided	$ 726	$363	$502	$ 813	$492	$519
Four Lanes or More, Undivided	448	434	439	1,759	306	439
Four Lanes or More, Divided	1,227	312	989	623	265	356

Source State Road Commission of Utah, Cost of Passenger Car Accidents to Motorists in 1955 (Utah, 1959) Tables B-1 34, B2 34, B1.35, B2.35, B1.33, B2.33, B1 37, B2.37, B1 38, B2 38, B1 36, and B2 36

Note Values cover both reported and unreported accidents.

TABLE A-13

DIRECT TRAFFIC ACCIDENT COSTS PER INVOLVEMENT FOR WASHINGTON, D.C., AREA, CLASSIFIED BY ACCIDENT SEVERITY FOR EACH ROADWAY FUNCTION

Function (Roadway Type)	Fatal Injury	Non-Fatal Injury	Property Damage Only	All Severity Classes
Express Highway [1]				
Percent of Involvements	0 7	38 8	60 5	100 0
Average Cost	$44,815	$948	$263	$829
Arterial Street				
Percent of Involvements	0 3	32 1	67 6	100 0
Average Cost	$46,889	$891	$195	$569
Local Street				
Percent of Involvements	0 1	25 0	74 9	100 0
Average Cost	$52,488	$785	$186	$414

[1] Includes freeways, expressways, and parkways (controlled-access highways)

Source Wilbur Smith and Associates, Motor Vehicle Accident Costs Washington Metropolitan Area (1966), p 57

Note Values are for reported accidents only

TABLE A-14

AVERAGE TRAFFIC ACCIDENT COST PER INVOLVEMENT, BY TYPE OF TRAFFIC CONTROL AND ROADWAY CHARACTERISTIC

Traffic Control	Roadway Characteristic					
	At-Grade Intersections				Traffic Circles	Inter-Changes
	3-Leg	4-Leg	5-Leg	All		
Traffic signal	$273	$388	$ 479	$380	$190	$ 232
Flashing signal	413	508	495	499	136	-
Police Officer	35	472	124	327	169	132
Stop Sign (One-Way)	387	509	232	486	108	374
Stop Sign (Two-Way)	122	431	93	368	50	-
Stop Sign (Four-Way)	524	359	1,666	451	169	264
Yield Sign (Intersection)	230	432	240	305	221	389
Yield Sign (Merging)	580	308	223	501	-	1,846
Other	495	435	721	469	97	585
No Traffic Control	490	256	-	460	207	183
Not Stated	719	391	262	530	321	2,163
All Types of Control	416	433	462	431	162	713

Source Wilbur Smith and Associates, Motor Vehicle Accident Costs Washington Metropolitan Area (1966), pp 258-259

Note Values are for reported accidents only

TABLE A-15

AVERAGE COST PER INVOLVEMENT IN WASHINGTON, D.C., BY TYPE OF TWO-WAY OPERATION AND TYPE OF ACCIDENT

Type of Two-Way Operation	Involvement Cost by Type of Accident					
	Collision Between Vehicles	Collision With Fixed Object	Collision With Other Object	Ran Off Roadway	Non-Collision on Roadway	All Types
2 or 3 Lanes, Undivided	$ 518	$2,291	$2,035	$2,052	$ 985	$ 726
4 or More Lanes, Undivided	355	2,496	956	2,883	491	428
4 Lanes, Divided (No Access Control)	349	2,052	3,015	1,896	2,765	497
4 Lanes, Divided (Partial Access Control)	1,347	497	-	216	184	1,254
4 Lanes, Divided (Full Access Control)	714	1,991	410	1,281	663	827
6 Lanes, Divided (No Access Control)	436	1,084	926	3,826	308	483
6 Lanes, Divided (Partial Access Control)	677	8,487	44	36,226	688	1,968
6 Lanes, Divided (Full Access Control)	603	2,892	9,526	1,206	1,553	977

Source· Wilbur Smith and Associates, Motor Vehicle Accident Costs: Washington Metropolitan Area (1966), pp 256-257

Note Values are for reported accidents only.

APPENDIX B

NONUSER IMPACT

NOTES ON HIGHWAY ECONOMIC IMPACT

Appendix B contains a general summary of the background materials for the economic impact implications of highway access limitation and control. The primary emphasis of these materials is the effects of highways on the nonuser. An effort has been made, however, to point out relationships between user and nonuser effects. For some purposes the two types of effects can be conveniently defined as separate, but, to a great extent, the same persons are affected by the different types of highway impact. In addition, there are complements, as well as trade-offs, between the so-called user and nonuser segments. Thus, information which might otherwise be classed as "user effects" has been included in several sections. Similarly, certain legal points are touched on in this appendix, although no concerted effort has been made to include such materials.

The greatest difficulty in the assembly of information pertinent to the over-all study was that, in the vast body of literature relating to the economic impact of highways, very few studies are found which are concerned with direct medial and marginal access per se. The conclusions that have been reached bear much more heavily on the value of highway accessibility and the improvement of area accessibility by highway development, rather than on variations in impact associated with levels of access control.

Classifying Highway Benefits

Benefits arising from construction of a highway have been subdivided into what are generally known as vehicular, or user, and nonvehicular, or nonuser, benefits. The division of highway effects into user and nonuser benefits is a somewhat misleading dichotomy. The difficulty is that user benefits are, by nature, transferable or shiftable to nonuser beneficiaries. Nonuser benefits may have different meanings for different people. To some, nonuser benefits flow from the expenditures made directly for the highway improvement—in terms of numbers and kinds of employment the road program will provide and materials consumed in its construction. Still others may be more concerned with the economic consequences of providing improved highways, in terms of both direct and indirect nonvehicular net benefits. Included in this would be the creation of new industrial areas, changes in land values and land uses, and alterations in the patterns of retail distribution.

In general, user benefits are those that are realized directly by the motor-vehicle user. These include savings in operating costs, time and accident costs, and reductions in the strain and annoyance of driving under unfavorable circumstances. Nonuser or nonvehicular benefits are those more indirect benefits that accrue to adjacent property, business enterprise, the community at large, and others.

There have been some differences of opinion among researchers in the field of transportation economics as to whether the kind of nonuser benefits generally investigated are truly user or nonuser benefits. One school of thought asserts that land values at a particular highway location have increased dramatically, largely because vacant land has been transformed into high-intensity commercial use, and that the new use is possible only because excellent vehicular accessibility has been provided by the highway to a market that is now oriented around travel time, rather than distance. They would concede, however, that the improvement of neighborhood drainage, resulting from highway improvement, is a nonuser benefit and has little to do with the highway as such.

Another group of researchers tends to discount the need to formulate a completely precise distinction between user and nonuser benefits. What seems most significant to this group is not labels, but the presence of real and extensive beneficiary groups, other than highway users as such, that reap the advantages of highway improvement. They believe that the total magnitude of these benefits is substantial. Although "transferred" benefits and disbenefits are not as readily subject to proof as are the user consequences, they are nonetheless far removed from the speculative and conjectural sphere, and continuing research has yielded a substantial fund of economic data from which these effects may be realistically inferred.

Access and Accessibility

Direct access to a roadway gives rise to nonuser benefits of considerable significance. All land uses seek such locational advantage, for without it they are isolated and have little chance for economic returns. Such access points, in an economy so dependent on public roads, constitute the origins of most economic activity. One must not argue, however, that direct access to all public roads is a necessary requirement for economic development. It is the general accessibility within areas and between areas which highways give that is critical to the creation of suitable locations for land uses.

Direct access and, similarly, near proximity to highway access points are of demonstrated value. Most importantly, any frontage on a public-built road is valuable, if only because it substitutes for privately built (and dedicated) roads and streets. But, more than this, the higher the road type and the more the traffic, the more valuable the abutting lands are likely to be. This is due to the high demand for quality sites which can be put to a large number of uses capable of paying relatively high rents.

The value of accessibility, however, is tremendous and is spread over large areas. The study of the effects of Lake Washington floating bridge on Mercer Island demonstrates the area development impact of accessibility in a rather pure case (*71*). As discussed later, most economic impact studies have dealt with accessibility values, rather than direct access values.

Although highway accessibility is important to practically all types of land uses, direct access to highways is prized by businesses, especially retail establishments. This is shown in Figures B-1 and B-2. Highway access and exposure (that is, access to the commercial property from the highway, and visibility of the business establishment from the highway) appear to be the critical factors to a much greater degree in the case of retail enterprises than in the selection of new locations for warehouses and distribution facilities (Fig. B-2). It should be pointed out, however, that such preferences do not deny that location requirements can otherwise be met.

Benefits In General

Generally, benefits that accrue to property as a result of a public road improvement can be considered in three classes. The first two, although distinguished as general and neighborhood, are basically classed as general benefits. The last one is commonly referred to as special benefits.

1. General benefits affect the entire community and perhaps raise the value of land in an entire city, county, or town.
2. Neighborhood benefits accrue to a definite district by reason of its nearness to the public improvement.
3. Special benefits affect a particular estate or parcel of land by reason of its direct relationship to the public improvement.

Figure B-3 shows this classification of nonuser benefits and their generally expected pattern in relation to access and accessibility.

One source has pointed out that a distinguishing feature between a special benefit and a general benefit is that a special benefit is different in amount or degree from those accruing to others in the area. General benefits are those of the same kind and degree as received by all land within the area of the public improvement (*55*).

Some courts have further distinguished between general and special benefits as reflected in the property's value after the completion of the public improvements. A Missouri court held that the general benefits derived by the particular tract in litigation might be greater than those enjoyed by any other land, and would be reflected in its increase in value. In this event, only that part of the increase resulting from special benefits (i e., those arising from the land's position directly on the highway improvement) would be chargeable (as enhancements). The position criteria could be the availability of the land for new or better uses, facilities for ingress and egress, improved drainage, flood protection and the like. The same court also stated that an improved street or highway, by reason solely of its physical proximity to adjacent lots or tracts of land, confers on such lots or tracts a special benefit. The Texas Supreme Court has held that new or increased access to remaining and abutting property may be considered in offsetting any damages (*55, 61, 64*).

Nonuser Access Benefits

General benefits have been defined as those benefits shared by the community as a whole as a result of constructing a highway facility. These benefits reflect the economic impact of a public improvement on an area. One measure of this economic effect is the altered structure of property values after the construction of the facility. Because general benefits are of economic value and are reflected in rises in property values in general, they can be estimated through statistical analysis of real estate sales data. This simply means that general benefits can be measured in terms of general increases in property values as a result

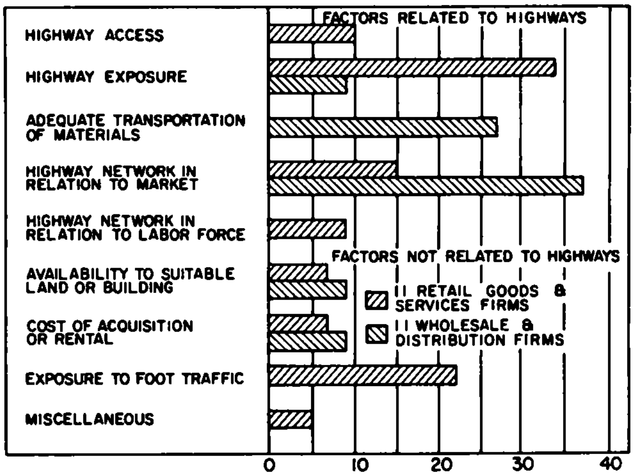


Figure B-1. Factors in the selection of new business locations. Frequency of various factors as the dominant criteria in selection of new locations by two categories of business firms (Real Estate Res. Corp., "Highway Networks as a Factor in the Selection of Commercial and Industrial Locations.") Source: 87th Congress (*34, p. 33*).

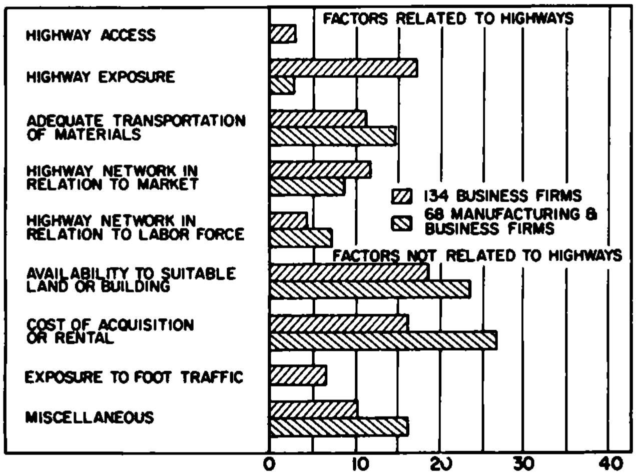


Figure B-2. Factors in the selection of manufacturing locations. Frequency of various factors as the dominant criteria in selection of new locations—manufacturing and processing compared to the total (Real Estate Res. Corp., "Highway Networks as a Factor in the Selection of Commercial and Industrial Locations"). Source: 87th Congress (*34, p. 28*).

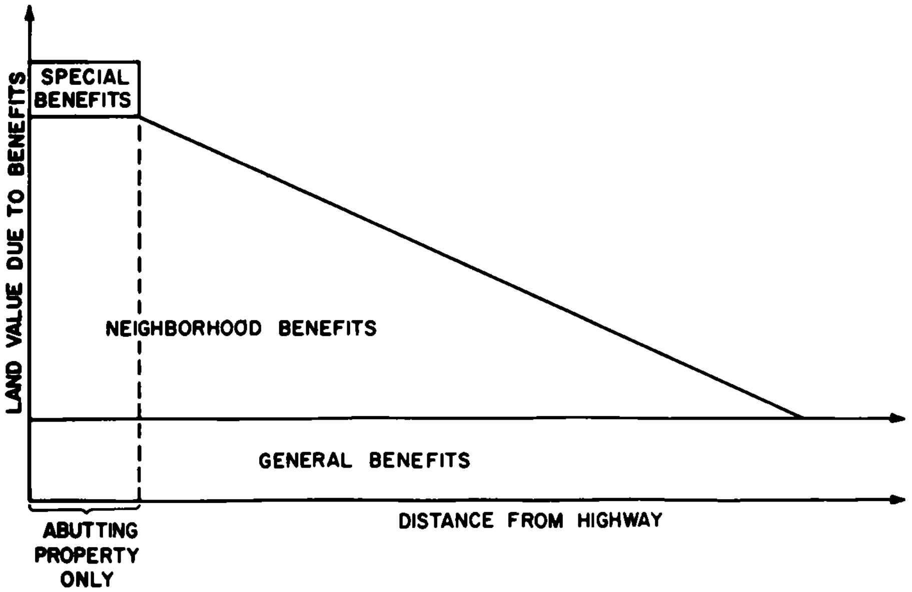


Figure B-3 Hypothetical relation of benefits to highway facility.

of construction of the highway. If average property value in the area is higher than before (excluding any increase attributable to general economic factors), then it may be said that general benefits have resulted from the highway.

The methodology for establishing the value of general benefits also may be used for estimating the value of special benefits accruing to individual properties affected by highway location. If general benefits are reflected by the average change in value of all properties in an area affected by a highway, then the change in value of individual parcels of remainder property may be compared to the average change for all properties of the same type and used to ascertain special benefits or damages.

Access rights include the right of ingress to and egress from property that abuts on a public facility, such as a major highway. With the exception of a new facility constructed where no previous right of access existed, the right of access cannot be denied nor unreasonably restricted, nor can an owner be deprived of such right, except by due process of law and on payment of compensation.

The value of an access right is influenced by various conditions. The taking of access can be considered a damage to remaining property. On the other hand, the granting of access can be considered an enhancement, or special benefit, offsetting any calculated damages. The variety and complexity of access problems are numerous In some instances, the creation of an outer highway or frontage road can completely offset damages (*28*).

The measurement of access within the framework of special benefits is an elaboration of the procedure previously emphasized. If the increase in value of an individual parcel of remainder property over the average for all properties of the same type and use can be considered to be a special benefit, then the relationship of the remainder and access to the highway is a part of that special benefit.

Specifically, measurement of access requires that a comparison be made between property abutting the facility that has access, as opposed to property abutting the facility that does not have access. All other things being equal, the percentage differential between the market price of the two properties will be the amount attributed to access, as shown in the hypothetical case in Figure B-4. The special benefits associated with access can be defined mathematically by the equation $SB = VP_f - VP_n$, when it is used to denote the relationship between access differentials. This equation can be further elaborated to include a variable to adjust for locational differences. The identity for net access benefits is now $SB_a = (VP_f - VP_n) + L_n$, in which

SB_a = net access special benefit to abutting remainders adjusted for locational differences along the facility;

VP_f = net differential in value of remainder abutting on a facility with access minus value of nonabutting comparable;

VP_n = net differential in value of remainder abutting on a facility without access minus value of nonabutting comparable; and

L_n = net adjustment for differences in location along the facility with respect to interchanges and ramps, etc.

To summarize, the method for calculation of the net access special benefit to an abutting remainder is the net differential in appraised value of the remainder abutting on the facility, with access adjusted by a nonabutting comparable; minus the net differential in appraised value of a comparable remainder abutting on the facility without access, adjusted by a nonabutting comparable; plus or minus an adjustment for differences in location along the facility with respect to interchanges and ramps (*29*).

In the application of these criteria to the appraisal and evaluation of the value of access, a basic distinction must always be kept in mind; i.e., is the proposed improvement within the sphere of the police power of the state (control of traffic, etc.), or is the action a "taking" in the constitutional sense?

Public Versus Private Viewpoint

Public bodies, by the very nature of the functions they are supposed to perform, must take a broad overview in the planning and operation of public enterprises. This viewpoint necessitates consideration of both the near and the distant future and the optimizing of the public good over long periods of time. Just as their accepted functions are relatively perpetual in nature, so does their forward view reach indefinitely into time. In public enterprise, the planning horizon can, and often does, reach to 50 years or more.

This long run is reinforced by low interest or discount rates as compared to those of the private sector. Funded expenditures may be costed at municipal rates, and expenditures from current revenues (vs bond sales) often are considered interest- or discount-free by public authorities.

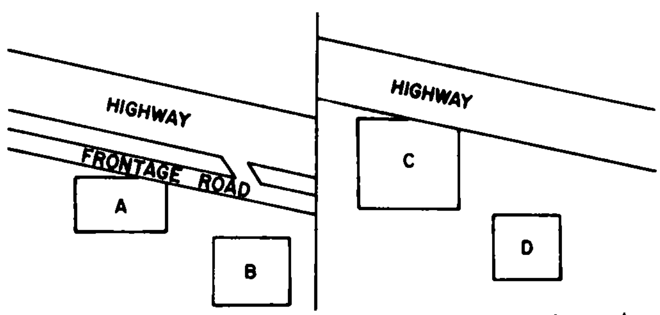
Furthermore, public enterprise almost never faces the threat of bankruptcy, nor is it threatened by short life expectancies and failure of the line of descent. The vantage is as on-going and stable as the permanence of governments themselves. Risks and interim reversals in particular actions are spread and obscured among the numerous undertakings of governments, and further are minimized by the police power, the taxation power, and the power of the purse.

Thus, public enterprise can, with a great deal of flexibility, decide the relative merits of short-run versus longer-run consequences of various actions.

Only the largest of corporations can have an overview of time similar to that of governments. Most private activities are decided with much shorter planning horizons or periods of interest. There is less certainty in private decisions, for both human lives and enterprise lives not only lack predictability of length but also are more uncertain during their span. The human mechanism may fail, and the enterprise is subject to changes in tastes and preferences of customers, the threat of competition, the cyclical nature of economic activity, and perhaps even the intra-area shifts of population and its travel patterns.

The interest that must be paid explicitly, or implicitly, by the private sector is real; it is, in fact, somewhat indistinguishable from profits, as far as motive is concerned. Thus, interest must be taken into account when a private enterprise is evaluated. Furthermore, interest is a sizable charge in private enterprise. It must cover a safe return on money, plus an allowance for the degree of risk involved; also, provisions for income taxes must be made. It is not unusual, therefore, that private enterprises often require an expected rate of return of 2 or 3 times that which may be suitable for public investment. It follows, then, that future earnings of private endeavor are highly discounted in terms of present value. This brings the short run into sharp focus and into higher preference than is necessary for public enterprise. The long planning horizon of the public body is rather hazy and obscure to the private investor. The latter must recapture capital and take profits (including interest) over a well-defined, shorter period of time. "In the long run he will be dead," and so will his enterprise if the promise of his gains and liquidity is very long deferred.

The public's long run is that time span which encompasses the public investment decision—all costs are variable, all internal costs are accountable, at least by intent. Such a long run may be identified as the period of interest for the total highway program, a particular project being only a part, but perhaps a representative part, of it. It is often heard, "How long can we go on paving additional land each time a traffic crisis arises?" Such a question suggests that there is a stopping point, one which may be freely selected. Unfortunately, this is not true. The more reasonable question may be, "How long are we going to continue to allow traffic crises to arise, simply because we fail to protect the primary function of arterial streets?" Or somewhat more precisely, and more harshly, "How long will we continue to nourish a system of windfalls along public highways?" This last question does not argue against land values in general and, thus, private ownership



VALUE OF PARCEL A ABUTTING FRONTAGE ROAD AFTER HIGHWAY CONSTRUCTION—$3,500
VALUE OF NONABUTTING COMPARABLE PARCEL AFTER HIGHWAY CONSTRUCTION—$2,000
SPECIAL BENEFIT ACCRUING TO PARCEL A—$1,500 ($3,500 MINUS $2,000)
VALUE OF PARCEL C ABUTTING HIGHWAY WITH NO FRONTAGE ROAD AFTER CONSTRUCTION—$2,500
VALUE OF NONABUTTING COMPARABLE PARCEL D AFTER HIGHWAY CONSTRUCTION—$2,000
SPECIAL BENEFIT ACCRUING TO PARCEL C—$500 ($2,500 MINUS $2,000)
VALUE OF ACCESS FOR PARCEL A—$1,000 ($1,500 MINUS $500)

Figure B-4. Hypothetical example of the determination of special benefits due to access.

and its inherent rights. Rather, reference is to particular land values along the margins of highways and, in turn, to windfalls that are not simply allowed, but are promoted, for a very few persons and at the direct expense of society. Here the discussion has drifted into interpersonal comparisons and thus into ethics. But economy also is involved, and it is this area that appropriately should receive increasing attention, aside from all normative considerations.

Trade-Offs

The elimination of restrictions of traffic flow, including reduction in the number of points of interference, leads *a priori* to (1) lower vehicle operating costs, (2) time savings, (3) higher traffic capacity, and (4) potential safety improvement, on a particular section of roadway. These benefits, or potential benefits, are obtained, however, within a framework of trade-offs. Internal optimization takes into account costs of the benefits and the fact that there may be some substitution between the types of benefits. Exogenous trade-offs arise from the fact that other users of the roadway system may experience adverse effects on the links that serve their desired movements and also from the different treatments accorded the adjacent land, in relation to grade, visibility, and access. In regard to the last, if roadway level of service is attained or protected by access control, the incidence of benefits is at least partially transferred from the nonuser group, as such, to the user group. Access control also may transfer benefits between nonuser subgroups and over time.

There are other locations for economic (or social) activity which are good substitutes for, and indeed compete with, sites along the subject roadway section. Land uses, and perhaps land value increments, restricted or denied along one segment may enhance the relative locations and values of land along other segments. Over and above some provision for road user services, the creation of situs through direct access to road improvements has certain more dynamic aspects than herein discussed. In a viable progressing economy, the land resource, as well as other resources, can become relatively scarce. In the case of land, suitable or optimum sites for particular uses can be in short supply; however, as noted previously, such are not always in short supply When such a condition prevails, road (or transportation) improvements become a positive and obvious factor in land development. Nevertheless, it does not necessarily follow that direct access is the best means of encouraging economic development, for the key to most area enhancement may be accessibility; that is, general area access rather than point or direct access. In fact, direct access, just as it may impede traffic flow, may detract from the goal of area accessibility.

Assuming that some direct access to high-type arterials is an acceptable policy, in that roadway functions are not overly impaired, it still does not follow that each roadway section of a given arterial must be given a minimum of access. In other words, it does not follow that every block, every ownership, and every conceivable land use should be accommodated. Road users need services, and some businesses can survive only if they are convenient, by direct access, to road users. Similarly, certain businesses (such as shopping centers) must have high-type road location in that they attempt to serve rather large areas. It appears argumentative that this is the situation for barber shops, beauty shops, plumbing shops, and other retail activities which have little dependence on the road user, as such. It is unlikely, too, that such activities could compete for direct access points, if these points were made somewhat scarcer in nature.

Another aspect of the land use-highway design problem might be called the "atrophy of the golden goose." As more and more development occurs on the margins of a roadway, it becomes more attractive for a still greater variety of land uses in businesses aggregating to serve each other, as well as through traffic (the barber arrives to offer his services to other businessmen, etc.). Somewhere in the development process, the point is reached (unheeded) where the integrity of the roadway is much eroded, if not lost. A new roadway on a new location may become the only alternative solution for through traffic movements.

Nonuser Effects Literature

Within the past 15 years a body of more than 600 research reports, critical articles, books, and other writings has been developed on the subject of nonuser consequences of highway development (Fig. B-5). Since the report of the Secretary of Commerce to the Congress in 1961, reporting on the outcome of activity under Section 210 of the National Highway Revenue Act of 1956, there has been little correlation or appraisal of this body of literature.

Alfred Marshall, the English economist, once said that the dominant fact in the industrial development of the western world was not manufacturing, but transportation. Because this judgment preceded the full impact of the automotive revolution, it would be even more true today. This revolution has brought about a new way of life in the U.S. It has influenced nearly all the activities of the individual, the family, commerce, and agriculture. Unlike other modes of transportation, the motor vehicle provides direct access to homes, recreation areas, shops, factories, offices, etc.

For this direct access, the various levels of government had to provide highways. Because roads, streets, and highways provide access to and egress from the lands in their service areas, the roadway pattern and the design and improvement of individual roadways are closely associated with the use and value of lands served, and with the life and livelihood of people located on those lands.

Systems of roadways are developed to meet the needs of the areas and communities they serve; but, once in being, they form a rigid framework which very permanently molds the development and pattern of the area or community. Growth and changing activities in the community frequently call for revisions or improvements of the roadway system. In addition, changes or improvements of roadway, or of the roadway system, will affect the use and value of neighboring lands and the well-being of the resident population.

Many long-used routes in both urban and rural areas are being relocated, and in numerous instances these relocations will bypass villages, towns, and cities, or at least their congested areas. Moreover, on most of the new mileage, entrance to the roadway is limited to designated points, and access from the immediate roadside is completely excluded.

This has posed the need to investigate the influence of past highway improvements in relation to land as a means toward foreseeing and preparing for the impacts of new highway construction on the use and value of land and on the activities of individuals in the affected areas. Despite the more than 600 reports of various kinds dealing with the nonuser consequences of highway development in general, the specific evaluation of the effects of direct access on the nonuser sector has largely been left undone.

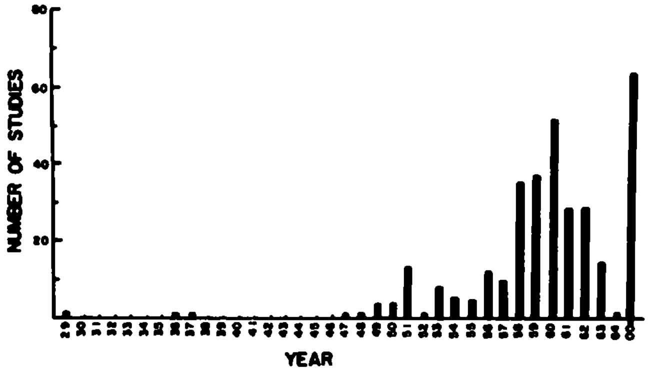


Figure B-5. Nonuser impact studies, by year. Source: "Community Consequences of Highway Improvement," NCHRP Report 18 *(1965) p. 5.*

HIGHWAY SERVICE AND LAND USE

The Utility of Location

Economic utility is gained when a site is used as one of the factors of production of some enterprise. Land value is the capitalization of the utility of a site. It will reflect the productivity of greatest value which the landowners and entrepreneurs anticipate will be achieved during the future use of the site.

The role that rent plays in an enterprise has been a much debated question in economics, but the intricacies of these arguments are not presented in this brief summary. A site has no rental value except as it is developed by some activity although, of course, it may have market value for some anticipated activities. The utility that is added by a site, which cannot be explained by the capital and labor applied to it, is primarily locational. Rent is a charge landowners can levy as a substitute for savings in transportation costs.

The locational pattern of land use is a result of basic economic forces, and the arrangement of activities at strategic points on the web of transportation lines is a part of the interaction of several parts within the over-all mechanism of the economy. Several pertinent economic forces and mechanisms consist of the following:

1. Each economic activity has an ability to derive utility from every piece of land. The utility is measured by the rent that the activity is willing to pay for the land.

2. The greater the derivable utility, the greater the rent that an activity is willing to pay. In the long run, competitive bidding for land will be such that each site is occupied by the highest and best use. This use is the use that can derive the greatest utility from the site, and is, therefore, willing to pay most to occupy it.

3. As an outgrowth of the occupation of each site by the highest and best use, there results an orderly pattern of land use in which rents throughout the system tend to be maximized.

One of the first analyses of this relationship between differences in spatial location and land-use patterns was developed by Johann Heinrich von Thunen, a German landowner and economist, in *Der isolierte Staat* (1826). Von Thunen assumed an isolated state with a single European-type village or city located in a level productive plain surrounded in turn by a wilderness area that separated it from other markets. He also assumed uniform climate and soils, uniform topography, and relatively uniform transportation facilities.

Except for location and distance to market, von Thunen's analysis held constant all of the natural factors affecting land use. Differences in land use could be attributed directly to variations in transportation costs. These, in turn, were dependent on such factors as distance to market; ease of transportation; and bulk, weight, and perishability of the products sent to market. The land-use pattern envisaged by von Thunen assumed that lands near the market would be used in an intensive manner and would be used to produce crop and livestock products which are highly perishable or heavy and bulky to transport. His model is concerned primarily with the role that transportation costs play in allocating the land resources found at varying distances from the market, between different agricultural uses. He recognized that transportation costs involve not only the transfer of produce to market, but also the time, effort, and inconvenience associated with moving workers and supplies to and from various production sites. With this reasoning, he indicated that the first zone around his central city would be used for garden plots and other intensive uses which call for considerable care and travel on the part of the villagers. The second and third zones were allocated to uses involving heavy, bulky, and hard-to-transport commodities, whereas those uses involving more easily transported products were located at even greater distances from the city.

The arrangement of the concentric land-use zones in this model strongly reflects the influence of transportation costs and convenience considerations. But these factors provide only a partial explanation of why the various land-use zones are used as they are. For a more complete answer, one must consider the effect of transportation and other costs on the amount of economic rent different sites can earn under various alternative uses. Von Thunen maintained that the optimal spatial pattern of land use, resulting from competitive bidding for land, would be one in which friction of distance in the system was minimized. The dual of this is interpreted as implying that, where the friction of distance is minimized, rents are maximized; therefore, rents vary directly with accessibility. As accessibility increases, friction of distance is diminished. More funds are available to the firm to bid for the land, and rents therefore increase. Surpluses available to bid for land will be greatest for those activities that receive the greatest benefits from occupying accessible locations. Activities, therefore, may be ranked according to the advantages they receive from occupying central locations. The ability to compete for these locations results in an orderly pattern of land use in which sites are occupied not merely by the activity which can pay most but by the activity which receives the greatest positive advantages in terms of accessibility of the site.

One of the theories designed to explain the internal land-use structure of cities was presented by Ernest W. Burgess. He developed a concentric-zone approach which in many ways paralleled von Thunen's explanation of land uses.

Burgess used Chicago as an example of his theory. Although he recognized that this example did not exactly fit his idealized scheme, he assumed that the concentric-zone pattern was more or less typical. In practice, this theory is subject to the same weaknesses as the von Thunen approach. Numerous allowances and modifications are needed to explain the roles played by important streets and transportation routes, and by changing land-use capacities.

An alternative to the concentric-zone hypothesis is provided by the sector theory of urban growth. This theory was developed by Homer Hoyt during the late 1930's and resulted from his analysis of residential neighborhood trends in a study involving more than 200,000 blocks in approximately 70 American cities.

Hoyt assumes a pie-shaped city with a central business district and with numerous sectors or slices extending out from this central district to the city's outskirts. He then argues a theory of axial development, in which the particular land uses found in various sectors tend to expand outward along principal transportation routes and along the lines of least resistance. This theory provides a logical explanation for string-street developments. It also explains the tendency of commercial districts to expand along important streets, skip several blocks, and then reappear along the same streets. Where possible, factory and industrial districts also tend to continue their expansion along railroads, waterways, and sometimes principal streets.

Each level of the land-use hierarchy has to pay a minimum rent in order to keep alternate potential uses from occupying the site with the desired access characteristics. Because desired accessibility varies with each level of the hierarchy, it follows from the earlier discussion of the relations of utility and distance (accessibility) that so does general rent level. In addition, the general rent comprises an additional threshold requirement of each use at every level, if they are to occupy the desired site.

To the extent that business centers provide focal points for the system of urban land uses, it is, therefore, plain that a hierarchially structured spatial system of rent peaks will be found within the city. To the extent that accessibility provides the key to understanding of patterns of urban land uses other than business, these land uses will be oriented to a ranked spatial system of rents, and types of uses about business foci will be directly related to the rate of diminution of rents, as distance from the foci increases.

The multiple nuclei concept of Harris and Ullman combines the concentric zone and sector theories to explain the arrangement of land uses. In many cities, the land-use pattern is built not around a single center but around several discrete nuclei. In some cities these nuclei have existed from the origins of the city; in others, they have developed as city growth stimulated migration and specialization. The initial nucleus may be the retail district in a central-place city; the port or rail facilities in a break-of-bulk city; or the factory, mine, or beach in a specialized-function city.

The rise of separate nuclei and differentiated districts reflects a combination of four factors: (1) certain activities require specialized facilities, (2) certain similar activities group together because they profit from cohesion, (3) certain unlike activities are detrimental to each other, and (4) certain activities cannot afford the high rents of the most desirable sites. The number of nuclei which result from historical development and the operation of localization forces varies greatly from city to city. The larger the city, the more numerous and specialized are the nuclei.

The general theories reviewed here are not a means to the actual and precise description of the spatial structure of land uses in any city but are more or less normative descriptions of over-all urban growth and structure. These general models are of some assistance in the search for information on the way in which transport innovations affect the spatial structure of land use.

Land Use and Traffic

Control of access enables or denies certain land uses and often is the major factor determining the highest and best use of land adjacent to the highway and, consequently, the amount of rent paid for any particular location. Relating volumes of traffic to various land uses is a major step in developing specific guidelines for optimum access control. As low-traffic-generation land uses give way to high-traffic-generation uses, greater and greater amounts of traffic are fed into the system. Land uses are not alike in their generation or attraction of trip movements. They show a wide range of difference. The following relationships from a study of land uses in Duluth (*27*) sharply focuses this statement:

1. Residential uses—6 to 10 vehicle trips per dwelling unit per day.
2. Industrial uses—20 to 30 vehicle trips per acre per day.
3. Highway-oriented uses—200 to several thousand vehicle trips per acre per day.

According to the study, development around major intersections increases traffic on the roadway and the intersecting arterials, and the vehicular capacity of the area becomes more critical. Highway-oriented uses aggravate this situation far more than most other uses, yet such locations are desirable for highway-oriented uses (*27*).

The study found that 56 percent of all highway-oriented uses along a 16-mile section of highway were located within 1,000 ft of eight major intersections. Ninety-one percent of all highway-oriented uses were located within 2,500 ft of these same intersections.

Although highway-oriented uses are extreme generators of traffic, their location near highways is necessary to provide adequate service to road users. The amount of land properly devoted to such uses and their specific location constitute a delicate problem, because three interests must be served simultaneously. These are: the general public, the abutting property owner, and the road user (*27*).

Recent progress in state and interstate highway planning has placed increasing emphasis on the theory that the generation and distribution of traffic is a function of land use. Thiel (*67*) recently demonstrated the interrelationship between trip generation and land use (Figs. B-6 through B-10).

According to one observer, small commercial establishments have found it difficult to take advantage of major highway locations which attract the following larger-scale land uses (*69*):

1. Residential subdivisions and garden apartments.
2. Regional shopping centers and major regional stores.
3. Manufacturing plants and industrial parks.
4. Distribution warehouses, truck terminals, and area sales offices.
5. Amusement centers (bowling alleys, skating rinks, drive-in theaters).
6. Large motels.
7. Central office buildings (insurance, utility, and other).
8. Service stations and eating places.
9. Hospitals, churches, and other institutions.
10. Auction yards, farm equipment and used car sales lots.
11. Trailer parks.
12. Private and public airports.

Although such land uses have long been highway-oriented, they apparently expand in scale at locations along a major limited access facility. This is because of the increased potential created for them by one or more of the following functions that are especially characteristic of this type of highway:

1. Provides quick accessibility to other parts of the adjacent area
2. Collects labor from a much wider area (perhaps up to 30 to 50 miles)
3. Attracts customers, clients, pupils, and spectators from even greater distances
4. Collects and distributes supplies and products over a greatly extended range ("overnight delivery" radius may be 400 miles)
5. Serves as advertising channel of enormous volume and penetration.

All of these functions draw the land uses in question to the vicinity of a major highway. The fifth function attracts them to sites immediately adjacent to the facility. The land uses that have been described require being visible to the highway traveler. A major establishment situated at the top of a long rise, at the foot of a decline, or in the hollow of a curve, has an "exposure" with outstanding advertising merits (*69*).

By preventing the premature functional obsolescence of the adjacent roadway, access control and land-use control enable the landowner to develop, with greater certainty, his land to its highest and best use. Nonusers historically have felt that the more access points they are given, the better their business; however, many now seem to be aware that, if traffic congestion develops, they lose business. Unlimited access and uncontrolled land-use development result in early obsolescence of the highway by excess traffic, high accident rates, ribbon development, and, not infrequently, declining land values.

Problems Unique to the Highway-Land Interface

Whether land-use planning can provide protection for highways depends on whether there is a causal relationship between different forms of land use and changes in highway capacity. If there is no linakge between the two, there is little hope for a remedy through land-use planning. On the other hand, if there is a linkage that can be clearly defined, land-use planning holds promise of providing a workable solution.

The development of a transport system grows out of a demand for the movement of goods and persons between particular locations. Land management units and parcels of real property, owned or managed as separate estates, are basic units from which all flows of goods and persons originate and to which all flows of goods and persons are destined. These units are not self-contained, but are highly interdependent. This interdependence requires that they have access to a transportation system.

Society places a somewhat unique responsibility on highways. Broadly interpreted, public roads are expected to furnish every land use with a direct transportation outlet. This contention is not intended to rule out the importance of other forms of transportation, but to emphasize how sensitive highway use is to changes in the land resource base and to delimit these special relationships for consideration.

Land-use units alter both the practical capacity of roadways and the volume of traffic constituting the flow. Of primary importance, the private thoroughfare or approach of each land-use unit forms an intersection with some segment of the public highway system. The impact of this intersection is to lower practical capacity. The amount that capacity is lowered depends, among other things, on the design characteristics of the intersection, the volume and direction of traffic flowing through the intersection, and the composition of the traffic. These factors, in turn, are a function of the physical, social, and economic attributes of the land use. Furthermore, each land use influences the size of the traffic stream flowing through the public highway network. Volume additions to various links

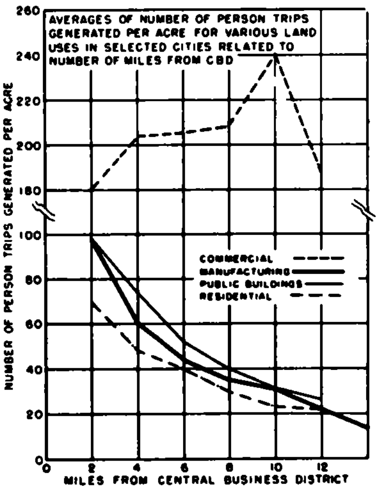


Figure B-6. Averages of number of person trips generated per acre for various land uses in selected cities related to distance from central business district. Source: Thiel (67).

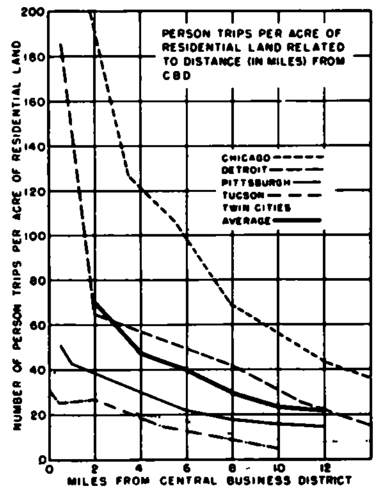


Figure B-7. Person trips per acre of residential land related to distance from central business district. Source: Thiel (67).

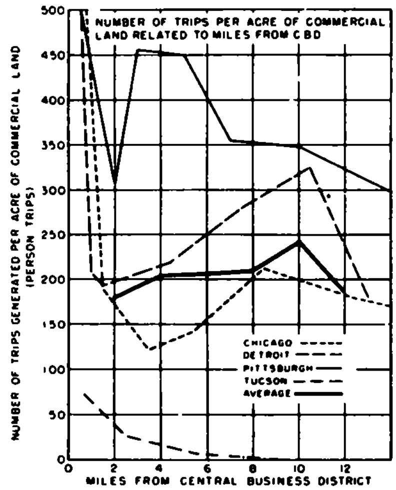


Figure B-8. Person trips per acre of manufacturing related to distance from central business district. Source: Thiel (67).

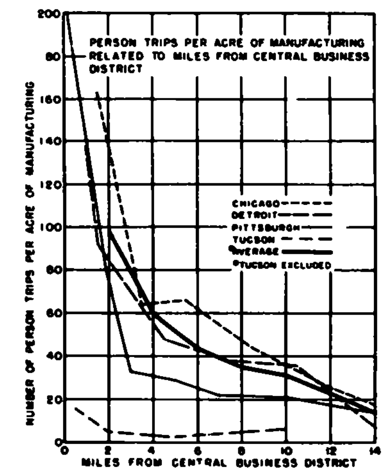


Figure B-9. Number of trips per acre of commercial land related to distance from central business district Source: Thiel (67).

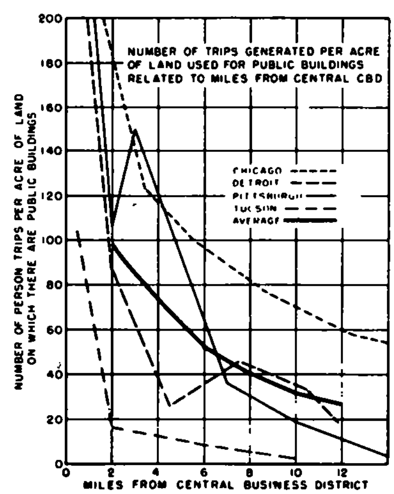


Figure B-10. Number of trips generated per acre of land used for public buildings related to distance from central business district Source: Thiel (67).

in the network are a function of the amount of traffic generated and attracted by individual uses and the location of the land with respect to other such interacting uses.

Each volume addition by a land use not only pushes the traffic load of the system closer to practical capacity, but also indirectly affects capacity itself. It does this by changing the kind and number of vehicles moving through established intersections in the highway network. Thus, it is that the number of land uses attached to a segment of highway, the characteristics of these uses, and their location with respect to one another are associated with the ability of a roadway to accommodate traffic.

Conversion of farm land to industrial-urban uses often is accomplished by subdivision. This increases the number of land uses and creates new points of access to the existing highway network. Each new unit must have an outlet. Even though a spatial expansion of the system takes place in the form of new streets, capacity is affected by the juncture of these streets with existing roads. Furthermore, the traffic generated and attracted by the new land use increases volume throughout the system and, in this way, chips away at the practical capacity of the roadway.

In some instances, changes in the characteristics of land uses occur without an increase in the number of access points. Examples are the replacement of a single household dwelling with an apartment building, the change from a farm to an industrial plant, or the expansion of an industrial plant. Even if no new approaches are created, and frequently no new streets are built, the practical capacity of the highway is altered because more, and possibly different, kinds of vehicles are entering and leaving, adding to the restriction of the traffic flow. Finally, the spatial arrangement of land uses influences the mileage of different kinds of highways needed to satisfy a particular transport demand. Lond distances between units with a high level of interaction call for more miles of high-capacity highways than do shorter distances.

This relationship between land use and the highway system makes it necessary for the physical development of each to be *balanced* with the other. Hence, the often-expressed need to balance the highway transportation system with the land use it serves involves a continuing process of coordination. Logically, coordination must extend to all the elements of balance. Three of the most important of these elements are timing of development, intensity of land use, and location of traffic generators.

Intensity of land use has an obvious relationship to the traffic problem. Limiting population density, restricting the type or character of land use; limiting the height of buildings; requiring front, rear and side yards; and requiring minimum lot areas—can all aid in promoting a balance between intensity of land use and the highway system. Controlling the location and separation of land uses also has an obvious relationship to the traffic problem.

The feasibility of regulating the intensity of land use and the location of traffic generators will depend on *when* the regulation is to take place. Control over the intensity of land use is most feasible and easily achieved through land-use controls that take effect before the land is developed. Similarly, a desirable distribution of traffic generators can perhaps be accomplished by completing a land-use plan before development occurs and then permitting development only if it promotes the objectives of the plan.

Although land-use control measures are not as effective when the land has already been developed extensively, the intensity of land use and the location of traffic generators can normally be influenced to some degree, even where all the land is already highly developed.

Access control is a key consideration that must be taken into account in the administration of planning controls in a highway system. Commercial and industrial development in the vicinity of highway interchanges usually includes land uses that generate large amounts of traffic. Instances where the resulting induced traffic obstructs the free flow of traffic on the intersecting highway, or crossroad, and on other approach roads, are becoming commonplace. The protection gained for the highway facility, as a result of access control, effectively preserves the usefulness of these facilities; however, uncontrolled access on the crossroad and approach roads can lessen this protection considerably. Major comprehensive access planning, therefore, must include: (1) maintenance of the traffic-carrying capability of the crossroad and other feeder roads through controlling the location, design, and use of access to the arterial, (2) development of freeway characteristics on these roads, (3) provision for future expansion of the transportation system in the area, and (4) provision for future control of access to the crossroads and feeder roads.

MARGINAL ACCESS CONTROL AND LAND VALUE

The Property Market

Highway improvements reduce the cost and time of travel and increase the freedom of movement of persons and goods. This is the function of transportation, and it is the basic purpose for which roads are built. It also is understood that an improvement in road service may enhance the usefulness, and thus the value, of the land served. The better the road service available to a tract of land, the better will be the relative location of the land. For agricultural land, as well as land in other uses, improved road service may lead to lower production costs and to increased marketing efficiencies. Such advantages in turn give rise to larger profits (or margins), which presumably may be reflected in higher land values. In addition, through improved location, land could be made suitable for a higher and better use and would, therefore, be more valuable. Agricultural land, for example, might become suited for residential or commercial use and change from one particular land market to another market.

The proposition that there are several local markets for property, rather than a single market, presents the possibility that there exists something less than full knowledge of market conditions within the area economy. To attain an equilibrium that maximizes welfare, it is necessary that each buyer have full knowledge of his own personal tastes and preferences, the prices of the product, and the relative capacity of different products to satisfy his own desires. The degree of knowledge concerning market factors is also important in a discussion of markets.

The existence of separate local land markets, rather than one market, poses the possibility of not one, but several equilibria. In other words, different units of a product may be exchanged within the general market at different prices per unit. In economics, markets are classified and described according to the number of buyers and sellers operating within them and the degree of homogeneity of the product they trade. Further description is also provided by the degree of knowledge existing within each market.

The term "market" as used in economics is quite distinct from its everyday usage. In the latter usage, the term may refer solely to a particular physical or geographical location, such as a building or a town. On the other hand, in economics its meaning is not restricted to a particular location and it is not defined in terms of physical boundaries; rather, the word "market" refers to the whole area wherein a price is determined for a particular commodity by those individuals who are buyers and sellers of that commodity. The fundamental characteristic of a market that, within the same market, two prices for the same commodity cannot exist at the same time. Any divergence in the prices of a unit of the same commodity arises from the lack of perfect communication between all parties in the market and constitutes an imperfect market.

Although markets are not defined on the basis of geographical areas, the extension of a market over an area presents a problem of communication and may provide the rationale for the existence of several local markets, rather than one broad market. If sellers are not aware of all prices paid and received for units, they may be willing to accept lower prices than they otherwise might receive. On the other hand, buyers may, for the same reason, pay more than necessary.

Markets for land are imperfect by the very nature of the commodity. All parcels are unique, at least in location, although there may be near-perfect substitutes among parcels. Full knowledge of the complex of availability and exchange values is not a possibility.

The economic effects of highway improvements impinge, in many instances, on land and its improvements, in whole or in part. The market value of such land and property responds accordingly. Land use and land values comprise an almost inseparable complex; what affects the one must affect the other. The two, nevertheless, are definitely distinguishable. Land use is tangible, and its changes are tangible, with the exception that potential or possible future uses are reflected in land values and not demonstrated in a physical sense until some later date. Land use and land values, therefore, may be differentiated in the physical sense and also in time, because land values anticipate or precede land use and land use requires consideration of alternatives and delay in the implementation of the selected plan of use.

Highway improvements change the time-distance factor and, through increased accessibility, bring about changes in land use and land values. Increased accessibility of land can mean an increased number of alternative uses of land. Gains in land values do not necessarily wait for physical development to occur. Such increases in value are expectational in nature. As soon as it becomes known that a major highway project has been approved, the impact on land values begins to be manifested. In this connection, various studies of property values indicate that the value of land itself generally increases much faster than the value of improvements on the land.

Investigation of the land uses involved in these land-value changes reveals that the amount of the value influence depends primarily on the type of land use of the property, prior to highway construction, and the proximity of the property to the highway. Most spectacular increases seem to occur when the improved facility has been responsible for a conversion in the land use of the property under study, or an acceleration in such a conversion. A conversion from agriculture or vacant land to residential, commercial, or industrial use produces a high percentage increase in land values. Vacant lands adjacent to improved highways generally develop faster than others.

Highways frequently help create conditions which "ripen" nearby land for new or more intensified uses. Although the total land area in the United States is fixed, the amount of land used for any particular purpose can be changed, as is illustrated by the fact that about 1 million acres of rural land are converted to urban uses each year. The importance which good highway access has on land development is indicated by the fact that traffic interchange areas tend to develop faster and more intensively than areas with poorer access.

The Land Market and Highway Access

Localized land markets are ordinarily somewhat monopolistic in nature. This is more especially the case in the immediate area of new highway impact. Even when the land is owned by a large number of individuals, it tends to move to the "stronger hand" (speculators) and to be held while various would-be land users (developers) evaluate the economic potential of the tracts and proceed to bid, one against the other.

This environment, which also may be pervaded by a rather irrational "top dollar" psychology and, not rarely, by more than somewhat arbitrary zoning decisions, leads to an artificial scarcity of lands for various uses. This sometimes irrational framework for land supply is often met by a similar irrational pattern of land demand. The results are, more often than not, chaotic as opposed to orderly Some land uses are decided, not so much by which persons can pay the highest rent, but by which are fortunate enough, wealthy enough, or foolish enough to contract for the artificially high supply prices.

There is no implied "ism" intended in this statement. It is by no means an attack on private property and its attendant rights, including freedom of contract. It rather describes how local land markets frequently operate and raises the question whether public highways (and, thus, public expenditures) should be the avowed instruments for creating such localized land booms.

It should be remembered that the preceeding argument relates primarily to direct access. (It does have a corollary regarding the frequency and design of intersection points) Area service or area accessibility is considered to be a primary purpose of road improvement, and direct access is not considered prima facie bad. The point is, rather, that little social or economic justification can be found for penalizing the traffic functions and the economic life of a roadway, merely to bestow exploitation opportunities on a very few persons. This position is more meaningful in view of the likelihood that what is good for the roadway may also be good for the lands (and the nonusers to be served in the long run). This latter probability constitutes a recurrent criterion as various access policies are considered.

Reconsidering the subject of trade-offs between road user and nonuser interests, frequently it has been observed that speculators in land are the primary beneficiaries of land-value impacts of highway improvements. This is not to suggest that speculators are unworthy or undesirable; on the contrary, they perform an important service in risk taking. The point is, however, that conjectural, interpersonal comparisons, as those made between road users and particular property owners, are often more than a little misconstrued. Economic consequences to land, including windfalls, often are not experienced by the parties involved in the immediate short run.

Frequently, when a parcel of land gains particular qualities of situs, due to highway improvement (and for other causes), it must undergo a waiting period before the indicated higher and best use is economically feasible and implementable. The potentially higher land rent gradient is capitalized immediately, however, either by probable users or land speculators. The capitalization rate will reflect the length of the "ripening" period, as well as expected waiting or holding costs. In turn, there arises a tendency to offset waiting costs through seeking interim land income from "catch" uses. Catch uses range from billboards to rather substantial semi-permanent or alterable improvements. Included in possible catch uses are fruit stands, flower stands, trailer sales, Christmas tree sales, and parking lots. Any of these, on occasion, may generate more traffic and more highway disruption than well-planned, permanent site uses. Just as the length of ripening periods for sites can be predicted with little exactness, so are catch uses unpredictable. It is erroneous, therefore, to conclude for any particular site or row of sites that "it will be a long time before this land will be used." Such a prediction can be depended on only if reinforced by legal or access constraints.

Gross errors often are made in capitalizing land income because it is not realized that there is quick and easy competition to the business and to the site. It may be true that the "early bird gets the worm," but it is also true that he sooner or later must share it, if it is big enough to draw the attention of others and if he does not have it extremely well protected. The analogy often is applicable to land uses. The first root beer stand in an area may do very well indeed, covering all costs, including full wages for management, with appreciable net profits. It is easy to conceive, however, that the second such stand could make both enterprises submarginal. One result is disinvestment, as maintenance is deferred or totally neglected.

The early, substantial profits of the first business have very frequently been interpreted as attributable to location, and thus were accepted as land rent (and land value). In economic jargon the supposed land rent was "quasi-rent," subject to sudden erosion, but nevertheless a factor in land speculation and in a build-up of submarginal, uneconomic, and perhaps undesirable land uses.

The granting of substantial quantities of direct access thus may detract from the functional qualities of the highway, while bestowing few, if any, lasting benefits to abutting lands.

Measurement of Access Value

The objective measurement of access as a quantitative factor in property value involves the isolation of this particular variable from other applicable variables. The complexity is compounded by the fact that relatively none of the variables is completely independent. Access alone is not the price determinant of property value in relation to a highway facility; rather, it is access in conjunction with other factors. The mutual interdependence of the variables affecting value requires a method of analysis that can take this interrelationship into consideration. An exhaustive review of the literature has revealed that almost no studies have dealt with access variations and land values.

An exception is a state-wide study conducted in Texas by Franklin and Evans (*29*) which used least squares analysis in an attempt to measure access value. With this approach the interaction among and between variables could be examined. In the development of the model, two major problems were encountered. The first of these was the existence of two major types of independent variables—discrete and continuous. In a general solution of a multiple regression equation, discrete variables are handled by assigning weights to the levels of each one. They are then treated as continuous variables, and the equation is developed accordingly. This procedure is acceptable, as long as it can be implicitly assumed that the levels of a discrete variable can be ranked in some logical manner and that the weights assigned are correct. The second major difficulty was unbalanced data, in that there were unequal frequencies of occurrence of the several independent variables used.

To solve both the problem of data imbalance and the mixture between discrete and continuous variables, the Texas study developed a linear covariate model.

The flow chart (Fig. B-11) indicates the variables used in the analysis. The state-wide sample consisted of 715 individual land sale observations with their selected characteristics. There were approximately 43,680 acres of abutting remainder property included in the study.

It should be recognized that within the context of practical problems certain kinds of exogenous factors, apparently connected with changes in the chain of economic causation, are commonly involved. There is a penumbra of economic interactions that are somewhat difficult to include as variables in an analysis; nevertheless, for purely practical reasons, it is often necessary to take them into account.

Economic models of the type used in a least squares model involve stochastic relationships. A stochastic relationship is one in which variations in the dependent variable are not completely and exactly explained by variations in the specified independent variables; rather, some variations are attributed to factors which have not been specified but which, in combination, may affect the relationship in some manner. In a model of this type, observed variations in the independent variables are not expected to explain all the observed variations in the dependent variable. These relationships are not expected to be exact for a number of reasons, the most important one being the assumption of *ceteris paribus*.

All models are abstractions which, by necessity, deal only with the relevant factors involved in the problem at hand. All other factors that might, in some way, influence the variables under examination are assumed, according to the *ceteris paribus* assumption, to be constant. Nevertheless, in the real world these ignored factors may account for some variation in the model. This study was only partially successful. The value of highway access was measured, as cited later, but the effect of the type of access on land values was not clearly demonstrated.

The following discussion of the nonuser effects of highway facilities and their relationship to property values uses a wide range of studies conducted throughout the United States. Most of the reports deal with access in a somewhat general and indirect manner, but an examination of the

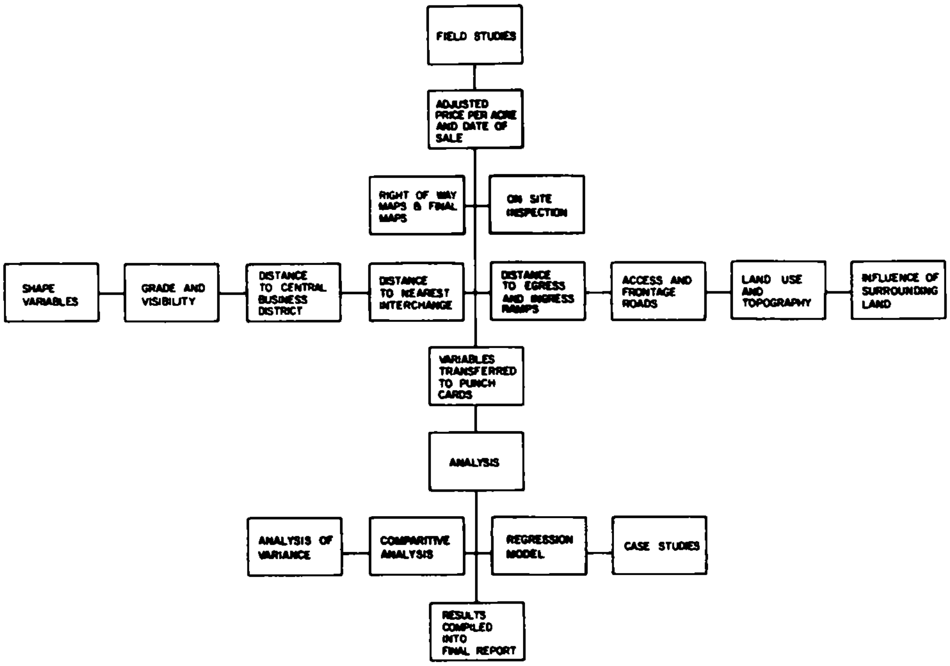


Figure B-11 Land value data generation and analysis flow chart

results is helpful in the over-all determination of nonuser impact. These findings are compared in each instance with the findings derived from the studies dealing specifically with direct access effects on the property market.

Unimproved Land Value

The change from one land use to another depends on many interrelated factors. If two properties are relatively equal in relation to access and location to a major roadway, the cost of either property being moved into a higher and better use depends, to a large degree, on the principle of substitution. This states that, when two or more properties with substantially the same utility are available, the one with the lowest price receives the greatest initial demand If, then, one of the two previously mentioned properties has a structure on it, that improved property would likely not move into the market until the cost of supersession had decreased to that of the unimproved property with no structure on it.

Unimproved property usually experiences a great increase in value after a highway is completed. This is a logical occurrence, because this type of property includes the bulk of what is normally considered speculative property. The percentage increases in this category of property has, on occasions, ranged over 2,000 percent, and has normally increased about 100 to 200 percent within a few years (Table B-1). The Texas study by Franklin and Evans (*29*), concerning property values and their relation to highway access, indicated that the per acre value of abutting, unimproved property with access to a major highway facility increased 187.83 percent more than did properties in control areas. Abutting, unimproved property without access increased only a modest 35.19 percent more than control properties. It was concluded that unimproved land values increased a substantial 152 64 percent between the before and after study periods due entirely to their superior access position.

Table B-1 gives appreciable increases in value, regardless of the type of access control. Comparisons from area to area are not likely to give conclusive findings; however, the greatest access control (Design A, full control of access, no frontage roads) apparently did not prevent significant highway benefits for unimproved lands.

Commercial Property

Commercial enterprises seek to locate themselves so that they can serve their markets as effectively as possible, and ordinarily place more importance on highway proximity than do industrial establishments. Interviews with leading officials of 52 business firms located on highways revealed the dominant factors that motivated each firm in selecting its location (*34*). Only 10 percent of the firms gave direct highway access as the most important location factor. "Highway exposure" and "highway network in relation to market" were named as the most dominant factors by approximately 30 percent of the respondents.

Although highway access is important to many commercial and industrial enterprises, retail establishments more frequently place the greater emphasis on highway access. For some types of retail business, customers need to have direct physical access from the highway to the business premises.

Direct driveway access, however, is not the only suitable highway accessibility. Placement of a roadside business establishment on a frontage road, parallel to the roadway for through traffic, does not necessarily destroy the attractiveness of that site for so-called drop-in patronage, so long as the frontage road itself has access to the thoroughfare at reasonable intervals and the site remains visible to thoroughfare users.

Table B-2 gives percentage changes in the value of commercial property found in several highway impact studies (*34*). Although no clear-cut pattern of changes is evident in relation to access control, fully controlled access (Design A) apparently had no comparative adverse effects. In Atlanta, properties in Band A (abutting) fared about as well as those in the more distant B and C bands. In Dallas, the abutting properties on frontage roads had higher changes in value than did more remote properties in B and C bands. Areas with road improvements but no access control (Section 1 in Houston, Texas, and Lexington, Ky.) did not show superior effects. The state-wide Texas study, which included fully controlled access roads, some with and some without frontage roads, showed abutting commercial properties gaining more than 80 percent in value, while controls lost about 15 percent (on a constant dollar basis).

It had been hoped at the outset of the project that previous studies of remainder parcels might yield clear-cut information on relationships between land value and types of access. This inquiry was not fruitful. Figures B-12 and B-13 show the typical format and case method of such remainder studies. No aggregation of such cases for comparative analysis has been made. The cases shown in Figures B-12 and B-13 reflect enhancements on frontage roads, but another important factor to consider was a zoning change.

Industrial Property

Highways of modern design obviously facilitate access to markets and supplies, and, in this way, foster the decentralization of industry. Many firms at sites on the fringe of metropolitan areas are able to serve the central city, a large suburban area, and a large hinterland as well. Decentralization of industry has resulted in the development of industrial districts or parks which place important reliance on highway transportation. Industrial parks tend to maximize the advantage of decentralized locations by careful control of the use which is made of land and by facilitating the exchange of services between neighboring firms.

Highways have a tendency to channel investment into nearby locations. This channeling apparently occurs because there are situations awaiting a "triggering" by an outside agent, in order to effectuate a shift. Highways often provide this triggering, and, because of the complex linkages between industries, the effect of the original investment is multiplied. For example, industrial investment along Massachusetts Route 128 during a recent year amounted to almost two-fifths of all new investment in the Boston metropolitan area (Fig. B-14).

When Route 128's location was fixed, industrial land brokers began buying large tracts in the vicinity of the proposed roadway. Towns and cities along the route zoned large tracts of land for industrial use; land values increased from a $50-$100 per acre range to $2,000-$5,000 per acre. "More than forty plants costing $100 million were under construction before the route opened. By March 1957, a total of 141 new plants had been built and 24 old ones had been expanded" (*4*). It may safely be concluded in this case that locations sought accessibility via Route 128, because access was allowed only at interchanges.

In the San Francisco Bay area, 43.1 percent of expenditures in new industrial plants in Alameda County were in

TABLE B-1

PERCENTAGE CHANGE OF UNIMPROVED LAND VALUE BEFORE AND AFTER HIGHWAY IMPROVEMENTS

			Percentage Changes			
			Study Area		Control Area	
State and Study	Design[1]	Dates of Changes	Total	Annual	Total	Annual
California·						
Camarillo	A	1951-55	101 0	25.3		
Escondido	D	1945-49	1,088.7	272.2		
Fresno Vacant "before" vacant "after"	D	1946-49	233.3	77 8		
Colorado						
New highway	U	1946-57	187.9	17.1		
Improved old highway	U	1946-57	-92 5	-8.4		
Georgia (Atlanta)						
East side		1943-54			48.1	4.4
Band A	A		184 9	16.8		
Band B	A		121 7	11.1		
Band C	A		50 3	4.6		
West side		1943-54				
Band A	A		209.9	19.1		
Band B	A		41 2	3.7		
Band C	A		6.0	.5		
Texas						
Dallas (Central)		1943-53				
Band A	B		290.1	29.0	57 5	5.8
Band B	B		205 2	20.5	65.0	6.5
Band C	B		146.7	14.7	80.8	8.1
Dallas-Stemmons Freeway	A	1946-55 to 1955-59	21.0	3 2		
San Antonio						
Residential	C	1941-45 to 1952-56	531.0	48 3	38.2	3.5
Nonresidential	C	same	106 4	9.7	-89.9	-8.2
Temple	B	1943-48 to 1955-61	2,602.0		39 0	
Austin	B	1941-48 to 1954-61	402 0		383.0	
Rockwall	B	1944-48 to 1949-61	196 0		73.0	
Merkel	B	1950-55 to 1959-62	94.0		2.0	
Waxahachie	B	1951-55 to 1959-62	310 0		29 0	
Houston	B	1950-54 to 1959-62	113 0		57 0	
Conroe	B	1952-58 to 1963-65	82 0		-12 0	
Huntsville	B	1950-54 to 1960-64	267 0		20 0	
Chambers County	B	1947-55 to 1960-65	262 0		246 0	
State-wide Study (29	A&B	1956-65	291 2		103 4	

SOURCES Derived from U S Department of Commerce, Bureau of Public Roads, Highways and Economic and Social Changes, U. S Government Printing Office, Washington, D C , 1964
Bureau of Public Roads put all percentage changes on the same dollar base General design description was added from original study reports

Information for Texas locations other than Dallas is from a series of economic impact studies conducted by the Texas Transportation Institute, individual reports are entries 8 through 16 in the List of References to Appendix B Percentages were not adjusted by Bureau but are deflated to reflect change in value of dollar

[1]Design codes A = Full control of access with no frontage roads
B = Full control of access with continuous frontage roads
C = Full control of access with some frontage roads
D = Limited access control, grade intersections, no access driveways
E = No access control
U = Design unknown
UA = Access control, design unknown

a so-called area of highway influence (Fig. B-15). The influence area contained only 9 percent of the total industrial acreage in Alameda County (*20*).

A study of the northern belt line around Lexington, Ky., found that this belt line (no access control) had a substantial positive influence on the value of abutting and nearby commercial and industrial property, ranging from 21 percent for the larger parcels to more than 300 percent for the smallest parcels (*19*). Type of access control apparently was important in determining the pattern of land value effects. When the best line impact was compared with that of the limited access Watterson Expressway in Louisville, it revealed that (1) the belt line was responsible for the conversion of relatively more land to a higher use than was the expressway; (2) but the positive influence of the belt line was largely confined to commercial and industrial property within ¼ mile of the facility, whereas the expressway had a broader area of effects.

The percentage changes of industrial land value before and after highway improvement, as shown by the studies given in Table B-3, reveal no tendency for full control of access to inhibit industrial land values. As has been pointed out previously, however, such area-to-area comparisons allow very few firm conclusions.

The needs of industry regarding direct highway access are very different from the needs of commercial, traffic-oriented users. The actual direct access to a major roadway seems to be of less importance to industrial development than adequate accessibility The movement of land into industrial uses appears to take place in conjunction with accessibility via the intersecting street system and seems to depend little on direct access to a major facility.

A study conducted in Texas, dealing with the relationship between frontage road access and industry location, found that 221 of the 1,495 industrial firms included in the study selected plant sites within less than ½ mile of a facility having frontage road access (*54*). Only 38 of these firms, however, were located on properties abutting frontage roads. Other highways provided access to the facility for approximately 46 percent of the study firms.

As industry seeks industrial sites located near major highways having the "best" access available, how important is frontage road access to plant location? The report concluded that direct access may no longer be the most important factor in the selection of a particular industrial location. For example, related street access may now become an integral part of the location decision. Other locational factors also change their significance, in order of importance to the overall site selection.

Residential Property

Available market data from sales and resales of residential sites abutting major highways argue strongly for recognition of accessibility, rather than direct access, as the most important effect on value for residential land use. This premise, if applied consistently to the range of possible situations where the effect of access control is an issue, could substantially affect the extent to which frontage-roads or secondary-street access are considered reasonable and suit-

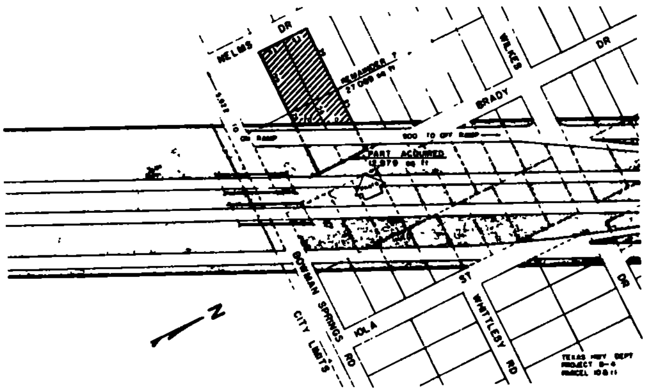
TABLE B-2

PERCENTAGE CHANGE OF COMMERCIAL LAND VALUE BEFORE AND AFTER HIGHWAY IMPROVEMENTS

			Percentage Changes			
			Study Area		Control Area	
State and Study	Design[1]	Dates of Changes	Total	Annual	Total	Annual
California						
Anderson	C	1948–52				
Assessed value of lots 50 x 150			42 2	10 6		
Assessed value of retail sales lots			54.9	13 7		
Camarillo	A	1951–55	118.2	29.6		
Fresno: Vacant "before" improved "after"	A	1946–49	136 4	45.5		
North Sacramento Downtown properties	E		36 9	9.2		
Georgia (Atlanta)		1943–54				
East side						
Band A						
Sec 1	A		45 5	4 1		
Sec 2	A		149 7	13 6		
Band B						
Sec. 1	A		163 6	15 0		
Sec 2	A		79.0	7.2		
Band C						
Sec 1	A		140 9	12 8		
West side						
Band A						
Sec. 1	A		29.3	2.7		
Sec. 2	A		3.3	.3		
Band B						
Sec. 1	A		30 5	2 8		
Sec. 2	A		17.5	1.6		
Band C						
Sec 1	A		5.9	.5		
Kentucky						
Lexington	E	1940–47 to 1951–58	281 4	25 6	124.3	11 3
Louisville	A	1940–46 to 1952–58				
Bardstown Road			1,344 7	112 1		
U. S 42-Brownsboro Rd.			126 1	10.5		
Texas						
Dallas (Central)		1941–45 to 1951–56				
Band A (abutting)	B					
Sec. 1						
Land			201 6	18 3		
Improvements			109 9	10 0		
Total			159 9	14 5		
Sec. 2						
Land			1,583.3	143.9		
Improvements			29 8	2 7		
Total			370 0	33 6		
Sec 3						
Land			661.5	60 1		
Improvements			-1.2	-.1		
Total			662.8	60 3		
Band B (second tier)	B					
Sec 1						
Land			110 1	10 0		
Improvements			-67.0	-6 1		
Total			56 5	5 1		
Sec 2						
Land			75 4	6 9		
Improvements			61.8	5.6		
Total			49.5	4.5		
Sec 3						
Land			-35.6	-3 2		
Improvements			-90 9	-8 3		
Total			-62.1	-5.6		
Band C (third tier)	B					
Sec 1						
Land			269.1	24 5		
Improvements			82 1	7.5		
Total			194 6	17 7		
Sec 2						
Land			214.8	19.5		
Improvements			205 2	18 7		
Total			243 8	22 2		
Sec. 3						
Land			63 4	5 8		
Improvements			600.3	54.6		
Total			209 8	19 1		
Houston		1940–55				
Group 1 Sec 1	E					
Land			274 6	18 3		
Improvements			-19 3	-1 3		
Total			162 4	10.8		
Group 2 Sec. 1	E					
Land			-18 4	-1 2		
Improvements			-13.3	-.9		
Total			-17.7	-1 2		
San Antonio	C	1941–45 to 1952–56				
Land			104.5	9 5	22 6	2.1
Improvements			39.9	3.6	85 3	7 8
Total			76.3	6 9	19 4	1.8
State-wide Study(29)	A&B	1956–65	81.4		-15 6	

Sources: Derived from U S Department of Commerce, Bureau of Public Roads, Highways and Economic and Social Changes, U S. Government Printing Office, Washington, D C., 1964.
Bureau of Public Roads put all percentage changes on the same dollar base. General design description was added from original study reports.

[1] Design codes:
A = Full control of access with no frontage roads
B = Full control of access with continuous frontage roads
C = Full control of access with some frontage roads
D = Limited access control, grade intersections, no direct access driveways
E = No access control
U = Design unknown
UA = Access control, design unknown



A Before Acquisition

1 Four vacant interior lots (each 63' x 159')

2 Whole property and value Date appraised 1956

Land 40,068 sq ft	@ $ 068 per sq ft	$ 2,725
Improvements		0
Total value		$ 2,725

B Property Acquired and Payment Date closed 4-6-56

Land 12,979 sq ft	@ $ 068 per sq ft	$ 883
Damages		0
Total property payment		$ 883

C After Acquisition

1 At remainder, new facility has through lanes rising to about 18 feet above grade passing over Bowman Springs Rd, with a one way frontage road at grade

2 All of remainder sold Date 9-1-60
Land 27,089 sq ft @ $ 092 per sq ft. $ 2,500

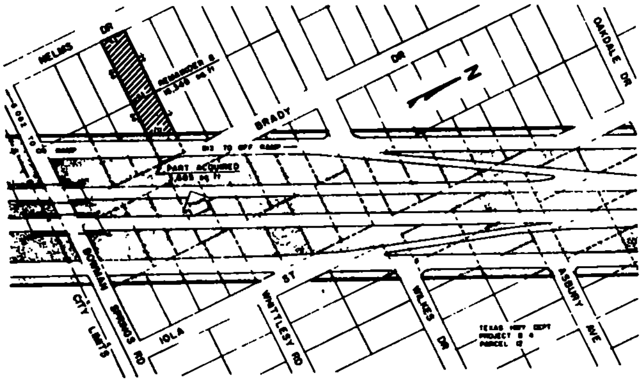
3 *Increase* in value of remainder = 36%

4 *Decrease* in value of comparable land = −15%

5 Subsequent improvements None

D Conclusions The results show that the remainder was enhanced in value due to new facility A significant point to mention in this case is that the remainder's zoning was changed from residential to commercial before the remainder sold. Comparables lost value

Figure B-12. Example of highway access effect in relation to commercial property. Source: Buffington and Adkins (7).



A Before Acquisition

1 Two vacant interior lots (each 63' x 159')

2 Whole property and value Date appraised 1956

Land 20,034 sq ft.	@ $ 068 per sq ft	$ 1,362
Improvements		0
Total value		$ 1,362

B Property Acquired and Payment Date closed 4-6-56

Land 3,685 sq ft.	@ $ 068 per sq ft	$ 250
Damages		0
Total property payment		$ 250

C. After Acquisition

1 At remainder, new facility has through lanes rising to about 17 feet above grade passing over Bowman Springs Rd., with a one-way frontage road at grade

2 All of remainder sold Date 4-26-61
Land 16,349 sq ft @ $ 080 per sq ft $ 1,300

3 *Increase* in value of remainder = 17%

4 *Decrease* in value of comparable land = −26%

5 Subsequent improvement A small three-room frame residence was moved onto remainder during 1958, but was considered of little or no value on commercial lots in 1961

D Conclusions The remainder was enhanced in value due to new facility The remainder's zoning was changed from residential to commercial before the remainder sold Comparables lost value

Figure B-13. Example of highway access effect in relation to commercial property. Source: Buffington and Adkins (7).

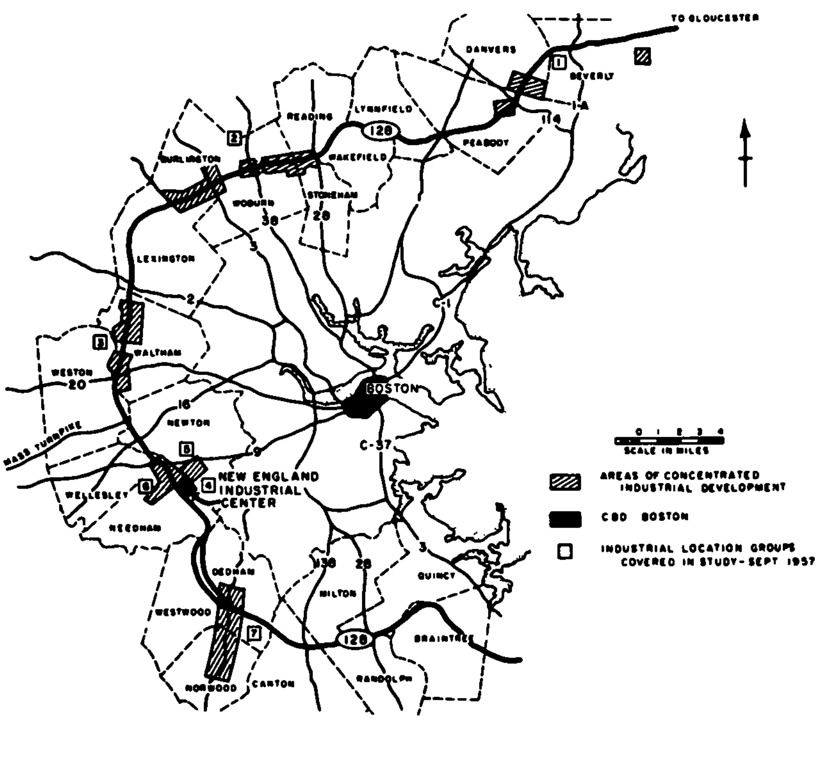


Figure B-14. Industrial development along Massachusetts Route 128 in Boston Metropolitan Area. Source: Economic Impact Study of Massachusetts Route 128. *MIT (Dec. 1958)*

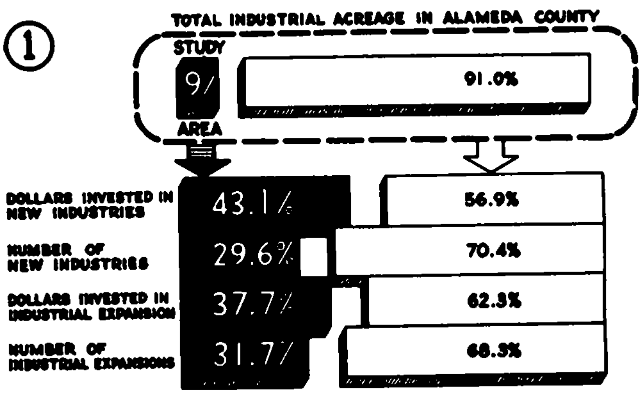


Figure B-15. Effect of Eastshore Freeway, California, on industrial growth. Source Calif. Highways and Pub. Works (*May 1954*).

able for certain land as substitutes for direct access to the expressway.

The single-family residence, the largest consumer of land in urban areas, accounts for from 50 to 75 percent of the total city area. Thus, the extent of the physical expansion of the nation's urbanized areas is largely governed by the quantities of land converted to residential use. Improved highway transportation tends to bring much land close enough, in travel time, to be suitable for such development. The effect of highways in increasing the supply of land readily available for residential use has been observed and recorded in a number of locations.

In San Antonio, for example, the number of residences increased by 500 percent along a section of that city's Loop 13 Expressway in the 1955-58 period when this section was opened to the public. Similar land removed from the highway's influence experienced only a 16 percent increase in number of residences and apartments during this same period.

A state-wide analysis in California, covering a 3-year period, found that comparable residences, located one block away from the freeway, increased slightly more in value during the post-construction period than did residences abutting such facilities (*39*).

RESIDENCES AWAY FROM FREEWAY	% HIGHER THAN PROPERTIES ADJOINING FREEWAYS
1954 comparables	1 30
1955 comparables	1.50
1956 comparables	1.88

Although this slight increase became progressively larger during the 3 years covered, the study pointed out that one could not assume that the breach would grow wider each year, any more than it could be assumed that the annual price trends for residences adjoining the highway, or comparables, would continue to increase at the same rate.

The previously mentioned remainder studies in Texas contain an illustration of some possible negative effects to residential property abutting a major highway, even though the subject property was granted access to the highway facility via a frontage road location. The decrease in the value of the remainder between the before-after periods amounted to 29 percent (Fig. B-16). The value of comparable property in the same residential category decreased by 22 percent between periods. In this case, the result implies that direct access to a major highway does not always cause an appreciation in residential property values. The subject facility cut across existing residential lands. A zoning change probably would reverse the trend. It should be noted, also, that a single sale does not necessarily allow a firm conclusion. (See the previous discussion of the land market.)

TABLE B-3

PERCENTAGE CHANGE OF INDUSTRIAL LAND VALUE BEFORE AND AFTER HIGHWAY IMPROVEMENTS

			Percentage Changes			
			Study Area		Control Area	
State and Study	Design[1]	Dates of Changes	Total	Annual	Total	Annual
California:						
Alameda County						
High St. to c'ty limits of Oakland	C	1941-53	836.4	69.7		
South city limits of Oakland to Lewelling Blvd.	C	1947-53	272.4	45.4		
Los Angeles						
Test area A	C	1949-54	48 9	9.8	36.5	7.3
Test area B	C	1947-54	486.0	69.4	282.4	40.3
Test area C	C	1946-54	199.2	24.9	183.2	22.9
Georgia (Atlanta).						
Westside, band A, sec 3	A	1943-54				
Vacant			1,382.0	125.6		
Improved			278.5	25.3		
Total			1,287.6	117.1		
Texas:						
Dallas		1946-55 to 1955-59				
Stemmons Freeway						
Trinity District	B		-7.0	-1.1		
Brook Hollow District	B		-1.0	-0.2		
Houston						
Group 1. Sec 3	B	1940-55				
Land			285.4	19.0		
Improvements			-17 2	-1.1		
Total			281.5	18.8		
Group 2 Sec 3	B					
Land			175.6	11 7		
Improvements			28.6	1.9		
Total			105.0	7.0		
San Antonio	C	1941-45 to 1952-56				
Land			98 9	9 0	-25 6	-2 3
Improvements			125 1	11 4	-21 7	-2 0
Total			107 6	9.8	-22 5	-2 0

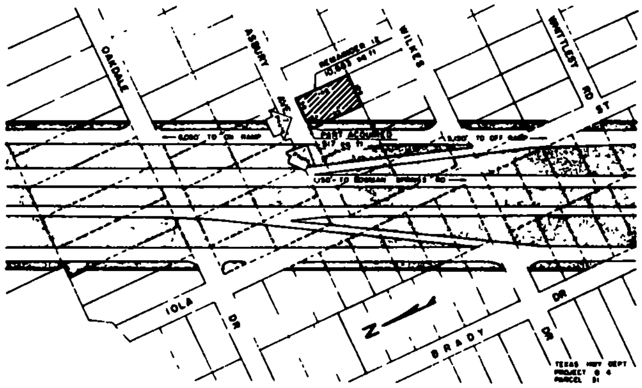
Sources Derived from U S Department of Commerce, Bureau of Public Roads, Highways and Economic and Social Changes, U S Government Printing Office, Washington, D C., 1964
Bureau of Public Roads put all percentage changes on the same dollar base General design description was added from original study reports

[1]Design codes
A = Full control of access with no frontage roads
B = Full control of access with continuous frontage roads
C = Full control of access with some frontage roads
D = Limited access control, grade intersections, no direct access driveways
E = No access control
U = Design unknown
UA = Access control, design unknown

The study conducted in Texas by Franklin and Evans (*29*), relating access to major highways and land value throughout the state, found that direct access to the facility seemed to have minor influence on increasing the value of residential property when analyzed on a before-and-after basis. It found that property of this type removed from the highway (control area) increased in value more than did property abutting the facility with frontage road access. Abutting property without access increased in value more than did nonabutting control property (*29*). It should be noted that these findings related to existing residences.

In general, a wide range of studies concerning the effects of major roadways on residential value have indicated a fairly uneven relationship between percentage increases in residential values and highway facilities (Table B-4). It might be seen that access and location on a high-traffic major roadway seem to be generally less attractive to residential development than location on a lower-traffic street with adequate accessibility to the major roadway.

There are several reasons for the uneven trends in residential property values and their relation to direct highway access on a major high-traffic roadway. The most obvious one is due to the possible negative effects of noise, fumes, etc., associated with the highway. Negative aspects associated with highway access will be discussed in another section. On the other hand, from Table B-4, it is obvious that residential lands fared rather well along highways of all designs.



A Before Acquisition

1 An interior lot improved with a frame residence

2 Whole property and value Date appraised 1-7 59

Land 11,200 sq ft.	@ $ 077 per sq ft	$ 862
Improvements		5,800
Total value		$ 6,662

B Property Acquired and Payment Date closed 7-7-59

Land 517 sq ft	@ $ 120 per sq ft.	$ 60
Improvements		90
Damages		0
Total property payment		$ 150

C After Acquisition

1 At remainder, new facility has through lanes about three feet below grade, with a one-way frontage at grade

2 All of remainder sold Date 9-16-60
Land 10,683 sq ft and improvements $ 4,600

3 *Decrease* in value of remainder ($6,512 to $4,600) = −29%

4. *Decrease* in value of comparable property = −22%

5 Subsequent improvement A redwood fence was built by the new owner on the west side of lot and adjacent to the new facility

D Conclusions The remainder decreased more in value than the comparable, indicating damages due to the new facility

Figure B-16. Example of highway access effect in relation to residential property. Source: Buffington and Adkins (7).

EFFECTS OF MEDIAL ACCESS CONTROL

The preceding sections of the report are concerned primarily with the nonuser effects of marginal access. A much more common form of restriction on major roadways is that of medial access control. This, generally, is accomplished by the construction of a median barrier in the center of the roadway, separating the two opposing streams of traffic. The effects of these barriers on the behavior of the traffic stream, as well as on the off-highway nonusers, is pronounced. Like many of the measures necessary to keep traffic moving, the median restricts some traffic movements. Indirection, therefore, results for a portion of the traffic, but some restrictions are often a matter of public necessity.

Medians are generally classified into three types:

1. The traversable median is one which consists of paint stripes, buttons, pavement of contrasting color or texture, or a combination of any of these. Its purpose should be obvious to the driver, but it does not present a physical barrier to traffic movements.

2. The deterring median is one which may incorporate any of the features of a traversable median, plus a minor physical barrier, such as a rolled asphalt curb, bars or corrugations, or a mountable curb.

3. The barrier median is one which traffic will not cross intentionally. It may be a barrier curb, a guardrail, some type of wall, or an open ditch section.

Medians are normally expected to accomplish the following (*66*):

1. Provide an insulating area between opposing traffic streams, reducing the strain on drivers and usually reducing the accident rate, particularly from head-on collisions.

2. Protect and control cross and turning traffic.

3. Create a refuge for pedestrians, making it safer for them to cross a wide street.

4. Encourage and complement efficient signing and signalization, by regulating traffic movements into orderly channels.

5. Provide space for left-turn storage at intersections, improving the efficiency and safety of the intersection.

6. Allow traffic to move smoothly and safely at higher operating speeds.

The main body of study literature relating to medians and their relationship to nonuser access effects has been concerned with the problems involved in improving highway routes along city streets. These routes are usually major traffic arteries in the larger cities and often serve as the main street in the smaller towns. As such, they are usually heavily developed with commercial businesses throughout their length.

TABLE B-4

PERCENTAGE CHANGE OF RESIDENTIAL LAND VALUE BEFORE AND AFTER HIGHWAY IMPROVEMENTS

			Percentage Changes			
			Study Area		Control Area	
State and Study	Design[1]	Dates of Changes	Total	Annual	Total	Annual
California·(76)						
Southern California	C	1954-56				
Resale price trend						
Adjoining freeway			6.1	3.0		
One block from freeway			8.0	4.0		
Two blocks or more from freeway			4.1	2.0		
Similar group						
Adjoining freeway			3.2	1.6		
One block or more from freeway			3.1	1.5		
Georgia (Atlanta).						
East side, Band B	A	1943-54				
Sec. 6.						
Land			724.2	65.8		
Improvements			-33.1	-3.0		
Total			138.1	12.6		
Illinois·						
Cook County	UA	1941-56				
Section north of Harrison St.			222.1	14.7		
East						
1/2 mile			166.7	11.1		
1 mile			111.1	7.4		
1 1/2 miles			85.0	5.7		
2 miles			72.0	4.8		
Section north of Harrison St.						
West						
1/2 mile			353.0	23.6		
1 mile			282.0	18.8		
1 1/2 miles			235.0	15.7		
2 miles			233.8	15.6		
Section between Harrison and Dempster Sts.			319.5	21.3		
East						
1/2 mile			252.6	16.9		
1 mile			216.6	14.4		
1 1/2 miles			224.2	15.0		
2 miles			39.1	2.6		
West						
1/2 mile			314.8	21.0		
1 mile			380.5	25.4		
1 1/2 miles			396.0	26.4		
2 miles			319.4	21.3		
Section south of Dempster St.			280.0	18.7		
East						
1/2 mile			231.5	15.4		
1 mile			262.0	17.5		
1 1/2 miles			218.5	14.6		
2 miles			189.4	12.6		
West						
1/2 mile			242.0	16.1		
1 mile			183.1	12.2		
1 1/2 miles			222 0	14.8		
2 miles			227.9	15.2		
Lawrence County	UA	1939-58	422.8	22.3	-32.9	-1.7
Calumet-Kingery Expressway	UA	1940-57	126.6	7 5		
East						
1/2 mile			177.0	6.9		
1 mile			76.8	4.5		
1 1/2 miles			88.7	5.2		
2 miles			78.3	4.6		
2 1/2 miles			73.3	4.3		
West						
1/2 mile			103.5	6.1		
1 mile			94.2	5.5		
1 1/2 miles			91.7	5.4		
2 miles			109 2	6.4		
2 1/2 miles			81.2	4.8		
Kentucky						
Lexington	E	1940-47 to 1951-58				
Old residential Highlawn.			-7.0	-.6	-12.9	-1.2
New lower-priced Meadows-Northwood			758.1	68.9	1,000.4	90.9
Elkhorn Park			668.4	60.8	762.6	69.3
Louisville	A	1940-46 to 1955-58				
Camp Taylor			19.7	1.4		
Portland			15.2	1.1		
Massachusetts						
Lexington	D					
Assessments		1945-57	148.3	12.4	52.7	4.4
Sales		1945-57				
Entire town			60.1	5.0		
Adjacent band zone			44.1	3.7	65 8	5.5
Access distance zone			35.3	2.9	82.8	6.9
Needham	D					
Houses built before 1942		1945-57	20.7	1.7	38.4	3.2
New houses		1946-57	75.4	6.9	74.6	6.8
New York						
Bronx River	UA	1940-51	37.0	3.4	4.5	.4
Hutchinson River Parkway	UA	1944-49	64.3	4.3	38.9	2.6
White Plains Road	U	1941-52	29.8	2.7	11.1	1.0
Texas						
Dallas (Central)	B	1941-45 to 1951-55				
Portions annexed before 1941						
Band A - single family residence						
Sec. 3			73.6	7.3		
Sec. 4			168.2	16.8		
Band B - single family residence						
Sec 2			55.7	5.6		
Sec. 3			66.3	6.6		
Sec. 4			43.9	4.3		
Sec. 5			176.0	17.6		
Band C - single family residence						
Sec 2			48.3	4.8		
Sec. 3			77.4	7.7		
Sec 4			470.0	47.0		
Sec 5			101.5	10 2		
Band A - duplex and multiunit apartments						
Sec. 1			244.5	24 5		
Sec. 2			128.8	12.9		
Sec. 3						
Band B - duplex and multiunit apartments						
Sec. 1			58 8	5.9		
Sec. 2			22 4	2.2		
Sec 3			97.2	9.7		
Sec. 4			24.8	2 5		
Band C - duplex and multiunit apartments						
Sec. 1			61.3	6.1		
Sec 2			69.4	6.9		
Sec. 4			156.6	18 7		
Houston		1940-55				
Group 1, sec. 4	B					
Land			159.2	10.6		
Improvements			-3.2	-0.2		
Total			83 7	5.6		
Group 2, sec. 4	B					
Land			955.6	63.7		
Improvements			-10.3	-0.7		
Total			249.8	16.7		
San Antonio - one family dwellings and apartments		1941-45 to 1952-56				
Expressway fronting	C		77.6	7.1	23.2	2.1
Expressway not fronting	A		37.6	3.4	23.2	2.1
Expressway fronting and not fronting	A&C		66.3	6.0	23.2	2 1
Main thoroughfare, not at expressway	E		51.3	4.7	89.4	8 1
Not main thoroughfare, not expressway	E		16.3	1.5	17.6	1.6
Austin	B	1941-48 to 1954-61				
Unimproved residential			513.0		176 0	

TABLE B-4 (*Continued*)

State and Study	Design[1]	Dates of Changes	Percentage Changes Study Area Total	Study Area Annual	Control Area Total	Control Area Annual
Conroe	B	1952-58 to 1963-65				
Improved residential			42.0		33.0	
Unimproved residential			88.0		-34.0	
Houston	B	1950-54 to 1959-62				
Improved residential			-5.0		34.0	
Unimproved residential			27.0		4.0	
Huntsville	D	1950-54 to 1960-64				
Improved residential			53.0		—	
Waxahachie	B	1951-55 to 1959-62				
Improved residential			40.0		-7.0	
Unimproved residential			24.0		18.0	

Sources Derived from U S. Department of Commerce, Bureau of Public Roads, Highways and Economic and Social Changes, U.S. Government Printing Office, Washington, D.C., 1964.

Bureau of Public Roads put all percentage changes on the same dollar base. General design description was added from original study reports

Information for Texas locations except Dallas, Houston and San Antonio, is taken from a series of economic impact studies conducted by the Texas Transportation Institute; individual reports are entries 8 through 16 in the List of References to Appendix B. Percentages not adjusted by Bureau but are deflated to reflect change in value of dollar.

[1]Design codes. A = Full control of access with no frontage roads
B = Full control of access with continuous frontage roads
C = Full control of access with some frontage roads
D = Limited access control, grade intersections, no direct access driveways
E = No access control
U = Design unknown
UA = Access control, design unknown

These combination highway routes and city streets are charged with fulfilling two opposite functions. In the smaller towns, they must move the transient traffic through the town as quickly, safely, and efficiently as possible and still function as service streets to the businesses located on the adjacent land. In the larger cities, they must perform these same functions and, in addition, carry traffic moving between the major sections of the city or between the suburban and central downtown areas. The difficulty in performing these functions concurrently has long been recognized.

Several procedures have been tried in an attempt to increase the efficiency with which this dual-purpose facility can be made to perform its functions. Among the more successful have been: speed zoning and signalization to regulate traffic flow; street widening, or the creation of additional traffic lanes to increase the physical size of the facility; the creation of bypasses or alternate routes to remove through traffic; and, finally, the addition of a median barrier to increase traffic speed and decrease the number of accident exposure points. Median barriers are, of course, usually operated in conjunction with some type of traffic signalization and control.

With the advent of the median barrier, however, have come additional problems. Businesses which had been accessible to the total traffic flow from each direction are now directly accessible from only one direction. Motorists wishing to patronize businesses on the left side of the street are forced to go to the next median opening, turn around and return to the merchant. Merchants have been skeptical about the proportion of their customers who would go to the additional trouble of crossing the median to trade at their firms.

Influence on Market-Oriented Traffic

Numerous studies have been conducted involving medians, but the bulk of them were attempts to relate differing median types to accident rates. Few studies concentrated on the economic effects of median access control to the nonuser sector. The most extensive research in this area has been conducted by Wootan, Meuth, Rowan, and Williams (*73, 74, 75*). These research studies covered the relationship between medial control and the effects on economic activity, traffic movement, and accident rates.

A motion picture study of selected areas was conducted to investigate the extent to which improper maneuvers were occurring during the "before" period of study. These maneuvers were highly variable in nature and difficult to classify, however, they consisted mainly of long, sweeping turns into and out of intersecting streets and various business establishments in the study area. A summary of "before" period maneuvers is shown for one study area (small city) in Figure B-17.

Observation of the study area after the median was installed indicated that the type of irregular movement observed during the "before" period was virtually eliminated; however, there was observed a substantial number of U-turns at the median openings. These were generated by the installation of the median. The proportionate number of U-turns observed was much smaller than the number of irregular maneuvers observed during the "before" study.

The analysis covered three different-sized cities in Texas —a small city, a medium-sized city, and a large city. It was found that the irregular movements observed in the "before" period were most frequent in the smaller city and grew progressively fewer as city size increased. There appeared to be a general correlation of irregular driving habits with the size of the city and the traffic volume on the major facility.

Because U-turns are increased by the construction of a median on a major facility, additional attention was paid to determining the distribution within the study areas and their occurrence throughout the day. Figure B-18 shows the area studied in San Antonio with businesses located in relation to the median openings. The figure shows the number of U-turns at each median opening and the num-

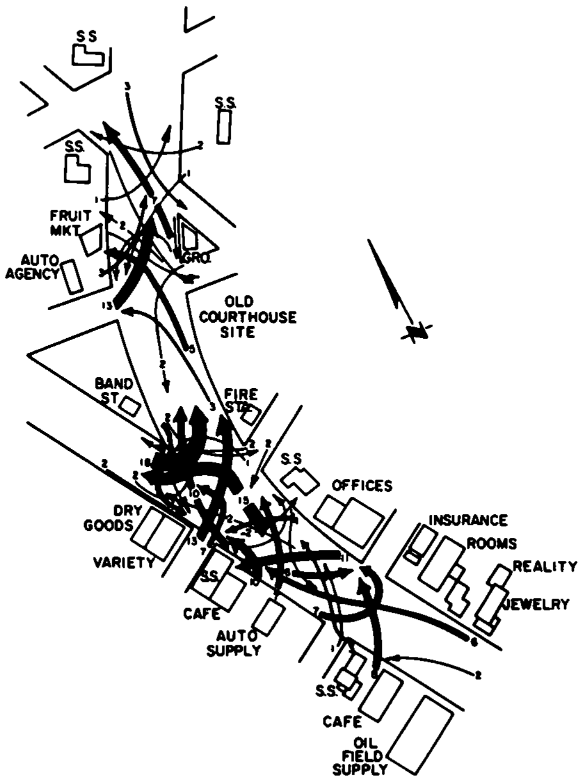


Figure B-17. Irregular maneuvers "before" study in Pleasanton, Texas. Source: Wootan et al. (74).

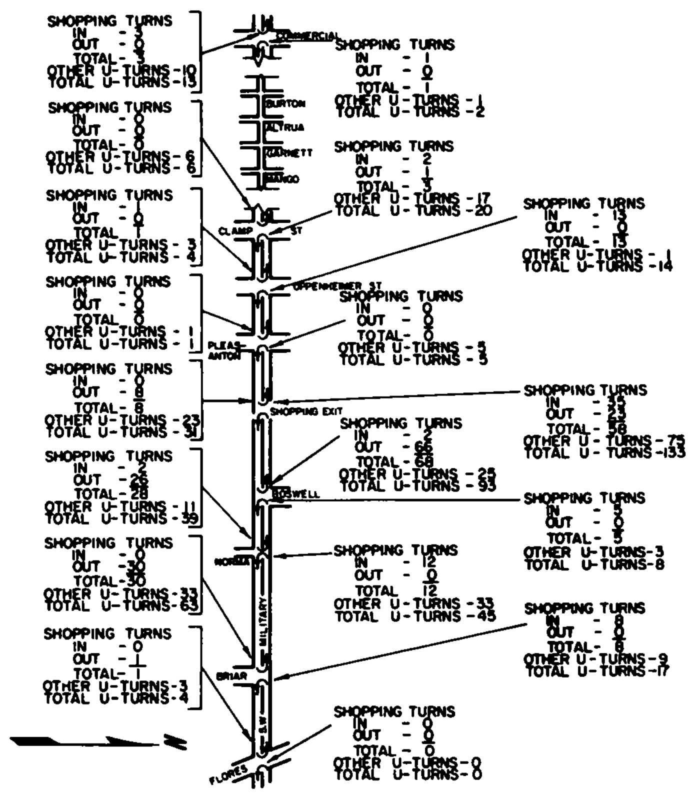


Figure B-18. Characteristics of U-turns on Southwest Military Drive in 1963 after construction of medians. Source: Wootan et al. (75).

ber of these that were directly connected to a shopping trip. These shopping U-turns are also divided as to those made into and those made out of businesses along the route.

By studying the character of the turns at each opening, the business generation of U-turn traffic can be better appreciated, however, the businesses in San Antonio did not generate nearly as many U-turns as were generated in the small and medium-sized cities. This indicates that the increased speed and heavier volume of traffic in San Antonio probably had a tendency to reduce the number of U-turns.

A concerted effort was made to determine the effect that the median had on customer traffic entering and leaving study area firms. Because the commercial establishments had been well-distributed along the highway, each business furnished its own customer parking. Unlike a shopping center where complementary businesses furnish a joint parking lot and joint attractions to customers, it was unusual for a driver to park at one business and walk to others in the vicinity. Thus, it was possible to relate turn-in traffic to motor-borne customers with a high degree of confidence. An analysis of business dependence on two-way or left-turn traffic should serve as further indication of the effect of the median on business.

Traffic entering or leaving a business from a street with no median has quite a bit of leeway in its movements. It can enter from the same side of the street by making a right turn or from the opposite side by making a left turn and crossing the opposing traffic stream. It can also leave in either direction The addition of a median barrier restricts only this second, or left turn, movement. It is the loss of the left-turn traffic that the retailer fears will hurt him.

The Texas study attempted to answer two questions about customer traffic: (1) the extent to which a median would restrict it, (2) the influence that the change would have on the sales of the businesses concerned.

Customer turns into study area firms in the medium-sized city were about 7 percent lower in the "after" period than they were before the median was installed (Fig. B-19).

The lower level of shopping turns in the "after" period may have been caused by the increased difficulty of entering and leaving study area firms under median conditions. This could have caused potential customers to postpone the less-essential trips or combine shopping into fewer trips. If so, the lower level of customer exposure, and its subsequent effect on "impulse buying" would be expected to lower total sales by a small amount. It is also possib'e, of course (though not as certain as believed by most businessmen), that the median could have dissuaded certain through traffic from stopping at all. If so, the loss of these stops would appear as a net loss in the sales volumes of all firms in the area.

The studies assumed that the medians would restrict left turns into businesses, with a corresponding increase in right turns, because the median was not considered an obstacle to this type of turning movement; however, this was found to be only partially true. The medians did reduce the number of left turns into businesses located along the margin of the highway; in addition, they also reduced the number of right turns into firms located along the facility (Fig. B-20).

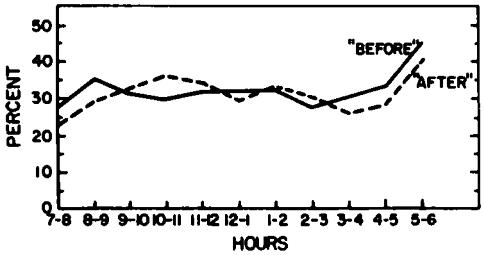


Figure B-19 Turns into businesses as a percentage of total hour by traffic along Highway 146, Baytown, Texas Source: Wootan et al. (73)

The analysis of these changes of turning movements in San Antonio indicated that there was a 59 percent reduction in the left-turn and U-turn movements and a 23 percent reduction in the right-turn movements into businesses in the "after" period (Table B-5).

There are a number of possible explanations for this decrease. Businessmen along the route felt that the increased traffic speed made it more hazardous to make right turns into businesses because of the rapid deceleration necessary to change average traffic speed to safe turning speed. They believed the motorist feared a rear-end accident when slowing down to make a turn; consequently, he passed by, rather than risk an accident.

Regardless of the motive for the changes, it is clear that medial access control has an influence on market-oriented traffic. Superficially, this would seem overwhelmingly important to the nonuser sector, but further analysis indicates that it is not the total volume of traffic that is of paramount importance to the abutting operations; rather it is the economic composition of the market-oriented flow.

Economic Effects of Medial Access Control

Relationships between business location and U-turns point out the importance of keeping both present and potential business development in mind when designing a median

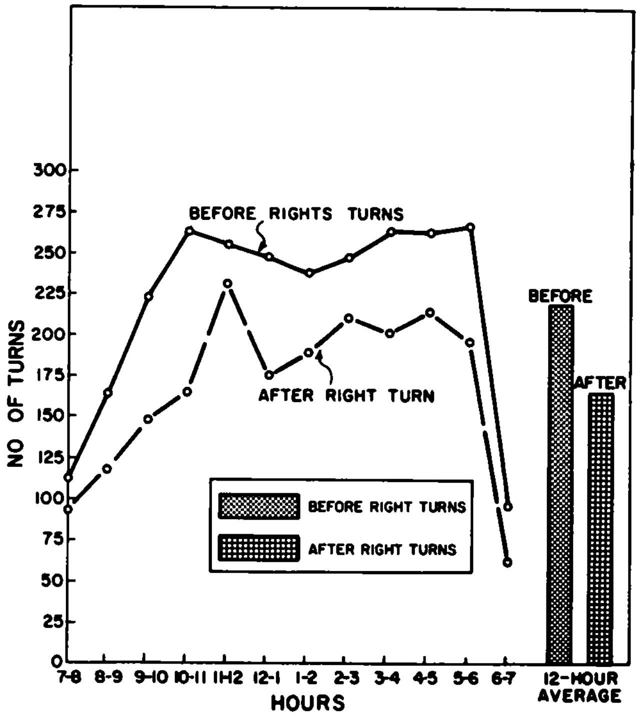


Figure B-20 Influence of median on right turns into business firms along Southwest Military Drive, San Antonio. Source: Wootan et al. (75).

type facility. A comparison was made in an attempt to relate changes in individual business volumes to changes in left-turn traffic entering the business. For this comparison, all businesses for which records were available for both the "before" and "after" periods were arrayed in ascending order of positive changes in sales volumes. Changes in left-turn traffic were then determined for each business and compared to these data, as given in Table B-6.

There appears to be little consistency between the percentage changes in sales volumes and the percentage changes in the number of left turns into individual firms.

TABLE B-5

INFLUENCE OF A MEDIAN ON TURNS INTO TRAFFIC- AND NONTRAFFIC-SERVING BUSINESSES ALONG SOUTHWEST MILITARY DRIVE, SAN ANTONIO, TEXAS

	TRAFFIC-SERVING			NONTRAFFIC-SERVING			TOTAL		
TURNS	BEFORE	AFTER	% CHANGE	BEFORE	AFTER	% CHANGE	BEFORE	AFTER	% CHANGE
Right turns	499	385	−23	2,117	1,622	−23	2,616	2,007	−23
		L—71			L—1,079			L—1,069	
Left and U-turns [a]	577		−76	2,264		−49	2,841		−59
		U—10			U—71			U—81	
Total	1,076	466	−57	4,381	2,772	−37	5,457	3,238	−41

[a] No U-turns in the "before" period

Source Wootan et al. (75)

TABLE B-6

COMPARISON OF CHANGES IN FIRM SALES WITH CHANGES IN CUSTOMER LEFT TURNS

Firm Code	Business Orientation	Left Turns into Business Firms			
		Change in Sales	Before	After	Percent Change
		(Percent)	(Number)	(Number)	(Percent)
1	Traffic	- 44	18	9	-50
2	Traffic	- 38	131	46	-65
3	Traffic	- 28	23	5	-78
4	Traffic	- 26	16	2	-87
5	Traffic	- 16	51	12	-76
6	Nontraffic	- 12	38	19	-50
7	Traffic	- 9	49	9	-82
8	Nontraffic	- 9	311	203	-35
9	Traffic	- 4	33	34	3
Subtotal of Firms Losing in Sales		- 15	670	339	-49
10	Traffic	1	42	27	-15
11	Nontraffic	4	11	3	-73
12	Nontraffic	7	60	29	-52
13	Nontraffic	12	175	147	-16
14	Traffic	43	11	7	-36
15	Traffic	44	16	14	-13
16	Traffic	61	6	1	-83
17	Nontraffic	147	23	22	- 4
18	Nontraffic	382	17	19	12
Subtotal of Firms Gaining in Sales		35	361	269	- 5

Source C V Wootan, H G Meuth, N J Rowan, R G Williams, A Median Study in Baytown, Texas, Texas Transportation Institute, Texas A&M University, 1964

To pursue this relationship further, however, a simple statistical test was made of the ranked data. In this test the businesses were first ranked in ascending order of positive percentage changes in sales (Table B-6). These firms then were assigned a second ranking in accordance with their ascending order of positive percentage changes in left turns. The extent to which these rankings were correlated was then determined through use of the "rank correlation" formula:

$$r_s = 1 - \frac{6\,(\Sigma d^2)}{n\,(n^2 - 1)}$$

The resulting r_s (measure of rank correlation) of 0.637 indicates there there is a positive correlation between rankings, and that this relationship is significant at the 1 percent level.

In nonstatistical terms, this means that, in general, the firms with the greatest percentage losses in sales also had the greatest percentage losses in left turns. The analysis did not attempt to measure or estimate the extent of these losses.

Another statistical test, a linear correlation analysis, was then run in an attempt to determine the extent to which changes in sales were caused by changes in left-turn traffic. This test, based upon actual changes in annual sales and actual changes in left turns, yielded a coefficient of determination of 0.049. In this case, at least, only 5 percent of the change in sales could be explained by changes in left-turn traffic.

If the firms are considered as groups, the relationship between losses in sales and losses in left turns becomes more readily apparent. When all firms that lost sales were grouped together, their aggregate loss in left-turn traffic was 49 percent Those that gained in sales lost only 26 percent of their left-turn traffic.

This would seem to bear out the contention that there is some relationship, although not specific to every case, between the extent of losses in left turns and losses in business volumes. This relationship is not strong enough, however, to enable one to predict, with any degree of accuracy, the extent of the influence of a restriction in left-turn traffic on an individual firm's sales volumes. Many additional factors (such as management, general location, and extent of competition) are of equal or greater importance in determining this effect. Accessibility to traffic is, of course, a very important factor to most businesses. It is by no means always the most important one.

When a new facility is to be constructed which calls for a median with limited openings, businessmen in the area are reluctant to accept its design unless there is a median opening in front of each adjacent business. Generally, it is their contention that a business near an opening in the median is benefitted greatly, because this provides its customers convenient access to and from both streams of traffic.

As part of the study, it was decided to test the validity of the above contention, insofar as the data would permit. Each firm was classified as being located either at or away from a median opening. All firms which could be approached by a *legal* left turn were considered as being located at a median opening. Those that could not be entered by a legal left turn were placed in the non-opening group.

An analysis by the various types of businesses was not possible, because the additional breakdown of firms would expose the identity of several cooperating businesses. The businesses, however, were divided into two groups—traffic-serving and nontraffic-serving. The comparison of sales, with respect to the firms' location to a median opening, is given in Table B-7.

In each of the groups mentioned, firms fared better in the "during" or "construction" period than in the period after construction was completed. Firms at median openings showed an 8 percent drop in sales in the "during" period from their base level, whereas the other group had only a 2 percent drop.

As expected, most of the firms located at median openings were of the traffic-serving nature, whereas the nontraffic-serving businesses made up the majority of the firms located away from a median opening.

From the data given in Table B-7, it would appear that the four nontraffic-serving businesses were definitely hindered by being located near an opening in the median; however, it was believed that there were factors other than location affecting the sales of these firms. The managements of the two firms showing the largest drop in sales felt

TABLE B-7

INDEX OF THE EFFECT OF FIRM LOCATION WITH RESPECT TO MEDIAN OPENINGS ON SALES VOLUME (YEAR, NOV. 1958-OCT. 1959=100)

GROUP I-FIRMS LOCATED AT MEDIAN OPENINGS				GROUP II-FIRMS NOT LOCATED AT MEDIAN OPENINGS			
Firm No.	Before Number	During Number	After Number	Firm No.	Before Number	During Number	After Number
	Traffic-Serving				Traffic-Serving		
21	100	88	110	18	100	113	112
22	100	97	95	19	100	137	126
24	100	105	104	20	100	44	52
25	100	117	134	23	100	71	56
26	100	87	68				
28	100	85	99	Subtotal	100	72	56
29	100	71	89		Nontraffic-Serving		
30	100	87	86	1	100	113	121
31	100	118	112	2	100	90	95
32	100	116	135	3	100	107	97
33	100	77	77	6	100	95	94
35	100	94	79	10	100	97	92
Subtotal	100	97	99	11	100	105	90
				13	100	112	103
	Nontraffic-Serving			14	100	104	123
5	100	79	64	15	100	107	102
7	100	64	50	17	100	107	137
12	100	98	92	36	100	102	91
16	100	96	87	37	100	109	114
				38	100	83	52
Subtotal	100	80	68	39	100	83	108
TOTALS	100	92	89	40	100	98	131
				Subtotal	100	102	100
				TOTALS	100	98	94

Source C. V. Wootan, H. G. Meuth, N J Rowan and T. G Williams, A Median Study in Pleasanton, Texas, Texas Transportation Institute, Texas A&M University, 1964.

that their losses were caused not by the median but by a cyclical decline in demand for their products.

From an analysis of data in Table B-7 it would appear that there was no advantage to a firm in being located near a median opening. The variation in sales of firms, both with and without median openings, strongly supports the contention that, within the competitive framework existing in city size and character, 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.

Figure B-21 shows the effect that the construction of a median had on businesses during the three periods studied. This pattern of business sales was generally the same for all city sizes. The reasons may have been different for the changes observed in the small, medium, and large cities, but the result was the same.

Another method used in analyzing the effect of the construction of a median on business activity is given in Tables B-8 through B-11. Each of the tables represents the sales of individual firms. To facilitate comparison, they are grouped into traffic- and nontraffic-serving businesses. Firms are arrayed in these tables according to the magnitude of the changes in their sales as revealed by the index numbers in the "after" period. The "before" period sales represent the base for which all index numbers are equal to 100. Individual firm names have been omitted to protect the identity of cooperating firms. Again, the index sales in each table show that both the traffic- and nontraffic-serving firms in the study areas generally experienced a decline in the "after" period relative to the base period.

Over-all, however, the evidence indicates that the median did not adversely affect study area firms in an absolute sense, because sales continued a steady increase throughout the period. In comparison to the control firms, however, the rate of increase was somewhat lower. This indicates that there was perhaps a small adverse effect chargeable to the median, because, in its absence, study area firms would have been expected to perform with a rate of increase equal to their control.

From an economic standpoint, the stimulus to new growth was perhaps the most significant effect of the median program as a street improvement. The program

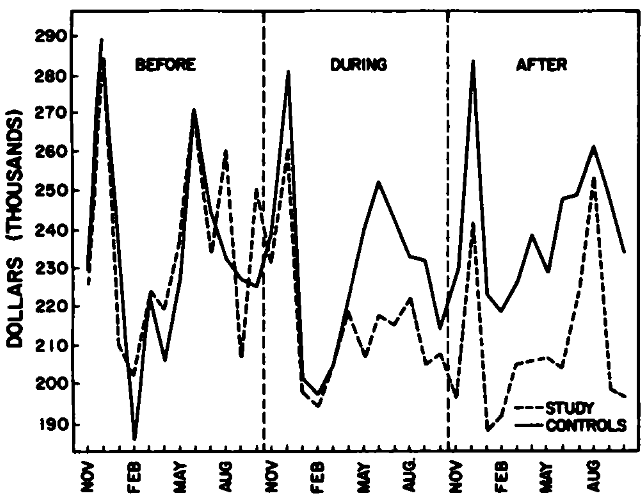


Figure B-21. Monthly sales of all study and control area firms that were in operation during any one of the study periods. Source: Wootan et al. (74).

TABLE B-8

INDEX OF SALES SHOWING THE EFFECT OF THE CONSTRUCTION OF A MEDIAN ON EACH TRAFFIC-SERVING BUSINESS (YEAR NOV. 1958-OCT. 1959=100)

Business	Before Base Period*	During Number	After Number
	STUDY AREA FIRMS		
Service Stations	100	115.8	135.2
	100	117.2	133.6
	100	118.0	112.4
	100	105.4	104.2
	100	85.1	98.7
	100	71.4	88.8
	100	87.2	86.0
	100	94.4	78.6
	100	77.2	76.8
	100	86.9	67.7
Sub Total	100	99.9	101.1
Motels and Restaurants	100	137.1	125.6
	100	112.9	112.1
	100	87.6	109.8
	100	96.7	95.2
	100	71.5	56.1
	100	43.8	52.1
Sub Total	100	90.5	83.0
TOTAL	100	95.4	95.8
	CONTROL AREA FIRMS		
Service Stations	100	130.4	124.8
	100	113.3	120.7
	100	101.1	118.3
	100	120.4	110.2
	100	103.4	101.9
	100	94.4	98.1
	100	107.7	98.1
	100	94.7	94.5
	100	84.4	93.3
	100	88.5	91.2
	100	79.8	72.2
	100	79.5	59.9
Sub Total	100	100.3	98.9
Motels and Restaurants	100	117.2	151.4
	100	103.9	135.5
	100	107.4	105.6
	100	86.4	104.4
	100	99.4	96.3
	100	96.9	90.3
Sub Total	100	102.5	109.4
TOTAL	100	100.7	100.8

*Base period equals 100

Source: C. V. Wootan, H. G. Meuth, N. J. Rowan and T. G. Williams, A Median Study in Pleasanton, Texas, Texas Transportation Institute, Texas A&M University, 1964.

TABLE B-9

INDEX OF SALES SHOWING THE EFFECT OF THE CONSTRUCTION OF A MEDIAN ON NONTRAFFIC-SERVING BUSINESSES (YEAR NOV. 1958-OCT. 1959=100)

Type of Business	Before	During	After
	STUDY AREA FIRMS		
Miscellaneous Retail	100	83.1	147.9
Personal Services	100	107.3	137.1
Miscellaneous Retail	100	98.3	130.9
Personal Services	100	104.3	123.3
Hardware	100	112.7	120.8
Miscellaneous Retail	100	109.1	113.8
Miscellaneous Retail	100	116.8	107.9
Grocery	100	111.6	102.8
Personal Services	100	107.4	102.3
Hardware	100	107.0	97.1
Hardware	100	90.5	95.1
Auto and Farm Machinery	100	94.6	94.0
Grocery	100	97.0	91.8
Grocery	100	97.5	91.8
Miscellaneous Retail	100	101.7	91.5
Grocery	100	105.1	89.8
Personal Services	100	95.6	87.0
Auto and Farm Machinery	100	79.1	64.3
Auto and Farm Machinery	100	64.3	49.8
Grocery	100	71.2	
	100	87.3	82.4
	CONTROL AREA FIRMS		
Miscellaneous Retail	100	135.9	183.0
Auto and Farm Machinery	100	110.6	121.7
Grocery	100	111.9	120.3
Personal Services	100	113.9	117.2
Auto and Farm Machinery	100	97.0	115.2
Grocery	100	101.0	114.4
Miscellaneous Retail	100	113.6	114.0
Miscellaneous Retail	100	116.5	110.9
Miscellaneous Retail	100	104.3	105.8
Personal Services	100	91.4	102.4
Grocery	100	107.9	100.0
Hardware	100	66.5	98.8
Auto and Farm Machinery	100	92.8	95.3
Grocery	100	103.8	93.3
Miscellaneous Retail	100	93.3	92.9
Miscellaneous Retail	100	109.2	92.4
Miscellaneous Retail	100	91.6	86.6
Hardware	100	77.6	77.2
Personal Services	100	96.2	72.5
Hardware	100	77.7	68.0
Auto and Farm Machinery	100	65.6	65.5
Grocery	100	42.6	24.0
Hardware	100	57.9	17.0
	100	98.5	104.3

Source: C. V. Wootan, H. G. Meuth, N. J. Rowan and T. G. Williams, A Median Study in Pleasanton, Texas, Texas Transportation Institute, Texas A&M University, 1964.

created attractive and desirable commercial sites in each of the three areas. The desirability of these sites is attested by the rapid influx of new businesses which began immediately after construction was completed. Some business lost in a comparative sense in that old firms may have been absorbed by the new businesses.

In general, the construction process itself provided the most severe shock to the economic system of the community. This shock was most severe in Baytown, the middle-sized city, where some businesses were completely isolated from traffic for varying lengths of time, due to both the contractor's scheduling and inclement weather conditions. It was less severe in Pleasanton, the smallest city, where local customers had few alternative firms with which to shop. In San Antonio, the largest city, the effect was less uniform. Certain classes of firms, such as service stations, were severely affected; but, from the standpoint of the area as a whole, their losses were made up by gains in the non-traffic-serving businesses. After the new facility was completed, business as a whole began to rapidly recover the sales lost during construction. After a full year of operation with the median, total business volume was above the pre-construction level in both San Antonio and Baytown. Of course, some of this gain was due to the establishment of new businesses along the facility, and many old firms were still below their base volumes. In general, the businesses operating in older, less modern, less well-kept buildings were most severely affected and were not able to regain their lost sales volumes. More modern firms with vigorous, progressive management often increased their sales much above their base levels.

TABLE B-10

INDEX OF SALES SHOWING THE EFFECT OF THE CONSTRUCTION OF A MEDIAN ON TRAFFIC-SERVING BUSINESSES (YEAR 1959=100%)

Type of Business	Before	During	After
	STUDY AREA		
Service Stations	100	84.7	91.2
	100	90.6	80.0
	100	130 2	96.7
	100	46 8	61.2
Sub Total	100%	80.1	78.5
Restaurants	100	43.8	52.6
	100	101.5	87 3
	100	91 1	80.5
Sub Total	100%	77.4	72.8
TOTAL	100%	79.1	76.4
	CONTROL AREA		
Service Stations	100	83.7	87.4
	100	113.2	93.7
	100	109.3	149.4
	100	91.5	92.6
Sub Total	100%	95.3	95.9
Restaurants	100	98.6	115.1
	100	109.0	105.5
	100	125 2	142.5
Sub Total	100%	108.0	119.7
TOTAL	100%	98.6	102.0

[1]1960 was used as a base period for those firms beginning operation in 1959.

Source. C. V. Wootan, H. G. Meuth, N. J. Rowan, T. G. Williams, A Median Study in San Antonio, Texas, Texas Transportation Institute, Texas A&M University, 1964.

TABLE B-11

INDEX OF SALES SHOWING THE EFFECT OF THE CONSTRUCTION OF A MEDIAN ON EACH NONTRAFFIC-SERVING BUSINESS IN THE STUDY AREA (YEAR 1959=100%)

Type of Business	Before	During	After
Grocery	100[1]	85.2[1]	88.3[1]
	100	50.5	73.8
	100	81.9	95.4
Sub Total[2]	100	51.6	74.5
Auto and Auto Parts and Allied Business	100[1]	90 [1]	75 [1]
	100	117.9	141.3
	100[3]	123.6	134.8
	100	83.4	57.5
	100	91.0	115.0
	100	108.8	65.3
	100	121.0	219.4
	100	131.3	135.1
Sub Total[2]	100	109.8	119.3
Furniture Appliances and Hardware	100[3]	110.5	120.0
	100	16.7	11.1
	100	111.8	128.8
	100	71.6	75.6
	100	57.5	41.3
Sub Total	100	93.8	88.3
Personal Services· Barber and Beauty Shops and Cleaners	100	31.0	38.0
	100	64.2	68.0
	100	93.2	66.8
	100	96.8	76.8
	100	37.1	35.7
	100	55.8	63.8
Sub Total	100	68.2	61.0
Other Retail. Drugs, Apparel and Jewelry	100[1]	87 1[1]	83.1[1]
	100[1]	104 2[1]	106.0[1]
	100[3]	108 2	108.9
	1003	114.7	120.0
	100	56 7	67.2
Sub Total[2]	100	106.8	111.6
TOTAL	100%	93.9%	103.4%

[1]Percentage figures furnished by firms that would not reveal actual sales

[2]Totals do not include those firms furnishing percentage figures.

[3]1960 was used as the base period for those firms beginning operation in 1959.

Source C. V. Wootan, H. G Meuth, N. J Rowan, T. G. Williams, A Median Study in San Antonio, Texas, Texas Transportation Institute, Texas A&M University, 1964

The assumption that losses in left-turn customer traffic into businesses would be offset by increases in right-turn traffic was not completely borne out. Customer turns appear to be inversely related to city size and traffic volume. In both of the smaller cities, there was an increase in right-turn customer traffic after the median was built. In San Antonio, however, where traffic volume was very heavy and speeds high, there was an actual reduction in right turns. In the three cities as a whole, the reduction in total customer traffic averaged about 10 percent after the median was installed.

HIGHWAYS AND ECONOMIC DEVELOPMENT

Interchanges

One of the major types of access provided to a major facility is by means of a highway interchange. The design of these interchanges can vary from a fairly low-level design that may be little more than a cross street intersecting a major artery to a high-level design that provides controlled access to the facility by means of entrance-exit ramps and divided minor-street and major-street geometrics.

Interchanges vary in function and have been classified accordingly by one writer into three types or levels.

1. Express interchanges transmit road users from one road system to another for purposes of continuing their trip.
2. Arterial interchanges have the dual function of exchanging traffic between two road systems and providing access to arterial streets which service abutting land uses.
3. Service interchanges primarily give convenient service for road users and secondarily serve both important abutting land uses and traffic-exchange purposes.

A study of interchanges along 180 miles of highway in Michigan (*3*) demonstrated the following.

All major city interchanges developed high commercial land values, with service station sites selling for as much as $75,000 per site or $170,000 per acre, and restaurant and motel sites selling for $12,500 per acre. Almost 80 percent of the major city interchange quadrants had some form of commercial development. Major city interchanges averaged 3.38 service stations, 2.38 restaurants, 1.25 motels, and 0.38 shopping centers per interchange (Table B-12).

At the secondary city interchanges, 40 percent of the quadrants were in commercial use. The average per inter-

TABLE B-12

QUANTITY OF COMMERCIAL DEVELOPMENT PER INTERCHANGE ON FULL INTERCHANGES (180 MILES OF HIGHWAY, MICHIGAN)

INTERCHANGE CLASSIFICATION	NO.	SERVICE STATIONS	RESTAU-RANTS	MOTELS	SHOPPING CENTERS	SALES UN-COMMITTED
Major city	8	3.38	2.38	1.25	0.38	0.38
Secondary city	13	1.38	0.46	0.15	0.08	0.54
Small town	13	1.23	0.54	0.00	0.00	0.62
Rural	18	0.44	0.28	0.00	0.00	0.50
Average	—	1.33	0.71	0.31	0.08	0.52

Source Flaherty (*27*)

change was 1.38 service stations, 0.46 restaurants, and 0.15 motels. In addition, there was some industrial development.

Most small-town interchanges had some commercial development, with an average of 1.23 service stations and 0.54 restaurants per interchange.

Potential service station sites increased fivefold. The averages of all other land sales indicated a doubling of values. Partial or half interchanges showed little reaction to the highway, except where such interchanges were closely associated with full interchanges. Closed interchanges (the intersection of two limited-access roadways) showed no signs of enhancement from the freeway.

At major city interchanges, service stations within 400 ft of the interchange averaged twice the gallonage of those 400 ft to 1 mile away, indicating that proximity to the interchange afforded a better business location and would, therefore, command a higher value.

Why parcels near interchanges tend to have a high rate of land value increase is fairly obvious. Interchange areas offer special opportunities for economic development. A study in Texas provided evidence of the peaking of land values at major traffic intersections (*29*). To approximate the influence of interchanges and ramps on the value of abutting property, the study used a land value regression equation. This interchange complex evaluated was defined to be that area of the highway system that included an intersection of the highway with some other road, involving a transfer of traffic between the two, and encompassed by the ingress-egress ramps and the intersection of the frontage roads with the intersecting road.

An examination of abutting properties and their relation to the interchange revealed that proximity to the interchange held definite advantages. A ½-mile area, a distance often used to distinguish between interchange and noninterchange areas, was analyzed.

Figure B-22 shows the relationship between price per acre and distance from an interchange for 72 interchange observations. The vertical axis is price per acre in thousands of dollars and the horizontal axis is distance from the interchange expressed in feet. The mean values fell between a high of $17,642 per acre for land directly on the interchange to $5,528 per acre for locations approximately ½ mile from the interchange (Table B-13).

The cluster of high values around the complex probably has its basis in a physical reality associated with interchanges. There are a limited number of interchanges, and each interchange has only four quadrants. Additionally, these quadrants may be of unlike quality, depending on unique design and probable or existing traffic flow. The high-quality interchange parcels will be under vigorous competitive pressure as soon as construction begins and their design and situation become relatively assured. Buyers are aware that there are a limited number of suitable interchange sites and, if they wait until their competitor purchases a site, it will, to all intents and purposes, be out of the market permanently, because the competition is not likely to sell to them. They may bid for alternate properties of somewhat lower or equal quality. The intense competitive activity forces the price of the choice interchange properties upward.

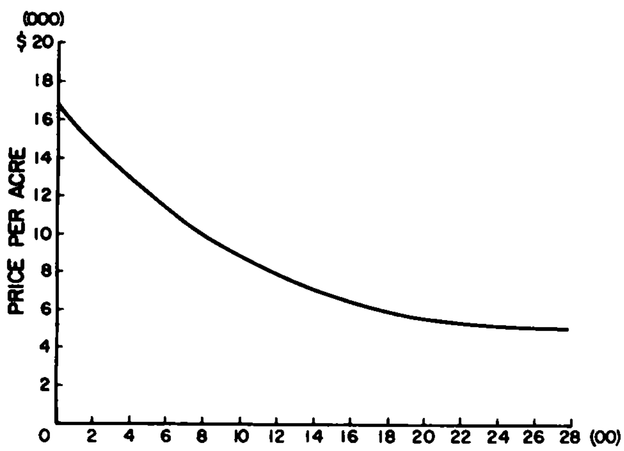


Figure B-22. Relationship between property price per acre and distance from interchange.

Shopping Centers

Although shopping centers have long been a part of the commercial scene, for many years they evolved largely on an unplanned basis, primarily as a result of aggregation of business establishments near intersections of major streets or highways or at other points of easy access. In recent years, the number of planned shopping centers has increased dramatically. By 1961, there were over 4,000 of these shopping centers, 2,500 of which had been constructed since World War II (*34*). These planned shopping centers, though differing in size, composition, and area served, are alike in the emphasis they give to good highway accessibility and customer parking.

Large, planned shopping centers should be of great concern to those responsible for the planning, design, and operation of major highway systems. The traffic-generating potential of such centers can be substantial. According to one set of observations made in 1958, two large shopping centers located a short distance apart attracted more than 60,000 vehicles on a single day. "This volume is equal to that entering the central business district of a city with a population of nearly 400,000" (*21*).

Highways surrounding a shopping center also facilitate parking by simplifying ingress and egress at times of peak traffic. To assure ample parking, adequate space (ordinarily equal to three or four times the amount of floor space) must be provided, as well as facilities for entering and leaving this space. In a 40-acre parking lot, 5,000 or 6,000 cars might park at one time. As many as 3,000 cars an hour, or 50 cars each minute, may be entering or leaving the lot.

The effects of such magnitude of traffic on the operation of the traffic system and accident rate can be significant. The over-all viewpoint must take into account a complex interrelationship between the user and nonuser of the complete system.

Highway Bypass Effects

The most extensive studies in the area of nonuser impact as a result of highway construction has been in the analysis of bypass effects. Buffington analyzed the bypass influence on nine cities in Texas (*17*). The nine study areas involved 74 miles of the highway system. The strips selected for a study of highway impact on land values and land uses aggregatively encompassed about 95,000 acres. A sizable portion of this acreage was made up of 593 right-of-way remainder tracts.

Using control areas to account for other economic influences, an attempt was made to determine the approximate highway influence on land values, land uses, travel patterns, business activity, and community development in each study area. The "after" period for the nine areas averaged about 5 yr.

In seven of the affected towns, a total of 533 retail businesses and 65 nonretail business located along the old routes were bypassed by the highway system. Of these, the retail businesses were studied in detail to determine the bypass effects on them. Prior to the construction of the bypasses, the average daily traffic volumes on the old routes ranged from 4,000 to 10,000 vehicles. Changes in the old route traffic volumes were studied in relation to those created on the new facilities.

Table B-14 gives the percentage changes in retail sales in seven bypass areas for both old and new routes. Six of the old bypassed routes showed decreases ranging up to 8.3 percent in gross sales of traffic-serving businesses. Nontraffic-service businesses lost total sales along only one old route; the same area (Rockwall) lost sales for both traffic- and nontraffic-serving business taken together in the amount of 2.4 percent.

TABLE B-13

RELATIONSHIP BETWEEN INCREASE IN PROPERTY VALUE BETWEEN PERIODS AND LOCATION WITHIN THE INTERCHANGE COMPLEX

DISTANCE FROM INTERCHANGE (FT)	PRICE, POST-CONSTRUCTION PERIOD ($/ACRE)	INCREASE BETWEEN PERIODS ($)	%
Interchange property [a]	17,642	12,907	272.58
Property on ramps [b]	14,432	9,697	204.79
<500 [c]	16,731	11,996	258.34
500–1,000	10,297	5,562	117.46
1,000–1,500	8,429	3,694	78.01
1,500–2,000	7,017	2,282	48.19
2,000–2,500	5,528	793	16.74

[a] Property located directly abutting the interchange-intersection complex.
[b] Property located at a zero distance from an egress ramp
[c] Measured beginning with first tier of property behind that located directly on the interchange
Source Franklin and Evans (*29*)

Table B-15 summarizes the highway influence on land values in the respective study areas. These percentages are based on an analysis of 5,595 study areas and 4,445 control area real property sales, where the prices of individual properties were determined from deed records. Many of these prices were confirmed by the local real estate people, as well as by individual owners. General land value increases (established by the control areas) have been accounted for in the percentages presented.

Unimproved acreage tracts showed the greatest highway influence among types of property. Abutting properties received a much greater highway influence than the nonabutting properties, all of which were within 1 mile of the highway system. In two areas, nonabutting properties received no positive highway influence. Two agricultural areas which had no access to a major highway in the "before" period, received the least highway influence.

The least-developed portions of the study areas generally received greater land value benefits than the more-developed portions. A special study conducted in one area revealed that property values on the town side of the facility increased more than on the opposite side. This was true for both abutting and nonabutting properties. This suggests that users of land considered the properties on the town side to be best situated for higher uses because of the added advantage of proximity to the town (likely because of more readily available city utilities, as well as superior accessibility).

The number of commercial tracts probably would have been greater in one area (Conroe), had it not been for the

TABLE B-14

ANNUAL PERCENTAGE CHANGES IN GROSS RETAIL SALES OF STUDY BUSINESS BETWEEN THE BEFORE AND AFTER YEARS[a]

	ANNUAL CHANGE IN GROSS RETAIL SALES (%)					
	TRAFFIC-SERVING		NONTRAFFIC-SERVING		TRAFFIC- AND NONTRAFFIC-SERVING	
AREA	OLD ROUTE	OLD AND NEW ROUTE	OLD ROUTE	OLD AND NEW ROUTE	OLD ROUTE	OLD AND NEW ROUTE
Conroe	−8.3	−5 7	14 3	17.6	3.0	4 0
Waxahachie	−3.8	−3.5	2 5	2 5	0 8	1 0
Austin	−2.1	−1 9	11.5	13.0	7.0	9.0
Merkel	−1.8	16 2	10.0	6.2	6.3	8.3
Rockwall	−1.8	11.7	−2.6	−2 6	−2.4	−1.0
Temple	−0.1	2 3	5.2	6.6	3.8	4.8
Huntsville	0.3	4.8	9.5	9.7	6.7	8.2

[a] The Houston and Chambers County areas were left out because they had no old routes like the other areas According to *Sales Management Magazine*, "Survey of Buying Power," the annual increase in gross sales for the State of Texas during the period covering all areas was 5 percent

"no access" restrictions at the interchanges and the absence of service roads. Also, every other "interchange" had no "on" and "off" ramps. The limited commercial development along this particular bypass area demonstrates the effectiveness of the no access, no ramps, no frontage roads restrictions in impeding strip development. As a result, abutting land values in some areas have not increased as much as in other areas with greater access.

TABLE B-15

HIGHWAY INFLUENCE ON LAND VALUES IN THE RESPECTIVE STUDY AREAS, REPORTED AS A PERCENTAGE OF THE "BEFORE" PERIOD PRICE

	Percentage of Before Period Price					
	Acreage Land				Subdivided Land[1]	
	Unimproved			Improved	Unimproved	Improved
Area	Abutting Properties	Non-abutting Properties	All Properties	All Properties[1]	All Properties	All Properties
Temple	2,986%	1,989%	2,562%	--	--	--
Huntsville	489	2	253	15%		--
Waxahachie	369	222	288	--	- 1%	35%
Austin	363	-111	163	--	- 13	--
Conroe	256	59	95	47	126	9
Rockwall	218	118	137	--	--	
Chambers County	133	- 13	25	--	--	--
Houston	104	64	73	--	23	-56
Merkel	--	--	--	--	38	24

[1] Improved acreage and subdivided lots sales were analyzed only when there was a sufficient quantity of sales of each type in both the study and control areas

Source Buffington, Jesse L , "The Economic Impact of Interstate Highway Bypasses," Texas Transportation Researcher, Texas A&M University, Vol 4, No 1, January, 1968

The increased potential for higher uses of the study area land (especially abutting land) caused the prices of such land to rise sharply.

The highway system brought about a phenomenal increase in the income potential for abutting tracts, especially those located at interchanges. These tracts commanded the highest prices among all land in the study areas.

The net change in land uses of the tracts abutting the highway facility indicates that the most significant change is out of other land uses into the commercial traffic-serving category (Fig. B-23). The bypass initially attracts the usual traffic-oriented type of business, because this particular business depends on two factors for survival: (1) direct access to the highway facility, and (2) access to the physical traffic stream. This type of firm usually relocates from its former position to a location on the bypass to take advantage of the two factors needed for its continued existence.

The removal of the through traffic from the old route usually had two results:

1. Traffic-serving businesses suffered a decline in sales volume and generally attempted to relocate on the new bypass, where access was granted to the facility.
2. There was an increase in the number of nontraffic businesses along the margin of the old route, due to the decrease in through traffic volume.

Buffington found that along the old route, traffic-serving businesses were the only group which experienced an overall decline in number and percent between the "before" and "after" years. On the other hand, many new businesses of this type set up along the new route. Quite frequently, those who had previously operated traffic-serving businesses along the old route relocated along the new route.

He also found that there was a significant increase in the number of nontraffic-serving businesses along the old routes. Many merchants with this type of business were pleased with the alleviation of noise and traffic congestion. Generally speaking, the increases in nontraffic-serving and nonretail businesses along old routes indicate that bypass routes become much more desirable locations for business activity, as through traffic is diminished. On the other hand, new routes tend to become desirable locations for traffic-serving businesses.

As a result of his study of the nine areas, Buffington concluded the following for all areas studied:

1. Significant increases in land values, especially for abutting tracts.
2. Significant changes in land from lower to higher land uses, particularly in the case of abutting properties.
3. Significant reductions in the average daily traffic volume on old routes in the bypassed towns.
4. Significant increase in business activity along bypass routes, especially the traffic-serving type, and significant decreases in gross sales of traffic-serving businesses along the old route.

Finally, the effects of the bypass routes on the general community development of areas and towns studied appeared to be favorable.

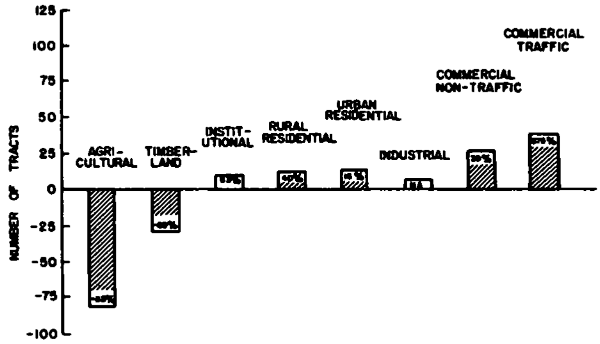


Figure B-23. Net change in the number and percentage of abutting tracts in various uses between the "before" and "after" years in nine study areas. Source: Buffington (17).

Ribbon Development

Many of the main routes leading into and through cities and towns are characterized by excessive commercial development and congestion of city streets with highway travelers. For certain types of businesses, major highways are preferred locations, and many roadside areas have evolved into commercial "ribbon developments." Frequently, these ribbon developments leave the land behind them undeveloped. Unattractive structures in developments of this type sometimes give the approaches to cities and towns a cluttered and untidy appearance. In addition, development of this type greatly reduces the traffic-carrying capacity of the highway and increases accident hazard (*34*).

Motor vehicular traffic and ribbon development have become almost interdependent because commercial developers wish to locate where traffic is thickest, and because traffic is generated by commercial land uses.

Traffic volume and type vary widely, depending on the size and purpose of a building. Dwellings generate little pedestrian or vehicular traffic, theaters concentrate a high volume of pedestrians at certain times, and service stations attract few pedestrians but many vehicles (*26*).

Ribbon development causes delays in traffic movement and increased running costs. It usually consists of a mixture of many land uses, the accommodations for which are designed and built separately and have no uniformity of architecture and appearance (*26*).

As has been noted by Faithful (*26*) and others, ribbon development usually demonstrates the following pattern. In the beginning land values increase, sometimes substantially. There may be immediate obsolescence, as property owners allow buildings to deteriorate in anticipation of higher profits from another use. When development has reached its peak, or traffic congestion has worsened sufficiently, values may start to fall, particularly near the extremities of the development (*26*).

If ribbon development is to be taken into account in highway planning, its effect on the quality of traffic service must be given precise, quantitative definition. A coefficient of roadside friction has been suggested as a means to take into account the effects of various combinations of roadside structures on highways of various types (*72*).

Correlation analyses reported by McMonagle (*46*) in Michigan between accidents and roadside features indicated that the high correlation between accidents and roadside establishments gives support to the theory that accidents are a result of the effect on drivers of an accumulation of features in a group. Individual features are not nearly as hazardous as a group of those features (Fig. B-24, B-25, and Table B-16).

The foregoing disadvantages of ribbon development can be largely offset by various forms of access control. As was pointed out in the section on the effects of medial access control, the relationship between business location and various traffic movements points out the importance of keeping both the present and potential business development in mind when designing access control into a highway facility. Marginal access control can limit the amount and type of development that is to take place along the highway facility, but this form of control can frequently be very expensive if access rights must be purchased from abutting land owners.

As indicated in the section on medial access control, the land-use development abutting the margin of the highway can be influenced by the type of median constructed on the roadway. This type of access control is not as absolute as is marginal control, but it avoids the great expense involved in the purchase of access rights. This is especially significant where there is already a good deal of development along the roadway, and any form of marginal control would involve these expensive rights. Medial control does not prohibit development, but it does inhibit the various types of development that contribute to the hazardous conditions and obsolescence of the roadway.

PROXIMITY AND NOISE

A relationship appears to exist between the proximity of a person's residence to the highway and his attitude toward that highway (Fig. B-26). Resale prices were found in one study to average from 1 to 2 percent less for residences adjoining major highways, as compared with similar homes one block or more away (*20*). This indicates that there

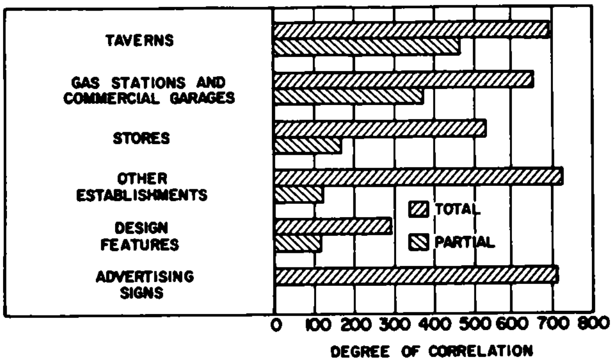


Figure B-24. Coefficients of total and partial correlation for various features with accidents (total correlation shows the cumulative effects of features and partial correlation reveals their individual relationship to accidents). Source: McMonagle (47).

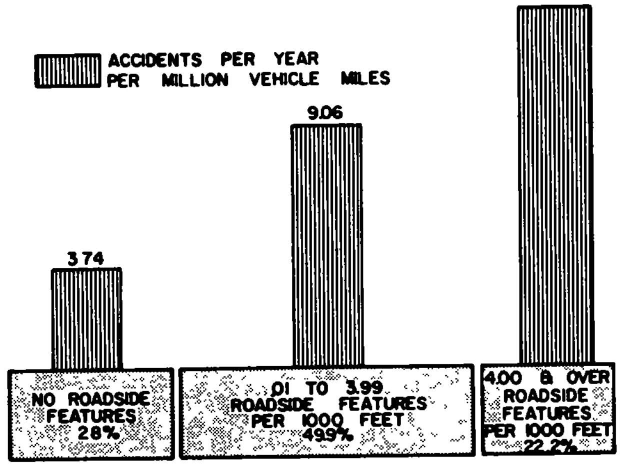


Figure B-25. Intersections, features, and accident occurrence (concentration of roadside features near intersections increases accident hazard). Source: McMonagle (47).

may be a nominal depression in market value caused by close proximity to the roadway. A review of cash down-payments for resale transactions indicates that those residences adjoining major highways required a smaller average down-payment than all other residences having real estate loans, perhaps suggesting some reduction in equity values.

An additional factor to be considered as a highway influence is the sound intensity levels resulting from traffic frequency. An Ohio study found that the chief complaint with respect to noise is usually in regard to truck traffic (*6, 22*). As one study reported, expressways have been shown to have the highest noise level contour along their path, generally about 5 decibels higher than the contours parallel to major streets (*22*).

The study found maximum noise levels at the right-of-way line, where the roadway was at grade level. Noise near the right-of-way at cut sections was lower than comparable values for grade level sections by 5 decibels or more. Noise level at the right-of-way line or fill sections were also lower by 5 to 10 decibels than at comparable grade level sections. "In built-up areas, there was no substantial difference in the configuration of noise level contours beyond a distance of about 500 feet from the right-of-way, regardless of highway profile" (*22*). Properties which have experienced large (1,000% or more) increases in estimated market value tended to be concentrated in areas of comparatively low sound level.

Harris (*6, 31*) prepared a graph of measured sound-level reduction versus distance and, for comparison with measured values, plotted a theoretical curve of the same coordinates using the equation

$$L_p = L_x - 20 \log r/r_x$$

in which

L_p = sound-pressure level at distance r from sound source;
L_x = sound-pressure level at distance r_x from sound source; and
r and r_x are measured perpendicular from the centerline of the outside lane to the respective microphones.

Because 20 log r/r_x = sound-level reduction, then $r_x = 19$ ft.

In an early (1957) study, Adkins found that noise, mainly caused by trucks at overpass and underpass grades, was the disadvantage given by about one-third of the resident respondents interviewed (*2*).

Traffic noise is more of a nuisance in residential areas than in commercial areas. Buffer planting, which provides privacy, has a definite psychological value for roadside residents. It has been found that, when properly designed, marginal border plantings contribute to a reduction in highway noise (*56*).

Various methods of noise abatement that might be used are: (1) wider right-of-way and building setbacks, (2) marginal buffer planting, (3) fences and walls, (4) embankments, and (5) combinations of these methods, all of which involve some degree of access control (*56*).

A recent (1968) study by Franklin Institute (*6*) of the

TABLE B-16

MULTIPLE CORRELATIONS BETWEEN ACCIDENTS AND VARIOUS ROADSIDE AND DESIGN FEATURES

ITEM CORRELATED	CORRELATION COEFFICIENT
Accidents with intersections Gas stations and other establishments	0.83
Accidents with intersections Gas stations and stores	0.78
Accidents with intersections Gas stations and total advertising signs	0.77
Accidents with intersections Gas stations, stores, and other establishments	0.89

Source McMonagle (*46*)

effect of highway landscape development on nearby property considered four basic factors in an economic analysis: (1) property-value changes, (2) relation of property to highway, (3) quantity of landscaping, and (4) highway disturbances. Six meaningful relationships exist among these factors, as shown in Figure B-27. The study conclusions regarding the impact of highways on property value were as follows:

1. The most objective measure of economic impact usable for large numbers of homes was sale and resale price differences.
2. The value of homes, whether next to or away from a highway, changes at the same rate.
3. Average expenditures for landscaping do not differ statistically for properties next to and away from the highway.
4. Sound levels and depression are related to property values, but the relationship is not statistically significant.
5. Change in property values is unrelated to quantity of landscaping.

In a large-scale interview analysis, the same study (*6*) found that: (1) noise from trucks is the most serious disturbance (other disturbance factors were present, but were not as objectionable or as acute); (2) highways cause economic problems for high-rise apartments adjacent to the highway and in the line of sound (rent concessions and higher turnover were found for units located next to the highway); (3) farm owners are bothered by the same problems as are urban and suburban property owners (truck noise and maintenance of right-of-way); however, their complaints are not as strong or as frequent; (4) people accept highways more readily in older, less expensive areas; and (5) shielding the highway through plantings hastens acceptance of an expressway.

Accidents and Access Control

The relationship between the user and nonuser sectors becomes clear when medial and marginal access, roadside development, and vehicle accidents are examined together. The analysis of any one factor in isolation leads to incomplete, and possibly erroneous, conclusions; but, when they are studied as an interrelated whole, the results reveal meaningful answers. The kind and amount of medial and marginal access control bear heavily on the kind and amount of roadside development. In addition, the kind and amount of roadside development determine the kind and amount of vehicle traffic entering the traffic stream at any particular access point. The number of access points and the traffic entering the traffic stream at these points determines, in some measure, the over-all accident rate for any particular length of highway.

With respect to access points, a Minnesota study (*41*) found no significant difference in accident rates for road sections having no access points and those having access points serving noncommercial purposes. This would seem to indicate that access points which are used relatively infrequently do not make a major contribution to the accident potential of a road section. The rate for sections with access points serving commercial activities was twice as great as the rates in the other two categories (no access points and noncommercial access points).

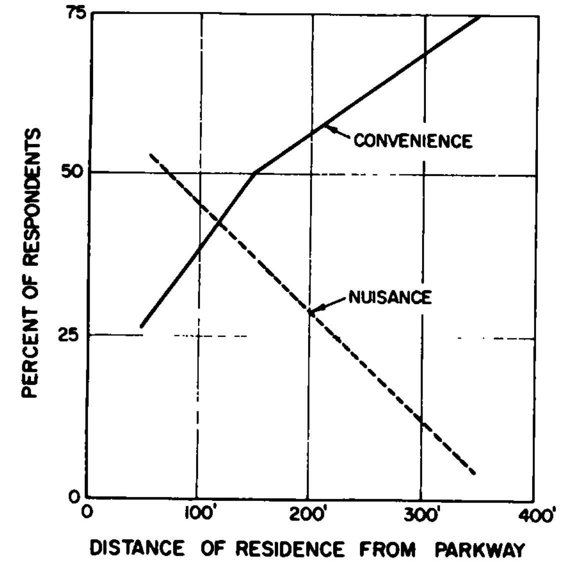


Figure B-26. Opinions of residents of nearby highway in Westchester County, New York. Source: BPR (68).

When road sections were analyzed by traffic volume groups, correlation was found between the number of access points per mile and the accident rate. Road sections with commercial activities on abutting lands had relatively high accident rates. The rate for these sections was between two and three times the rate found on sections having no commercial development and nearly four times as great as the rate for strictly rural sections with few intersections. Intersections influenced by these marginal developments had higher accident rates than other intersections (*41*).

A study conducted in Indiana (*52*) indicated that intersection accidents per 100 million vehicles increased when:

1. Percent green time on the bypass decreased.
2. Bypass or cross-street ADT increased.
3. Percent left turns from the bypass increased.
4. Maximum approach speed increased.
5. Number of intersection approaches increased.

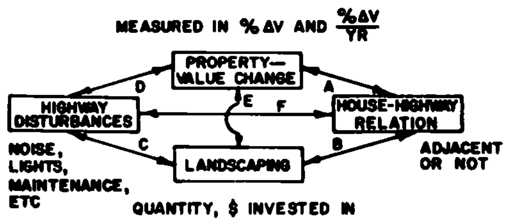


Figure B-27. Relationships among economic factors in the user-nonuser sector. Source: Briton and Bloom (6).

6. Total width of driveways within 200 ft of the intersection increased.

The same study found that, for nonintersection study sections, accidents per 100 million vehicle-miles increased when:

1. Total number of establishments per mile increased.
2. Total number of driveways per mile increased.
3. Total number of low volume intersections per mile increased.
4. Geometric modulus increased.
5. ADT increased.
6. Operating speed decreased.
7. Total width of driveways per mile increased.
8. Length of intersection turning lanes in the section increased.

A study conducted in North Carolina by Cribbins and Summer (*24*) indicated that, as traffic volumes increase, use of median openings rapidly becomes hazardous. When combined with intensive roadside development, use of median openings under high-volume conditions becomes more hazardous (Fig. B-28). They reported that signalization of median openings does not necessarily reduce the hazard of using openings under high-volume conditions; rather, it tends to make the traffic flow in a more orderly way by offering a more equitable time distribution for movements. They also found that as roadside development increases and crossovers of any type are permitted, accidents will increase.

> The mere reduction in speed limit, when volumes are high and roadside development is intense, does not suffice to keep the accident rate at a low level. The increased hazards associated with turning movements under high volume conditions far exceed the benefits occasioned by reducing the speed limit (*24*).

Jorgensen and Westat Research Analysts (*38*) extended the results of Cribbins' findings to forecast the accident reduction possible through selective closing of median openings (Fig. B-29).

Safety on a road is determined largely by freedom of interference with the free flow of traffic. The factors that determine capacity also have their effect on safety. There is a definite correlation between accidents and ribbon development (*26*).

The association between lineal feet of highway-oriented uses and traffic volume was computed in a Minnesota study (*27*). This analysis showed a correlation coefficient of 0.81.

A study by Major and Buckley (*44*) of access point spacing along an arterial stream of traffic considered the problem from the abutting property viewpoint in evaluating arrangements to provide for minimum delay to and maximum capacity for entering traffic. They found that a multiplicity of driveways or access points at close intervals produced undue conflict with the arterial and mutual conflict with each other, resulting in lower capacity and increased delays for traffic from abutting property entering the highway.

Another recent study (*40*) found that four-lane highways had higher accident rates than two-lane highways when there was no median and no access control. Full access control reduced accidents most effectively, partial control of access being somewhat less effective. Medians seemed to decrease the number of accidents, although the effect was not clearcut. The number of one-vehicle accidents per million vehicle-miles (MVM rates) decreased with increasing ADT, and the MVM rate for multi-vehicle accidents increased with increasing ADT. The presence of curves, grades, intersections, and structures was related to increased accident rates on highways. Intersections often gave accident rates three time as high as the rates for pure segments.

Combinations of the geometric elements generated higher accident rates than did individual elements. Combinations

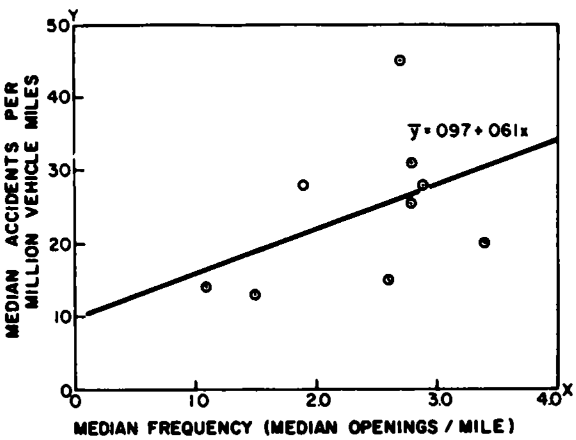


Figure B-28 Relation of median opening frequency and accident rate. Source: Cribbins, P. D., and Summer, H. S. The Correlation of Accident Rates with Geometric Design Components on Various Types of Highways. *Eng. Res. Dep., N. C. State Univ.* (1964).

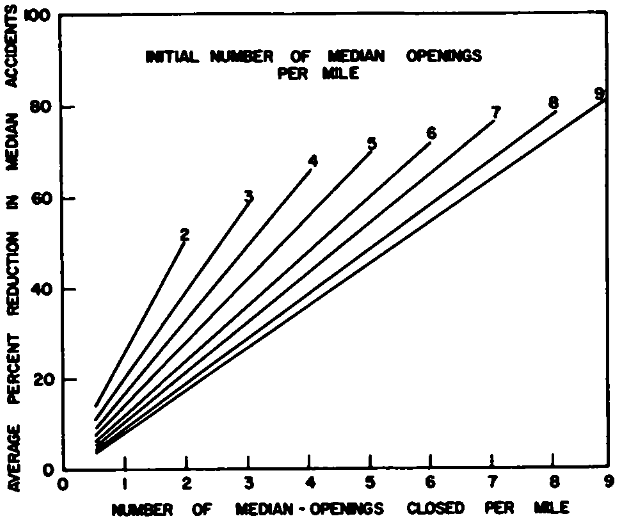


Figure B-29. Forecast of median accident reduction through closing of median openings. Source: Jorgensen and Westet Research Analysts (38).

gave accident rates as high as six times the rates on pure segments (*40, 46*).

It was indicated that an increase in traffic on a major facility has small accident rate effects. An increse in traffic volume, or an increase in the percentage of traffic, from the minor facility results in a rapid jump in the accident rate (*40*).

Four-lane highways (with or without medians but having no access control) have accident rates comparable with, or higher than, those of two-lane facilities. The high rate is attributed to such factors as roadside development, heavier traffic volumes, and more intersections (*40*).

Perhaps the primary consideration in the use of medians is safety—that is, if opposing vehicles are separated by a barrier, either physical or distance, collision between these vehicles is theoretically impossible. Wide medians reduce head-on collisions, but even extreme widths do not prevent all such accidents (*40*).

Hurd concluded that a traversable median must be at least 40 ft wide when the possibility of head-on collisions at high speed is considered (*35*). One study of the effectiveness of various types of median barriers used regression analysis to determine the relative efficiency of different type barriers and different width barriers with general results as shown in Figure B-30.

Although access control is a major item in the reduction of the number of accidents, it is generally accompanied by high design standards, which also tend to reduce accident rates. For uncontrolled-access four-lane highways, no clearcut difference was detected between undivided and divided roads, although there was a suggestion that divided roads have lower rates. On divided four-lane roads, accident rates decrease with partial access control versus no access control. Divided four-lane roads with full access control had the best safety record among the road types studied (*40*).

Divided four-lane roads with full access control had the lowest accident rates Undivided and uncontrolled four-lane roads often had the highest rate. On four-lane roads, increased access control decreases accident rates. The study found data on the effects of medians on four-lane roads insufficient for definite conclusions, but suggested, at least for Ohio and Florida, that divided roads have lower accident rates than undivided roads. All these differences were distinct for multi-vehicle accidents, less marked for one-vehicle accidents (*40*).

The study concluded that: (1) access control has the most powerful accident-reducing effect; (2) without access control, four-lane highways have higher accident rates than two-lane facilities; (3) medians tend to decrease the number of accidents, although the effect is not clearcut; (4) curvature, gradient, intersections, and structures increase accident rates, intersections being the dominant element and gradient being the least significant; (5) when the median is narrow, guardrails or barriers are often installed (these barriers tend to reduce the severity of accidents, although the total number of accidents may increase); and (6) intersections have more accidents when the number of vehicles from the minor facility increases (*40*).

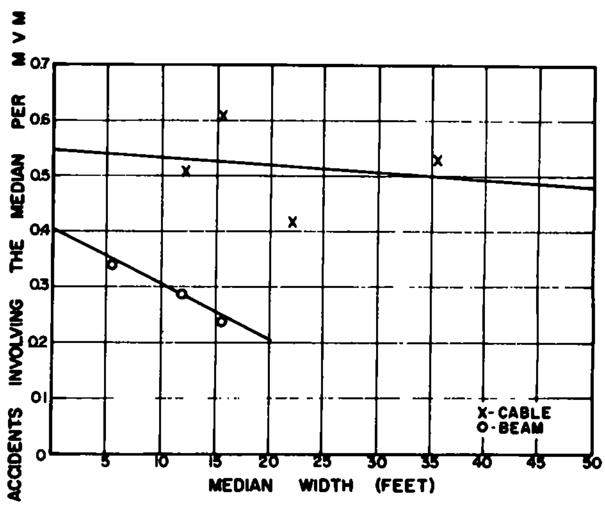


Figure B-30. Relationship between median width and accidents per MVM. Source: Johnson, R. T., "Effectiveness of Median Barriers." Hwy. Res. Record No. 105, (*1966*).

A recent study by Mulinazzi and Michael (*50*) examined the correlation of design characteristics and operational controls with accident rates on urban arterials. They concluded that accident rates are lowest for highways with full access control and highest for no access control. On the other hand, the number of fatalities was highest under partial access control (Fig. B-31).

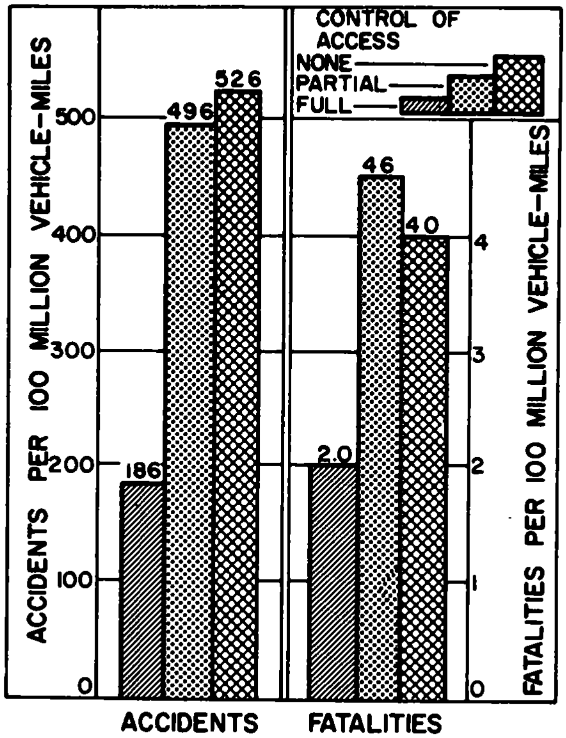


Figure B-31. Effect of control of access on accidents and facilities in urban areas. Source: Mulinazzi and Michael (50).

Using Massachusetts data, Wilbur Smith and Associates (*58*) examined the relationship between accident cost (on the bases of both a vehicle-mile and the annual cost per mile of highway) and control of access. This study found that access control greatly reduced accident costs. The effectiveness of access control increased as average daily traffic increased.

The foregoing analysis points out the complex interrelationship between the user and nonuser sectors and their overlapping nature when accident rates and costs are considered. The kind and degree of access control are primary determinants of roadside development, and, conversely, the overall accident rate for any particular segment of highway. Not only does the kind of access control exert an influence on the speed of the traffic stream and the kind and amount of irregular movements connected with this traffic, but it also determines the kind and number of marginal access points affecting the traffic stream.

It is clear that the accident rates, and the costs associated with those rates, make the evaluation of the type and degree of access control on any major roadway of primary significance. It also is evident that the nonuser, as well as user, groups have a stake in access control from the standpoint of safety.

OTHER NONUSER CONSIDERATIONS

To return to the first section of this study, it might be asked what the validity of the nonuser studies cited might be, because most of them do not, and perhaps cannot, differentiate between vehicular and nonvehicular, or user and nonuser, net access benefits in any precise manner. The viewpoint of Goldstein and Thiel (*68*) may be helpful in this respect. They state that some differences of opinion may exist among economic researchers as to whether the kind of benefits being investigated are nonvehicular benefits or largely transferred vehicular benefits.

> The important point is that real and extensive beneficiary groups other than highway users as such are affected (perhaps sometimes adversely) by highway construction. The magnitude of the benefits for these groups is extensive even though their extent has not been measured precisely However, patterns and quantitative relationships have been indicated. . . .
>
> . a wide array of benefits accrue to various land-use arrangements, residences, businesses, labor, and other segments of the economy, which may arise from the improved accessibility provided by highway facilities Some have construed these to be transferred benefits. In other words, the benefits are derived essentially from the savings in time, etc., through motor-vehicle use, and these savings are capitalized into such items as benefits to land (in terms of property values), business (in terms of reduced transportation costs), and similar items. . . .
>
> If benefits are regarded as the total increase in community well-being provided by a highway improvement, both direct and indirect benefits must be considered . The appraisal of benefits should include the reorganization benefits that accrue to a community from the reorganization of activities following construction of a highway improvement . . .
>
> The very nature of highway improvement, however, serves to reorganize local activity. These improvements have a tendency to cluster developments about them. They aid in channeling economic growth along specific locations and, in addition, they make it possible to reduce production costs (through transportation savings) and thus aid in the more efficient distribution of economic resources. . . .
>
> . . . There is no definite certainty that a particular type of highway improvement will lead inevitably to a particular set of consequences. . . . All results are dependent upon the economic and social activities served by the highway improvement The nature of the impact is determined by both the type of transportation systems developed and the existing complex of cultural interrelationships associated with transportation demand (*68*, pp 7-9).
>
> . . the activities that highways attract to an area may constitute a loss to another area and be of no net benefit to the overall area or region This is . . . a static . way of looking at these effects. In the process of regrouping activity and in the cost savings introduced into the economy by highway improvement and the release of investment forces that might otherwise have not been released at that time, a benefit to the economic system in general occurs and comes to rest in a specific location . . . (*68*, p. 7).

It should be clear from the earlier examination of the relationship between transportation and urban growth patterns that these forces do actually exist, and that highway construction, in large measure, is a prime determinant in channeling investment into a general location and subsequently influencing the over-all direction of both urban and nonurban growth. "If a highway is regarded as a technological innovation, it might 'trigger' investment and consumer expenditures that could not have been fully predicted from the size of the expenditure for the highway investment alone (*68*)."

Certain businesses are successful only when highway-oriented. They exist, not only between urban nucleations, but are scattered within urban areas of all types at intersections of arterials (*45*). This type of business results in what is sometimes known as "ribbon development," growth along the margin of the highway. Most highway administrators and land-use planners tend to deplore the practice of strip commercial development along major roadways. Garrison (*30*), Creighton (*23*), Buffington (*17*) and others, however, believe that such development serves a necessary function by providing locations for highway-oriented businesses which cannot be accommodated elsewhere, at least partly because these depend on traffic exposure for their existence (*45*).

It is possible, however, to limit the amount of such land use and its location, if the design of the roadway is such that the various forms of medial and marginal access control are applied with logic and consistency. Earlier sections of the report point out some economic consequences of marginal control and its corresponding influence on land value and land use to properties abutting the roadway. The not-so-obvious consequences of medial access control also are discussed. The application of medial control is not normally associated with the nonuser sector, but rather with its effect on the highway user. It is clear, however, that both the design of a median and the time it is constructed as part of the roadway have powerful influence on the nonuser sector.

Marks and Spitz (*45*) pointed out that many of the problems of existing surface highways can be traced directly to the lack of access control.

Prior to extensive application of the freeway concept, most arterial highways were developed with little control of direct land access. The high traffic volumes . . . along such routes created a demand for commercial development, which resulted in a proliferation of commercial uses along the facility. The most profitable marketing of adjoining properties was achieved by subdiving the highway frontage into the largest number of frontage units, which were then sold to individual owners. When the need for parking and servicing became obvious, individual property owners sought individual driveways, resulting in highways with an endless series of access points. Each of these represents an intersection with the highway, and their proximity is a prime cause of the chaotic situation existing today in some areas

The highway administration is only too conscious of the deterioration and functional obsolescence of an entire generation of new arterial facilities which were built only a few decades ago. The huge investment that was intended to develop much needed highway capacity was largely dissipated through the premature obsolescence of these facilities as abutting developments grew along the entire length Most of these older main roads are structurally adequate, but operationally deficient as arterial routes. The cost of improving these facilities to regenerate their traffic utility is often so great that it is generally less expensive to build a new facility than to salvage the old one, and a completely new facility is built, paralleling the old one but in a different location.

In many instances, highway planners condemn the land-use practices which permitted the problem to develop. Obviously, if commercial development had not been permitted to expand along the highway, this obsolescence would not have taken place (*45*).

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APPENDIX C

MEDIAL AND MARGINAL ROADWAY ELEMENTS

This appendix is an extraction of what is considered by the researchers to be some of the better practices followed by various highway departments. The primary purpose of this appendix is to present suggestions as to design of specific roadway elements relating to medial and marginal access control. It is, therefore, presented as a separate section even though it is also a review of current practice.

In developing guidelines for access control, the basic elements of the roadway were divided into two general categories—medial elements and marginal elements. Marginal elements include frontage roads, outer separation, and turning roadways. Medial elements include medians, crossovers, cross section, and median turn lanes. Common to both groups are such features as curb design and shoulders.

It should be pointed out that although each element is individually analyzed here, all are closely related. In the design of a facility, it is undesirable to choose only certain of these elements and adhere to the recommendations for them, while ignoring the others. The result of such a practice will be a design lacking in the necessary over-all physical qualities to provide for safe, economical, expedient, and convenient movement of traffic.

In the development of the warrants and design, it was necessary first to identify the function of each element. For elements having multiple functions (as is frequently the case), designs were provided for each function when feasible; in many cases it was, of course, necessary to make trade-offs between competing considerations.

Warrants are frequently multiple in nature, with modifications in design required according to the objective of each warrant. Designs other than those included herein have been used with varying degrees of success, usually in isolated conditions; however, as a general rule, the practices outlined herein are recommended.

MEDIAN ELEMENTS

Function

Median strips provide protection for and control of left-turning and crossing traffic; prevent left or U-turns, except at designated locations; separate opposing streams of traffic, so as to favorably influence vehicle behavior; and increase driver comfort and convenience.

Medians are recommended as a medial access control device under the following conditions:

1. On all primary arterials.
2. On secondary arterial roadways of two or more through lanes in each direction, having average speeds in excess of 35 mph and a volume over 20,000 vpd, in rural or urban areas.
3. Where there are a large number of access points along an arterial, creating a need for positive control of the left turns in and out of the access points.
4. Where other conditions exist which may be improved entirely, or in part, by the installation of a median. Additional considerations in this category may include the need for pedestrian refuge areas, the reduction of head-on collisions, or the location of structural appurtenances in the roadway.

Design

For roadways on new location it is desirable to provide a median of sufficient width to insure that a vehicle crossing the through lanes will be completely shadowed by the median, thereby enabling it to cross one roadway at a time.

The actual design of the median will depend in part on the function to be served, and in part on the type of roadway in which it will be located. On freeway-type facilities, where vehicles do not normally cross the through lanes at grade, the primary consideration in median design is the separation of the opposing traffic streams. On arterial roadways the considerations are multiple and the design is more variable. Table C-1 gives the recommended median width for various functions and roadway types.

Medians may be grouped into several cross section types, depending on width, treatment of the median area, and drainage arrangement. The medians discussed in the following are believed to be appropriate for all normal applications. Typical cross sections are shown in Figure C-1.

As a general rule, those median types which are curbed are considered applicable to urban conditions, and the wider, uncurbed medians are applicable to rural conditions.

TABLE C-1

RECOMMENDED MEDIAN WIDTH CRITERIA

FUNCTION	FACILITY	URBAN (FT) MINIMUM	URBAN (FT) DESIRED	RURAL (FT) MINIMUM	RURAL (FT) DESIRED
Separation of opposing traffic streams	Freeway	20	40	40	60
	Primary	4	10	20	20
	Secondary	4	10	14	14
Provide pedestrian refuge and room for signs and appurtenances	Freeway	20	40	40	40
	Primary	6	14	14	14
	Secondary	6	14	14	14
Provide storage of left-exiting vehicles	Freeway	[a]	[a]	[a]	[a]
	Primary	16	20	20	20
	Secondary	14	20	14	20
Provide protection for vehicles crossing through lanes	Freeway	[a]	[a]	[a]	[a]
	Primary	25	30	30	30
	Secondary	25	30	30	30
Provide for U-turns, inside lane to outside lane (four-lane facilities)	Freeway	[a]	[a]	[a]	[a]
	Primary	45	45	45	45
	Secondary	20	45	20	45
Provide for U-turns, inside lane to outside lane (six-lane facilities)	Freeway	[a]	[a]	[a]	[a]
	Primary	33	33	40	40
	Secondary	6	33	20	33
Provide for U-turns, inside lane to inside lane (four-lane facilities)	Freeway	[a]	[a]	[a]	[a]
	Primary	56	60	60	60
	Secondary	54	60	54	60

[a] Not applicable.

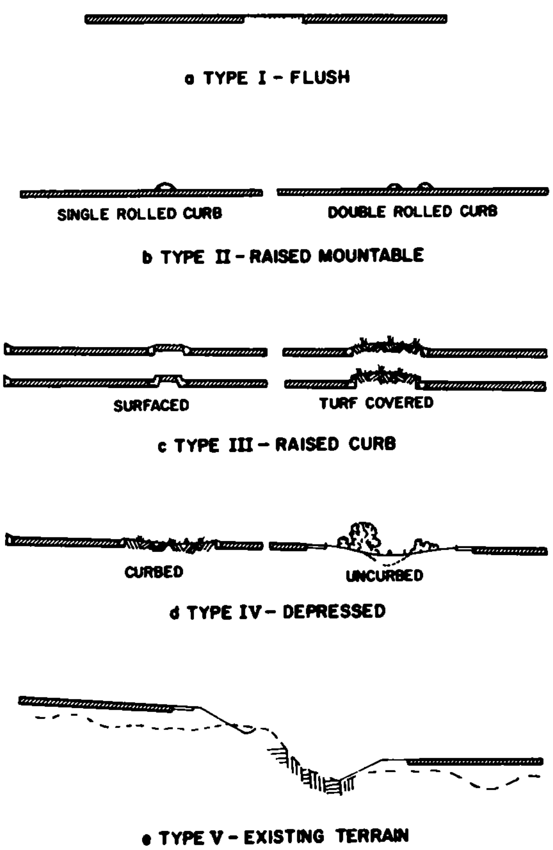


Figure C-1 Typical median design types.

In suburban areas, either type may be used, depending on the local conditions, available right-of-way, and design policies.

Type I Medians

Type I medians are flush with the roadway and are of variable width, but seldom exceed 25 ft. Type I medians provide separation of opposing traffic streams and provide an area for the location of structural appurtenances while permitting left turns to adjacent properties. This design may be used where crossings of the median are prohibited by the installation of a median barrier. This type of median may also serve to provide an area for left-turn lanes, or continuous left turns in both directions when the width is 12 or more ft wide (preferably 14 ft).

Flush medians should be delineated from the through lanes with a single yellow line located along the edge of the median and adjacent to the through lanes on each side. This line should be a minimum of 4 in. wide and desirably not less than 6 in. wide. Painted diagonal white lines may be used to add to the visibility. A preferable practice is to construct the median of materials which contrast in both color and texture with the through lanes. This would call for an asphalt median with portland cement concrete traffic lanes and a light-colored aggregate rolled into the surface of the median, with asphaltic concrete traffic lanes. Except where the median is to be used as a two-way left-turn lane (discussed later here), or if a physical barrier is situated down the middle of the median, the flush median should not be used, as it presents no deterrent to left-turning or crossing vehicles.

Type II Medians

Type II medians are variable in width, although they seldom exceed 25 ft, and have a rolled curb section not more than 4 in. in height. In most cases the curb section is provided along both edges of the median, if the median width exceeds 3 ft. On narrower widths a blister type, raised design may be used.

As a substitute for curbing, raised pavement markers (frequently reflective) are being used with some success. These markers are usually not more than 2 in. high and are installed with an epoxy adhesive on top of the pavement.

Although this design provides for improved delineation over the flush median, it still does not present an effective deterrent to left-turning and crossing vehicles, as it produces only a slight and uncomfortable bump. It is not considered suitable for continuous two-way left-turn operation. For these reasons, it is recommended that this median design not be used on any section of roadway where there is potential roadside development.

Type III Medians

Type III medians consist of a raised curb section, generally more than 4 in. in height. Widths commonly vary from 4 ft to approximately 30 ft. The area between curbs is generally paved for the narrower widths and turf-covered for wider widths.

Type III medians provide pedestrian refuge and space for the installation of structural appurtenances. Widths of more than 16 ft provide room for storage of left-turning vehicles from the through lanes to an intersecting facility. Widths of 25 ft or more shadow passenger cars which are crossing the through lanes or making left turns from an intersecting street or highway.

The curb edge of the median should be offset from the through roadway a minimum of 2 ft—desirably 4 ft when this median type is used along a facility where speeds exceed 40 to 45 mph.

With barrier curbs this median design provides a sufficient deterrent to vehicles crossing it and is recommended for urban and suburban locations. It is not recommended in rural areas or where very high operating speeds (over 50 mph) are anticipated.

Type IV Median

Type IV medians are generally 25 to 44 ft in width, are generally depressed with a swale ditch to provide for drainage, and may be curbed or uncurbed. Without a curb edge it is desirable to provide a pavement edge line as an aid in delineating the pavement edge.

Medians of this type may be used in urban, suburban, and rural areas. It is preferable over the Type III median for high-speed urban and suburban arterials.

Type V Medians

Type V medians are uncurbed and more than 44 ft in width. With greater widths they provide for the separate design of each roadway. Medians of this type are primarily found in rural areas. The wide median widths, common with this type of design, provide ample room for shadowing left-turning and crossing vehicles. Particular attention must be given, however, in the design and signing at marginal access points, to prevent vehicles from going the wrong way.

Median Openings

Median openings should not be permitted on roadways having full control of access in either urban or rural conditions. Crossings for emergency use are, of course, the exception; however, in these cases, it is suggested that a removable barrier section be used to prevent normal traffic from using the opening.

On roadways with partial control of access, median openings should generally be limited to the intersections of dedicated public streets. Openings should not be provided for individual businesses. Median openings might be provided at entrances/exits of large traffic generators which have substantial frontage (such as regional shopping centers), provided that the location conforms to spacing criteria for median openings. Median openings at main entrances/exits which are expected to be signalized should conform to intersection spacing criteria.

The length of median openings should be equal to the width of the intersecting roadway, plus 8 ft, in urban areas. In rural areas the opening should be equal to the width of the intersecting roadway, including shoulders. In no case should the median opening be less than 40 ft in width. At the intersection of two divided highways, the exceptionally large intersection area may require added channelization.

Table C-2 gives the length of median openings for various design vehicles and median widths. These values are calculated on the basis of the inner rear wheel placed 2 ft from the edge of the median at the beginning of the left turn, and 2 ft to the right of the centerline of an undivided cross street at the end of the maneuver.

The shape of the median end should approximate the path of the left rear wheel of a left-turning vehicle; therefore, the bullet-nose design is recommended at all median openings (except U-turn openings).

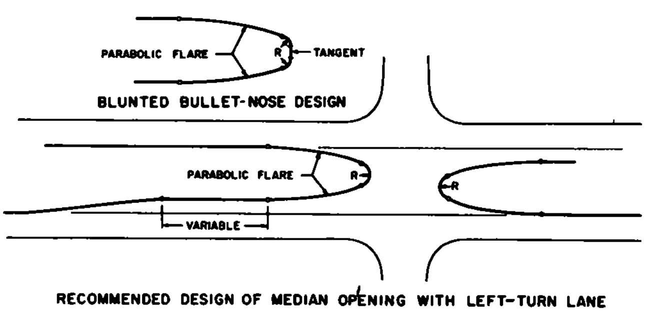


Figure C-2. Recommended design for median openings.

TABLE C-2

LENGTHS OF MEDIAN OPENINGS AT INTERSECTIONS

MEDIAN WIDTH (FT)	MINIMUM LENGTH OF MEDIAN OPENING (FT) PASSENGER CAR	SINGLE-UNIT TRUCK	TRACTOR-TRAILER COMBINATIONS
6	60	76	93
8	53	68	85
10	47	62	77
12	43	58	73
16	[a]	50	64
20	[a]	44	57
24	[a]	[a]	51
28	[a]	[a]	45
32	[a]	[a]	[a]
36	[a]	[a]	[a]
40	[a]	[a]	[a]
50	[a]	[a]	[a]
60	[a]	[a]	[a]
80	[a]	[a]	[a]

[a] Minimum length of opening, 40 ft.

For median widths greater than 14 ft, the minimum opening length of 40 ft becomes a positive control for openings designed from passenger-car criteria. The ends of medians at and above this width take the shape of blunted bullet ends, with the blunt end parallel to the cross-street centerline (Fig. C-2).

Where median openings are to be designed for U-turns, consideration must be given to the location of the vehicle at the start and end of the turn. The most significant feature controlling the practicality of a vehicle making a satisfactory U-turn is the width of the median. Table C-3 shows the minimum design for U-turns for vehicles of different design. The use of the U-turn design should be considered particularly in rural areas where median openings cannot be provided for each driveway, and access cannot be provided along the infrequent crossroads. In urban areas, they might be used to accommodate left turns in the New Orleans manner.

TABLE C-3

MINIMUM MEDIAN WIDTHS FOR U-TURNS ON FOUR-LANE DIVIDED ROADWAY

TYPE OF MANEUVER	MINIMUM WIDTH OF MEDIAN FOR DESIGN VEHICLE (FT) PASSENGER CAR	SINGLE-UNIT TRUCK	WB–50
Turn lane to inner lane	46	78	84
Turn lane to outer lane	34	66	72
Inner lane to inner lane	32	64	70

CURBS

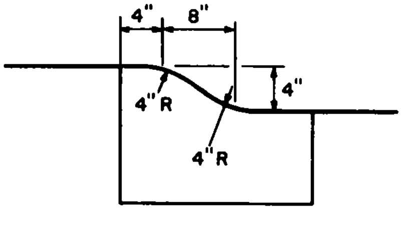
Curbs along the median edge improve the delineation and discourage crossing over the median.

Mountable curbs are so designed that vehicles may readily cross them when required. For median use, mountable curbs should not exceed 4 in. in height, with a slope not steeper than 1:1. This type of curb may be used along medians where the width or type is such as to discourage vehicles from attempting to traverse it.

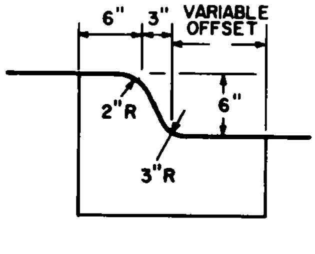
Barrier curbs are usually 6 in. high and have a vertical, or near vertical face. This type of curb is used along median edges where the median is being used to provide for pedestrian refuge or has fixtures within it. A typical design for each type of curb is shown in Figure C-3.

A mountable curb should not be used along a median that is easily traversable (such as a narrow paved median), where left turns are not desired and/or are illegal. If the mountable curb is desired for any reason, an auxiliary feature should be used to prevent vehicles from crossing the median. A lightweight guardrail or cable barrier will serve as a physical barrier to prevent vehicles from crossing, although they do not necessarily have sufficient strength to stop a vehicle which is out of control.

It is recommended, however, that a minimum offset of 2 ft be provided between the lane edge and the face of the curb, and that, along relatively high-speed facilities, this value be increased to 4 ft. Where this offset cannot be provided along high-speed roads, it may be more desirable to eliminate the curb and to provide a flush or uncurbed median. Where short sections of curbs are to be introduced for end treatment of median openings or similar conditions, the curb should be no closer than 4 ft to the through lanes, and 2 ft to the turn lane. When this clearance cannot be provided, it is recommended that the curb not be used.



MOUNTABLE CURB



BARRIER CURB

Figure C-3. Typical curb designs.

Median Turn Lanes

The turning lanes should permit the maneuvering vehicle to leave the traffic stream traveling at or near the speed of the stream and to complete its deceleration in the protected left-turn lane. Turning lanes should also be able to accommodate the maximum number of vehicles that are expected to be stored while waiting to complete their turn.

Median turn lanes should be provided:

1. At all public streets or roads which intersect a multi-lane divided street or highway.
2. At major intersections on multi-lane undivided highways.
3. At major traffic generators where a median opening is provided.
4. At major intersections on two-lane highways where the through traffic lanes are flared apart, to separate opposing traffic streams.
5. At all median openings (including farm residence driveways) on multi-lane divided rural highways.

For turns in which passenger vehicles predominate, the left turn should be a minimum of 12 ft in width, with large turning volumes of commercial vehicles, the width should be 14 ft or more, to insure adequate side clearance between the turning commercial vehicle and the through traffic.

Curb should be provided along the median side of all turn lanes. With uncurbed median sections, the full height of curb should be obtained gradually and should begin at least 100 ft in advance of the taper.

In addition to providing adequate storage for the number of vehicles that will be stopped waiting to turn, the length of the turn lane should permit a vehicle to leave the traffic stream and to adequately reduce its speed only after it has left the through lanes.

Table C-4 gives the required length of a deceleration lane and a taper, to permit a vehicle to leave the through lane at the stream speed, decelerate without braking in the taper section, and then come to a comfortable stop at the end of the full turn lane width, in position to make the turn. The storage requirements should be added to the value in this table for the deceleration distance, to obtain the length of the full width turn lane.

Generally, two types of tapers are in use—the direct taper and the reverse curve taper. Either design may be used, although the direct taper is recommended along high-speed facilities, and the reverse curve along lower-speed roadways.

Where wide medians are used, the turn lane may be located farther into the median and away from traffic moving in the same direction, in order to provide an island between the median turn lane and the through traffic lanes.

The practice of "hooking" the end of the median lane, in order to place the vehicle in a more desirable position to begin the turn, is not recommended with narrower median widths. A rear-end collision on a "hooked" turn lane may result in the front vehicle being driven into the opposing traffic lane.

Two-Way Left-Turn Lanes

The two-way left-turn lane has been used in recent years with some success and is gaining in popularity. It provides storage for left-turning vehicles in opposing directions for a minimum width, while allowing for more flexibility in operation than is permitted with normal medians.

Any of the following considerations in combination are sufficient justification for the installation of a two-way left-turn lane. The more of these considerations that exist, the more desirable is this design. Two-way left-turn lanes generally should be limited to urban facilities, where there are numerous closely spaced driveways along one or both sides of the street, and where there is a low traffic volume using the individual driveways. They have been effectively used on facilities having through traffic speeds up to 45 mph.

Continuous two-way left-turn lanes may be carried through minor intersections having a low cross-street volume; however, at major intersections, a standard left-turn lane should be used (see Fig. C-4).

TABLE C-4

RECOMMENDED DESIGN STANDARDS FOR DECELERATION LANE

RUNNING SPEED (MPH)	LENGTH OF TAPER (FT)	DECELERATION DISTANCE (FT)
70	600	430
65	600	350
60	600	300
55	450	300
50	400	250
45	200	250
40	100	250
<40	100	180

MARGINAL ELEMENTS

Frontage Roads

Function

Frontage roads serve as an aid in maintaining access control along a facility, by providing access to and from adjacent properties and local and collector streets without disrupting the flow along the main, through lanes. As a secondary function, continuous frontage roads may provide additional capacity during peak-hour operation, while maintenance is being carried on along the main roadway, and when accidents occur. When used along freeways with full control of access, frontage roads function primarily in an arterial capacity, whereas along facilities without full control of access, the local service function is more important. In the context of this discussion, the local service function is the primary consideration.

Design

A basic consideration in the design of frontage roads is whether the traffic operation desired will be one- or two-way. This decision is based on the location being considered, whether the frontage roads will be continuous or not, and whether they will be located along one or both sides of the arterial. In areas where frontage roads are located along one side, or where they are discontinuous, operation should normally be two-way; where access points to the arterial are at greater than 1-mile intervals, two-way operation is also suggested.

In addition, consideration must be given to designs that will prevent vehicles from entering the through lanes of the arterial in the wrong direction. This is primarily a problem along two-way frontage roads. The proper application of channelizing techniques normally will minimize this problem.

The frontage road cross section generally should resemble that of a collector passing through the same area and generally will provide for two lanes of traffic. In establishing the design, the edge along the arterial should be considered first, to achieve satisfactory ramp terminal and intersection design. This will provide the basic horizontal and vertical alignment of the frontage road.

Where frontage roads intersect other streets, additional lanes for turning movements may be added. The design would follow that for any intersection.

Curbs should be provided at least along the property edge of the frontage road where development has occurred to any great extent. The arterial edge of the frontage road may be left uncurbed, to aid in drainage runoff and to avoid any problems that would be created by a vehicle going out of control as a result of hitting the curb. Providing curb along both edges of the frontage road will, however, minimize the use of the frontage road shoulders for parking and minimize maintenance requirements from erosion and pavement deterioration.

The curb may be mountable along the arterial edge, whereas along the property edge it is desirable to provide a barrier curb for more positive control over driveways to and from adjacent properties. Where the design of the outer separation is such that vehicles may attempt to enter

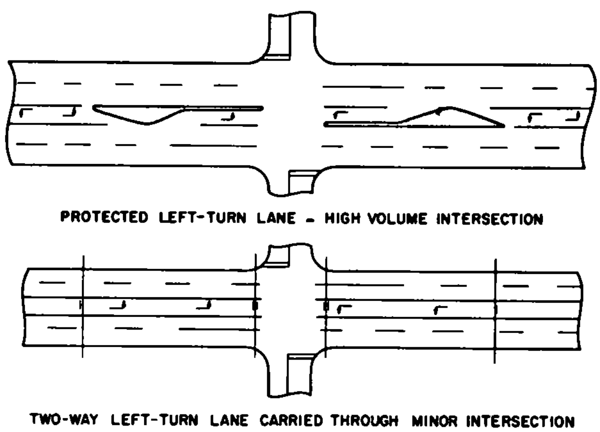


Figure C-4. Intersection treatment with two-way left-turn lanes.

or leave the through lanes across the outer separation, barrier curb might be installed.

Where a frontage road intersects a cross street that also intersects an arterial at grade, the suggested minimum separation between the two intersections is:

CROSS-STREET SPEED (MPH)	ROAD AND ARTERIAL AT INTERSECTION WITH CROSS STREET DISTANCE BETWEEN FRONTAGE (FT)
<30	250
30	270
40	300
50	370
60	440
70	520

Where it is necessary to flare the frontage road away from the arterial in order to obtain this separation, a tangent section of at least 100 ft (and preferably 250 ft) should be provided on the frontage road in advance of the intersection.

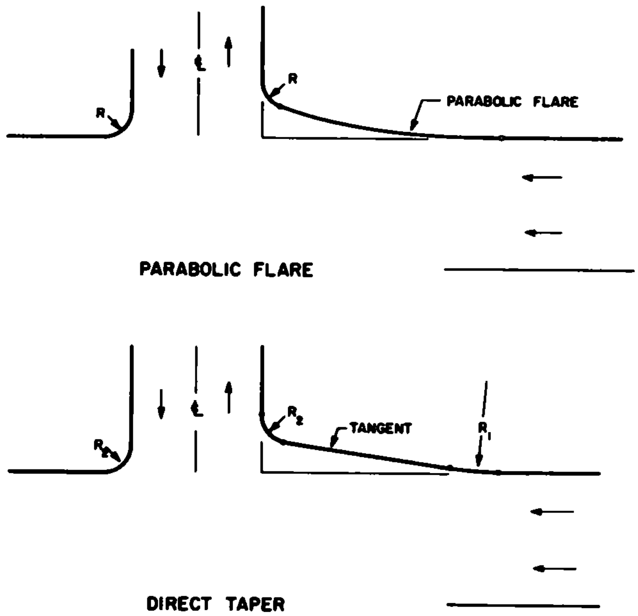


Figure C-5. Tapered right turn at minor intersection.

Right-Turn Lanes

All intersections on primary arterials, both urban and rural, as well as on rural secondary arterials, should be designed with separate (channelized) right-turn lanes. Secondary arterials in urban areas should have right-turn lanes at intersections with other secondary arterials and provision for right turns from the secondary arterial to a collector street. Right turns from an urban secondary to any intersecting local street and right turns from collector streets should be accommodated by a direct taper or parabolic flare (Fig. C-5).

The inside curb radius (or edge of pavement at uncurbed locations) must be sufficient so that a turning vehicle will not encroach on the lane adjacent to the one it is entering. Spiralized or compound curves are recommended, to produce a more natural path for the vehicle. Minimum radii are given in Table C-5.

As the turning radius decreases, the width of the turn lane should be increased; suggested values are given in Table C-6.

Parking Lanes

Because of the detrimental effects of parking on the operation of a major street, it is recommended that on-street parking be prohibited along primary arterials.

Along collector streets and some secondary arterial facilities, the provision of on-street parking may be unavoidable. Parking, however, should be prohibited in the vicinity of driveways and intersections to avoid interfering with their operation. The acceptable proximity will depend on the speed along the through lanes, turning radius of the intersection or driveway, and sight distance upstream from the intersection or driveway. As a general rule, it is recommended that the minimum corner clearances recommended for driveways (see Appendix F, "Direct Access Driveways") be applied also to parking stalls at corners and that "no-parking" stalls be located within 50 ft of any driveway.

"Parallel parking only" should be permitted on collector and secondary arterials.

The pairing of parking stalls, as shown in Figure C-6, is

TABLE C-5
MINIMUM RADII FOR RIGHT-TURN LANES

TURNING SPEED (MPH)	MINIMUM CURVE RADIUS (FT)
15	60
20	100
25	125
30	200
40	400
50	650

TABLE C-6
RECOMMENDED WIDTH FOR TURN LANES

RADIUS OF OUTER PAVEMENT EDGE (FT)	LANE WIDTH (FT)
75	20
100	17
130	16
150	15
180	15
200+	14

recommended, as it will allow parking of a vehicle quickly and with relative ease. The vehicle may "nose" into the parking space with this design, instead of stopping in the through lanes and backing into position adjacent to the curb.

Stall widths on all collector or arterial streets should be at least 12 ft. This will provide satisfactory clearance between parked vehicles and the through lanes, so that the circulation of pedestrains and the opening of car doors will not be excessively hazardous or disruptive to the through traffic movements.

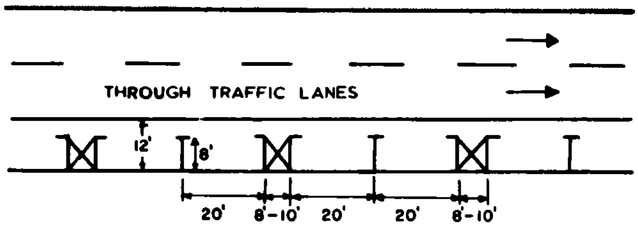


Figure C-6. Recommended parking layout.

APPENDIX D

INTERSECTION SPACING

The primary function of an arterial street or highway is to move a large volume of through traffic as quickly, efficiently, and safely as possible. For major roadways with at-grade intersections this can best be done by providing progressive signal operation. Signal spacing and timing are two of the limiting factors in providing such operation.

Standard procedure in signal timing is to attempt to establish offsets, cycle lengths, and phasings for given conditions, as determined by existing intersection spacings. More efficient operation, however, can be obtained if the intersections are uniformly spaced within a certain optimum range. By providing for proper intersection spacing during the development of an area or, in some cases, modifying existing intersection or signal spacings, a high degree of efficiency in operation of the major roadway and flexibility of adaptation to daily volume fluctuations can be realized.

Subject to the constraints of providing reasonable access to the arterial, and avoiding excessive circuity of travel for crossing traffic, the following analysis attempts to define the "optimum" range of intersection spacings. In evaluating the effects of signal spacing on the operating costs of through traffic along an arterial, comparisons are made for varying cycle lengths, volumes, speeds, and type of signal operation. Unit values for vehicle operating costs and time costs used as the basis for this analysis appear in Appendix A.

In addition to providing for maximum progression under a single set of given conditions, it is desirable that intersection spacing on a major roadway provide flexibility in the operation of the signal system, in order to allow adaptation to changing conditions and increase in traffic volume. Certain of these ramifications are also discussed in this appendix.

PHYSICAL CONSIDERATIONS FOR PROGRESSIVE SIGNALIZATION

Driver Behavior and Acceptance

The maximum spacing between signals is a function of the stability of platoons and the ability of drivers to maintain appropriate speeds. With short spacings between signals, there are frequent opportunities for speed adjustment and for confirmation that the speed at which the vehicle is traveling is or is not appropriate for progression through a given signal system. Thus, for short signal spacings, drivers can be expected to maintain relatively uniform speeds with little, if any, platoon decay.

A California study (*1*) observed that 85 percent of the vehicles remained in a platoon ½ mile downstream of an isolated intersection on a four-lane rural expressway. At a distance of 1 mile downstream of the signal, 77 percent still remained in a platoon. Another study in Michigan (*2*) showed that progression could be achieved on a partially controlled, divided facility at spacings near 4,500 ft. If platoon stability is a problem, special variable-speed signs that display the recommended speed might make drivers more aware of the necessity of traveling at the speed of progression. With appropriate control devices, therefore, traffic operational considerations appear to impose no upper limit on practical intersection spacing.

Type of Progressive System

Single alternate and simultaneous signal systems will provide high use of green time for uniformly spaced intersections (i.e., the band width will be equal to the duration of the shortest green phase). If signal (intersection) spacing is appropriately selected, desired speeds of progression may be obtained.

Considering intersection as a variable, the signal spacing as a function of speed and cycle length is:

For the simultaneous system: $D = 1.47CS$
For the single alternate system: $D = 0.735CS$

in which

D = spacing of signals (ft);
C = cycle length (sec); and
S = speed (mph).

All other factors being equal, a simultaneous system will yield twice the spacing of the single alternate system. By examining the relationship between speed, cycle length, and spacing (Fig. D-1), it is evident that the simultaneous signal system will yield very large intersection spacings for reasonable ranges in speed and cycle length. Table D-1 gives the intersection spacing for different combinations of cycle length and speed of progression; the numbers in parentheses are for a simultaneous system.

Cycle Length and Speed of Progression

Because of the "lost" capacity during clearance intervals, it is seldom feasible to operate on cycle lengths of less than 50 sec; however, to minimize delay at low volumes, cycle lengths should be kept as short as feasible. On the other hand, a cycle length of 90 sec is considered, in this report, to be the maximum desirable cycle length at volumes approaching capacity.

Within the constraints of the desirable range in cycle length, resulting ranges in speed of progression are given in Table D-2 for intersection spacings ranging from 1,000 to 2,600 ft. The speed ranges in Table D-2 are limited by a minimum speed of 25 mph and a maximum speed of 55 mph. These speeds were selected because signalized at-grade arterials are not anticipated to operate above 55 mph for free-flow conditions. During peak periods, when traffic volumes are higher, speeds are significantly lower and need to be accommodated, while progression is still maintained. Speeds below approximately 25 mph, however, are not considered desirable, because the possible flow rate decreases as speed decreases.

The same ranges in speed of operation, within the desirable range in cycle length, can be provided at half the intersection spacing given in Table D-2, using a double alternate signal system. Such a system, however, will result in a band width that is half of that for a single alternate system. Consequently, a double alternate signal system would not provide sufficient band width to efficiently use available street capacity. With larger intersection spacing, its only application might be at periods of very low volume.

COST OF ARTERIAL TRAVEL

Assumed Operation

To assist an evaluation of "optimum" intersection spacing, road user costs per lane-mile of arterial roadway were calculated from the estimated number of stops and vehicle delay for various lane volumes, cycle lengths, speeds, and intersection spacings, based on the following assumptions:

1. Red time is half the cycle length for all signals; this assumption is considered realistic for two-phase signal operation. Red time less than half the cycle length might be possible for arterials with only minor cross traffic. In a grid system, however, arterial streets of similar class will intersect at regular intervals, and such crossing arterials will require a proportional green time.

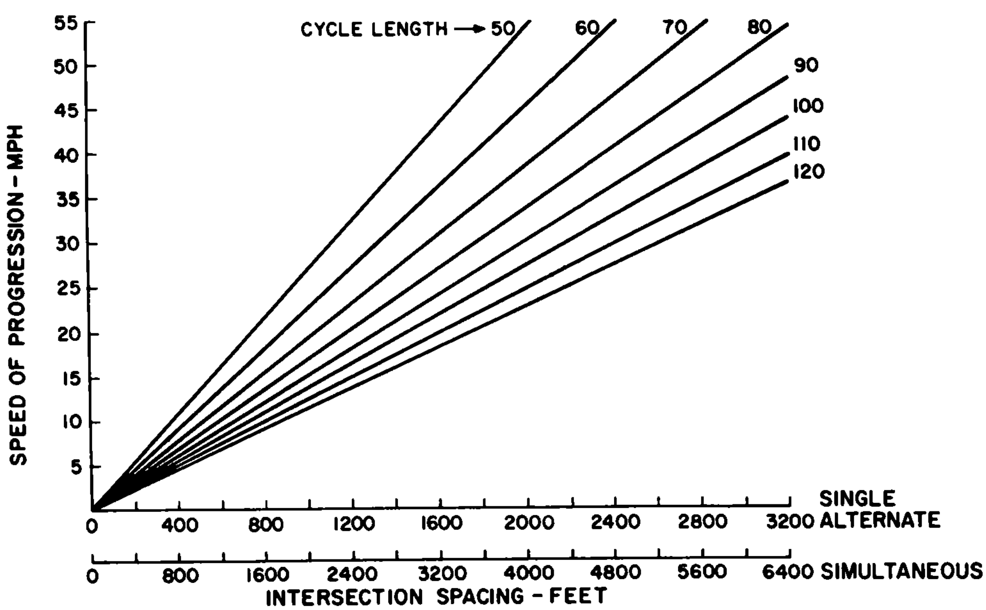


Figure D-1. Speed of progression versus intersection spacing for different cycle lengths.

TABLE D-1

INTERSECTION SPACING CORRESPONDING TO GIVEN SPEEDS AND CYCLE LENGTHS FOR THE SINGLE ALTERNATE SIGNAL SYSTEM *

SPEED (mph)	INTERSECTION SPACING (FT) FOR CYCLE LENGTH OF 40 sec	50 sec	60 sec	70 sec	80 sec	90 sec	100 sec	110 sec	120 sec
25	735 (1470)	919 (1838)	1103 (2205)	1286 (2573)	1470 (2940)	1654 (3308)	1838 (3675)	2021 (4043)	2180 (4360)
30	882 (1764)	1103 (2205)	1323 (2646)	1544 (3087)	1764 (3528)	1985 (3969)	2205 (4410)	2426 (4851)	2616 (5232)
35	1029 (2058)	1286 (2573)	1544 (3087)	1801 (3602)	2058 (4116)	2315 (4631)	2573 (5145)	2830 (5660)	3052 (6104)
40	1176 (2352)	1470 (2940)	1764 (3528)	2058 (4116)	2352 (4704)	2646 (5292)	2940 (5880)	3234 (6468)	3488 (6976)
45	1323 (2646)	1654 (3308)	1985 (3969)	2315 (4631)	2646 (5292)	2977 (5954)	3308 (6615)	3638 (7277)	3924 (7848)
50	1470 (2940)	1838 (3675)	2205 (4410)	2573 (5145)	2940 (5880)	3308 (6615)	3775 (7550)	4153 (8305)	4360 (8720)
55	1617 (3234)	2021 (4043)	2426 (4851)	2830 (5660)	3234 (6468)	3638 (7277)	4153 (8305)	4447 (8894)	4796 (9592)

*Numbers in parentheses are for a simultaneous system.

2. All signals are two-phase operation and costs of delay to left-turning vehicles are not included.

3. At speeds greater than speed of progression, all vehicles in a platoon stop when the first vehicle in the platoon arrives at an intersection on the red indication.

4. Vehicles waiting for the green light at an intersection, as a platoon approaches, will not interfere with the progression of a platoon. Vehicles that enter an arterial from cross streets would be stopped by a red light at the first intersection.

5. All vehicles in a platoon will maintain a uniform speed, and platoon decay will be negligible.

These conditions are considered to be sufficiently realistic for the evaluation of relative user costs in view of the precision of unit operating and time costs. Even though three-phase operation should be required at some intersections, delay and cost per vehicle would not be materially affected so long as progressive movement is provided. The reduced green time for through movement, however, would result in a smaller band width and, hence, a reduced capacity.

In developing cost estimates, two different types of signal operation were considered: (1) random offset between consecutive signals; and (2) a progressive signal system. The following additional specific considerations and assumptions apply for each of these two types of signal operation;

Random Offset Between Consecutive Signals

Platoons will arrive at each signal randomly. The duration of delay and the percentage of vehicles encountering this delay are given by:

$$\text{Average delay per stopped vehicle } (3) = \tfrac{1}{2}(R + 4.75)$$

$$\text{Percent of vehicles stopped } (3) = \frac{100(R + 4.75)}{C(1 - 2.1q)}$$

in which

R = red time (sec);
C = cycle length (sec); and
q = traffic flow rate (vps).

Progressive Signal Operation

The following types of signal operation were considered in the cost evaluation for the flexible progressive signal system:

1. Simultaneous signal operation.
2. Single alternate signal operation.
3. Double alternate signal operation.

Based on the foregoing representative operating conditions, a computer program was written to facilitate the calculation of the number of stops, duration of delays, etc.,

TABLE D-2

RANGE IN CYCLE LENGTH AND SPEED FOR SELECTED INTERSECTION SPACING (SINGLE ALTERNATE SYSTEM)

INTERSECTION SPACING (FT)	RANGE IN CYCLE LENGTH (TO NEAREST SEC) FROM	TO	RANGE IN SPEED OF PROGRESSION (MPH) HIGH	LOW
1,000	50	54	27	25
1,200	50	65	33	25
1,400	50	76	38	25
1,600	50	87	44	25
1,800	50	90	49	27
2,000	50	90	54	30
2,200	55	90	55	33
2,400	59	90	55	36
2,600	65	90	55	39

affecting the vehicle operating and time costs. The unit operating costs and value of time given in Appendix A were input to the computer for the calculation of the estimated road user costs, under different combinations of intersection spacing and signal operation.

Estimation of User Costs

Hourly Costs

Based on the estimated number of stops and delay for various lane volumes, cycle lengths, speeds, and intersection spacings, user cost per hour per lane-mile of arterial roadway were calculated. These user costs include time costs and vehicle operating costs associated with traveling at a uniform speed, with stopping from and returning to that uniform speed, and with idling. The costs used in these calculations are given in Appendix A in Tables A-2, A-4, A-5, A-6, and A-7. Costs were calculated using two different percentages of passenger cars (86 and 95 percent); these calculations indicated that user costs are not highly sensitive to this range of variation in the percentage of passenger cars. Because 86 percent passenger cars has been reported as a representative national average for urban arterials (*4*), this figure was used in the further development of cost values.

Random Offset System.—Operating cost and total user costs for the random offset signal system are shown in Figure D-2. The upper curves show only the hourly operating cost per lane-mile for selected speeds and cycle lengths; the lower curves indicate the total user costs, including costs of vehicle operation, as well as passenger time costs.

Where intersection spacings are short, vehicles will not be able to attain the assumed speed between consecutive intersections, if vehicles are stopped at both of these intersections. For this reason, cost curves for random signal operation are not shown for intersection spacings that do not provide sufficient distance for passenger cars to accelerate to speed of operation and, subsequently, decelerate to a stop.

Operating and total user costs (including a value for time) decrease significantly as intersection spacing increases. The decrease in operating cost is due largely to the smaller number of stops per mile at the longer spacings. Total costs also reflect the reduction in delay resulting from fewer stops.

The figures also indicate that only minor reduction in operating and total user costs is to be expected by increasing intersection spacings above 1,600 ft with a random offset signal operation.

Progressive System.—Hourly costs per lane per mile (Fig. D-3) with progressive signal operation are composite curves representing the most favorable signal operation for different combinations of intersection spacing and traffic volume at various cycle lengths. The signal operation which would produce the lowest user cost was selected as most favorable for any given intersection spacing. The upper curves in Figure D-3 indicate the estimated operating costs only; the lower curves show the total user cost—including the value of time. As with Figure D-2, this shows selected curves from the family of user cost curves for different cycle lengths and various volume levels.

As is apparent in Figure D-3, discontinuities exist in the cost curves with progressive signal operation. These discontinuities result when an increase in signal spacing facilitates the use of a timing plan which can provide for the same traffic flow rate at a substantially lower cost. For example: for a speed of 25 mph, a simultaneous system (with cycle lengths between 50 and 90 sec) provides progression at a substantially lower cost than any timing plan at signal spacings more than about 900 ft. At shorter spacings, however, this type of operation is extremely costly, in terms of highway user costs, for acceptable cycle lengths (i.e., over 50 sec).

It should also be noted that, at the shorter signal spacings (less than about 900 ft for a speed of progression of 25 mph, and 1,000 ft at 45 mph), the estimated operating and total user costs fluctuate widely at different spacings. This indicates that, although the traffic volume might be accommodated at certain shorter intersection spacings, the user costs are substantially greater than if progression is provided at longer spacings.

Daily Costs

Because of hourly traffic fluctuations, the same spacing would not yield the lowest user costs on a given facility for each hour throughout the day. It is, of course, quite impractical (indeed, impossible) to change the spacing between operating signals in such a time frame. The alternative is to identify the range in signal spacings that will provide progress movement at the lowest 24-hr cost, considering the pattern in daily traffic volumes on arterial streets.

To develop daily costs from the hourly costs, variations in volume as percentages of the 24-hr volume were used. Information on the hourly variation in traffic volumes was taken from transportation study reports for various urban areas and other secondary sources. The hourly volumes, as a percentage of the 24-hr traffic for each of the 24 hourly periods, were arrayed from high to low (Fig. D-4). Similar plots for selected individual routes are shown in Figure D-5.

Although there is variation between the individual data sets, the same pattern is apparent in all curves. The idealized curve shown in Figure D-6 is, therefore, considered to be generally applicable for the purposes of estimating daily (24-hr) user costs.

The 24-hr user costs were estimated by accumulating the hourly costs for each of the 24 hourly periods. The 24-hr volumes were multiplied by the percentages indicated by the curve in Figure D-6 to obtain the hourly volumes. The 24-hr costs were then obtained by summing the user costs for each hour of operation, at the volume for that hour, as given by the family of hourly cost curves (selected curves are shown in Fig. D-2 and D-3). The resulting estimated total user costs (operating costs plus time cost) for a signal system with random offset are shown by the curves in Figure D-7. The estimated total user costs, with a progressive signal system for various daily traffic volumes and different speeds of operation, are shown in Figure D-8.

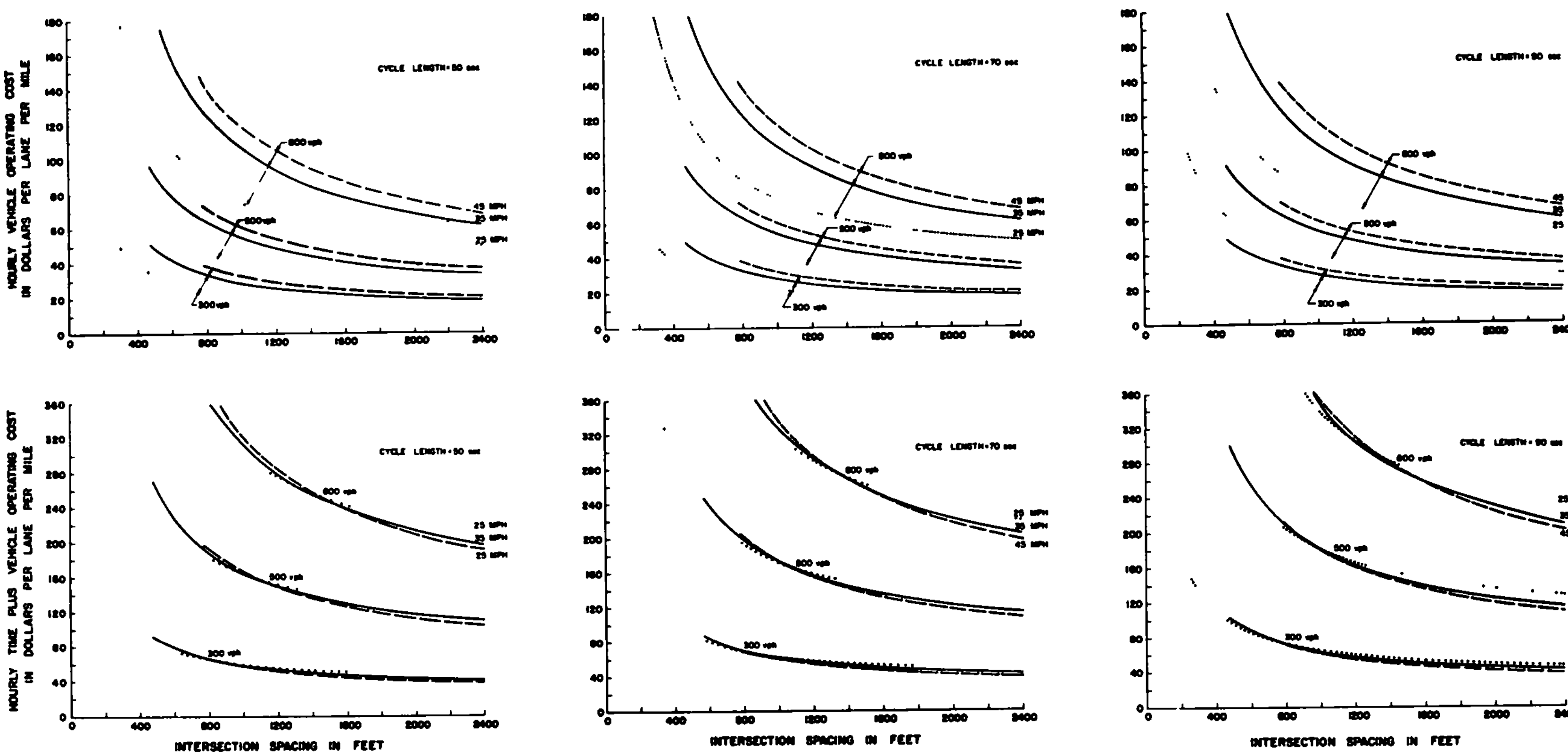


Figure D-2. Hourly costs per lane-mile for various intersection spacings with random offset signal operation.

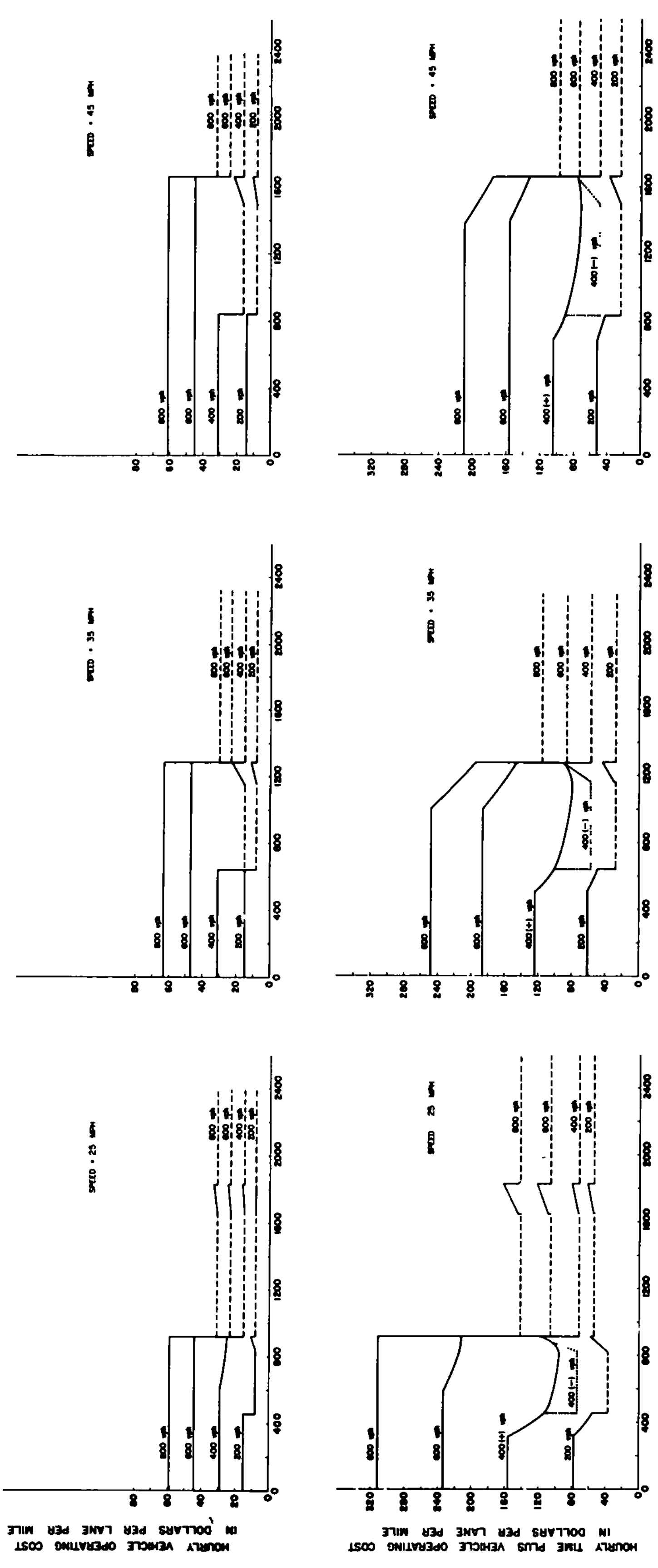


Figure D-3. Hourly costs per lane-mile for various intersection spacings with flexible progressive signal operation.

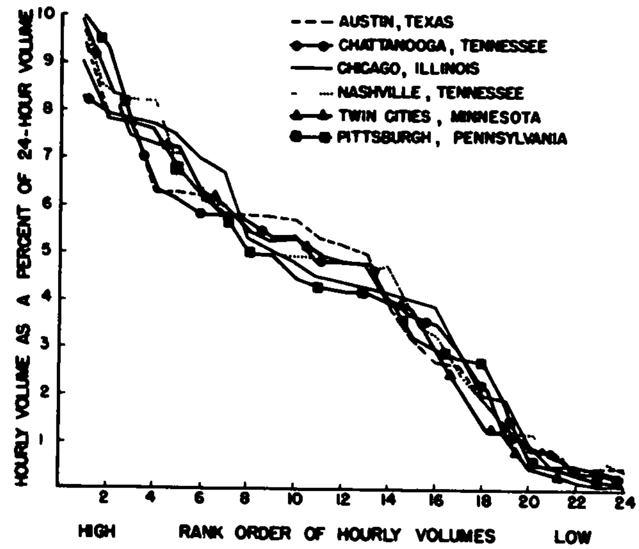


Figure D-4. Observed hourly volumes as a percentage of 24-hr volume. Source: Urban Transportation Study Reports.

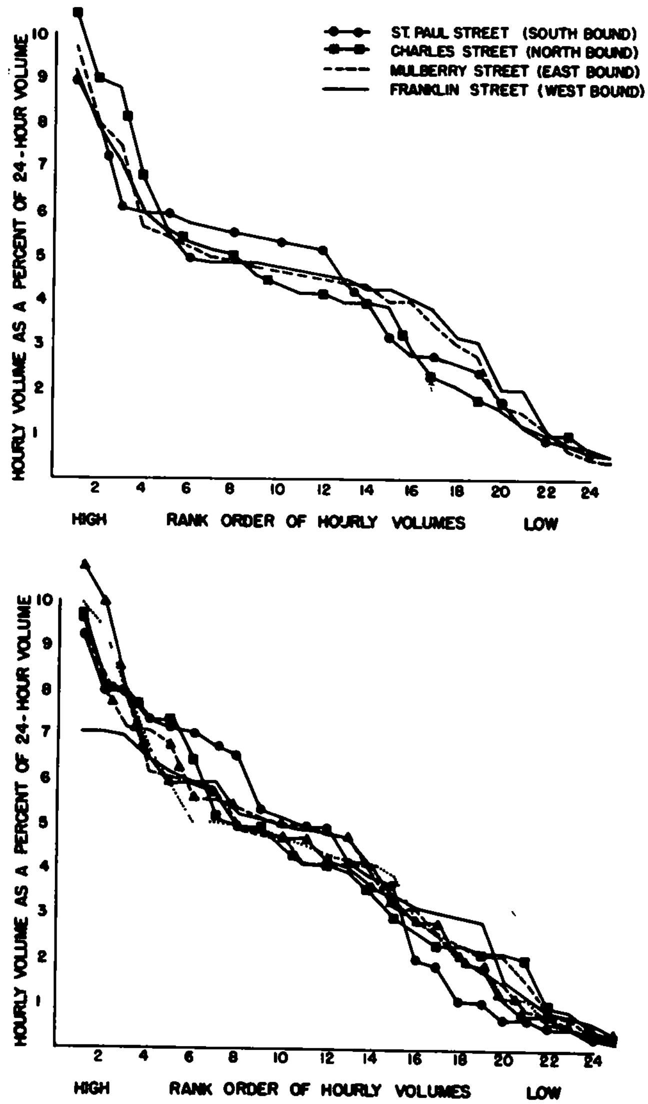


Figure D-5. Observed hourly volumes as a percentage of 24-hr volume on selected streets. Source: Baltimore Metropolitan Annex Transportation Study; *and Wagner, F. A., Jr., and May, A. D., Jr., "Volume and Speed Characteristics at Seven Study Locations."* HRB Bull. 281 *(1961).*

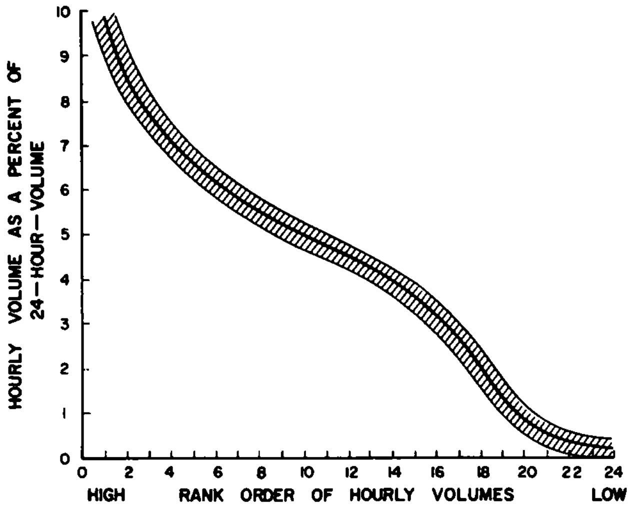


Figure D-6. Idealized curve for hourly volumes as a percentage of 24-hr volume.

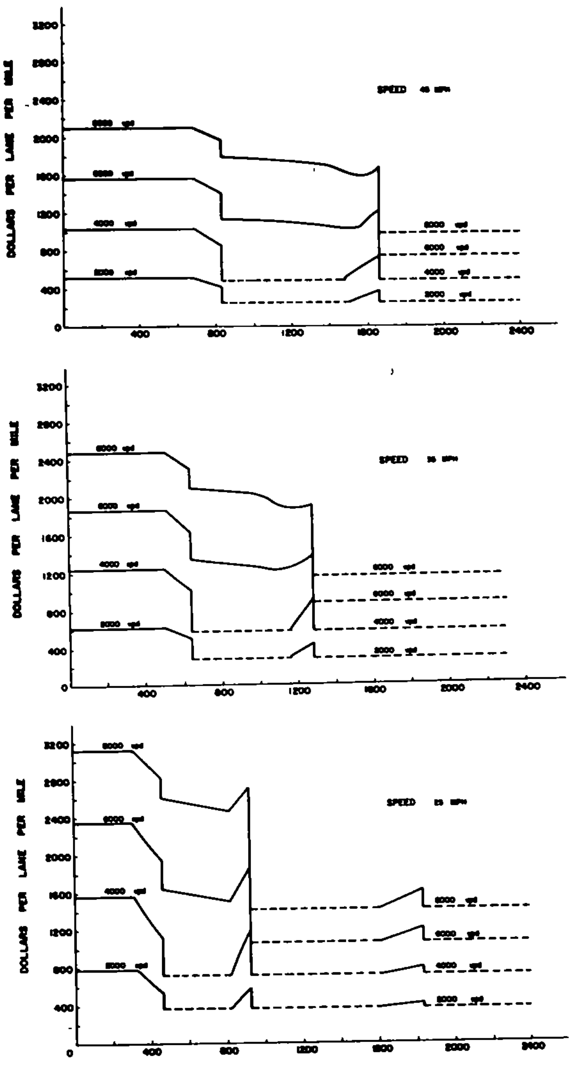


Figure D-8. Total daily costs with flexible progressive signal operation.

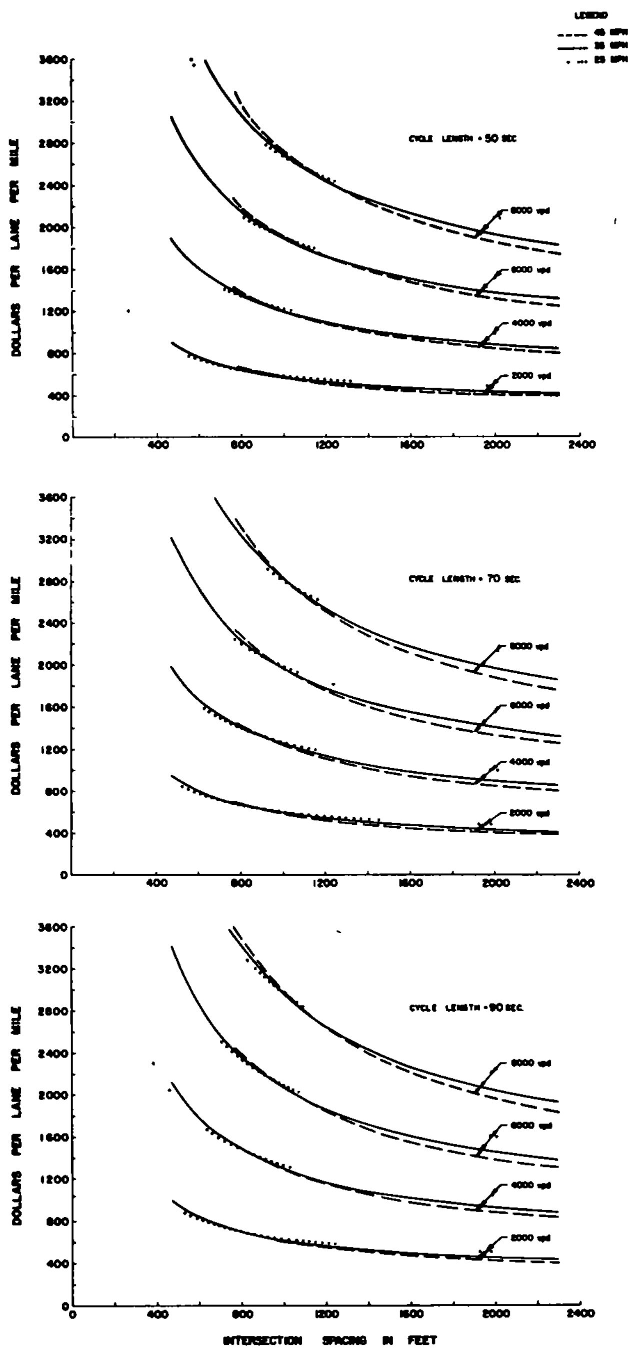


Figure D-7. Total daily costs with random offset signal operation.

From comparison of the two figures, it is readily apparent that the higher speeds give lower estimated total user (operating plus time) costs for short intersection spacings with a flexible progressive signal system. Time costs represent the major portion of this cost difference.

As expected, comparison of Figures D-7 and D-8, at the same volume and speed, also shows that the total user costs with a progressive signal system are significantly less than with random offset signal operation. The magnitude of the difference increases with shorter intersection spacing, higher volumes, and higher speeds.

Composite Daily Costs

To facilitate evaluation, costs curves for different speeds of operation were combined on the same figure for each of three volume levels, as shown in Figure D-9. The shaded area on each set of curves represents the estimated cost envelope within which total user cost may be expected to vary. The more nearly horizontal and the narrower (measured vertically) this envelope, the more efficient and desirable will be the intersection spacing for a given traffic volume. That is, intersection spacings at which the cost envelope is narrow can accommodate a range in speeds with little difference in user cost.

The intersection spacing at which the cost envelope becomes or approaches horizontal can provide progression as efficiently (at the same user cost) as longer spacings. As may be seen in Figure D-9, the envelope approaches the horizontal at longer intersection spacing at higher traffic volume.

This can be illustrated by the following comparison for

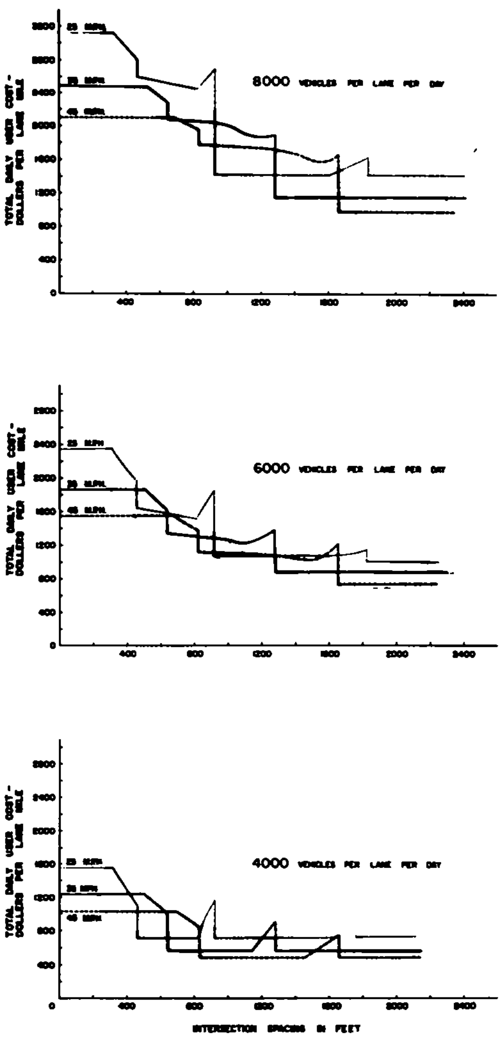


Figure D-9. Composite total daily user costs.

4,000 and 8,000 vpd per lane at two different intersection spacings.

Inter-section spacing (ft)	Volume per lane	Lower limit of total daily user cost ($ per lane mile)	Increase in user cost	
			$	%
600	4,000	600	1,400	233
	8,000	2,000		
1,800	4,000	500		
	8,000	1,000	500	100

This indicates that the longer intersection spacings (much longer than commonly used at present) can accommodate greater growth in traffic at a smaller road user cost. This suggests that, where forecast future traffic volumes are very uncertain, the intersection spacing on new construction ought to be the maximum that is practical.

The marginal savings of increased spacing approach zero as the limits of the cost envelope approach the horizontal. This occurs at about 1,000 ft and 1,500 ft for the lower and upper limits, respectively, of the cost envelope, at 4,000 vpd per lane. At 6,000 vehicles per lane per day, this occurs at about 1,800 ft for both the upper and lower limits, and near 2,400 ft at 8,000 vehicles per lane per day.

Based on considerations relative to total road user costs, it appears that intersections should be spaced approximately 1,000 ft, or farther, apart on secondary arterials, with speeds of operation between 25 and 45 mph. (It may be noted that 1,000 ft is the minimum spacing for efficient progressive two-way movement at reasonable speed.) Primary arterials operating between 35 and 55 mph should have spacings of 1,600 ft or greater. At very high volumes there appear to be economic advantages in providing spacings up to about 2,600 ft.

Flexibility of Operation

For the foregoing spacings suggested, considerable flexibility in adapting to varying traffic conditions can be obtained by changing the cycle length and, as a result, the speed progression. There are, however, other characteristics, conditions, and requirements that, in actual practice, will affect the operation of an arterial and, therefore, influence intersection spacing. These include the following:

1. Configuration of the basic street system.
2. Directional difference (unbalance) in traffic volume during peak periods.
3. Variations in volume on different sections along an arterial roadway.

Configuration of the Basic Street System

Suggested idealized spacings for streets of different functional classification have been set forth in the literature and recognized by professional engineers and planners. Perhaps the most notable work is by the National Committee on Urban Transportation (*5*). Criteria for urban street systems recommended by the National Committee suggested a collector street spacing of approximately ¼ mile and arterial spacing of 1 mile.

It also has been recognized that actual spacing may vary considerably from the ideal because of unique characteristics of different cities, including the density and pattern of development and geographical barriers. Creighton et al. (*6*) developed a procedure for estimating efficient spacing for arterials and expressways and proposed different spacings for various portions of the Chicago area.

Obviously, any given arterial must intersect other streets of the same functional classification. Hence, the intersection spacing will, in large measure, be influenced by considerations of arterial street spacing. Streets of lower classification must intersect at intermediate locations between the primary arterials. The spacing of primary arterials must, therefore, be such that a given number of signalized intersections can be located at uniform intervals which will allow maximum progression of the lowest user cost.

It therefore follows that with any system of primary arterials there is some maximum spacing between adjacent intersections that may be used and still provide for intermediate signalized intersections. This suggests a maximum intersection spacing of about 2,000 ft, if primary arterials are spaced on a 1-mile grid (see Table D-3). The location of an individual intersection may present a further problem in the uniform spacing of intersections. It is often impossible or impractical to locate a particular intersection at the specific point desired because of natural obstructions or existing conditions. Obviously, the frequency of such instances is reduced with increasing intersection spacing. Furthermore, when shifting the location of an intersection is necessary, the adverse effects of dislocation by a given distance will be lessened at longer intersection spacings.

TABLE D-3

MAXIMUM INTERSECTION SPACING ON PRIMARY ARTERIALS IN AN IDEALIZED GRID SYSTEM

IDEALIZED SPACING OF PRIMARY ARTERIALS (FT)	NO. OF INTERMEDIATE INTERSECTIONS	UNIFORM SPACING OF INTERSECTIONS (FT)
6000	5	1000
	4	1200
	3	1500
	2	2000
5600	3	1600
5200	3	1300
5100	2	1700
5000	4	1000
	1	2500
4800	5	800
	3	1200
	2	1700
4000	4	800
	3	1000
	1	2000

Unbalanced Flow

Unbalanced flow is common on many arterial roadways. In these situations it is often desirable to provide for different speeds of progression in each direction.

Within reasonable limits of cycle length and speed of progression, the flexibility to accommodate unbalanced flow is essentially the same over the range of acceptable intersection spacing.

Volume Differences

Different sections along an arterial frequently have different traffic volumes. Also, as an urban area expands, the volumes, as well as the location of these different volume sections, will change. It is, therefore, desirable that different speeds of progression be provided on the different sections of an arterial. As traffic conditions change, it may also be desirable to shift the points at which the speed of progression is changed.

Again, the longer signalized intersection spacings provide the greater flexibility. Longer spacings will provide for a greater range in speed of progression, for the same range in cycle lengths. As given in Table D-4, for cycle lengths between 50 and 90 sec, a spacing of 2,000 ft will accommodate progressive movement at speeds from 30 to 54 mph (a 24-mph difference), whereas a spacing of 1,000 ft will accommodate progression in the range of 15 to 27 mph (or a 12-mph difference).

Effect on Cross-Street Traffic

The effect of increasing the intersection spacing on cross-street traffic is shown schematically in Figures D-10 and D-11. If the intersection spacing were increased by eliminating every other intersection, as shown in Figure D-10, the maximum additional travel distance requirements would be equal to twice the increase in intersection spacing. Only those trips between points on the eliminated street, and on

TABLE D-4

DESIGN SPEED FOR PROGRESSIVE MOVEMENT FOR VARIOUS CYCLE LENGTHS AND SIGNAL SPACINGS WITH EQUAL SPEED IN BOTH DIRECTIONS

	SPEED TO NEAREST MPH FOR CYCLE LENGTH OF				
SPACING (FT)	50 SEC	60 SEC	70 SEC	80 SEC	90 SEC
500	14	11	10	9	8
600	16	14	12	10	9
700	19	16	14	12	11
800	22	18	16	14	12
900	24	20	18	15	14
1,000	27	24	19	17	15
1,200	33	27	23	20	18
1,400	38	32	27	24	21
1,600	44	36	31	27	24
1,800	49	41	35	31	27
2,000	54	45	39	34	30
2,200	60	50	43	37	33

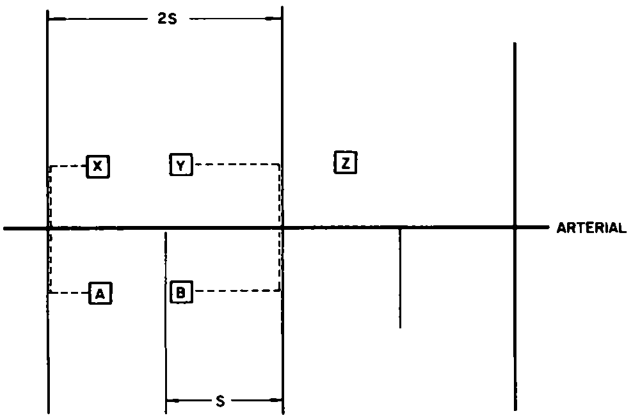


Figure D-10. Schematic representation effect of increase in intersection spacing by eliminating alternate streets.

opposite sides of the arterial (such as trips between B and Y in Fig. D-10), are affected by this amount. The distance between points situated such as A and X would not increase; trips from points A and B to points X and Y would be affected by an intermediate amount.

For an arterial on new location, longer intersection spacings may be accomplished with complete feasibility in the location of all intersections. Under these conditions, the maximum additional travel distance between any pair of points would be equal to the increase in the intersection spacing.

Trips between points on the same side of the arterial would obviously not be affected. For trips between points on opposite sides of a street crossing, the affected arterial (movements between B and Z in Fig. D-10 and between L and N in Fig. D-11) would also be unaffected in terms of distance; however, the trip (or a portion of it) may take place on a street of lower functional classification and, as a result, the travel time and cost for that trip may be increased slightly. The increased distance of travel for these trips will be a function of the increase in intersection spacing. The exact number of vehicle-miles of travel is also a function of the travel pattern which will, of course, differ from case to case.

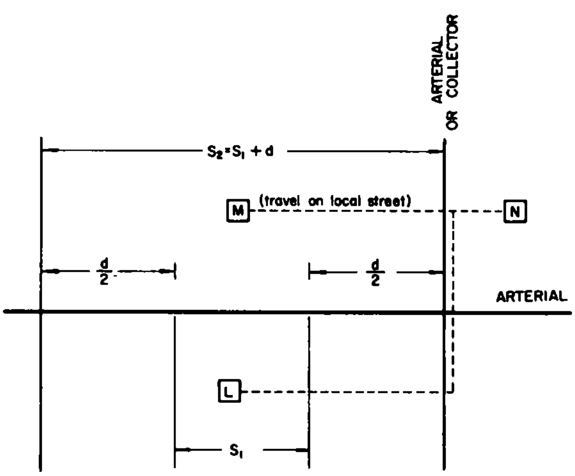


Figure D-11. Schematic representation effect of increase in intersection spacing by relocation of all intersections.

It may also be shown, however, that the magnitude of the cost of the increased travel must be very small. To demonstrate this, the following assumptions on travel pattern are made:

1. The volume crossing the arterial on each of the intersecting streets is the same.
2. Trip ends are uniformly distributed over the geographical area.

In reference to Figure D-12, these assumptions mean:

1. The volumes crossing the arterial on streets A-A', B-B', and C-C' are equal.
2. Trips crossing the arterial in the direction A-A' are uniformly distributed to points in areas a', b', and c'; that is, one-third of the trips crossing on A-A' go to area a', one-third to b', and one-third to c'. A similar condition is assumed on the other crossing streets, as well as in the reverse direction of travel.

Continuing with the example in Figure D-12, the travel distances from area a to the other areas are:

	LOCAL STREETS (A-A', B-B', C-C') INTERSECT THE ARTERIAL	
TO AREA	YES	NO
a'	—	$2L$
b'	L	$3L$
c'	$2L$	$4L$

The matrix of additional travel then becomes:

	a'	b'	c'
a	2	2	2
b	2	4	2
c	2	2	2

The operating cost of the total additional travel is:

$$C = \frac{Vc\,d}{5{,}280} = \frac{Vc\,ML}{5{,}280n}$$

in which

C = total added travel cost in dollars per 1,000 vpd;
V = number of vpd affected;
c = operating cost per 1,000 vehicle-miles;
d = added distance of travel for each vehicle in ft;
$d = M$ (the sum of the cells in the added travel matrix) times L (the intersection spacing, see Fig. D-12); and
n = number of intersecting streets involved.

At an operating cost of $0.0358 per vehicle-mile, the cost of additional travel per 100 vehicles on each intersecting street per day in each direction becomes

$$C = d(100/n)(35.80/5{,}280) = 0.000678\, ML/n$$

Thus, if the intersection spacing L in Figure D-12 were 400 ft, the added operating cost to 300 crossing vehicles (100 vehicles per street), due to increasing the spacing to 1,600 ft, would be:

$$C = (0.000678)(20)(400)/3 = 1.81$$

The additional travel time, due to the additional travel distance, at a speed of 30 mph is:

$$(100/n)(ML/5{,}280)(1/\text{speed}) = 1.68 \text{ vehicle-hours}$$

Then, at a value of time of $3.50 per vehicle-hour, the time cost of the additional travel per 100 vehicles is $5.90, yielding a total additional cost of $7.71 for the 300 vpd (100 on each crossing street) that would incur additional travel distance, as a result of the larger intersection spacing.

Developing the additional travel matrix for other frequencies of intermediate intersections, and summing the cell totals, gives the following values of M (sum of the cell entries in the additional travel matrix).

ORIGINAL NO. OF INTERMEDIATE INTERSECTIONS	NO. OF INTERMEDIATE INTERSECTIONS RETAINED	M
5	5	0
	3	6
	1	16
	0	70
4	4	0
	3	2
	2	6
	1	10
	0	40
3	3	0
	2	8/3
	1	4
	0	20
2	2	0
	1	2
	0	8

The cost of additional travel for different intersection spacings, and number of intermediate intersections, can be readily calculated in a manner similar to that for the above example. The additional travel costs for selected spacings are given in Table D-5.

CONCLUSIONS

Based on considerations relative to signal operation, it is recommended that intersections should be spaced approximately 1,200 to 1,600 ft apart for secondary arterials (speeds of operation between 25 and 45 mph) and 1,600 to 2,000 ft for primary arterials (operating at speeds between 30 and 55 mph). In both cases, spacings toward the higher end of the range are preferable.

Economic evaluation of arterial traffic indicates that, even at low volumes, intersections should be located at least 1,200 to 1,400 ft apart. At high volumes, spacings should be at least 1,600 ft; and there would be economic advantage from providing spacings up to 2,400 ft. Additional cost to cross-street traffic appears to be extremely nominal. Traffic which would be affected by longer intersection spacing would be primarily of a local nature. Such traffic should not be using an arterial for part of the trip under any functional organization of the street system.

These spacings also provide for the greatest flexibility for adjustment in traffic signal system operation, due to changing traffic conditions.

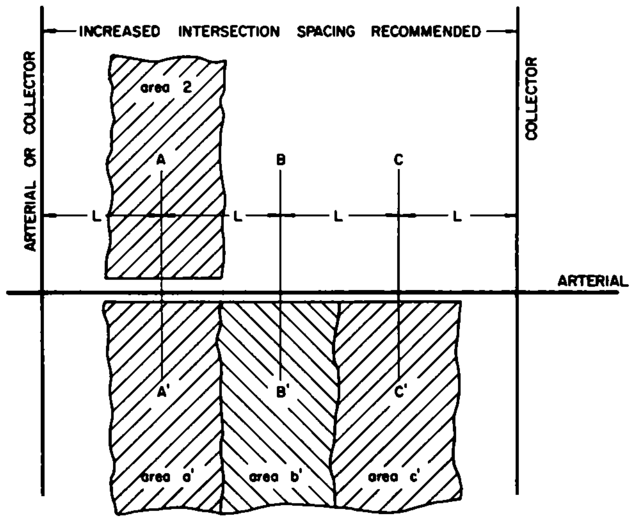


Figure D-12. Schematic representation of travel distance.

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6. CREIGHTON, R. L, et al., "Estimating Efficient Spacing for Arterials and Expressways." *HRB Bull. 253* (1960) pp. 1-44.
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TABLE D-5

DAILY OPERATING AND TIME COSTS OF ADDITIONAL TRAVEL BECAUSE OF INCREASED INTERSECTION SPACING

DESIRED SPACINGS OF INTERSECTIONS ON ARTERIALS (FT)	LOCAL STREET SPACING (FT)	INTERMEDIATE INTERSECTION SPACING		ADDED TRAVEL COST PER 100 VEHICLES ($) [a]			
					TIME		
		FT	NO.	OPERATING	HR	$	TOTAL
1,800	300	300	5	—	—	—	—
		600	3	0.12	0.23	0.80	0.92
		900	1	0.65	0.60	2.10	2.75
		1,800	0	2.85	2.65	9.27	12.12
2,000	500	500	3	—	—	—	—
		1,000	1	1.36	0.42	1.57	2.83
		2,000	0	2.26	2.10	7.35	9.61
1,600	400	400	3	—	—	—	—
		800	1	1.08	0.34	1.19	2.27
		1,600	0	1.81	1.68	5 88	7.79

[a] Number rounded to nearest cent and one-hundredth of an hour.

APPENDIX E

CURRENT HIGHWAY PRACTICE

Netherton, in *Control of Highway Access,* has provided a thorough review of the current status of the legal aspects of access control; he also presents an excellent discussion of the changes that have evolved (*1*). It appears to be neither reasonable nor appropriate to attempt to duplicate this work for the purposes of this research. Rather, with the essential and complete background provided by Netherton, this appendix briefly summarizes some of the current practices relative to the provision of medial and marginal access. Specific design practices, as they relate to the provision or denial of access, are not discussed herein.

A principal, but not surprising, finding is that partial access control as exercised frequently is not related to the functional purpose of the facility. Also, the application of access control is generally not exercised in a manner that is likely to develop continuity of access on a system basis.

STATE HIGHWAY DEPARTMENTS

As indicated from the replies received from the several highway departments, only one state does not have clear authority to designate partial access control of highways. Only two states (Alabama and Montana) had not as yet constructed controlled-access highways, other than that mileage within the state which is part of the Interstate System.

The authority, as well as procedures and standards, relating to access control differs considerably between the states. There are also substantial differences in organization and terminology, with which some liberty must be taken in attempting any summary of current practice in the administration of access control policies and procedures and in the application of standards or guidelines.

Policies and Procedures

There are significant differences in the organizational structure at which access control considerations are recommended, as well as where the final administrative review and decision are made. In those states that have a strong district structure, initial action on partial access control originates with the district office. In two states, district and central office personnel reportedly work closely together; in the remainder of the states, initial or principal action begins with one or more functional divisions within the central office. The following is a summary of the level and function at which initial action to designate a limited access facility is taken:

LEVEL AND FUNCTION	NO. OF STATES
District level	6
Central office:	
Planning	9
Right-of-way	1
Location	1
Design	10
Collectively by two or more functional divisions	9
Special committee	2
Chief administrator or commission	3
Partial control not exercised	2
Not indicated or no reply	7

The organizational structure of the highway department also affects the uniformity with which access control policies are implemented. In highly centralized organizations, greater uniformity in decisions and practices regarding access control is likely. Where the design responsibilities are divided among several districts, greater opportunity exists for variation between districts. One state reported that, as a result of this division of responsibility without clearly established guidelines, full control of access was recently provided on a section of relatively minor state highway. The department, however, does not ordinarily exercise this type of control on other highways with much greater volumes.

The replies from 21 states indicated that they had a written policy or guideline with regard to the application of partial access control, and two additional states reported that such a policy or guideline was in the process of being prepared. Sixteen states replied that they did not have a written policy or guideline; however, 14 of these states noted that some degree of partial access control was being exercised. Of the remaining states, several replies did not clearly indicate whether such a departmental document existed or not.

Several criteria are reported to be used by the various states in designating the degree of access control for particular facilities. These commonly include "traffic needs," location (i.e., rural vs urban), and geometric design standards (i.e., two-lane vs multi-lane); however, the exercise of access control on a project-by-project basis is reported to be the practice in most jurisdictions. In one state (New Hampshire) the governor must appoint a special committee to consider each individual project.

To provide for system continuity throughout the state, some highway departments use a functional classification as the basis for designating access control. The degree of control (within a limited range) is automatically established at the time the classification is made. This provides for continuity of individual routes, as well as for the planned development of a complete system of highways which is capable of serving long-range needs. The states of Washington and Wisconsin probably best represent the implementation of this practice. Both have state highway plans which identify the functional classifications of the route and degree of access (full or partial).

Wisconsin is also developing a statewide functional system of highways. Guides for the type and spacing of access have been developed for both rural and suburban facilities. These guides, which are more flexible than a set of standards, indicate the minimum spacing of access points for both public roads and private driveways, relative to the functional classification of the facility and design ADT.

Other states are attempting to obtain continuity of access control on particular routes, or on a specific class of highway. Maine, for example, attempts to control access on all reconstruction of U.S. 1. North Carolina exercises a general policy of some access control on its trunk highway system. Virginia permits intersections with secondary roads only (at ½-mile intervals) on primary highways.

A few states exercise access control on multi-lane facilities. Nebraska uses limited access on all relocations which are four lanes (or more), including those where only two lanes were originally constructed. Also, Michigan normally constructs all multi-lane rural highways to full freeway standards (full control of access); other rural trunk roads have free access.

Tennessee exercises full control of access on new construction having a design ADT of over 25,000; partial control is exercised when the design ADT is between 10,000 and 25,000. The policy in New York is not to provide private access on new location.

In Oregon, the abutting property owner has no right of access to state highways constructed, relocated, or reconstructed after May 12, 1951. Properties with access prior to that date have a right to reasonable access (but not necessarily to the said state highway); market value is the test as to reasonable access. The highway department has the authority to limit the number, location, and use of any access points permitted.

Limitation of Direct Access Points

Most state highway agencies exercise some control over the design, construction, and maintenance of direct access driveways. Standards for such control are commonly provided in separate driveway design manuals, or are included in the standard roadway design manual.* Wide diversity, however, does exist between the standards used by various agencies. Although some appear well advanced, with respect to minimizing the conflict between through and local traffic, others do little to afford safety and convenience of direct access and through service.

The exercise of control over driveway location likewise varies widely throughout the U.S. In many cases, the application for, and approval of, the driveway permit is largely a formality, with access provided to any abutting property owner. In other cases, the governing authority (particularly in the case of a municipality) may negotiate with an abutting landowner or developer to provide for direct access under conditions mutually beneficial to both the road user and the developer.

* Thirty-six states reported that they have their own driveway manual, although a number of them differ little from the AASHO recommendations, two reported using AASHO, and two reported that they did not have a manual on driveway policy/standards; in the remaining cases the information was not furnished or there was no reply

When access is provided for abutting property, the general practice is to furnish at least one access point to each parcel, regardless of how narrow the frontage may be; with wider frontage (generally more than 100 ft) two or more access points are commonly provided. Only a few states apparently exercise any controls which require relatively longer (greater than 100 ft) spacing between adjacent driveways. Utah specifies a minimum distance of 500 ft, with 1,000 ft being the preferred spacing. Idaho limits additional driveways to one per 660 ft of frontage under a single owner. (Each parcel under ownership, of course, has at least one driveway.)

Washington does not permit direct access driveways to commercial establishments on state highways. Driveways to private residences and farms are permitted; however, the permit is void and the driveway may be closed if the land is converted to another use. Oregon, as previously mentioned, also exercises control over the use of the driveway.

Wisconsin appears to have developed the most detailed guidelines for minimum spacing of access points in both rural and suburban areas (see Tables E-1 and E-2). As previously mentioned, these guidelines for minimum spacing are based on both functional classification and design ADT. At lower volumes and lower functional classes, closer spacings are permitted.

Wisconsin also follows a procedure by which an abutting owner must file a request for a driveway permit, at which time the state may either purchase the access rights or approve the permit. Facilities on which this practice is followed are identified and known to the property owner. This practice is followed in those areas of the state that have a low population density and limited potential for development.

Missouri and Washington also specify control of access for a minimum distance of 300 ft along any roadway intersecting a controlled access facility at grade. The Washington practice is shown in Figure E-1.

Median Openings

Practice with regard to median openings is characterized by considerable variability. Such guides as do exist for median openings are given in the highway department design manuals and generally relate to design aspects other than spacing. At this point it might be noted that most states specify the bullet-nose design for median openings.

Few states have a policy regarding the relation of median

TABLE E-1

STATE HIGHWAY PLAN, RURAL ACCESS TYPE AND MINIMUM SPACING GUIDELINES, WISCONSIN

	Intersecting Highway ↓ / Major Route Under Study →	Design Year ADT	1 Principal Fwy. All Volumes	2	3 Primary Fwy All Volumes	4	5 Primary Exp I 10,000-20,000	6 5,000-10,000	7 3,000-5,000	8	9 Primary II >5,000	10 <5,000	11	12 Primary Other 3,000-5,000	13 1,000-3,000	14 <1,000	15	16 Standard Fwy All Volumes	17	18 Standard Exp >15,000	19 10,000-15,000	20 5,000-10,000	21	22 Standard Exp II 10,000-15,000	23 5,000-10,000	24 3,000-5,000	25	26 Standard Other 5,000-10,000	27 3,000-5,000	28 1,000-3,000	29 <1,000	30	31 Minor Other 1,000-5,000	32 <1,000	33	34	35	36	37	38	39
1	Principal Freeway	All Volumes	1B																																						
2																																									
3	Primary Freeway	All Volumes	1B		1B																																				
4																																									
5	Primary Exp I	10,000-20,000	1B		1B		1B																																		
6		5,000-10,000	1B		1B		1B	1B																																	
7		3,000-5,000	1B		1B		1B	1B	1B																																
8																																									
9	Primary Exp II	>5,000	1B		1B		1B	1B	1B		1B																														
10		<5,000	1B		1B		1B	1B	1B		1B	1B																													
11																																									
12	Primary Other	3,000-5,000	1B		1B		1B	1B	1B		1B	1B		1B																											
13		1,000-3,000	1B		1B		1B	1B	1B		1B	1B		2C	2C																										
14		>1,000	1B		1B		1B	1B	1B		1B	1B		2C	2C	2C																									
15																																									
16	Standard Freeway	All Volumes	1B		1B		1B	1B	1B		1B	1B		1B	1B	1B		1B																							
17																																									
18	Standard Exp I	>15,000	1B		1B		1B	1B	1B		1B	1B		1B	1B	1B		1B		1B																					
19		10,000-15,000	1B		1B		1B	1B	1B		1B	1B		1B	1B	1B		1B		1B	1B																				
20		5,000-10,000	1B		1B		1B	1B	1B		1B	1B		1B	1B	2C		1B		1B	1B	1B																			
21																																									
22	Standard Exp II	10,000-15,000	1B		1B		1B	1B	1B		1B	1B		1B	1B	1B		1B		1B	1B	1B		1B																	
23		5,000-10,000	1B		1B		1B	1B	1B		1B	1B		1B	1B	1B		1B		1B	1B	1B		1B	1B																
24		3,000-5,000	1B		1B		1B	1B	1B		1B	1B		2C	2C	2C		1B		1B	1B	1B		1B	1B	1B															
25																																									
26	Standard Other	5,000-10,000	1B		1B		1B	1B	1B		1B	1B		1B	2C	2C		1B		1B	1B	1B		1B	1B	1B		1B													
27		3,000-5,000	1B		1B		1B	1B	2C		1B	2C		2C	2C	2C		1B		1B	1B	1B		1B	1B	1B		1B	2D												
28		1,000-3,000	1B		1B		1B	1B	2C		2C	2C		2C	2C	2C		1B		1B	1B	2D		1B	2D	2D		2D	2D	2D											
29		>1,000	1A		1A		1B	2C	2C		2C	2C		2C	2C	2C		1B		1B	2D	2D		2D	2D	2D		2D	2D	2D	2D										
30																																									
31	Minor Other	1,000-5,000	1B		1B		1B	1B	2C		1B	2C		2C	2C	2C		1B		1B	1B	2D		1B	2D	2D		1B	2D	2D	2D		2D								
32		<1,000	1A		1A		1B	2C	2C		2C	2C		2C	2C	2C		1B		1B	2D	2D		2D	2D	2D		2D	2D	2D	2D		2D	2G							
33																																									
34	H Coll Other	>500	1A		1A		1B	2D	2D		2D	2D		2D	2D	2D		1B		1B	1B	2D		1B	2D	2D		2D	2D	2E	2E		2F	2G							
35		<500	1A		1A		2D	2D	2D		2D	2D		2D	2D	2D		1B		2D	2D	2D		2D	2D	2D		2D	2D	2E	2E		2E	2G							
36																																									
37	I Coll Other	>500	1A		1A		1B	2D	2D		2D	2D		2D	2D	2D		1B		1B	1B	2D		1B	2D	2D		2D	2D	2E	2E		2E	2G							
38		<500	1A		1A		2D	2D	2D		2D	2D		2D	2D	2D		1B		2D	2D	2D		2D	2D	2D		2D	2D	2E	2E		2E	2G							
39																																									
40	Local Other	>500	0		0		1B	2D	2D		2D	2D		2D	2D	2D		0		1B	1B	2D		1B	2D	2D		2D	2D	2E	2E		2E	2G							
41		<500	0		0		2D	2D	2D		2D	2D		2D	2D	2D		0		2D	2D	2D		2D	2D	2D		2D	2D	2E	2E		2E	2G							
42																																									
43	Private Other	>500	0		0		0	0	0		2D	2D		2D	2E	2E		0		0	0	0		2D	2D	2D		2D	2E	2E	2E		2E	2G							
44		<500	0		0		0	0	0		2E	2E		2E	2F	2F		0		0	0	0		2E	2E	2E		2E	2F	2F	2F		2F	2G							

Legend

Access Type	Minimum Access Spacing
0 No Access	A 5 mi
1 Interchange	B 2 mi
2 At-Grade	C 1 mi
	D 2000'
	E 1000'
	F 500'
	G 300'

openings to access control. A few have no policy or practice at all; rather, they consider the problem project-by-project. Average spacings for a few states that do have a guideline relative to median openings are: California, ¼ mile; Illinois, ½ mile minimum, with 1 mile preferred in urban areas; Louisiana, 500 ft without service roads and 1,000 ft where there are parallel service roads; Michigan, 660 ft on sections with a median 30 ft or wider (measured from inside edges of pavement), and where there is unusual traffic and the median is less than 30 ft; and Mississippi, 880 ft in urban areas and 1,760 ft in rural areas.

LOCAL GOVERNMENT

Many larger local governments have highly qualified professional staffs and are making substantial progress in attempting to arrest further deterioration of existing arterials as a result of frequent and poorly designed access. Progress is also being made in the application of improved practice to new construction and the extension of existing arterials. This section does not attempt to provide a complete review of the current practice in all local jurisdictions. Rather, it is a review of certain practices in selected urban areas.

Policies and Procedures

The city of New Orleans requires the developer to pay for the redesign of streets adjacent to the proposed development and for such items as the purchase and installation of signals and the construction of median openings (where permitted). The developer also contributes one-half of the cost of major street improvements necessitated by the development; this contribution is not necessarily limited to the street immediately adjacent to the development, but may extend some distance from it. Under an ordinance implemented in April 1968, New Orleans has also developed a procedure for the coordinated review and approval of driveway and building permits. Under this procedure the developer must obtain approval of the driveway location before a building permit will be issued. The developer's proposed site plan is reviewed by the Traffic Engineer and redesign can be required before the driveway location is approved. A separate driveway permit is required prior to construction of a driveway; this permit is issued by the Construction Division, after approval by the Traffic Engineering Division (both divisions are in the Street Department). A deposit of $0.50 per square foot of driveway is required when the construction permit is issued. Ten per-

TABLE E-2

STATE HIGHWAY PLAN, SUBURBAN ACCESS TYPE AND MINIMUM SPACING GUIDELINES, WISCONSIN

	INTERSECTING HIGHWAY ↓ / MAJOR ROUTE UNDER STUDY →	Design Year ADT	1 Principal Fwy All Volumes	2	3 Primary Fwy All Volumes	4	5 Primary Exp I 30,000-60,000	6 15,000-30,000	7 9,000-15,000	8	9 Primary Exp II >15,000	10 <15,000	11	12 Primary Other 9,000-15,000	13 3,000-9,000	14 <3,000	15	16 Standard Fwy All Volumes	17	18 Standard Exp I >50,000	19 30,000-50,000	20 20,000-30,000	21	22 Standard Exp II 30,000-50,000	23 20,000-30,000	24 10,000-20,000	25	26 Standard Other 20,000-30,000	27 10,000-20,000	28 3,500-10,000	29 <3,500	30	31 Minor Other 5,000-25,000	32 <5,000
1	Principal Freeway	All Volumes	IC																															
2																																		
3	Primary Freeway	All Volumes	IC		IC																													
4																																		
5	Primary Exp. I	30,000-60,000	IC		IC		IC																											
6		15,000-30,000	IC		IC		IC	IC																										
7		9,000-15,000	IC		IC		IC	IC	IC																									
8																																		
9	Primary Exp II	>15,000	IC		IC		IC	IC	IC		IC																							
10		<15,000	IC		IC		IC	IC	IC		IC	IC																						
11																																		
12	Primary Other	9,000-15,000	IC		IC		IC	IC	IC		IC	IC		IC																				
13		3,000- 9,000	IC		IC		IC	IC	IC		IC	IC		IC	2D																			
14		<3,000	IC		IC		IC	IC	IC		IC	IC		2D	2D	2D																		
15																																		
16	Standard Freeway	All Volumes	IC		IC		IC	IC	IC		IC	IC		IC	IC	IC		IC																
17																																		
18	Standard Exp I	>50,000	IC		IC		IC	IC	IC		IC	IC		IC	IC	IC		IC		IC														
19		30,000-50,000	IC		IC		IC	IC	IC		IC	IC		IC	IC	IC		IC		IC	IC													
20		20,000-30,000	IC		IC		IC	IC	IC		IC	IC		IC	IC	2D		IC		IC	IC	IC												
21																																		
22	Standard Exp II	30,000-50,000	IC		IC		IC	IC	IC		IC	IC		IC	IC	IC		IC		IC	IC	IC		IC										
23		20,000-30,000	IC		IC		IC	IC	IC		IC	IC		IC	2D	2D		IC		IC	IC	IC		IC	IC									
24		10,000-20,000	IC		IC		IC	IC	IC		IC	IC		2D	2D	2D		IC		IC	IC	IC		IC	IC	IC								
25																																		
26	Standard Other	20,000-30,000	IC		IC		IC	IC	IC		IC	IC		IC	2D	2D		IC		IC	IC	IC		IC	IC	IC		IC						
27		10,000-20,000	IC		IC		IC	IC	2D		IC	2D		2D	2D	2D		IC		IC	IC	IC		IC	IC	IC		IC	2C					
28		3,500-10,000	IC		IC		IC	IC	2D		2D	2D		2D	2D	2D		IC		IC	IC	2E		IC	2E	2E		2E	2E	2E				
29		<3,500	IB		IB		IC	2D	2D		2D	2D		2D	2D	2D		IC		IC	2E	2E		2E	2E	2E		2E	2E	2E	2E			
30																																		
31	Minor Other	5,000-25,000	IC		IC		IC	IC	2D		IC	2D		2D	2D	2D		IC		IC	IC	2E		IC	2E	2E		IC	2E	2E	2E		2E	
32		<5,000	IB		IB		IC	2D	2D		2D	2D		2D	2D	2D		IC		IC	2E	2E		2E	2E	2E		2E	2E	2E	2E		2E	2G
33																																		
34	H Collector Other	>2,500	IB		IB		IC	2E	2E		2E	2E		2E	2E	2E		IC		IC	IC	2E		IC	2E	2E		2E	2E	2F	2F		2F	2G
35		<2,500	IB		IB		2E	2E	2E		2E	2E		2E	2E	2E		IC		2E	2E	2E		2E	2E	2E		2E	2E	2F	2F		2F	2G
36																																		
37	L. Collector Other	>2,500	IB		IB		IC	2E	2E		2E	2E		2E	2E	2E		IC		IC	IC	2E		IE	2E	2E		2E	2E	2F	2F		2F	2G
38		<2,500	IB		IB		2E	2E	2E		2E	2E		2E	2E	2E		IC		2E	2E	2E		2E	2E	2E		2E	2E	2F	2F		2F	2G
39																																		
40	Local Other	>2,500	0		0		IC	2E	2E		2E	2E		2E	2E	2E		0		IC	IC	2E		IC	2E	2E		2E	2E	2F	2F		2F	2G
41		<2,500	0		0		2E	2E	2E		2E	2E		2E	2E	2E		0		2E	2E	2E		2E	2E	2E		2E	2E	2F	2F		2F	2G
42																																		
43	Private Other	All Volumes	0		0		0	0	0		2E	2F		2F	2G	2G		0		0	0	0		2E	2F	2F		2F	2G	2G	2G		2G	2G

Legend

Access Type	Minimum Access Spacing
0 No Access	A 5 mi
1 Interchange	B 2 mi
2 At-Grade	C 1 mi
	D 2000'
	E 1000'
	F 500'
	G 300'

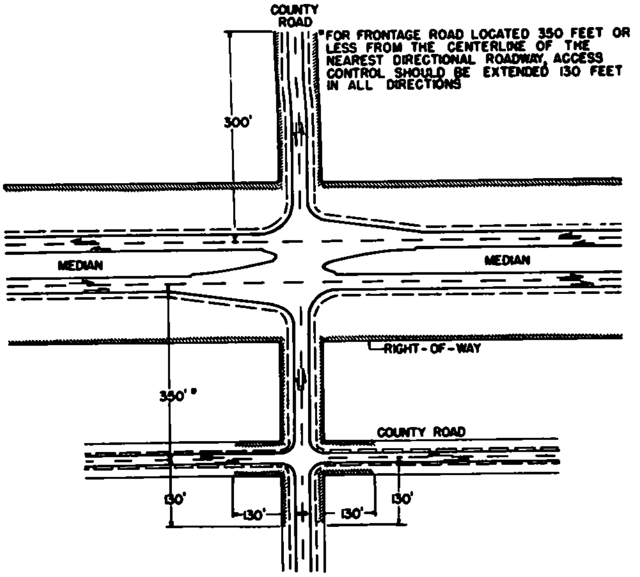


Figure E-1. Washington access control practice in the vicinity of at-grade intersections with limited-access highways.

cent is retained by the city as a service fee. The other 90 percent is returned after the construction has been inspected and is accepted.

To coordinate the several divisions of city government, a Planning Advisory Committee meets weekly. This committee acts as an advisory group to the Planning Commission, which generally follows the committee's recommendations. Furthermore, when traffic cannot be accommodated, requests for zoning changes are not approved upon appeal to the Board of Standards and Appeals.

By act of the Indiana General Assembly in 1967, the Mass Transportation Authority of Greater Indianapolis (MTA) has jurisdiction over all facilities in Marion County (except those under the jurisdiction of the Indiana State Highway Commission) designated as thoroughfares by the Metropolitan Plan Commission. The MTA, by this legislation, is empowered to plan, design, construct, and operate all such designated facilities. In addition, by intergovernmental agreement (May 1968) with the City of Indianapolis, MTA has responsibility for traffic control on all streets inside the corporate limits of Indianapolis. This agreement gives the MTA, among other powers, the authority for approval of all driveway permits within the city (administration of these permits is handled by the Board of Public Works).

The vesting of this authority in a single agency facilitates the use of uniform procedures in the approval of driveway permit requests and consistent treatment of access control over a wide metropolitan area. Other arrangements might be more applicable in other urban areas. Certain policies, procedures, and standards relating to access control recently adopted (January 23, 1969) are, however, considered to be generally applicable.

In the consideration of commercial driveway permit requests, the following information must be provided by the developer:

1. A vicinity map indicating the location of the property with respect to arterial streets, railroads, etc.

2. A map showing streets, alleys, right-of-way, and all utilities, together with the location and width of existing driveways, on both sides of the street, for a distance of 150 ft beyond the property lines.

3. Description of the proposed use of the property.

4. Location and geometrics of proposed access points and the use of each point (i.e., entrance only, exit only, or entrance and exit).

5. Location and size of all existing and proposed buildings.

6. Proposed parking arrangement and number of spaces.

7. Location and size of all permanent signs.

Other requirements include the number of copies to be provided, scales to be used, typical cross sections for pavement widening, existing and proposed drainage, and certification by a registered engineer, architect, or land surveyor.

In addition to specifying the agency from which driveway permit forms are to be obtained and the office location of such agency, the following procedures are specified for obtaining a commercial driveway permit:

Case I

If the site is properly zoned, the developer must obtain a commercial driveway permit before an *Improvement Location Permit and Building Permit* will be issued.

1. Obtain and file application and five (5) copies of plot plan with appropriate agency (city, county, state). Application must be completed and plot plan must meet all specifications before it will be accepted.
2. If driveway permit application and plot plan are acceptable, the agency will transmit copies of the application and the plot plan to the MTA, DIVISION OF TRAFFIC ENGINEERING.
3. After the plot plan has been returned by the MTA approved with only minor revisions, the application will be processed for approval by the appropriate Agency.
4. If major changes are necessary, the plot plan will be returned to the applicant. Applicant may then resubmit revised plot plan to the MTA Traffic Engineer and, if acceptable, he will then process the same as mentioned previously.

Case II

If a Variance of Rezoning is required, the developer must have preliminary access approval from the MTA, DIVISION OF TRAFFIC ENGINEERING before a hearing date can be given. This is necessary in order to insure that the developer has provided safe access to his property.

Developer must submit copies of the plot plan to the MTA, DIVISION OF TRAFFIC ENGINEERING.

This preliminary approval will not be considered a final driveway permit approval. The developer must follow the procedures outlined in CASE I in order to obtain final driveway permit approval.

Procedures for obtaining coordination between MTA and the Metropolitan Planning Department in the review of zoning changes have also been developed. The requirements for filing a petition for variance of zoning list the various items which the petitioner must complete and are indicated in the reproduction of the form shown in Figure E-2. The requirement of Item 2(i), relative to approval of access, together with the procedures for obtaining such approval, assures review of traffic considerations in any request for a change in zoning.

Considerable recent success is reported by the Traffic Engineering Department in Madison, Wis., in working with

REQUIREMENTS FOR FILING PETITION FOR VARIANCE OF ZONING ORDINANCE

Three copies of petition, completely filled out, signature/s of owner/s of 50% or more of area involved in petition, typewritten, notarized, filed at least 25 days prior to public hearing ☐

(a) Plot size (this is total of all parcels included in petition) ☐

(b) Acreage, to closest tenth (0 1) of an acre. ☐

(c) Legal description, and/or copy of plat map if recorded ☐

(d) Nature and size of existing improvements ☐

(e) Present Zoning ☐ (f) Proposed Use ☐

(g) Cost of proposed improvement ☐

(h) Description and reason for variance request ☐

(i) If petition is signed by representative/s of owner/s, letter/s indicating authority to file ☐

1 Three (3) copies of area map, 1" = 1000' scale, (Metropolitan Planning Dept map), showing zoning at least 200 feet distant from land involved if within corporate limits, at least 600 feet distant outside corporate limits. ☐

2 Three (3) copies of plot plan, scale 1" = 50' or larger, showing ☐

(a) Lot or plot, existing structures (dotted line), dimensions to nearest lot lines ☐

(b) Proposed location of buildings or structures on plot (solid line), dimensions to nearest lot lines ☐

(c) If petition is for accessory use, show primary buildings or structures ☐

(d) Location of right-of-way line of adjoining highway, streets or alleys, including center lines (and dimensions) ☐

(e) Parking area provided (show detail for each space, 10' x 20', and measurements). ☐

*(f) Drainage of land File a drainage plan approved by County Surveyor and/or Board of Sanitary Commissioners ☐

(g) Proposed location of sewage or septic system ☐

(h) Location of nearest sanitary sewer and size ☐

*(i) Approval of ingress or egress by Mass Transportation Authority and/or State Highway and/or Marion County Engineer ☐

*(j) A diagram and dimensions of all signs requested must be filed with petition ☐

3 One copy of building plans, including floor plans and elevations ☐

4 Three (3) copies of multiple dwelling project analysis sheet, if multi-family use is requested. ☐

*5 Letter approving septic system, from Health & Hospital Corporation, or letter from Board of Sanitary Commissioners, indicating sanitary sewer connection is available ☐

*6 If a court ditch is involved, letter of approval from the Drainage Board ☐

*7 If storm water outlet is into county road ditch/s, letter of approval from County Surveyor ☐

8 A fee of $50 00 must accompany the petition for use variance ($15 00 if other than use variance) ☐

*A letter of request to appropriate agency must be filed at time of filing of petition A letter of approval or approved plans must be obtained and placed in file before the public hearing of case If such letter or approved plan is not in file, the case will be continued to the next regular meeting

Clerk Initials - Date

Figure E-2. Form used by local agency where traffic considerations are involved in change in zoning.

developers and owners of properties adjacent to arterials. Although the department has no administrative authority to direct that changes be made in the site layout prior to 1962, individuals have made changes in the site plans after being shown that the changes are in their own best interest, as well as in the interest of the road user.

In one case, involving a parking lot, the advice was refused; however, after the lot was completed and placed in operation, the problems that the department staff had discussed with the owner did indeed occur. Faced with public criticism and loss of business, the owner requested the assistance of the Traffic Engineering Department and carried out its suggestions.

The ordinance, adopted by the City of Madison in 1962, provides for the Traffic Engineering Department's review of the developer's plans, relating to off-street parking (as required in the building code), for conformity to establish design standards and for driveway entrance and approach approval. Prospective developers are supplied with a list of items, together with the approved standards, that must be indicated on the plans which accompany the application. These must be approved by the Traffic Engineer, City Engineer, and Building Inspector, prior to issuance of a building permit. This list consists of the following:

1. A scaled drawing plot plan on a single sheet 1 in. = 20 ft or larger.
2. Address and parcel number of property.
3. Property lines, existing and proposed structures.
4. Width of right-of-way, roadway, and terrace.
5. Location of driveway approaches—existing, proposed, and adjoining.
6. Proposed driveway radii.
7. Type of surface—driveway approach, driveway, and parking lot.
8. Proposed routing of motor vehicles entering and leaving.
9. Proposed treatment of right-of-way area adjacent to or between approaches.
10. Rate of slope or grade of approaches and driveways, if over 15 percent.
11. Indicate utility poles, fire hydrants, trees, or other structures to be moved.
12. Means of separation between parking lot and sidewalk.
13. Indicate number, arrangement, and size of parking stalls.
14. Distance to intersecting streets within 500 ft; and location, elevation, and size of all storm sewers available.
15. Indicate elevations of existing site to city datum. Elevations to include top of sidewalk and flow line of gutter. Elevations to be spotted at 25 ft intervals or 1 ft contours.
16. If no storm sewers are available, the owner is to include elevation of the top of the curb.
17. If the street is unimproved, the plot plan is to indicate the location and elevation of the drainage ditches abutting the site.
18. Proposed method of drainage including the following:
    a. Proposed finished elevations of parking lot, including direction of drainage and elevations of proposed gutters or swales.
    b. Elevations, location, and size of inlets, catch basin, and storm sewers to be constructed in conjunction with the parking lot.
19. Location of all downspouts from the building and proposed method for disposing of surface water.
20. Name and address of person responsible for paying storm sewer connection charges that may be levied in conjunction with this project.

A building permit is also required for remodeling of existing structures. These plans also are reviewed and must be approved by the Traffic Engineer. In some instances the city has been successful in closing existing driveways which did not conform to adopted ordinances and standards.

Coordination (joint review) of the issuance of a building permit and a driveway permit should not result in any additional procedural problems for a developer/owner, where these permits are presently issued through a single administrative division. In Long Beach, Calif., for example, permits are handled by the building department; however, in this case, there presently is no review by traffic engineering.

Seattle, Wash., includes the driveway permit in the building permit. The city traffic ordinance states that it is the duty of the Traffic Engineer to inspect all applications for commercial building permits, with respect to new or existing driveways, and plans for commercial development are forwarded to the traffic engineer for approval of access, prior to issuance of a building permit. The traffic engineer does not, however, have authority to deny the driveways requested; rather, he must rely on powers of persuasion to convince the architect and his client that the recommendations will be of benefit to the development.

In the absence of a required review of site development plans by the Traffic Engineering Department, an informal review procedure has been developed in some cities. In Dallas and San Antonio, for example, this review responsibility rests with the Planning Department; however, Traffic Engineering's recommendations are actively sought and generally accepted.

Medians

Median openings generally are permitted at all intersections with dedicated streets. Some cities, however, do have the authority to carry a median through an intersection. The warrants for median opening on major streets adopted by the City of San Diego states that "Median openings will normally be permitted at all intersections with dedicated City Streets except where such openings will impair the movements of traffic." This policy also states that midblock median openings will not normally be permitted on major arterials unless:

1. The property to be served is a major traffic generator and has a continuing frontage of 1,200 ft or more along the major street between streets which intersect the major street from the side occupied by the property.

2. The median opening is not less than 600 ft from an intersection with a major or collector street.

3. The median opening is not less than 400 ft from an intersection with a local street.

4. The median opening is not less than 600 ft from any other existing or proposed midblock median opening.

Present practice in Madison, Wis., limits median openings to public street intersections. The standard for minimum spacing of median openings on new construction is 1,200 ft. Spacings less than this have been approved on reconstruction of existing streets, where the cross-street pattern is established. Median openings have been denied where new streets intersect an existing divided roadway in the proximity of a major intersection; this has been accomplished by a restriction on the plot plan, when it is recorded in the Register of Deeds Office. Median openings for the exclusive use of U-turns are permitted no less than 600 ft from another median opening.

Dallas and San Antonio provide median openings at major cross streets and major traffic generators, and construction is either raised concrete or landscaped. Although cross streets have not been barricaded to improve operation on an arterial in Dallas, some success has been obtained through encouraging abutting property owners to buy the street, when practical, and to close it.

Los Angeles County has pursued a policy of installing medians (where width is sufficient) on all "Master Plan Highways." These have been of both a painted and raised median design. Comparison was made of the accident experience on 12 pairs of roadway segments, over 10 ft in width (one painted and the other raised in each pair), of similar length, traffic volume, and adjacent development. The accident rate for segments with painted medians averaged 1.81 accidents per million vehicle-miles, as opposed to 1.00 for those segments having a raised median. There was also a substantial difference in the number of accidents occurring at driveways—a total of 47 on sections with painted median and 19 on raised median sections.

REFERENCE

1. Netherton, R. D, *Control of Highway Access.* Univ. of Wis. Press (1963).

APPENDIX F

DIRECT ACCESS DRIVEWAYS

The provisions of service for both through traffic and direct access are operationally incompatible functions of a roadway. Provision of an additional unit of direct access can be made only at the expense of additional units of capacity for through service. Roadway capacity is allocated between these two functions largely by the extent to which direct access is restricted, in terms of frequency of access points, as well as their design characteristics. Along a given roadway, therefore, restrictions imposed on direct access should allocate the available capacity according to the relative importance of the demands for through service and for local access.

Consistent with the research objective of providing guidelines for "access control for the optimum benefit of the highway user," the problem of driveway design is viewed here from the standpoint of optimizing the service to through traffic. Provision of local access is viewed as a constraint rather than as an objective. This discussion is, therefore, most directly applicable to the control of direct access along arterials or other major roadways, the primary function of which is to serve through movements.

This is not to say that considerations of local service are completely ignored. Indeed, designs that provide for good service to through traffic will, in many respects, also provide for a high level of local service; however, elements of driveway design concerned strictly with local service are considered here to be of secondary importance.

Ideally, standards for driveway location and design should be specified in terms of performance. For example, driveways serving a particular type of establishment along a roadway of a given class should permit vehicles to enter (or leave) the traffic stream at some specified speed and level-of-service (measured in terms of comfort, safety, delay, etc.). But data defining the relationship between level-of-service and driveway design characteristics are not available to the extent that specifications for driveway design, in terms of performance or desired operation, can be easily implemented.

Thus, the problem of specifying standards for driveway design is one of providing a set of characteristics which have been evaluated and found satisfactory. Certain limiting conditions such as minimum width, maximum profile grade change, or minimum sight distance can be specified. In some cases, even these limits are not sufficiently restrictive. On the other hand, for elements such as the profile, the number of combinations of vertical tangent lengths and grade changes which will provide for satisfactory driveway operation is infinite.

The following discussion attempts to provide the background necessary for the selection of the type of driveway operation most desirable for access to a particular development. Designs are then suggested which generally satisfy the requirements for various levels of driveway operation. To extend these recommendations to more specific cases, a discussion of the various factors affecting driveway operation is also presented.

It is to be emphasized that the recommendations contained herein seek to optimize the benefit to through traffic. It is certainly recognized that political, fiscal, geographical, or other local constraints may often override the importance of optimizing the benefit to the road user. The extent to which such local factors should take precedence over the road user benefit in the application of these recommendations is more appropriately a decision to be made by local authorities.

ACCESS REQUIREMENTS OF COMMERCIAL AND PRIVATE DEVELOPMENTS

A survey of current trends in commercial and private developments indicates a general increase in the size of the development site and a tendency toward greater restrictions on direct access to major roadways. In residential developments, access to property abutting major roadways is commonly provided via secondary streets, using side-on or back-up lots, cluster developments, or similar layouts. The shift of commercial establishments from strip developments to shopping centers represents a consolidation of demand for access and parking that can be more satisfactorily met with fewer, well-designed access points. Preferring corners over midblock locations, service stations and motels have similarly increased in size, and the motel industry appears willing to accept restriction of access to secondary streets, where such access can be satisfactorily provided. Perhaps more important than the actual restrictions imposed on the design and location of access points is the need to apply such restrictions uniformly, so that no development is provided with a competitive advantage or disadvantage by some variance.

In general, it appears that trends in both private and commercial developments will permit greater flexibility with respect to the design and location of access points. Larger sites obviate the need for very limited corner clearances. Similarly, larger sites allow for greater flexibility of on-site layout and more compatible arrangement of the access points with respect to the circulation system. Consolidation of establishments using common parking requires fewer driveways and, at the same time, allows for better design of the access points used. Although considerable resistance and constraints remain to implementation of high standards for access points, the direction of trends in both private and commercial development appears to favor the application of more "idealistic" standards.

TRAFFIC OPERATIONS CONSIDERATIONS

Driveway Accidents

A number of studies of driveway accidents have been made, in an attempt to relate accidents to driveway characteristics. The conclusions of such studies have been in rather general terms. For example, high accident rates have generally been associated with frequent access points to commercial establishments. Roadways along which left turns into or out of the driveways are permitted have also had higher accident rates than these with median barriers which restrict access to one direction of the through lanes.

In a study of accident rates in Skokie, Ill., Box (*1*) has reported a positive correlation between uncontrolled driveway width and accident rates. These results, however, were not adequate to establish a precise, quantitative relationship between driveway width and accident rate. Results of other studies have been affected by high degrees of variability and other biases resulting from lack of information on the numbers of various types of driveways, variations in volume, etc. A brief survey of these studies leads one to concur with Box's conclusion that present "abbreviated data-processing tabulation systems provide too coarse a summation to completely establish driveway influences on accidents" (*2*).

On the other hand, it is questionable whether driveway accidents actually constitute the most appropriate criteria for driveway design. Indeed, operational safety is of paramount importance in the design of any roadway element. Furthermore, when the proposed standards represent a significant departure from existing standards, the correlation between driveway design and accident rates provides a more convincing argument in attempting to implement more rigorous controls.

Optimizing access control to the benefit of the road user, however, includes minimizing the interference, delay, and inconvenience associated with poorly designed and located access points. From this standpoint, driveway operation may have become unsatisfactory long before the poor operation is reflected in higher accident rates; therefore, rather than considering accident rates per se, minimizing the potential for conflicts between vehicles using the driveways and those in the through lanes has been the principal consideration in developing this set of recommended guidelines for direct access driveways.

Relation of Driveway to Land Use

The character of traffic and the required level-of-service for the driveway will vary substantially with the type of land use served. For establishments such as supermarkets, Major and Buckley (*3*) have suggested that, with appreciable queueing, drivers become impatient and try to force their way into the traffic stream. For such driveways they suggest 20 sec as the maximum mean delay which drivers are generally willing to tolerate. On the other hand, for drive-in theaters or similar places of assembly where the "all leave at once" conditions apply, drivers are willing to tolerate greater delay.

Other characteristics pertinent to the driveway design include peaking (of both the roadway and the driveway). For example, even where daily volume is low, if this volume occurs during a limited time period, the effects on traffic movement along the roadway may be severe, especially if the driveway peak coincides with the peak flow along the roadway. Peaking and traffic characteristics that can generally be expected for several common land uses are given in Table F-1. Driveway volumes typical for various types of establishments commonly located along major roadways are given in Table F-2.

Because of factors such as peaking, the absolute driveway volume may be a poor indicator of the effects of driveway traffic on the operation of the through lanes. Nevertheless, to reduce the spectrum of driveway-roadway conditions to a manageable set, some classification of driveways by volume appears necessary. Committee 5-E of the Institute of Traffic Engineers has considered a dichotomous classification with a volume of 100 vehicles per hour representing the division between high- and low-volume driveways (*4*).

Outside the range of specific recommendations contained herein are driveways to such major generators as regional shopping centers or large industrial plants. Although the same general considerations discussed hold for access to these developments, such driveways are more properly treated as major intersections.

At the other extreme, residential driveways and farm entrances along local roads or streets need not generally conform to the more stringent standards recommended for higher-volume driveways. Along major roadways such as arterials or high-volume collectors, however, the hazard and interference resulting from even infrequent maneuvers at such driveways should be kept as low as feasible.

Relation Between Direct Access and Roadway Operation

Control of direct access may be viewed at two levels. At the macroscopic level, concern is centered mainly around the frequency and the magnitude of interference resulting to through vehicles from vehicles using driveways. Control at this level deals with the frequency or spacing of access points and the requirements for their operation. At the microscopic level, access control is concerned with specific design elements of access points. These include turning radius, profile, angle, and width.

Along major roadways where the principal concern is the movement of through traffic rather than the provision of direct access, there appears to be little justification for providing more than the minimum number of access points required to accommodate the volume of traffic demanding local access. It has been suggested that it is often the design and the number of access points, not the volume of traffic using them, that pose the greatest threat to the traffic-carrying capacity and safety of the roadway (*5*).

Major and Buckley (*3*) have indicated that, from the standpoint of delay to entering vehicles and the ability of the traffic stream to absorb vehicles exiting from driveways, additional driveways at close spacings provide no additional benefit and may increase traffic hazard. On the

TABLE F-1

DRIVEWAY TRAFFIC CHARACTERISTICS

PROPERTY USE	PEAKING	DRIVEWAY PEAK COINCIDES WITH ROADWAY PEAK	COMMERCIAL VEHICLES: FREQUENCY	COMMERCIAL VEHICLES: DESIGN CONSIDERATIONS
Residential	None	No	None	None
Convenience grocery	Low	Yes	Low	None
Service station	Low	Yes	Low	None
Restaurant	Moderate	Yes	Low	None
Church	High	No	None	None
School	High	Possibly	Low	None
Motel	Moderate	Possibly	Low	None
Small commercial	High	Yes	Low	None
Small industrial	High	Yes	High	Yes
Small public	Moderate	Yes	Low	None
Large commercial	High	Yes	High	Possibly
Large industrial	High	Yes	High	Yes
Large public	High	Yes	Low	None
Small recreational	Moderate	No	Low	None
Large recreational	High	No	Low	None
Neighborhood shopping center	Moderate	Yes	Low	None
Community shopping center	Moderate	Yes	Low	None
Regional shopping center	High	No	Low	None
High-rise apartment	High	Yes	Low	None
Drive-in theater	High	No	Low	None
Supermarket	Moderate	No	Low	None
Truck stop	Moderate	Possibly	High	Yes

TABLE F-2

TYPICAL DRIVEWAY VOLUMES

LAND USE	LAND AREA (1,000 SQ FT)	TWO-WAY VOLUMES (VPH) AM	MIDDAY	PM	EVE.
Drug store	25	—	90	175	175
Market or grocery	35	—	89	179	125
	14	12	50	53	—
	—	—	—	190	158
	42	13	135	98	111
	31	10	74	78	88
Drive-in restaurant	22	0	195	76	78
	—	0	268	130	218
	—	—	194	—	—
	—	0	294	—	—
	30	—	—	—	782
Shopping	32	53	163	213	116
	23	0	136	176	—
	41	20	74	81	96
Motel	—	81	103	78	—
	—	89	142	—	128
Apartments	—	140	—	145	—
Drive-in bank	—	—	360	398	—
	—	—	374	362	—
	—	—	194	—	—
Restaurant	10	—	77	47	67
	18	0	45	76	44
Liquor	10	—	126	173	100

Source Paul C Box and Assocs

other hand, for high-volume traffic generators, driveways spaced at distances of greater than 1.5 times the acceleration distance of the normal vehicle will reduce delay to vehicles entering the traffic stream and will improve the traffic absorption characteristics of the stream.

The design of individual access points can minimize the severity of disruptions to the through traffic stream largely by: (1) preventing encroachment of turning vehicles on adjacent through traffic lanes, (2) providing sufficient spacing between driveways to prevent excessive interference with traffic from adjacent driveways, (3) discouraging unparking by backing into the street, and (4) promoting relatively high-speed ingress movements. Liberal geometric designs, which permit vehicles to enter the traffic stream from the driveway at relatively high speeds, may permit drivers to accept short gaps and further enhance operation by avoiding excessive delay. Reduced delays, in turn, diminish the tendency for impatient drivers to force their way into the traffic stream.

At acceptable levels of direct access for major roadways, the turbulence in the traffic stream caused by the driveway entrance maneuver * is probably more critical than the exit maneuver, because the vehicle waiting to exit from the driveway has the option of waiting for an acceptable gap. This discussion, therefore, is concerned principally with the driveway entrance maneuver. To quantify the effect of driveway entrance speed † on the interference incurred by vehicles in the through lanes, computer simulation was used. Time-space data describing driveway entrance maneuvers and the speed adjustments of following vehicles were obtained from time-lapse aerial photographs of freeway frontage roads and were used to test the validity of the simulation model (see "Supplementary Information" in this appendix).

For an operating speed of 45 mph (typical of operating speeds along major urban roadways), curves representing the interference incurred at varying driveway speeds for different volumes of through traffic are shown in Figure F-1. The magnitude of the interference is represented in this discussion by the delay incurred by vehicles in the through lanes that are forced to reduce speed because of a turning vehicle downstream. In Figure F-1, the delay per driveway entrance maneuver refers to the ratio of the total delay incurred by through vehicles to the number of turning vehicles.

As the driveway entrance speed is increased from 2 to 10 mph, the interference falls off rapidly. For the increase from 10 to 15 mph some additional reduction is realized, but, at higher entrance speeds, the additional change is small. Because driveways that will accommodate entering speeds of 10 to 15 mph can be provided by using liberal return radii and driveway width, the cost of providing this type of operation for most driveways along major

* The driveway entrance maneuver refers to the movement of a vehicle from the through traffic stream onto a driveway to property abutting the roadway The exit maneuver is the movement from the abutting property into the traffic stream

† Driveway entrance speed is taken as the component of the speed of the turning vehicle parallel to the centerline of the roadway, at the instant the rear of the vehicle clears the edge of the through lane

roadways is not excessive compared to the cost of providing for only a minimal level of operation. It would, therefore, appear that for any roadway where interference from driveway maneuvers may lead to significant degradation of level-of-service or capacity, driveway entrance speeds below 10 to 15 mph should be avoided.

For rural roadways and for some urban roadways with higher operating speeds, even these entrance speeds may be too low. Solomon (*6*) has shown a strong correlation between the involvement rate for two-car, rear-end collisions and speed differences (Fig. F-2) for rural highways. His findings indicate that, at least from the standpoint of minimizing rear-end collisions, a differential of less than 10 mph between through speed and driveway speed would be desirable. Although driveways designed to accommodate entrance maneuvers from high-speed roadways with this speed differential are not generally practical, it is suggested that, where substantial volumes of access traffic are to be accommodated, the driveway be designed to permit operation at the highest speed practical.

In the ultimate selection of the operating conditions to be provided at a particular driveway, careful attention also should be given to the constraints imposed by individual sites and geographical areas. Especially in more densely developed areas, the maximum tolerable driveway speed may be restricted by hazard to pedestrians, hazard to small children or pets (in the case of residential driveways), site distance limitations, or distance available for speed changes. Because weather conditions vary widely, the need to provide for heavy rainfall or icy sidewalks in the driveway design will also depend on the locality.

Efficient driveway operation further requires careful integration of the driveway with the site layout. The site layout should include: (1) sufficient on-site circulation facilities to discourage the use of the through roadway lanes by circulating vehicles, (2) adequate delineation of the intended circulation paths; and (3) measures to discourage haphazard parking which may block or restrict driveway maneuvers. The design and location of on-site service units (drive-in bank windows, mail boxes, etc.) may also be critical to the operation of the through lanes, if substantial queueing is likely.

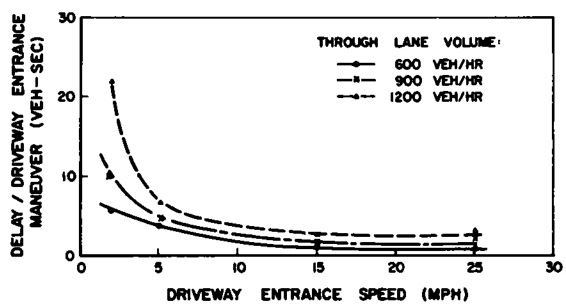


Figure F-1. Relationship between delay and driveway entrance speed.

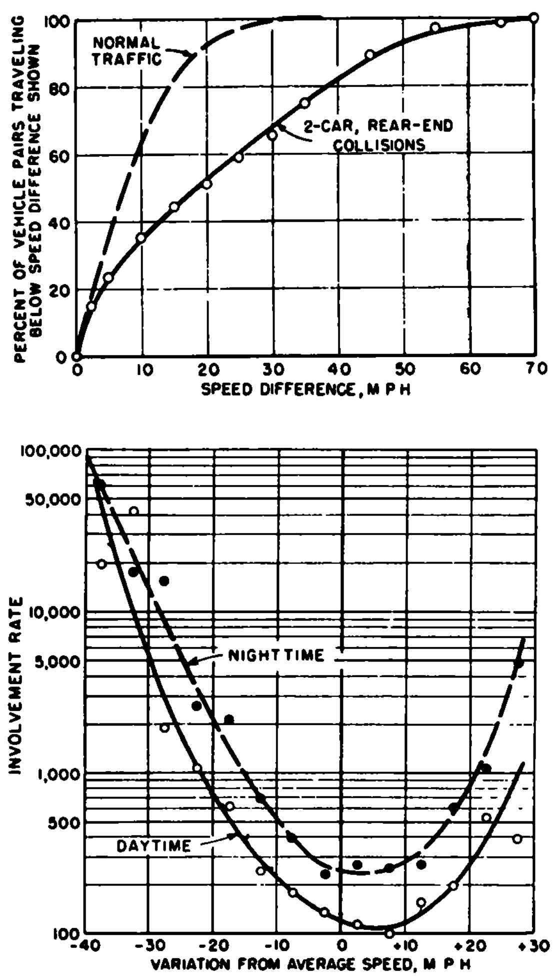


Figure F2. Effect of speed differential on incidence of two-car, rear-end collisions. Source: Solomon (6).

Driveway Design Criteria

Based on this speed-interference relationship and the assumptions regarding driveway characteristics for various classes of roadways as discussed in the following, recommended driveway design criteria are given in Table F-3. It should be recognized, however, that these recommendations are rather general, and that where roadway and/or driveway characteristics differ significantly, appropriate adjustments should be made to the design criteria.

Driveways on Arterial Roadways

For arterial roadways, where the principal concern is the safe and expeditious movement of through traffic, driveways should generally be few and designed so that their interference to through traffic is minimal. Abutting property served by direct access from an arterial will probably include major traffic generators such as shopping centers or industrial sites. A high level-of-service for vehicles using such driveways is most desirable.

Although a high frequency of interference at low-volume driveways along arterials is not likely, high speeds for ingress or egress movements are desirable. Along arterials, slow turning maneuvers at such driveways are hazardous.

TABLE F-3

DRIVEWAY DESIGN CRITERIA

ROADWAY CLASS	TYPE OF DRIVEWAY	VEHICLE	MINIMUM SPEED AT WHICH VEHICLE LEAVES THROUGH LANES (MPH) [a]	IS ENCROACHMENT ON THROUGH ROADWAY LANES BY VEHICLES USING THE DRIVEWAY PERMITTED?	IS ENCROACHMENT ON ADJACENT DRIVEWAY LANES BY VEHICLES USING THE DRIVEWAY PERMITTED?
Arterial	High volume	Passenger	15	No	No
		Commercial	5–10	No	Yes
	Low volume	Passenger	10	No	Yes
		Commercial	5–10	Yes	Yes
Collector	High volume	Passenger	15	No	No
		Commercial	5–10	Yes	Yes
	Low volume	Passenger	10	No	Yes
		Commercial	5	Yes	Yes
Local	High volume	Passenger	10	Yes	No
		Commercial	5	Yes	Yes
	Low volume	Passenger	5	Yes	Yes

[a] Recommended speeds for driveways along arterials are based on an assumed through speed of 45 mph Where the average speed is substantially higher (such as for rural roadways), an increase in the driveway entrance speed is suggested.

Furthermore, where such driveways are frequent, the aggregate effect of the interference may be particularly hazardous.

On arterial roadways, the encroachment of turning vehicles on adjacent lanes of the through roadway is highly undesirable. The extent to which encroachment on the adjacent driveway lane (i.e., the lane intended for traffic moving in the opposite direction) can be tolerated is a function of the volume of traffic using the driveway.

Driveways on Collector Roadways

Collector roadways accommodate substantial volumes of local as well as through traffic. This implies a lower level-of-service for through traffic with more convenient access to abutting property. Unparking by backing into the street is undesirable, as is encroachment on adjacent through lanes.

Driveways on Local Roadways

For local roadways, speeds are generally low and service to through traffic is of little concern. In residential areas, the safety of small children and pets is of special importance. Encroachment on adjacent lanes and unparking by backing into the street will not generally be detrimental to the roadway operation, although, for safer operation, designs that discourage backing are preferred.

Urban versus Rural Conditions

Significant differences exist between urban and rural conditions. In rural areas, speeds generally are higher, ditches are open, roadways are uncurbed, and pedestrian volumes are insignificant. Although level-of-service and capacity loss, as well as safety, are important to the location and design of urban driveways, safety is relatively more important in the design of rural highways. Higher speeds on rural highways require longer sight distances and make backing into the roadway more hazardous. Because of the high speeds, hazards associated with very slow entry and exit maneuvers are also generally greater for rural highways, so that even for very low volume driveways it is desirable to provide for entry and exit from the through lanes at relatively high speed.

Sight Distance

Of vital concern to the safe and efficient operation of driveways, as well as the through lanes, is the provision of adequate sight distance. The hazard associated with restricted visibility at direct access driveways is shown by the driveway in Figure F-3.

In general terms, desirable locations for access points, especially in rural areas, are shown in Figure F-4. This figure, taken directly from the driveway standards manuals used by several of the state highway departments, considers only the relationship between the access point and the terrain, and provides no specific, quantified guides for the location of access points.

To provide adequate sight distances, the location of direct access driveways must also allow for the location or setback of buildings and other fixtures, as well as any potential obstructions near the roadway, such as shrubbery, signs, parked vehicles, and driveways. The sight triangle analysis discussed in the AASHO *Policy* (*7*) can be applied to the location of direct access driveways to provide for adequate sight distances. Case III ("Enabling Stopped Vehicles to Cross a Major Highway") is similar to situations encountered at driveways.

Values recommended in the *Policy* (*7*), however, are not directly applicable for driveways. As presented, Case III assumes that vehicles simply cross the through lanes,

Figure F-3. Restricted sight distance at access point.

rather than turn into the traffic stream. At driveways the latter maneuver is the norm. Because of the additional time required for the driveway vehicle to accelerate to the running speed of the roadway, a longer gap, and hence a greater sight distance, is required for the turning maneuver.

Adjustments made to apply the sight distance recommendations to driveways are described in "Supplementary Information" in this appendix. Recommended values are shown in Figure F-5.

Referring to Figure F-5, for a given horizontal offset of the driver's eye from the road, the coordinates, *a* and *b*, of any point along the limit of the sight triangle can be calculated from simple geometry. AASHO *Policy* specifies that for stop-controlled intersections the sight "distance should be measured from height of eye of 3.75 ft to top of object 4.5 ft above the pavement" (*7*). These values are also applicable for driveways.

In applying these recommendations to driveway location, the influence of several other factors should also be considered. Where the driveway slopes downward away from the roadway, objects within the sight triangle must be reduced in height to allow for the reduced level of the driver's eye. In some cases the slope of the driveway profile may even be controlled by the sight distance.

Where the downward slope is severe, an increase in the sight distance should also be provided to allow for the reduced acceleration capabilities of vehicles entering the traffic stream. Likewise, if the driveway is to accommodate more than an occasional truck, similar adjustments should be made to allow for the different acceleration and visibility characteristics of such vehicles.

The effect of driveway profile and sight distance may also influence driveway operation in quite another way. Unless the driveway surface is readily visible to the driver ap-

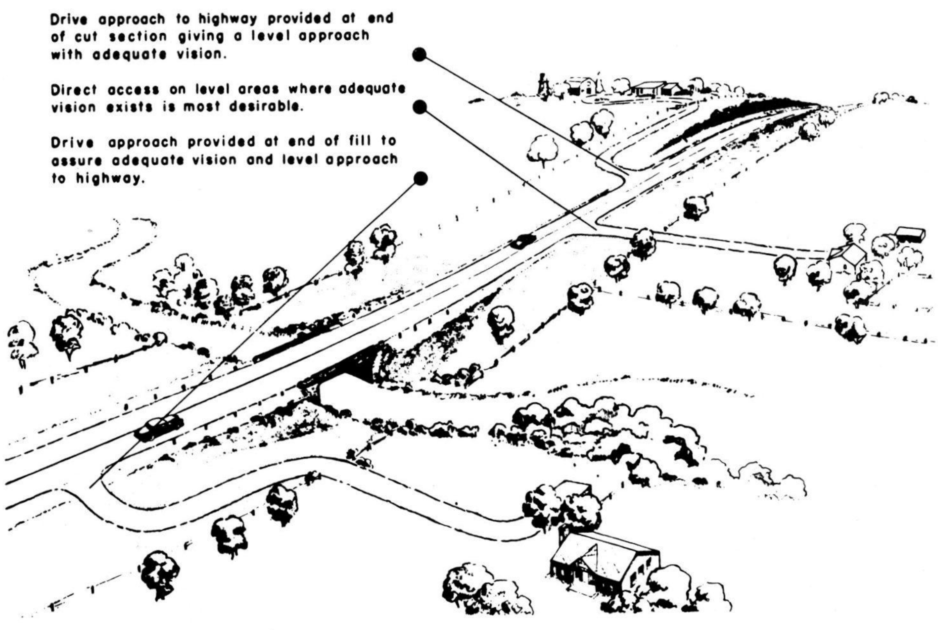
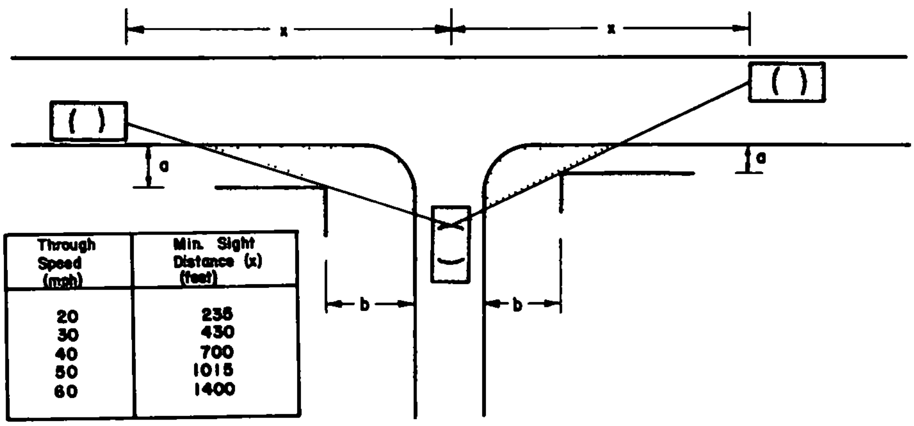


Figure F-4. Desirable locations of driveways. Source: Montana State Highway Commission, Standard Approaches for Montana Highways.



Through Speed (mph)	Min. Sight Distance (x) (feet)
20	235
30	430
40	700
50	1015
60	1400

Figure F-5. Required downstream sight distances at driveways.

proaching in the through lanes, he may enter the driveway at speeds lower than otherwise desirable, causing excessive interference to the through traffic.

Driveway Spacing and Corner Clearance

Several factors should be considered with regard to the minimum spacing between adjacent driveways or between driveways and intersections. A detailed discussion is included in "Supplementary Information." Driveways with substantial volumes should not open into the roadway within the sight triangle of an adjacent driveway, although some potential visibility restriction for very low-volume driveways can be tolerated. Spacings should be sufficient so that such vehicles can enter the stream simultaneously without danger of collision or the need for extreme evasive maneuvers.

For corner driveways, vehicles may enter the through lanes at relatively high turning speeds from the intersecting street, if traffic on the intersecting roadway is not required to stop at the intersection. Greater clearance than that between adjacent driveways is thus required, so that vehicles can enter the through lanes at the intersection and at the driveway simultaneously without endangering each other.

Another problem common at near corner locations * is the blocking of the driveway by vehicles queued at the intersection. Vehicles exiting from the driveway into the main lanes will be delayed if the queue extends beyond the driveway opening. For two-way roadways where access across the median is permitted, queues behind vehicles waiting to enter the driveway may even block the intersection.

Left turns at the intersection by vehicles exiting at near corner driveways or entering at far corner driveways require sufficient distance for the vehicles to weave to the lane from which the turn is being made. With inadequate clearance, the driveway may act as the fifth leg of the intersection, or left-turning vehicles may partially block the lane adjacent to the one from which the turn is being made. Even where left turns are not important, a clearance of at least 35 ft is suggested to provide enough distance for the exiting vehicle to "straighten up" before reaching the intersection.

Recommended corner clearances and driveway spacing are shown in Figure F-6. Assumptions and data on which these values are based are given in "Supplementary Information." In recognition of the differences in speeds, volumes, and level-of-service requirements characteristic of the various roadway classes, separate values are suggested for different classes.

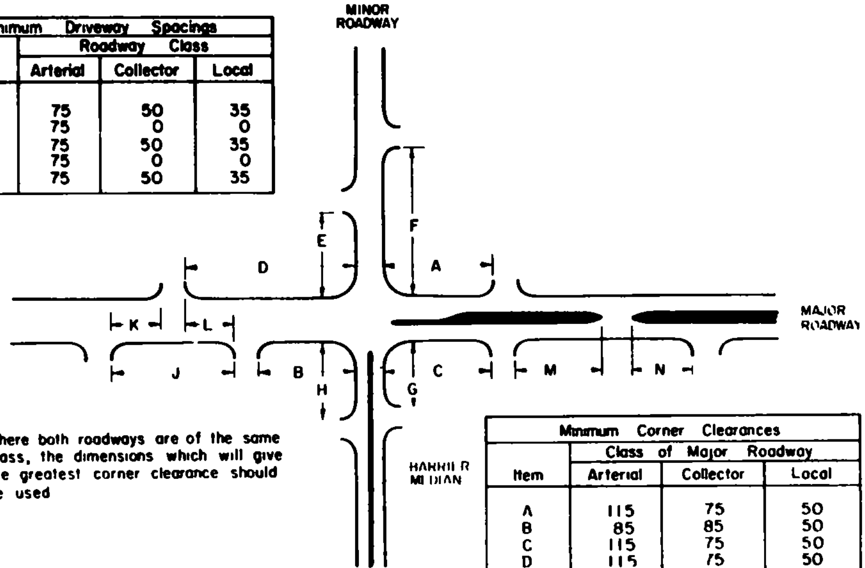
With respect to rural versus urban conditions, the principal factors that might be expected to influence driveway spacing requirements are the generally lower volumes and higher speeds for rural conditions. With lower volumes, queueing will be less important, but the higher speeds require greater sight distances. Recommendations shown in Figure F-6 do not consider the limitations imposed on driveway spacing by sight distance requirements; therefore, designs for specific conditions should consider recommendations shown in Figures F-5 and F-6.

Recommendations shown in Figure F-6 assume a 30-mph operating speed. For a moderate increase in speed, such maneuvers can still be accommodated with the same driveway spacing, although the degree of interference probably will be higher. For rural or other high-speed roadways, however, spacings on the order of two times as great as those shown would be desirable.

It is to be emphasized that these recommendations do not apply to the degree of access in terms of frequency of access points (i.e., allowable number of driveways per mile). Where two or more driveways are provided within this specified distance, the minimum values suggested in Figure F-6 are the separations needed to provide for safe and efficient operation of the individual driveways. Recommendations pertaining to the degree of access appropriate for specific roadway classes are included in Chapter Three of this report.

* For driveways located in close proximity to an intersection, the term "near corner driveway" refers to the driveway upstream from the intersection; "far corner driveway" refers to the driveway downstream.

Minimum Driveway Spacings			
	Roadway Class		
Item	Arterial	Collector	Local
J	75	50	35
K	75	0	0
L	75	50	35
M	75	0	0
N	75	50	35



Note Where both roadways are of the same class, the dimensions which will give the greatest corner clearance should be used

Minimum Corner Clearances			
	Class of Major Roadway		
Item	Arterial	Collector	Local
A	115	75	50
B	85	85	50
C	115	75	50
D	115	75	50
E	230	115	50
F	230	175	50
G	50	50	50
H	230	175	50

Figure F-6. Minimum corner clearances and driveway spacings for urban conditions.

DRIVEWAY DESIGN ELEMENTS

Horizontal Alignment

Vehicle Turning Radii and Driveway Configuration

As the damage to the adjacent unpaved areas in Figure F-7 shows, current driveway designs are frequently too restrictive to permit ingress and egress within the geometric bounds of the driveway at speeds acceptable to drivers and which are compatible with the high level-of-service desired for major roadways. The larger turning radii required for higher speed maneuvers can be accommodated by increasing the return radius, driveway angle, and/or driveway width. As an alternative to an increasingly large return radius, a compound curve or taper may be used. It is emphasized, however, that these elements are not independent of each other, but that their combined effects must be considered.

For a particular establishment, the driveway configuration most appropriate will depend largely on the type of land use served, on the available frontage, and on the volume and character of both the through traffic and traffic using the driveway. With the high speeds characteristic of rural highways or high-type urban arterials, the high speed desired for movement into or out of the through lanes may be provided for with a larger return radius, acceleration-deceleration lanes, or paved shoulders.

In urban areas, driveway volumes frequently are higher, speeds on the through lanes are lower, and available frontage is more limited. Under such conditions, provision for larger return radii instead of acceleration-deceleration lanes may be more desirable, because the speed differential is not as critical and this type of design may require less frontage.

For driveway speeds much in excess of 15 mph, angle driveways or separate turning roadways are desirable. For "T" driveways, the width of opening required for movements at higher speeds may be great enough so that channelization is desirable (Fig. F-8).

Angle driveways are most appropriate for one-way driveways where access is provided to or from the adjacent lane only. Where left turns across opposing traffic lanes are permitted, the lower speed required to execute acute-angle turns at angle driveways can be expected to increase the interference and the hazard associated with greater exposure to conflicting traffic. Where access to/from both directions of through traffic is provided, some form of the "T" driveway is more desirable.

Driveway Width

Driveway width is also constrained by factors other than the minimum width required at the approach to accommodate the turning maneuver. Excessive width, especially open frontage, will offer poor pedestrian protection and is likely to promote haphazard parking and circulation, unparking by backing into the street, and excessive friction to through traffic resulting from vehicles parking too close to the edge of the roadway. Figures F-9a and F-9b show the severely restricted sight distance associated with unrestricted parking and open frontage along a small shopping area. Box (*1*), in his study of driveway accidents, has reported accident rates on the order of four times as great for driveways with uncontrolled width as for those with width restrictions.

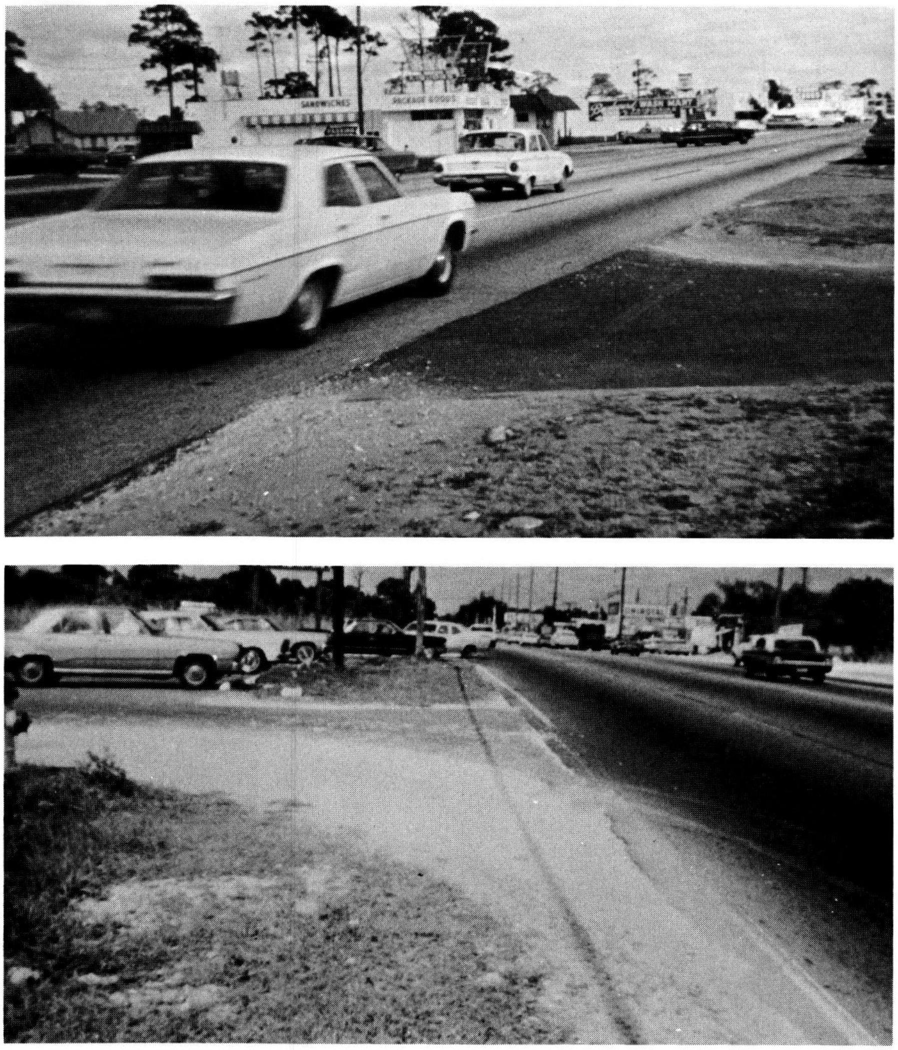


Figure F-7. Encroachment on unpaved area adjacent to driveway approach. Single driveway to an apartment development along a major arterial (upper). Double driveways to a restaurant along a major arterial (lower).

In contrast, for the service station-grocery store shown in Figure F-9c, the available parking area is ample and the frequency of simultaneous ingress and egress movements is low enough that the open frontage does not result in excessive conflicts. The paved roadway shoulders, together with the generous setback and wide paved frontage, permit high-speed ingress and egress movements with a minimum of interference to traffic in the through lanes. Establishments such as this are not the general rule, however, and new developments with the potential for generating even moderate volumes of traffic should not rely on this type of operation.

Except in very general terms, the specification of a maximum driveway width is difficult. The opening should be restrictive enough to discourage parallel entries into the traffic stream, haphazard parking or circulation, and other maneuvers which lead to visibility restrictions or conflicts

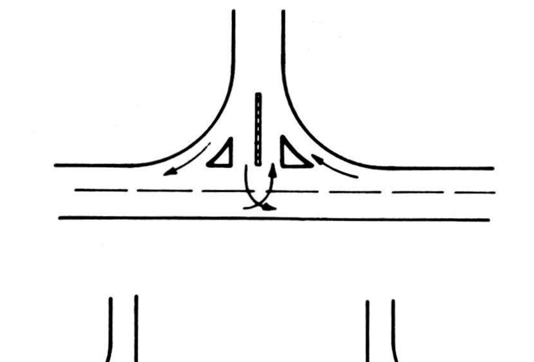


Figure F-8. Suggested channelization of "T" driveways to permit high turning speeds.

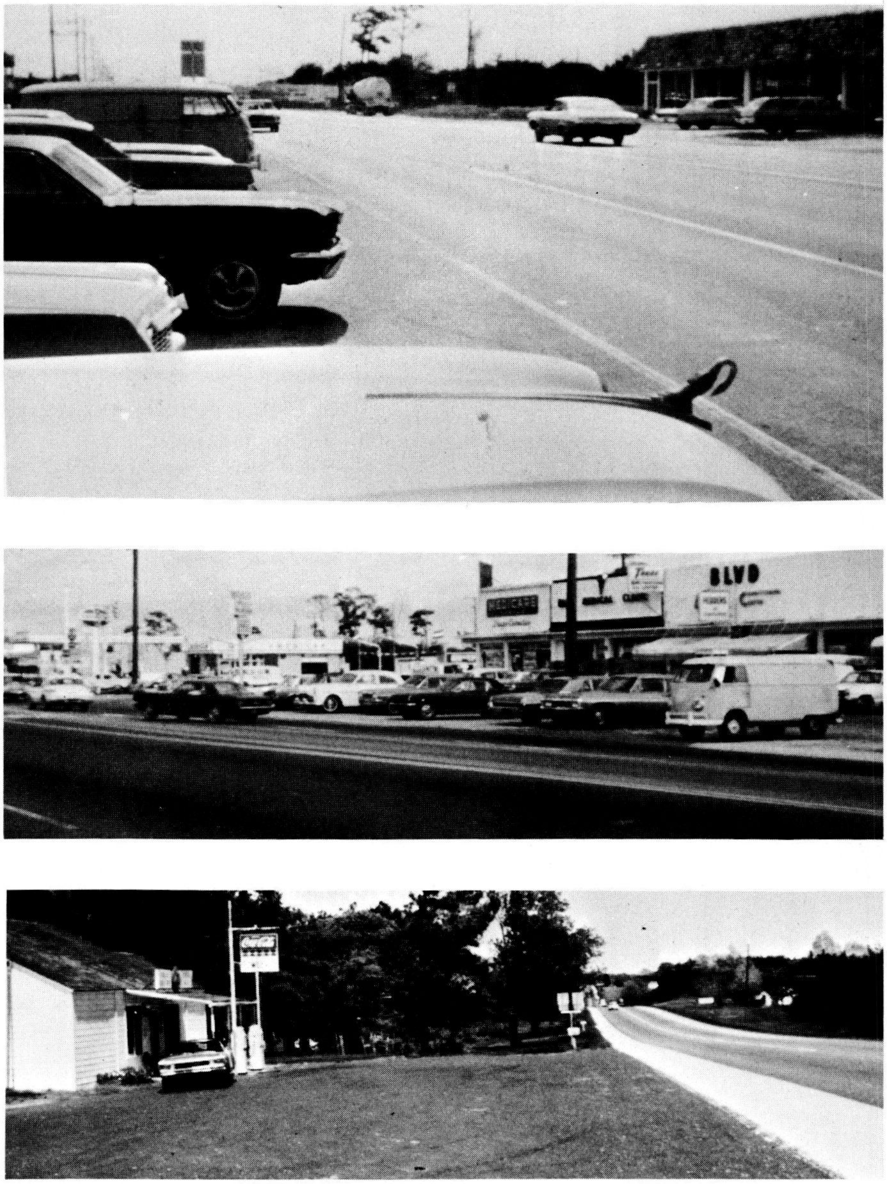


Figure F-9. Examples of open frontage along arterial highways.

between vehicles using the driveway. Although the maximum width that can be imposed for any specific driveway will depend on the type of land use and traffic served and geometric features of the driveway, there is little point in increasing the width beyond that necessary to accommodate maneuvers at the design speeds.

The practical minimum driveway width is constrained by requirements for convenient maneuvering of the vehicle on the site. For residential driveways, widths greater than 12 ft will provide adequate space for maneuvering, as well as paved walkway for passengers entering or leaving the vehicle. Figure F-10 is an example of a poor residential drive.

For higher volumes and higher speeds typical of commercial driveways, greater maneuvering space will be required. Minimum widths of at least 15 to 20 ft are suggested for one-way driveways, and at least 30 ft for two-way driveways.

For two-way driveways, passing of disabled vehicles will not generally be a problem; however, for one-way driveways, some provision for passing disabled vehicles may be desirable. Passing can be provided for either by a wider driveway or by using a mountable curb (if curbed) together with stabilized or paved shoulders along the driveway.

On the basis of turning requirements for the various design vehicles, combinations of width, return radii, offset or taper, and driveway angle are summarized in Tables F-4 and F-5 and Figures F-11 and F-12. These values allow for different design vehicles and speeds. Although values tabulated apply only to those driveway traffic conditions most common, geometric designs that will accommodate other mixes of design vehicles can similarly be obtained (see "Supplementary Information").

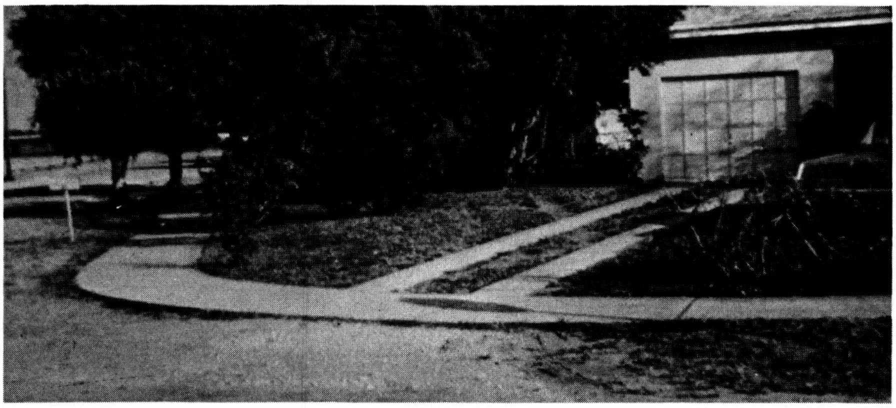


Figure F-10. Example of a poor residential driveway. This driveway is too narrow to provide a convenient walkway for persons entering or leaving the vehicle. Because the driveway opens into the intersection between a local and a collector street, to exit from the driveway it is necessary to back into the street. The hazard of this maneuver is compounded by visibility restrictions imposed by the shrubbery.

TABLE F-4

MINIMUM LANE WIDTHS FOR "T" DRIVEWAYS

Design Condition		Passenger Vehicle @ 0 + MPH					Passenger Vehicle @ 15 MPH					SU Vehicle @ 0 + MPH		WB-50 Vehicle @ 0 + MPH	
Offset (feet)		2	4	6	10	14	2	4	6	10	14	2	14	2	14
Return Radius (feet)	5	23	17	14	11	10	43	34	30	24	19	52	22	-	32
	10	20	13	12	10	10	39	31	26	20	16	47	19	50	29
	15	14	10	10	10	10	38	26	22	17	15	39	17	45	27
	20	10	10	10	10	10	29	22	19	15	15	35	15	40	25
	25	10	10	10	10	10	25	18	15	15	15	29	14	36	23
	30	10	10	10	10	10	20	15	15	15	15	25	13	31	20
	40	10	10	10	10	10	15	15	15	15	15	16	15	24	18

Design vehicles are the standard AASHO design vehicles.

Minimum widths shown will permit the designated vehicle to enter or leave the driveway at the indicated speed without encroaching on either the adjacent roadway or driveway lanes.

Dimensions shown here are illustrated in Figure F-11.

To apply lane widths to two-lane driveways, a minimum width of 30 feet should be used. If no encroachment on either driveway lane is to be permitted, the width is the sum of the lane widths required for the design entrance and exit speeds. If encroachment on the adjacent driveway lane is permitted, the width is the lane width required for the entrance turn except that the width should not be less than 30 feet.

TABLE F-5

MINIMUM LANE WIDTHS FOR ANGLE DRIVEWAYS

Driveway Angle (degrees)		30			45			60		
Offset (feet)		2	6	14	2	6	14	2	6	14
Return Radius (feet)	5	15	15	15	22	15	15	24	16	15
	10	15	15	15	20	15	15	22	15	15
	15	15	15	15	19	15	15	21	15	15
	20	15	15	15	17	15	15	18	15	15
	25	15	15	15	160	15	15	18	15	15

Minimum widths shown here will permit the AASHO passenger vehicle to enter the driveway at speeds up to 15 mph without encroaching on the adjacent roadway lane.

These dimensions are indicated in Figure F-12.

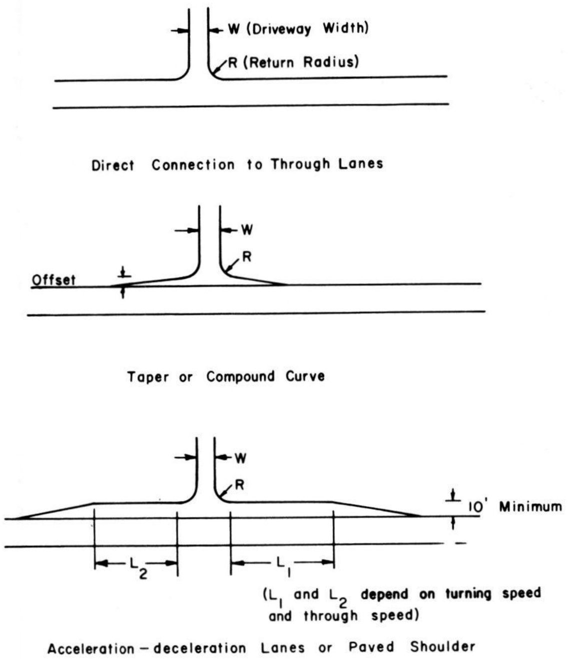


Figure F-11. Treatment of "T" driveways.

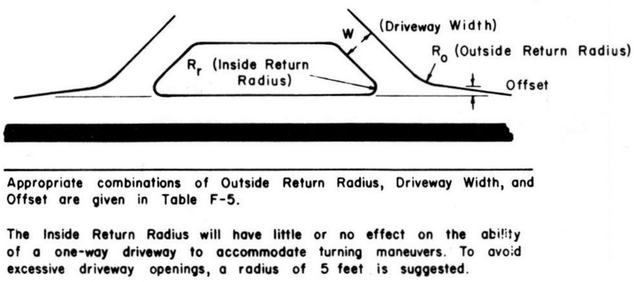


Figure F-12. Treatment of angle driveways.

Driveway Profile

Driver-Vehicle Considerations

To promote ingress and egress movements at the desired speeds, sufficient clearance between the vehicle underbody and the driveway surface must be provided, and the driveway surface must be relatively smooth. Clearance data summarized by McConnell (*8*) are reproduced in "Supplementary Information." Although these data are more than 10 years old, there has been no appreciable change in the clearance characteristics of vehicles during this period. Although the profiles for many driveways satisfy neither requirement (Fig. F-13), driveways smooth enough to permit ingress or egress at the desired speed usually will satisfy the clearance requirements.

For a given level-of-service, there exists an infinity of combinations of slopes, tangent lengths, and vertical curves that will provide a satisfactory profile. Hence, it is virtually impossible to specify a set of standards for maximum and minimum slopes, tangent lengths, and vertical curves that will include realistic profile designs; however, some generalizations concerning the factors affecting driveway smoothness are in order.

All other things being equal, the driveway profile with the fewest and least-severe grade changes or profile discontinuities is preferred. Where severe topography requires extreme grade changes, their undesirable effects can be largely offset by connecting the tangents with vertical curves. The cross section of fixtures such as gutters which must cross the driveway can be adjusted to conform with the slope of the roadway and the profile of the driveway.

Along roadways where mountable curbs are used, driveways are frequently constructed to the back of the curb. Except for driveways such as those to residences along local streets, the discontinuity resulting where such curbs are left intact across the driveway will be detrimental to the driveway operation; therefore, even where mountable curbs are used, the curb should be removed as part of the driveway construction.

Ideally, standards for driveway profile would be in terms of performance or smoothness, but sufficient data relating driveway profile to smoothness and acceptable vehicle speed are not available to permit application of this type of standard to driveway design. Thus, the suggestions shown in Figure F-14 are intended to represent only a set of driveway profiles that will be satisfactory.

Where differences in grade greater than the recommended value for *D* must be accommodated, a vertical curve to connect the tangents will enhance the driveway operation. The necessary length of the vertical curve will depend on the magnitude of the grade change. Although data concerning the desired length of curve for such cases are not readily available, a length of at least 10 ft (approximately

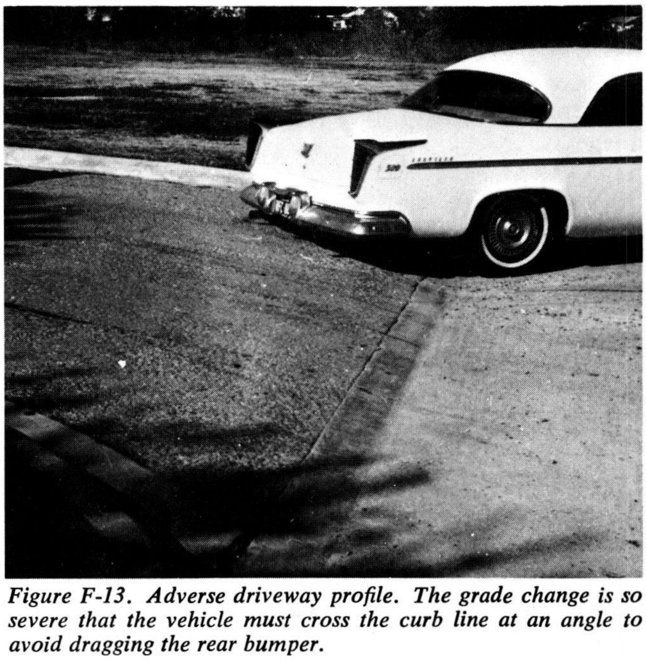
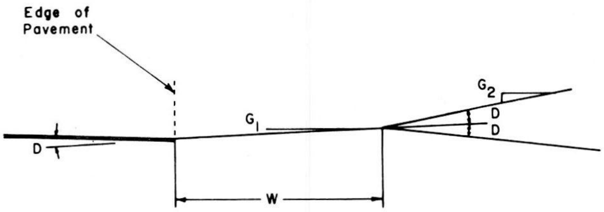


Figure F-13. Adverse driveway profile. The grade change is so severe that the vehicle must cross the curb line at an angle to avoid dragging the rear bumper.



Suggested Maximum Grade Change (D)

	Desirable	Maximum
High Volume Driveway	0%	± 3%
Low Volume Driveway on Arterial or Collector Streets	± 3%	± 6%
Low Volume Driveway on Local Streets	± 6%	Controlled by Vehicle Clearance

Maximum absolute grades, G_1 and G_2, must be compatible with the requirements for drainage and sight distance of the particular site.

Figure F-14. Suggested driveway profile.

the wheelbase of a passenger vehicle) should be satisfactory for most cases. With very sharp grade changes, of course, the vehicle underbody clearance should be checked.

Similarly, the desired tangent length, *W*, will depend on other elements of both the profile and the horizontal layout. Here also, a tangent length at least as great as the wheelbase of the design vehicle will, in most cases, be desirable for driveways with moderate-to-high volumes.

Pedestrians

Although the values suggested assume driveway design to be optimized with respect to serving the road user, in some cases the vehicular traffic must be subordinated to other considerations. In areas of high pedestrian activity, such as the CBD, lower driveway speeds and smoother or continuous sidewalk profiles are desirable. Where icing of the sidewalk is common, driveway profiles which include warped sidewalks should be avoided. In residential areas where local policy permits the use of the sidewalk for such activities as roller skating or bicycle riding, discontinuities of the sidewalk at driveways will also be undersirable.

Too frequently, however, the driveway profile is subordinated to the sidewalk without sufficient justification. A typical example is shown in Figure F-15, where the back edge of the warped sidewalk is continued across the driveway. Here a more satisfactory profile for both the driveway and the sidewalk would have been obtained if the back edge had been depressed at least to the level of the pavement in the parking area.

Drainage

Drainage requirements of both the roadway and the abutting property may have a marked effect on the driveway profile. Where the adjacent property slopes downward away from the roadway and drainage along the roadway is provided via curb and gutter, a bump in the driveway may be required to prevent the driveway from channeling the runoff onto the abutting property.

The gutter across the driveway shown in Figure F-16 provides only limited channelization along the roadway. Furthermore, the driveway conforms to the existing terrain and, as a result, a sharp discontinuity exists at the back of the gutter. A more satisfactory treatment would have included continuing the profile upward from the driveway to whatever level necessary to prevent runoff and then providing the transition downward by means of a vertical curve.

Shallow, dished gutters of the type shown in Figure F-17 are commonly used along the edge of the traffic lanes where the abutting area is paved. Gutters of this type have only a limited capacity for drainage, yet impose a discontinuity in the profiles of driveways connecting to the roadway. Where such gutters are required to provide a smooth flow line for the drainage channel, the cross section can be adjusted to match the cross section of the pavement and thus provide a smooth driveway profile.

Where uncurbed roadways are drained by shallow ditches

Figure F-15. Adverse profile due to poor sidewalk treatment.

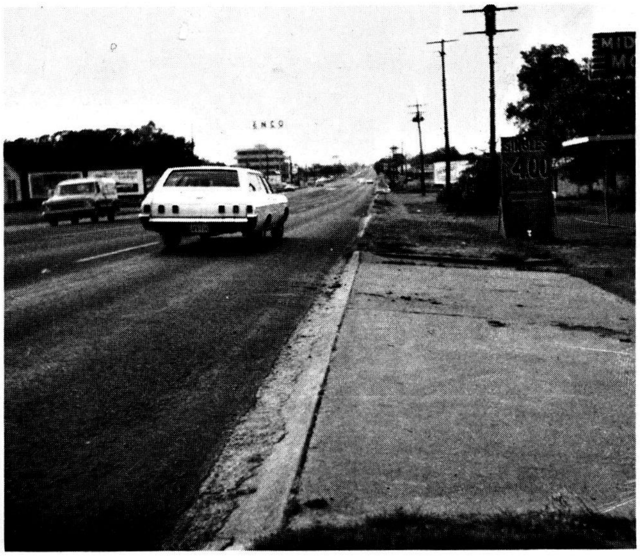


Figure F-16. Driveway to property below the roadway elevation.

Figure F-17. Discontinuities of driveway profile across gutter along arterial roadway.

adjacent to the shoulder, driveways are frequently constructed so that the driveway surface passes through the flow line of the ditch (Fig. F-18). If severe, grades for this type of design can substantially affect the driveway operating speed. In addition, water tends to pond on the driveway, further detracting from the efficiency and safety of the driveway operation. Use of a culvert to permit a flatter driveway profile may be preferred.

Construction and Maintenance

Driveway Surface

Unpaved and poorly maintained driveways are detrimental to movements in the through lanes of major roadways because of the slow driveway speeds caused by potholes or other surface irregularities (Fig. F-19). Other undesirable characteristics of non-permanent driveway surfacing include the difficulty in maintaining desired surface profile, increased maintenance requirements, reduced skid resistance, and possible damage to the pavement of through lanes where potholes are allowed to develop at the edge of the pavement.

To promote satisfactory ingress and egress movements, commercial and other moderate to high-volume driveways should be paved. The approach area of residential, farm, or other such very low-volume driveways along major roadways also should be paved, although, if well maintained, unpaved surfaces for such driveways along local roadways may be satisfactory.

Curb Cuts

Along curbed streets or highways, curb openings at driveways are commonly provided by means of depressed curbs. Where such openings conform to the recommended standards for driveway profiles and are of the appropriate length and location to satisfy the access requirements of the property served, the use of depressed curb openings generally is satisfactory.

Depressed openings are, at times, provided at arbitrary locations along undeveloped property. Such openings ignore the future access needs of the property, in terms of both design and location, and promote poor driveway operation. Likewise, where land use changes, poor driveway operation is likely to result if proper attention is not given

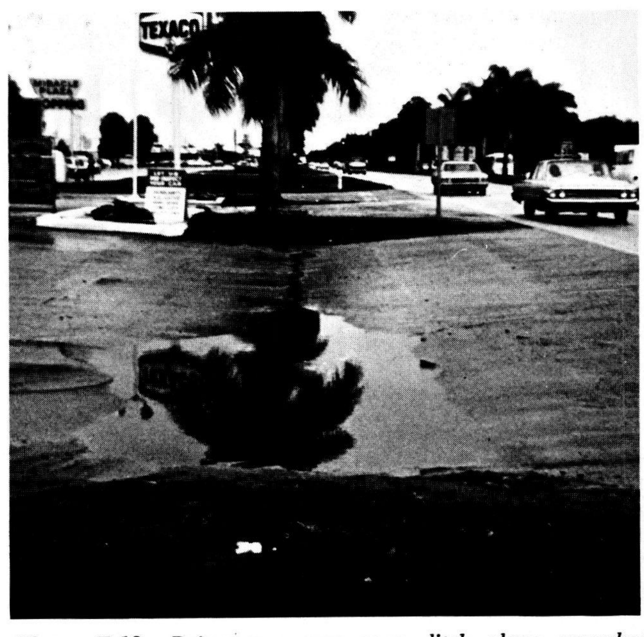


Figure F-18. Driveway across open ditch along uncurbed roadway.

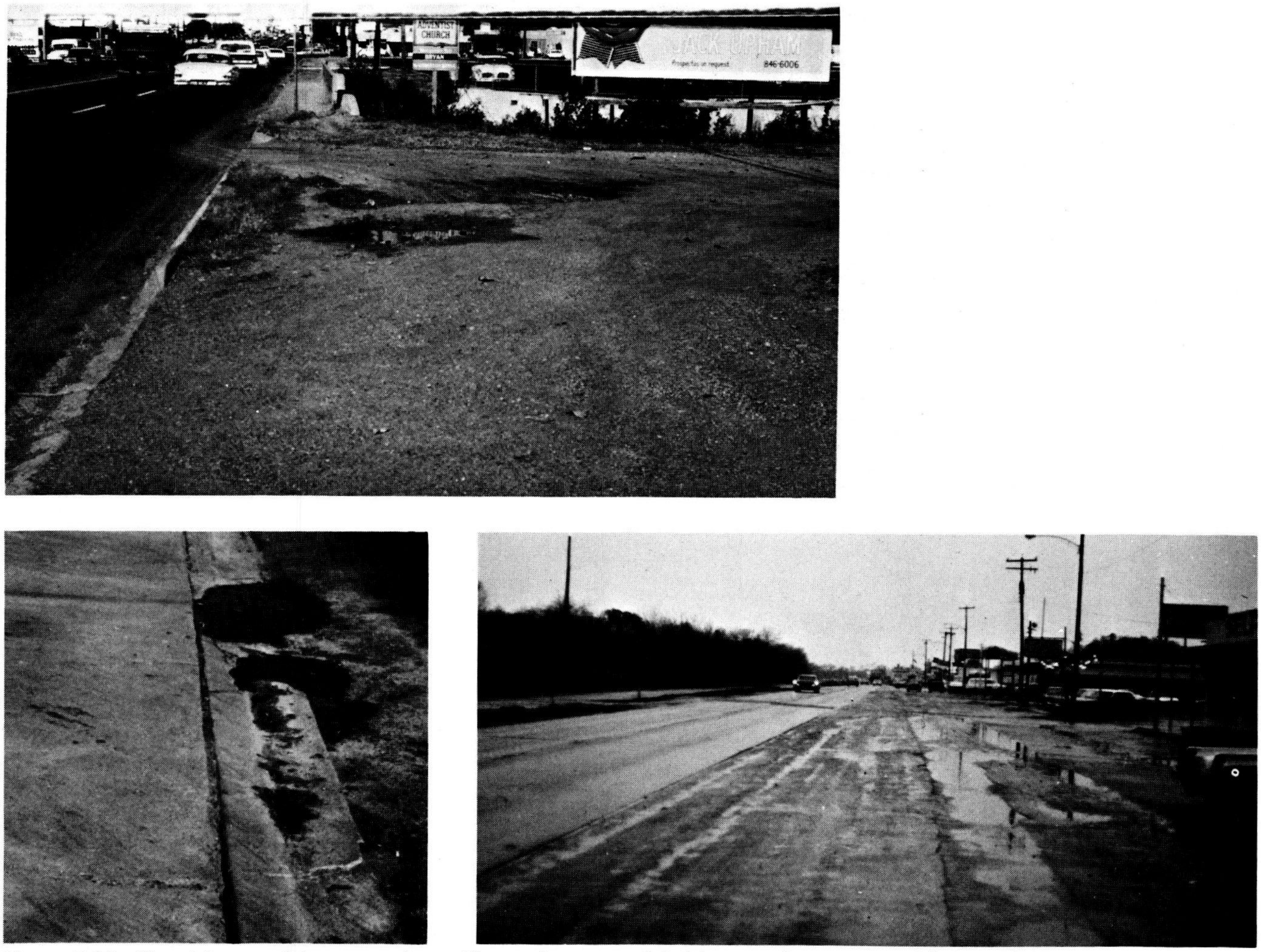


Figure F-19. Unsatisfactory driveway surfaces. Unpaved commercial driveway along an arterial (upper). Poor maintenance of commercial driveways (lower).

to satisfying the access needs of the property as it is redeveloped.

Where depressed curb openings are not provided, it is necessary to completely remove and reconstruct the existing curb and gutter in conformance with the recommended standards for the driveway profile. Simply paving to the back of the curb (in the case of mountable curbs) is not satisfactory. As shown in Figure F-20, removing only the raised portion of the curb and paving over the broken section is also undesirable, because this will result in a surface that is highly susceptible to spalling or ravelling. The recommended procedure for making curb cuts is shown in Figure F-21.

SUPPLEMENTARY INFORMATION

Summary of Current Access Driveway Standards of State Highway Agencies

Figures F-22 and F-23 and Table F-6 represent a partial summary of driveway standards in current use by the various state highway departments. Information used in the preparation of this summary was derived from the design manuals and standards of the various highway departments.

Effect of Driveway Entrance Speed on Interference to Through Traffic

Interference occurs when a vehicle entering a driveway from a through traffic lane causes following vehicles to adjust speed and/or change lanes. This is shown graphically on the time-space diagram (Fig. F-24). The magnitude of this interference to an individual vehicle can be represented by the delay or the time lost by that following vehicle while decelerating (and then accelerating) to conform to the speed reduction of a preceding vehicle.

The interference caused by a driveway entrance maneuver to traffic in the through lanes is shown by the time-space diagram in Figure F-25. Data from which this diagram was constructed were obtained from aerial time-lapse photographs of a driveway entrance maneuver from a freeway frontage road. Because this frontage road is of rela-

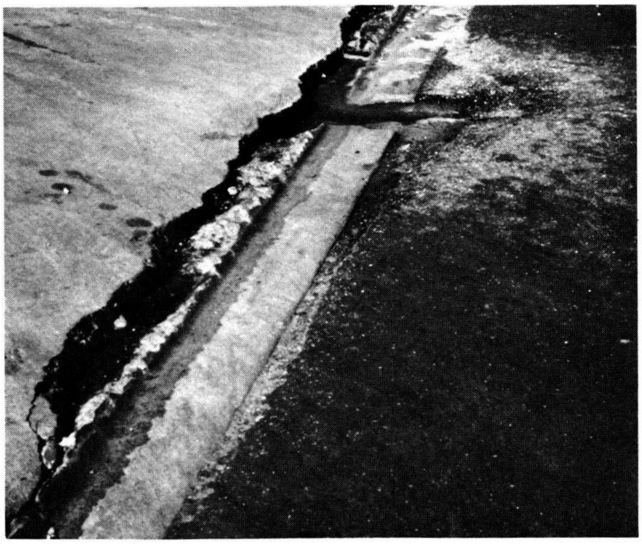


Figure F-20. Poorly constructed curb cuts. Such curb cuts may lead to the formation of large spall areas which are unsightly and a maintenance problem. To avoid this problem, the entire curb and gutter section should be removed when the curb cut is made.

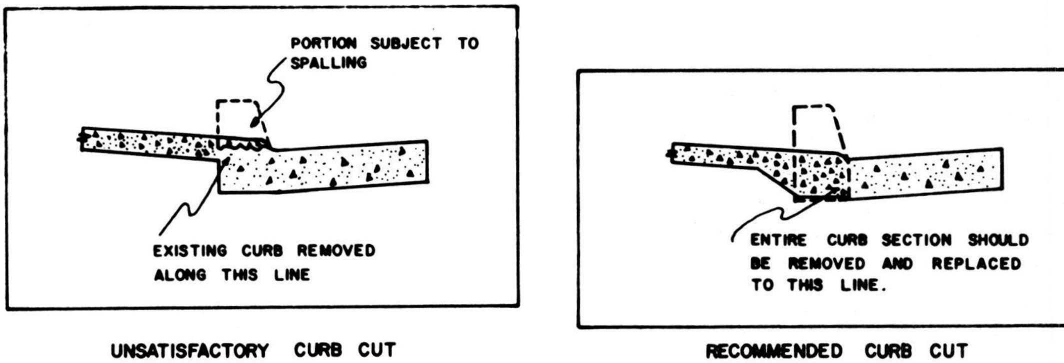


Figure F-21. Curb cut procedure.

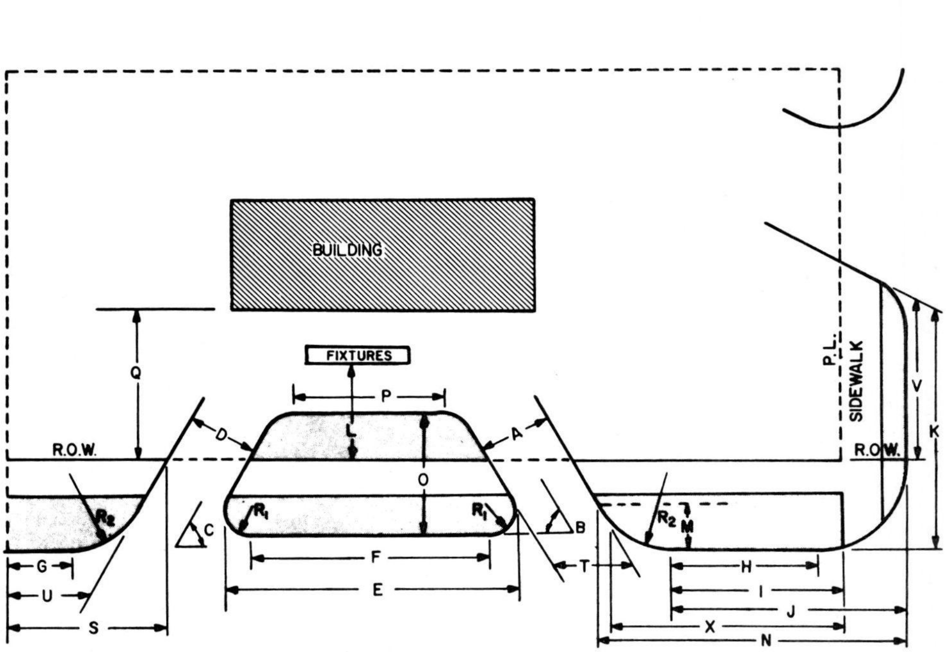


Figure F-22. Standard dimensions for commercial driveways.

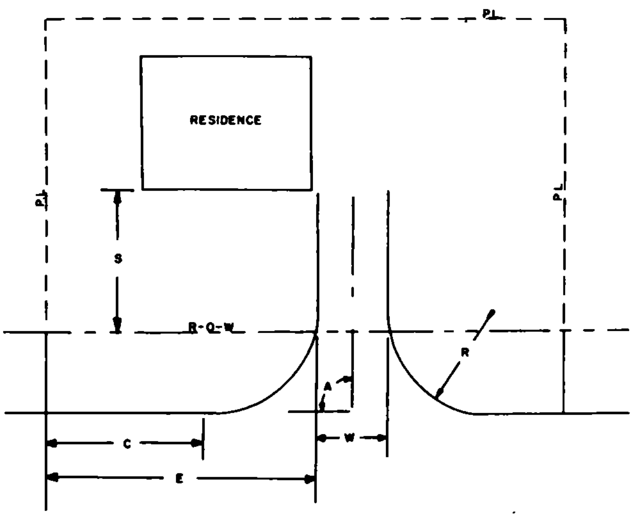


Figure F-23. Standard dimensions for residential driveways.

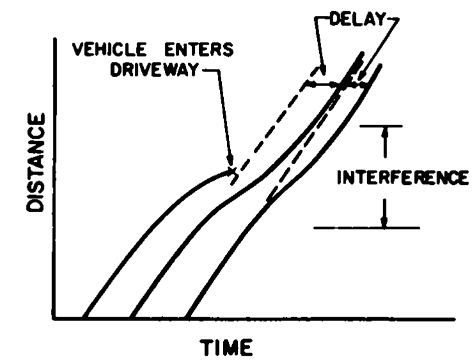


Figure F-24. Schematic example of interference due to entrance into a driveway.

tively high design standards (similar to a four-lane divided roadway) with two-lane, one-way operation, this and other similar driveway maneuvers studied can be taken as representative of traffic conditions along urban, arterial roadways. Approximations of the deceleration rates and driveway exit speeds for several such maneuvers are summarized in Table F-7.

To quantify the effect of driveway entrance speed on the interference incurred by vehicles in the through traffic lanes, these data were used to develop and calibrate a computer simulation model. This simulation analysis considered traffic flow along a section of a two-lane, one-way roadway with an operating speed of 45 mph. Mainline volume, driveway volume, and driveway entrance speed were varied to measure delay under different access conditions.

The relationships obtained between delay and mainline volume and delay and driveway entrance speed are shown in Figures F-26 and F-27. Delay per turning vehicle here refers to the ratio of total delay incurred by vehicles in the traffic stream to the total number of driveway entrance maneuvers. Because a certain amount of delay results from natural speed variation within the traffic stream, this ratio does include some delay from this source. Examination of the time-space data, however, indicated that this delay was only nominal. The differences in delay resulting from changes in driveway entrance speeds (Figs. F-26 and F-27) furnish further evidence that the delay measured can be attributed almost wholly to interference from vehicles turning at the driveway.

Effect of Volume

Under certain conditions, the delay caused by each driveway entrance maneuver will depend on the ratio of turning traffic to through traffic. With relatively low driveway volumes, each entrance maneuver should cause a maximum (at that through volume) of interference to the following

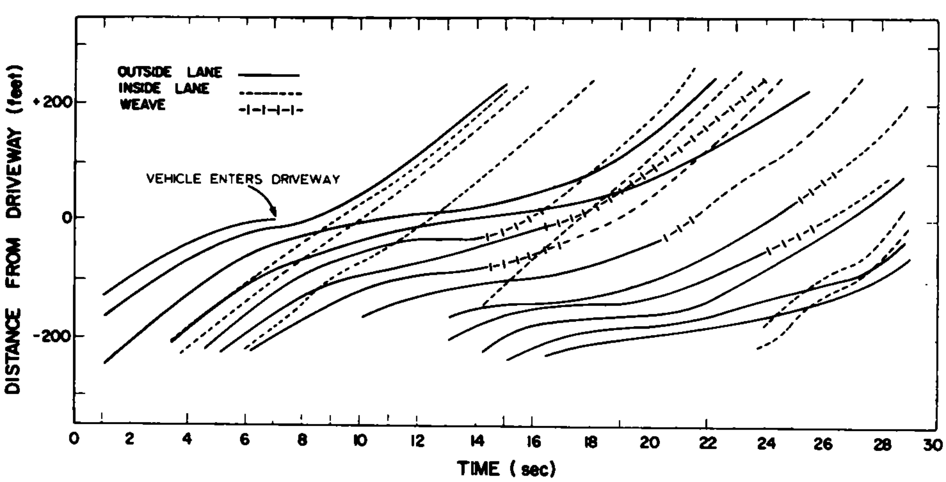


Figure F-25. Time-space diagram obtained from time-lapse photographs of driveway entrance maneuver.

TABLE F-6

NATIONWIDE ACCESS DRIVEWAY STANDARDS (URBAN-COMMERCIAL; RURAL-COMMERCIAL; URBAN-RESIDENTIAL; RURAL-RESIDENTIAL)

URBAN-COMMERCIAL — Dimension in Figure F-22

STATE	A TWO-WAY	A ONE-WAY	B TWO-WAY	B ONE-WAY	C TWO-WAY	C ONE-WAY	D TWO-WAY	D ONE-WAY	E	F	G	H	I	J	K	L	M	N	O	P	Q	R_1	R_2	S	T	U	V	X
Ark	40'mx	-	60°-90°	45°-60°	60°-90°	45°-60°	40'mx	-	25'mn.	-	0'mn.	10'mn	0'mn	-	-	15'mn.	-	-	-	-	-	5'-50'	5'mn	-	-	-	15'mn	-
Col	35'mx	-	60°mn	-	60°mn	-	35'mx	-	10'mn	-	3'mn	-	6'mn.	-	20'mn	-	6'	20'mn	6'mn	10'mn	-	-	50'mn	-	-	-	-	-
Del	-	-	60°mn	30°mn	60°mn	60°mn	-	-	-	10'mn	5'mn	-	15'mn	-	-	-	-	-	6'mn.	20'mn	5'-15'	5'-30'	-	50'mx	35'mx	10'mn.	-	-
Fla	40'-50'	25'-35'	60°-90°	45°-60°	60°-90°	45°-60°	40°-50°	25'-35'	-	-	-	-	-	-	-	10'-15'	-	-	-	10'mn	30'-50'	6'-10'	20'-30'	-	-	5'-10'	10'-20'	10'-20'
Haw	30'mx	20'mx	45°mn	45°mn	45°mn.	45°mn	30'mx	20'mx	-	-	-	15'mn.	-	-	-	15'mn	-	-	-	-	20'-40'	5'mn	15'mn.	-	-	-	-	-
Idaho	20'-40'	-	45°-90°	-	45°-90°	-	20'-40'	-	-	-	-	0'mn.	-	-	-	14'mn	-	-	4'-8'	10'mn	5'-10'	-	5'mn	-	-	-	-	-
Ill	35'mx	35'mx	45°mn	45°mn	45°mn.	45°mn	35'mx	35'mx	-	6'mn	3'mn	-	5'mn	-	-	13'mn	-	-	-	-	-	-	-	-	-	-	-	-
Iowa	45'mx	30'mx	60°-90°	45°-60°	60°-90°	60°-90°	45'mx	30'mx	15'mn.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
La	35'mx	-	45°-90°	-	45°-90°	-	35'mx	-	-	-	10'mn	-	25'mn.	-	-	10'mn	-	-	-	10'mn	3'-10'	10'-30'	-	-	-	-	25'mn	-
Md	35'mx	20'mn	60°mn	-	60°mn	-	35'mx	20	-	10'mn	5'mn	-	-	-	-	12'mn	-	-	-	-	30'mn	5'mn.	10'	-	-	-	-	-
Mass	24'mx	-	45°mn.	-	45°mn.	-	24'mx	-	-	-	0'mn	-	-	-	-	-	-	-	-	-	-	5'-10'	50'mx	-	-	-	-	-
Minn	26'-32'	-	60°-90°	-	60°-90°	-	26'-32'	-	-	-	5'mn	-	30'mn	-	-	-	-	-	-	20'mn.	-	5'-15'	5'-40'	-	-	5'mn.	30'	20'
Mo	-	-	45°mn	-	45°mn	-	-	-	15'mn	-	-	-	-	-	-	12'mn	-	-	-	5'mn	-	5'-15'	5'-40'	5'mn	60'mx	-	-	-
Mont	40'mx	40'mx	60°-90°	45°-90°	60°-90°	60°-90°	40'mx	40'mx	25'mn	-	-	10'mn.	-	-	-	15'mn.	-	-	-	-	-	-	10'-50'	-	-	10'mn	-	-
Nev	-	-	-	-	-	-	-	-	15'mn	-	-	-	10'mn	-	-	-	-	-	-	-	-	-	-	5'mn	50'mx	-	-	-
New Hamp	50'mx	-	60°-90°	-	60°-90°	-	50'mx	-	-	-	-	-	-	-	-	-	-	-	-	var	-	5'-15'	15'-30'	-	-	-	-	-
New Mex	-	-	45°-90°	45°-60°	45°-90°	45°-60°	-	-	-	-	-	0'mn.	-	-	-	12'mn	-	-	-	10'mn	20'-62'	to 10'	to 30'	5'mn	30'-40'	20'-30'	-	10'mn.
N Dak	30'mx	-	60°-90°	-	60°-90°	-	30'mx	-	-	-	-	-	-	-	-	10'mn	-	-	-	-	20'mn.	15'	15'	-	-	-	-	-
Ohio	35'mx	35'mx	70°-90°	45°-90°	70°-90°	45°-90°	35'mx	35'mx	-	6'mn	-	0'mn	-	20'mn.	-	-	-	-	-	-	-	3'-5'	3'mn	-	-	-	-	-
Ore	-	-	45°-90°	45°-90°	45°-90°	45°-90°	-	-	30'mn	-	-	-	10'mn	-	-	10'mn.	-	-	-	-	-	5'-10'	5'-35'	5'mn	50'mx	15'mn	-	-
Penn	-	-	45°-60°	30°mn	45°-60°	30°mn	-	-	-	15'mn	5'mn	-	-	15'mn	-	12'mn	-	-	-	10'mn	30'mn	5'mn	50'mx	-	35'mx	15'mn	-	-
S C	30'-40'	-	45°-90°	-	45 -90°	-	30'-40'	-	15'mn	-	6'mn.	-	10'mn	-	-	12'mn	-	-	-	15'mn	-	10'mn	2 5'-25'	-	-	-	13'mn	-
Tex	30'-40'	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7'mn	-	-	-	-	-	-	-	-	-
Va	-	-	60°mn	-	60 mn	-	-	-	25'mn	-	0'mn	0'-20'	-	-	-	12'mn	-	-	-	-	-	20'mx	35'mx	30'-50'	-	-	var	-
W Va	-	-	45°-90°	-	45°-90°	-	-	-	20'mn	-	5'mn.	15'mn.	-	-	-	12'mn	-	-	-	10'mn	-	-	-	-	50'mx	5'mn	15'mn	-
Wis	-	-	45°-90°	var	45°-90°	45°-90°	-	-	6'mn	-	3'mn.	-	-	-	-	-	-	-	-	-	-	-	40'mx	-	35'mx	-	-	-

RURAL-COMMERCIAL — Dimension in Figure F-22

STATE	A TWO-WAY	A ONE-WAY	B TWO-WAY	B ONE-WAY	C TWO-WAY	C ONE-WAY	D TWO-WAY	D ONE-WAY	E	F	G	H	I	J	K	L	M	N	O	P	Q	R_1	R_2	S	T	U	V	W
Ark	40'mx	-	60°-90°	45°-60°	60°-90°	45°-60°	40'mx	-	25'mn	-	no mn	10'mn.	-	-	-	15'mn	-	-	-	-	-	10'mn	10'-50'	-	-	-	20'mn	-
Colo	35'mx	-	60°-90°	-	60°-90°	-	35'mx	-	10'mn	-	-	-	-	-	-	-	6'	56'mn	6'mn	-	-	-	50'mn	-	-	-	-	-
Del	-	-	60°mn	60°mn	60°mn	60°mn	-	-	-	-	-	-	-	-	-	15'mn	-	-	-	20'mn	-	5'-15'	20'-40'	-	35'-50'	10'mn	10'mn	30'mn
Fla	40'-50'	25'-35'	60°-90°	45°-60°	60°-90°	45°-60°	40'-50'	25'-35'	-	-	-	-	-	-	-	10'-15'	-	-	-	20'-30'	20'-30'	10'-20'	30'-50'	-	-	10'-20'	20'-40'	20'-40'
Haw	30'mx	20'mx	45°mn	45°mn	45°mn	45°mn	30'mx	20'mx	-	-	no mn	15'mn	-	-	-	15'mn	-	-	-	-	20'-40'	5'mn	20'	-	-	-	-	-
Idaho	30'mx	20'mx	45°-90°	-	45°-90°	-	-	-	-	-	-	-	-	-	-	20'mn	-	-	-	10'mn	-	var	20'	5'mn	20'-40'	-	-	-
Ill	-	-	45°mn	45°mx	45°mn	45°mn	-	-	10'mn	-	-	-	-	var	var	13'mn	-	-	6'mn	-	-	-	40'mx	-	45'mx	5'mx	-	-
Iowa	45'mx	30'	60°-90°	45°-60°	60°-90°	60°-90°	45'mx	30'	-	-	no mn	-	-	-	-	-	-	-	-	30'mn	-	20'mx	60'mx	-	-	-	-	50'mn
La	30'-35'	-	45°-90°	-	45°-90°	-	30'-35'	-	-	-	5'mn	-	15'mn	-	-	10'mn	-	-	-	10'mn.	-	3'-10'	10'-30'	-	-	-	15'mn	-
Md	35'mx	20'mn	60°mn	-	60°mn	-	35'mx	20'mn	10'mn	-	5'mn	10'	-	-	-	12'mn	-	-	-	-	-	5'mn	10'	-	-	-	-	-
Mass	24'mx	-	45°	-	45°	-	24'mx	-	-	-	no mn	-	-	50'mn.	50'mn	-	-	-	-	-	-	5'-10'	50'mx	-	-	-	-	-
Minb	26'-32'	-	60°	-	60°	-	26'-32'	-	-	-	-	-	-	-	-	-	-	-	-	30'	-	5'-15'	10'-40'	-	-	10'mn	60'mn	60'mn
Mo	-	-	45°mn	-	45°mn	-	-	-	5'mn	-	-	-	30'mn	-	-	12'mn	-	-	-	5'mn	-	5'-15'	5'-40'	10'mn	60'mx	-	30'mn	-
Mont	40'mx	40'mx	60°-90°	45°-90°	60°-90°	60°-90°	40'mx	40'mx	25'mn	-	-	10'mn	-	-	-	15'mn.	-	-	-	-	-	-	10'-50'	-	-	10'mn	-	-
Nev	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
New Hamp	-	-	60°-90°	-	60°-90°	-	-	-	var	-	-	-	-	-	-	15'	-	-	-	var	-	5'-15'	15'-30'	-	50'mx	-	-	-
New Mex	30'-40'	20'-30'	45°-90°	45°-60°	45°-90°	60°-90°	30'-40'	30'mx	-	-	5'mn	10'mn	-	-	-	-	-	-	-	30'mn	20'-60'	10'-20'	5'mn	-	40'mx	-	10'mn	-
N Dak	20'-30'	-	60°-90°	-	60°-90°	-	20'-30'	-	-	-	-	-	-	-	-	10'mn	-	-	-	-	25'	15'	15'	-	-	-	-	-
Ohio	35'mx	-	45°-90°	-	45°-90°	-	35'mx	-	-	-	no. mn	-	-	-	-	-	-	-	-	6'mn	-	3'-5'	3'-25'	-	-	-	-	-
Ore	-	-	45°-90°	-	45°-90°	-	-	-	30'mn	-	10'mn	-	-	-	-	10'mn	-	-	-	-	-	5'-10'	5'-35'	5'mn	15'-50'	-	-	-
Penn	35'mx	-	45°mn	-	45°mn	-	35'mx	-	-	15'mn	10'mn	10'mn	-	30'mn	-	12'mn	-	-	-	10'mn	30'mn.	5'mn	50'mx	-	-	-	-	-
S C	50'mx	-	45°-90°	-	45°-90°	-	35'-50'	-	-	-	5'mn	-	10'mn	-	-	12'mn	-	-	-	15'mn	-	10'-15'	25'-50'	-	-	-	10'mn	-
Tex	30'-45'	-	60°-90°	30°-60°	60°-90°	60°-90°	30'-45'	-	var	-	no mn	5'-20'	-	-	-	12'mn.	-	-	7'mn	-	-	2 5'-30'	-	-	-	-	-	-
Va	-	-	60°mn	-	60°mn	-	-	-	-	-	no mn	-	-	-	42'mn	12'mn	-	-	-	25'mn	-	20'mx	35'mx	-	-	-	-	-
W Va	-	-	45°mn	30°mn	45°mn	45°mn	-	-	20'mn	-	-	-	-	-	-	12'mn	-	-	-	10'mn	-	5'mn	10'-30'	-	50'mx	5'mn	20'mn	30'mn
Wis	-	-	45°mn	45°mx	45°mn.	45°mn	-	-	10'mn	-	-	-	-	-	-	-	-	-	-	-	-	-	40'mx	35'mx.	-	-	-	-

URBAN-RESIDENTIAL — Dimension in Figure F-23

STATE	A	C	E	R	W Single	W Double
Ark	60°-90°	-	5'mn	5'mn	10'-12'	16'-24'
Del	60°-90°	5'mn	10'mn	5'-15'	10'mn	24'mx
Fla	60°-90°	-	5'mn	5'-15'	10'-12'	15'-20'
Haw	90°	-	-	15'	16'	16'
Ill	90°	-	-	10'mx	24'mx	24'mx
La	90°	-	-	10'-30'	30'mx	30'mx
Mass	90°	-	4'-9'	12'-18'	16'	16'
Minn	60°-90°	-	5'mn	5'-15'	12'	22'
Mo	90°	-	5'mn.	5'-40'	-	-
Mont	60°-90°	-	-	2 5'mn	12'	24'
Nev	90°	-	5'mn.	-	12'-16'	20'-24'
New Hamp	60°-90°	-	-	10'-15'	12'mn	50'mx
New Max.	90°	-	5'mn	0'-5'	10'	22'
Penn	90°	-	-	20'mx	10'mn	20'mx
S C	60°-90°	-	10'mn	2.5'-10'	10'-12'	16'-24'
Tex	60°-90°	-	-	2 5'mn	10'-12'	16'-24'
W Va	90°	-	10'mn	30'mx	10'mn	24'mx
Wis	var	0'	-	10'mx	24'mx	24'mx

RURAL-RESIDENTIAL — Dimension in Figure F-23

STATE	A	C	E	R	W ONE-WAY	W TWO-WAY
Ark	60°-90°	-	-	30'	10'-12'	16'-24'
Del	60°-90°	5'mn	10'mn	5'-15'	10'mn	24'mx
Fla	60°-90°	-	-	5'-20'	10'-12'	15'-20'
Haw	90°	-	-	18'	16'	16'
Ill	90°	0'mn	-	30'mx	12'	24'
La	90°	-	-	10'-30'	30'mx.	30'mx
Minn	60°-90°	-	5'mn.	5'-15'	12'	22'
Mo	90°	-	5'mn	5'-40'	-	-
Mont.	60°-90°	-	-	30'	12'	24'
Nev	90°	-	5'mn	-	12'-16'	20'-24'
New Hamp.	90°	-	-	-	40'	50'mx
New Max	90°	-	5'mn	5'-30'	10'	22'
Penn	90°	-	-	20'mx	10'mn	20'mx
S C	60°-90°	-	10'mn	10'-20'	10'-12'	16'-24'
Tex	60°-90°	-	-	30'	10'-12'	16'-24'
W Va	90°	-	10'mn	30'mx	10'mn	24'mx
Wis	90°	-	-	30'mx	16'mn	24'mx

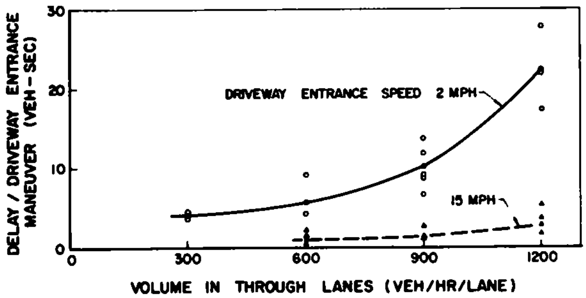


Figure F-26. Relationship between delay and volume in the through lanes.

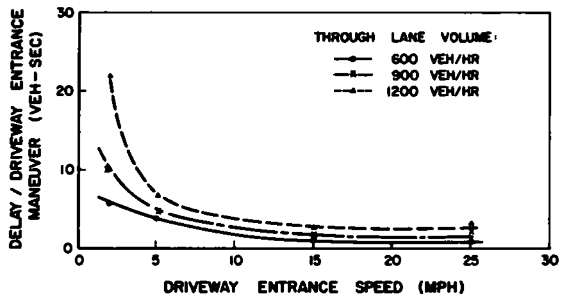


Figure F-27. Relationship between delay and driveway entrance speed.

vehicles. At the other extreme, where all vehicles enter the driveway, the rather trivial conclusion is reached that no delay is incurred to through vehicles because there are none.

For the simulation analysis, driveway volumes ranging from 25 to 300 vph were considered in combination with through volumes which gave ratios of driveway volume to through volume from 0.02 to 0.40. The higher ratios were for the lower mainline volumes, however, and within this range no significant variation in the delay per entry maneuver with different levels of driveway volume was noted.

Effect of Driveway Speed

As driveway speed is increased from 2 to about 10 mph, the interference falls off rapidly (Fig. F-27). For the increase from 10 to 15 mph, some additional reduction in delay is obtained, but, at higher entry speeds, the additional change is small. These figures were based on an assumed running speed of 45 mph. Although this is fairly representative of speeds desired on urban arterial roadways, for major rural roadways and some high-speed urban roadways, the effects of low-speed driveway entrance maneuvers may be even more pronounced.

Sight Distance

Assumptions made in extending Case III of the sight-distance recommendations of AASHO (*7*) are shown by the time-space diagram in Figure F-28.

Corner Clearance and Driveway Spacing

The potential conflict arising between vehicles that enter the traffic stream from driveways or intersections is shown in Figure F-29. Because both vehicles have equal right-of-way and frequently neither is able to predict the intended maneuver of the other, both vehicles may begin their maneuver at or about the same time. Unless sufficient spacing is provided between adjacent driveways, the two vehicles may move on a course requiring some evasive maneuver to avoid collision.

On major roadways where a high level-of-service is desired, such speed reductions may cause interference to other vehicles in the through lanes. On local roadways, some interference usually can be tolerated, if the required speed reduction is not so great as to be hazardous.

Using a running speed of 30 mph for the through lanes, a turning speed from intersecting through streets of 15 mph, and an acceleration of 3.0 ft/sec^2, minimum spacings shown in Figure F-29 were obtained. The upper limits represent the spacings for which the second vehicle will not be re-

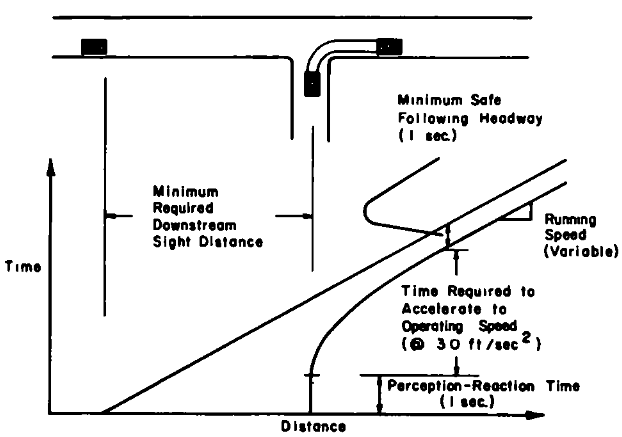


Figure F-28. Schematic representation of driveway exit maneuver.

TABLE F-7

DECELERATION AT DRIVEWAY ENTRANCES

SPEED OF TURNING VEHICLE (MPH)		AVERAGE DECELERATION
INITIAL	EXIT [a]	(FT/SEC^2)
29	7	3 1
31	7	3.1
30	9	5.7
23	<5	2.9
18	<5	3.9
20	<5	7.5
24	12	1.5

[a] Exit speed here refers to the component of speed parallel to the roadway

quired to reduce speed. The lower values assume some speed adjustment. Values shown for spacings assume the vehicle entering the driveway to be positioned at least 15 ft from the left edge of the pavement.

Driveway blocking by vehicles queued at an intersection is shown in Figure F-30. At exit driveways, such blocking will simply result in delay to vehicles waiting to enter the traffic stream. For entrance driveways, however, blocking will result in delays to vehicles waiting to enter the driveway, as well as to other vehicles following them.

For entrance maneuvers made from the lane adjacent to the driveway, such delay is not particularly critical. With the entrances made from the opposite lane, however, the delay can be much more serious if queues build up behind the turning vehicles and extend into the intersection. Such a situation is most often critical only for two-lane highways, because the frequency of four-lane highways having high volumes and unsignalized stops at the intersections is fairly low. Furthermore, with multi-lane highways the opportunity exists for vehicles to pass the turning vehicles. Because clearances that are adequate for two-lane roadways should be adequate and will probably provide the higher level-of-service generally desirable for four-lane roadways, it would seem reasonable to apply the same corner clearances to both cases.

Assuming random arrivals of vehicles at the intersection, principles of queueing theory were applied to estimate the probability that the intersection will be blocked. These probabilities, which vary with corner clearance, intersection service rate, and the volume of traffic in the lane adjacent to the driveway, are summarized for stop streets in Table F-8.

These values suggest that where the flow in the outside lane (adjacent to the driveway) approaches the capacity of the intersection, the probability that the intersection will be blocked increases rapidly for very limited corner clearances. Corner clearances of at least one vehicle would be desirable for roadways of all classes. An allowance of 25 ft for the space occupied by the vehicle and of 10 ft between the near curb line at the intersection and the stop line gives a minimum clearance of 35 ft. A clearance of at least three vehicles (85 ft) would be desirable to avoid blocking for most traffic levels where a high level-of-service is desired.

For signalized intersections, a similar tabulation (Table F-9) summarizes the probability that the intersection will be blocked at least sometime during each cycle (i.e., the percent of cycles) for different levels of volume and red phase length. Although the red phase length is only a portion of the total cycle, unless the queue and the next platoon clear the driveway early in the green phase, the driveway will be effectively blocked for the entire cycle.

Minimum corner clearance requirements for turning and weaving maneuvers at exit driveways are shown in Figure F-31. For high-volume roadways (Fig. F-31a), vehicles turning left after exiting must first enter the adjacent lane, then move across the roadway to the lane from which the turn is made. Values shown are those that will permit the vehicle to move diagonally to the next lane(s) and stop without blocking an additional lane. These values are actually less than adequate to permit the weaving maneuver.

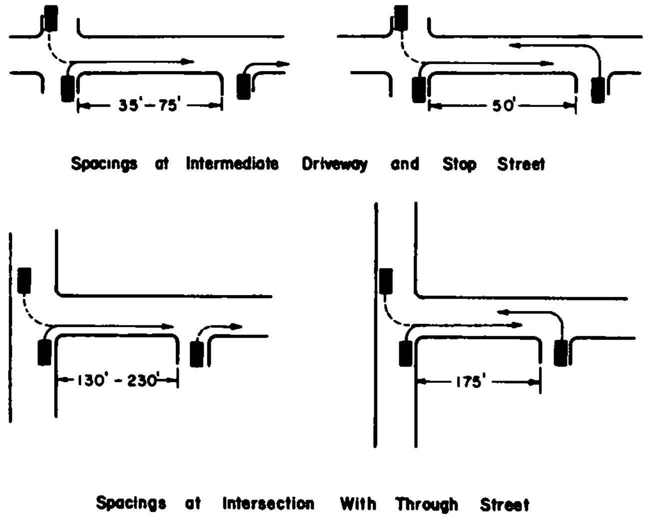


Figure F-29. Minimum driveway spacings as controlled by vehicle trajectories.

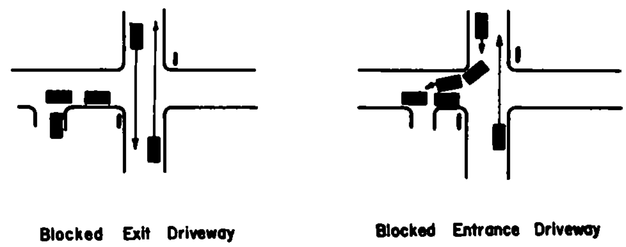


Figure F-30. Blocking of near corner driveways.

TABLE F-8

PROBABILITY OF DRIVEWAY BLOCKING (NEAR CORNER ON STOP STREET)

VOLUME IN LANE ADJACENT TO DRIVEWAY (VPH)	INTERSECTION SERVICE RATE (VPH)	PROBABILITY THAT DRIVEWAY IS BLOCKED (%), BY CORNER CLEARANCE (NO. OF VEHICLES)						
		0	1	2	3	4	5	6
50	100	50	25	13	6	3	2	1
	200	25	6	2				
	300	17	3	1				
	400	13	2					
	500	10	1					
100	200	50	25	13	6	3	2	1
	300	33	11	4	1			
	400	25	6	2				
	500	20	4	1				
	600	17	3	1				
150	200	75	56	42	32	24	18	13
	300	50	25	13	6	3	2	1
	400	38	10	5	2	1		
	500	30	9	3	1			
	600	25	6	2				

TABLE F-9

PERCENT OF CYCLES DURING WHICH DRIVEWAY AT SIGNALIZED INTERSECTION WILL BE BLOCKED

FLOW IN LANE ADJACENT TO DRIVEWAY (VPH)	DURATION OF RED PHASE (SEC)	PERCENT OF CYCLES DURING WHICH BLOCKING OCCURS, BY CORNER CLEARANCE (NO. OF VEHICLES)									
		1	2	3	4	5	6	7	8	9	10
200	15	20	5	1							
	25	40	16	5	1						
	35	58	31	13	5	2					
	45	71	46	24	11	4	1				
400	15	50	23	9	3	1					
	25	77	53	30	15	6	2	1			
	35	90	75	55	35	20	10	5	2	1	
	45	96	88	74	56	38	24	13	7	3	2
600	15	71	46	24	11	4	1				
	25	92	79	60	40	24	13	6	3	1	
	35	98	93	83	69	53	37	23	14	7	4
	45	100	98	94	87	76	62	48	34	22	14
800	15	85	65	43	24	12	5	2	1		
	25	98	92	81	65	49	32	20	11	6	3
	35	100	98	95	89	79	66	52	38	26	16
	45	100	100	99	97	93	87	78	67	54	42

For very low-volume roadways, vehicles may be able to move more directly into the lane from which the turn is made (Fig. F-31b). Again, however, the values shown are less than desirable and should be regarded as the lower limit for low-volume driveways on local streets.

Without additional quantitative research pertaining to characteristics of left-turn driveway entry maneuvers, it is difficult to assess with any reliability the adequacy of various corner clearances in effecting this maneuver. It would appear, however, that clearances at least as great as those required for near corner exit driveways would be desirable.

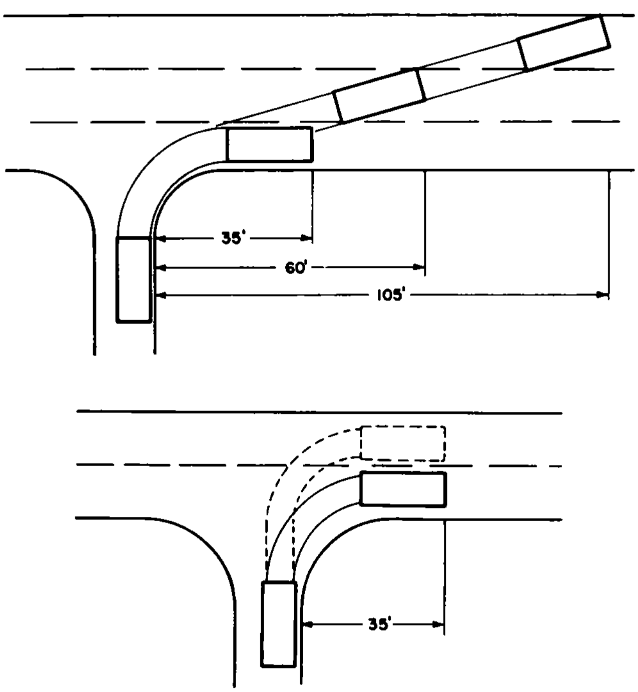


Figure F-31. Minimum clearance required for entering the traffic stream from corner driveway.

Horizontal Alignment

Recommended combinations of driveway width and return radius are based on turning requirements of the standard AASHO design vehicles (*7*). For entrance maneuvers, it was assumed that turning vehicles follow a circular curve beginning from a position parallel to the roadway with the right wheels 2 ft from the edge of the through lane from which the turn is being made. The combinations of driveway width and return radius further assume that at no point are the wheels of the vehicle closer than 1 ft to either edge of the pavement. Minimum widths were measured from a point 1 ft beyond the left wheels of the vehicle after the turn is completed (Fig. F-32).

To account for tapers, compound curves, shoulders, parking lanes, etc., several vehicle placements with respect to the edge of the pavement were considered. Offsets of 2, 4, 6, 10, and 14 ft were used for the passenger vehicles.

Vehicle Clearance Dimensions

Vehicle clearance dimensions from McConnell (*8*) are shown in Figures F-33 and -34.

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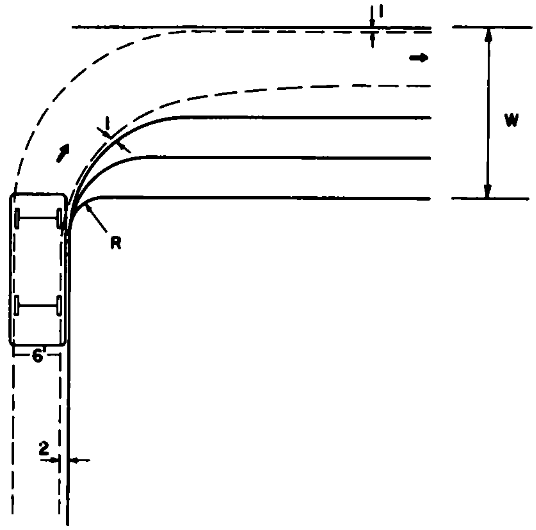


Figure F-32. Typical combinations of return radius and driveway width for a given turning radius.

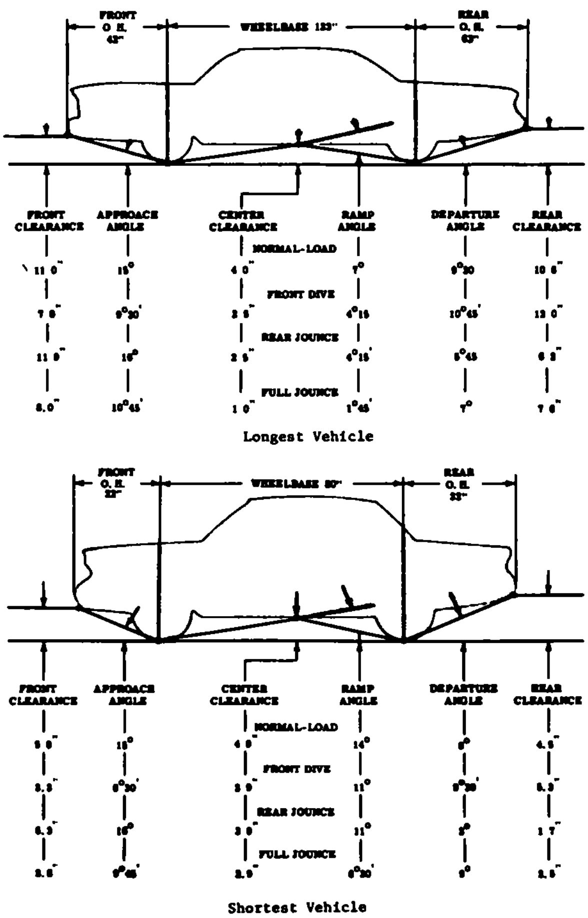
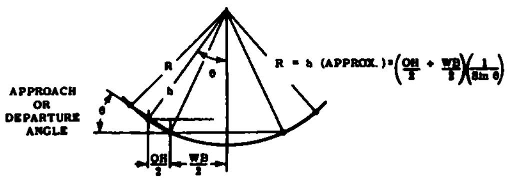
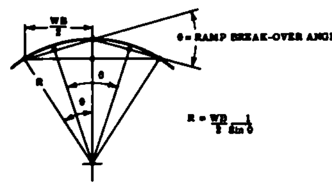


Figure F-33. Composite vehicle clearance dimensions under various conditions.



SITUATION	θ	(OH/2 + WB/2)	Sin θ	RADIUS
LONG VEHICLE				
NORMAL LOAD - FRONT INTERFERENCE	15°	7 3	2588	28'
NORMAL LOAD - REAR INTERFERENCE	9°30'	8 16'	1651	50'
DIVE - FRONT INTERFERENCE	9°30	7 3'	1651	44'
JOUNCE REAR INTERFERENCE	5°45	8 16'	1002	81'
SHORT VEHICLE				
NORMAL LOAD - FRONT INTERFERENCE	15°	4 25	2588	17'
NORMAL LOAD - REAR INTERFERENCE	8°	4 67'	1392	34'
DIVE - FRONT INTERFERENCE	8°30'	4 25'	1478	29'
JOUNCE - REAR INTERFERENCE	3°	4 67'	05234	89'

Sag vertical curve radii for overhang clearance



SITUATION	θ	Sin θ	WB/2	RADIUS
LONG VEHICLE				
NORMAL LOADED	7°	1219	5 58	46
DIVE - FRONT	4°15	0741		75
JOUNCE REAR	4°15	0741		75
FRONT & REAR JOUNCE	1°45	0305		180 *
SHORT VEHICLE				
NORMAL-LOADED	14°	2419	3 33'	14'
DIVE FRONT	11°	1908		18
JOUNCE REAR	11°	1908		18
FRONT & REAR JOUNCE	8°30'	1478		23

*NOTE THIS CONDITION EXPERIENCED ON CREST CURVES ONLY UNDER UNUSUAL CIRCUMSTANCES OF LOADING AND PAVEMENT GEOMETRY

Crest vertical curve radii for underbody clearance

Figure F-34. Vertical curve radii.

APPENDIX G

DEVELOPMENT TRENDS

The owner/developer of property adjacent to a major street or highway obviously has a vested interest in access control. The provision or denial of direct access to the through lanes may greatly affect the relative market potential of a particular parcel. Consequently, considerable pressure often has been brought to bear to get all the access possible; however, some developers have observed that a general deterioration of the traffic-carrying capability of a major roadway, due to conflict between local (land access) and through traffic, can be to the long-run disadvantage of their investment.

Trends in various sectors of the economy also are leading toward larger-scale, higher-quality, and better-planned development The past and expected future trends in residential, service station, motel, and shopping center developments provide examples where "restrictive" access control is not incompatible with the nonuser interests of the individual and the general public. Application of higher degrees of partial access control, therefore, is not expected to create as great a problem as it would have a few years ago.

However, before proceeding with a discussion of these trends, it might be pointed out that developers are very cognizant of the potential market position of their development relative to that of possible competitors. This suggests that the problem in applying access control is not so much a matter of the severity of the controls, but the consistency or danger of inconsistency with which they are applied

The fact is that the granting of curb-out permits often appears to be inconsistent and motivates the developer to get all the access he can to protect himself from another development coming in at a more competitive location As one developer stated, "We can live with any access limitation if we are assured that all other potential developers will have to live by the same rules. Then we can make decisions in regard to development of a parcel without worrying about some later development taking place on a more competitive site in the same general location "

RESIDENTIAL AREAS

The principles of good design of planned residential neighborhood development were first demonstrated by Stein and Wright in their layout of Radburn, N.J., prepared in 1929. The plan encompassed the elements of what is now known as the "limited access subdivision" with long blocks and a functional street layout to discourage through traffic.

In very recent years, there has been a growing trend to incorporate these elements and other improved design elements into new subdivisions. The general adoption of the limited access subdivision * is a recent trend which has extensive implications with regard to access control policy on major roadways. Specific practices in the layout of such residential development that complement more restrictive access controls include:

1. Long blocks: Block lengths of 1,000 ft are commonly used at present. Lengths of 1,800 to 2,000 ft are considered reasonable; it is anticipated that blocks of this length will become prevalent in the future. Such block lengths are in close agreement with the intersection spacings of 1,200 to 1,600 ft on secondary arterials and 1,600 to 2,000 ft on primary arterials recommended elsewhere in this report. It is believed that the greater marketability of residential areas having the longer blocks (together with the other characteristics of the limited access subdivision) will significantly reduce the pressure for the large number of access points commonly requested by residential developers a few years ago.

2. Limited access: The concept of limiting the access to a residential subdivision to a few points (together with an internal street layout having no through streets), so as to discourage through traffic, has gained near total acceptance during the past 10 yr. Residences in such subdivisions are protected from high-speed, high-volume traffic and are preferred by the home buyer. This acceptance by the public should continue to encourage developers to request a limited number of access points to any arterial.

However, it should be recognized that the location of such access points will be critical from both the standpoint of the arterial and the residential area. The higher traffic volume entering and leaving the arterial may require signalization of the intersection, at any rate, the access point(s) to the subdivision should conform to the adopted minimum intersection spacing. From the standpoint of the subdivision, it must be recognized that a relocation of the intersection, providing access to the subdivision by an increased distance, may require complete redesign of the subdivision. Therefore, if problems with the developer are to be avoided, notification as to the acceptable location of subdivision access points from an intersection spacing criterion must be given before substantial (preferably before any) time and funds have been expended on the design of the subdivision.

3. Treatment of lots fronting on an arterial: Recent practice has been to not provide direct access to individual residences adjacent to an arterial; rather, some lot arrangement and positioning of the residence is used that orients the property away from the arterial. In many cases substantial and aesthetically pleasing landscaping and/or walls are provided by the developer to screen the arterial from the subdivision.

* The best current practice in residential development is most ably covered in the *Community Builder's Handbook*, Section One, Part II, "Planning the Development," Urban Land Institute (1968) This publication should be of considerable value in dealing with local residential developers in attempting to encourage better subdivision design while encouraging adoption of residential development having limited access to arterial streets

Treatment Along Arterials

The following designs have been successfully used in subdivisions to protect the residences from a high-volume arterial (or from the standpoint of the arterial, to protect it from the subdivision). These approaches will generally result in slightly higher development costs than subdivision designs that provide direct access to each individual residence or apartment building. However, they will provide for a more livable and desirable area which the public indicates, through the market, that it is willing to pay for.

1. Back-up-lots: Lots are laid out in a conventional manner (short dimension parallel to the arterial) but houses are faced on the internal local street from which access to each residence (or apartment building) is provided. The back of the house faces the arterial. A wall or planting along the rear of the lot is frequently provided to screen the subdivision and insure a consistent treatment along the margin of the development; this also assists in protecting the access control to the arterial, especially in the case of a wall.
2. Side-on-lots: Lots are laid out with the long dimension parallel to the arterial; residences front on, and are provided access to, a cul-de-sac street which is at a right angle to the arterial.
3. Frontage road: Residences are arranged facing the arterial but access is provided to a frontage road, rather than directly to the main lanes of the arterial. Although this practice will serve the purpose of avoiding direct access to the arterial development, costs are high because the frontage road serves properties on one side only, although a full-width street is needed. Also, it may result in two intersections in close proximity at the intersection of cross streets which intersect the arterial.
4. Rear service: Residences face the arterial but no driveways are permitted to the arterial; rather, the dwellings are serviced by an alley or local street at the rear of the residence.

Although the back-up-lot design is more frequently used, any one or a combination of the preceding may be used in a given residential development, depending on local conditions and personal preferences. They can be used effectively for a range of dwelling unit types, including single-family residences and apartments (both garden and high-rise)

It appears, however, that the elements just discussed are voluntarily incorporated only in larger and more expensive developments. One reason is that a development must be of some minimum size before the designer has the flexibility to incorporate the elements that identify the limited-access subdivision. Fifty acres seems to be a minimum size necessary to begin to gain this flexibility. This presents a most critical problem in smaller communities where the growth is not sufficient to generate a demand for a development of this magnitude (100 to 300 dwelling units) in a period of two to three years.

Another reason may be that the higher sale price of homes in the more expensive residential developments provides a larger base for recovering the additional costs associated with the better-designed and -constructed subdivisions. The provision of walls and/or landscaping at the margins of the development, as well as the added engineering and construction costs associated with the better street layout, amounts to a smaller fraction of the price of each completed dwelling unit.

It would seem reasonable that the residents of lower-priced residential areas would appreciate the advantages provided by the limited-access subdivision. The recent concern at various levels of government over the availability (actually, nonavailability) of low-cost housing may provide an opportunity in this respect. However, it is probably necessary that the agency responsible for administering the access control make a special effort to educate less-well-informed land owners, developers, and officials in the benefits of such residential design.

SERVICE STATIONS

Interviews with officials of major oil companies indicated that the total gasoline sales of the average service station is expected to increase over threefold (from about 30,000 gal per month at present to about 100,000 gal) by 1985. Sales of products and services other than gasoline are expected to increase tenfold. This increase in volume, it was indicated, is necessary to maintain acceptable wages and profit margins in the face of rising costs and increased station operator/employee income expectations.

The average number of gallons delivered to the tank of an automobile is expected to remain constant or to increase very little from the present 10 gal; therefore, it is expected that a larger number of vehicles will have to be accommodated by a given station and that more and/or larger pump islands will be required.

Service stations are also providing increased motorist services, such as refreshment vending machine areas, larger and better restrooms, and larger, more comfortable waiting and display areas.

These trends have already increased the minimum service station site from 100 by 100 ft a few years ago to 150 by 150 ft for recent station developments. The minimum site for current developments is reported to be 200 by 200 ft; and further increases in site dimensions may be expected.

The acquisition of larger sites provides for greater flexibility to meet future marketing needs, in addition to the simple increase in the number of vehicles to be serviced at the pump islands. For example, the recent installation of automatic car washers in several Shell Oil stations has resulted in reduced adequacy of some existing properties. Although the site may have been more than ample before the installation of the car washer, the room required for maneuvering into the wash bay, queueing, and exiting from the bay more than used the surplus space.

Further, car care centers present the potential for even larger site requirements. If the current experimentations with such centers by a few of the major companies are as successful as they are expected to be, even larger sites will become the norm. Such centers would be equipped for diagnosis of motor vehicle ills, tune-ups, and minor mechanical adjustments. Such facilities will require many more stalls than are provided in the current standard designs. In addition to the substantially larger building, much more area will be required for storage of vehicles waiting to be serviced or already serviced, as well as for circulation of vehicles on the site. The result will be a site requirement several times that of the present.

The larger volume of sales and the services provided at larger volume stations and at the car care centers will, of course, mean substantially larger volumes of traffic operating through the access driveways.

Interviews with oil company managements indicate a clear preference for the corner location over a midblock site. The service station on corner locations can serve vehicles on two roadways, and it is reported that these stations, on the average, do higher volumes of business than those on midblock locations.

Further, the preference for corner locations is reported to be much stronger than the desire for access from both directions of the fronting roadway(s). At higher traffic volumes, the low frequency of gaps of sufficient length to allow a vehicle to make a left turn into or out of a service station forces the station to depend on traffic from one direction. In the interviews, oil-company managements indicated a knowledge of this situation and voiced no objection to the installation of nontraversable medians where traffic volumes are high.

As stated earlier, the gallonage of the average station will need to increase by more than threefold (from 30,000 to 100,000 gal) by 1985 to support the station operator. However, fuel used by highway vehicles is expected only to double by that time.

Motor fuel consumption by highway vehicles has been increasing by approximately 4.5 percent per year. Assuming that this rate of increase will continue, the total fuel consumption would increase from just under 77.7 billion gal in 1967 to 171 billion gal in 1985.

An alternative estimate of the total fuel use based on projections of vehicle registrations and vehicle-miles of travel and using a constant annual fuel consumption per vehicle, in 1985, yields a slightly lower figure.

YEAR	NO. OF VEHICLES (THOUSANDS)	EST. MILEAGE (MILLIONS)	EST. FUEL USE (MILLIONS OF GAL)
1962	79,683	767,774	61,696
1967	98,942	965,132	77,693
1972	118,202	1,162,492	93,688
1977	137,462	1,359,852	103,683
1982	156,720	1,557,212	125,678
1985	168,276	1,675,628	135,275

Source: Motor vehicle numbers, mileage, and fuel consumption: *Highway Statistics, 1962 and 1967,* B P.R. Projections for 1972 through 1985 were made by the researchers using a 1962-67 base.

Therefore, it might be concluded that the service station industry is overbuilt and that an increasing number of marginal stations will result. Many of these stations will be forced out of business, regardless of access points they may have or access control changes that are implemented. Some of these station locations will be converted to other businesses.

Figures G-1 and G-2 are examples of today's service station. The one shown in Figure G-1 includes a tire store. Although the site is larger than that of the normal service station, the pump islands are in the conventional location and the site appears congested, even during the nonpeak patronage periods. The station is located at the intersection of two four-lane arterials, one of which includes a barrier median.

Considerable originality is shown in the design and layout of the service station in Figure G-2. This station combines the normal fuel and lubrication facilities with a car-rental agency and a state-authorized inspection station. In addition to a display area, the main building houses the manager's office and an attractively appointed customer waiting room, equipped with a color TV and a coffee bar. This station is located mid-block on a four-lane undivided section of a major U.S. designated route, and access is provided to and from both directions of through traffic. Ingress and egress are provided by two driveways, one on each side of the pump islands. Circulation around the entire site is provided by a well-marked peripheral roadway. Good on-site separation of the various functions is maintained, with the fueling and pump service located near the center and the inspection station at the right end of the site. The car-rental activity is concentrated in the left front quadrant and the major service area is in the rear. Service bays open to the side and rear of the main building. Additional parking is located in the rear, in the service area, and around the inspection facility.

MOTELS

The motel industry has undergone revolutionary changes since the late 1940's. These changes are largely a result of increasing affluence, mobility, and leisure time. Also, greater emphasis on sales and service representation has led to a substantial increase in importance of the commercial market (often referred to as the traveling salesman trade) for the motel. These motel market changes have caused fundamental changes in the services available at the modern motel and the economics of motel operation.

The changes are, in part, exemplified by the fact that TV is now an expected part of the accommodations. The "quarter-eating" timers that were common on motel TV sets in the mid-1950's are gadgets outside of the experience of modern-day motel patrons; even the "Free TV and Pool" advertisements have disappeared from the entrance sign of the modern motel—these features are an expected part of the accommodations.

As opposed to the "Mom and Pop Motel" which provided overnight sleeping accommodations only, the modern motel incorporates restaurants, lounges, meeting rooms, and recreational facilities. In many of the most recently opened motels and motor hotels, these facilities are often quite plush. These trends have resulted in a change in the distribution of motel revenues. As given in Table G-1, rooms and meals provided nearly constant proportions of the total receipts through 1958. In 1963, a sizable decrease in room

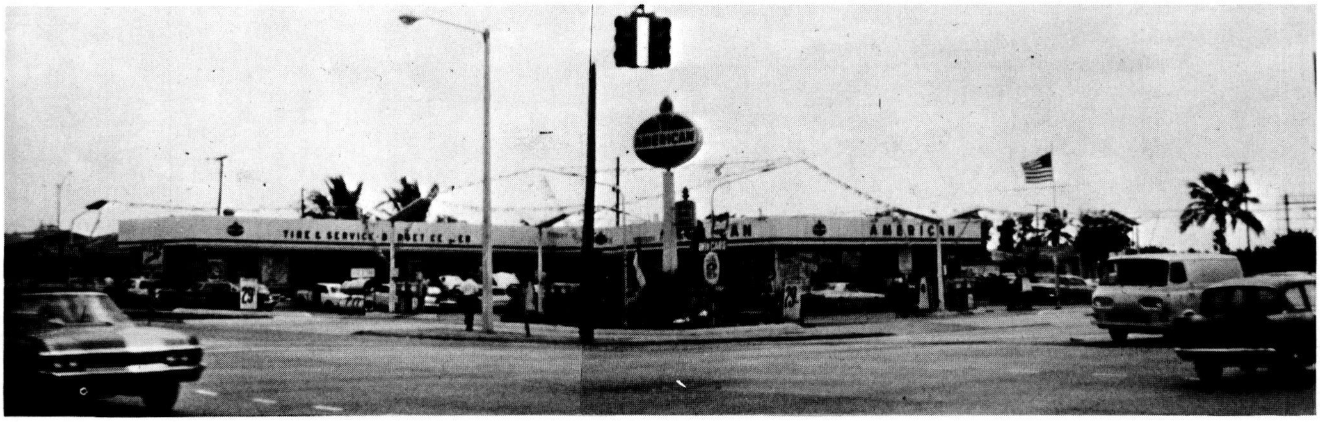


Figure G-1. Example of a service station and tire center combination.

Figure G-2. Example of a multi-function service station.

receipts as a percentage of total receipts, with a corresponding increase in meals and beverages, is apparent. Note also that whereas total receipts increased by about 60 percent from 1948 to 1954 and again from 1954 to 1958, they more than doubled from 1958 to 1963. Although similar and more recent data are not available, trends in the over-all economy would suggest that total receipts have increased sharply since 1963. Certainly, the services available at new motels are continuing to expand.

A corresponding change has occurred in the size and ownership of motels. Table G-2 gives the distribution of motels by the number of units. The fundamental change that has occurred in the motel industry is demonstrated by the fact that in 1948 over 50 percent of the motels contained fewer than 10 units; by 1963 this had decreased to just under 10 percent. The change in the percentage of motels having 50 or more units in 1963 is even more startling. In 1954, only 3 percent of the motels had more than 50 units; by 1963, this had increased to nearly 30 percent.

This trend toward larger motel complexes is also demonstrated by the opening of motels by one of the large national chains. The number of motel developments opened in each of the last 10 years, together with the average number of units per motel, is given in Table G-3. In the 6-year period from 1958 through 1963, the chain opened 60 new motel complexes, with an average of 123 units; the largest development in this period contained 200 units. In contrast, the 64 motels opened in the period 1964 through the first half of 1968 contained an average of 173 units, and the largest contained 584 units.

With the increase in motel size and the demise of the "Mom and Pop" motel, individual proprietorship has also given way to corporate ownership. (Changes in motel ownership over the period from 1958 to 1963 are given in

TABLE G-1

MAJOR SOURCES OF RECEIPTS FOR MOTELS WITH MORE THAN TEN UNITS, 1948-1963

Item		Tourist Courts(1) 1948	Motels and Tourist Courts(2) 1954	Motels and Tourist Courts(3) 1958	Motels and Motor Hotels (4) 1963
Number of Motels Reporting		25,919	10,765	12,407	19,952
Number of Units		303,900	225,777	313,739	452,951
Total Receipts ($1000)		$195,505	$296,887	$489,938	$1,363,598
Receipts for					
Rooms	($1,000)	$181,757	$250,559	$411,841	$1,028,283
	(% of total)	(92 8)	(84 5)	(84 2)	(75.0)
Meals	($1,000)	-	$23,131	$40,283	$210,657
	(% of total)		(7 8)	(8.2)	(15.4)
Alcoholic Beverages	($1,000)	$2,746	$5,081	$8,565	$70,112
	(% of total)	(1 4)	(1.7)	(1 7)	(5 1)
Service Station	($1,000)		$7,685	$10,049	$19,156
	(% of total)		(2 6)	(2 1)	(1.4)
Other Merchandise	($1,000)	$8,326	$7,199	$11,510	$12,381
	(% of total)	(4 4)	(2 4)	(2 4)	(9)
Other Services	($1,000)	$1,857	$3,252	$7,690	$23,009
	(% of total)	(1 0)	(1.1)	(1.6)	(1.7)

Sources.

(1) U.S. Census of Business-1948, Vol. VI, Service Trade-General Statistics, Table 11B, p. 11 03
(2) Ibid., 1954, Vol. V, Selected Service Trades-Summary Statistics, Table 6V, p 6-30.
(3) Ibid., 1958, Vol. V, Selected Services-Summary Statistics, Table 6U, p. 6-34
(4) Ibid , 1963, Vol. VI, Selected Services-Summary Statistics, Table 18, p. 6-55.

TABLE G-2

DISTRIBUTION OF MOTEL SIZES BY NUMBER OF RENTAL UNITS, 1948-1963

Number of Rental Units	Tourist Courts 1948 (1)	Motels and Tourist Courts 1954 (2)	Motels and Tourist Courts 1958 (3)	Motels and Tourist Courts 1963 (4)
less than 10	51 2	20 0	18 5	9 9
10-19	36 0	48 6	43 3	31 6
20-29	8.7	19 7	20 8	17 9
≥30	4 1	--	--	--
30-39	--	6.4	8 1	9 5
40-49	--	2 6	3.7	6 1
50 or more		3 0	5 3	--
50-99				15.3
100-299				9 3
300 or more				4 9

Sources

(1) U S Census of Business-1948, Vol VI, Service Trade-General Statistics, Table 11C, p 11 04
(2) U.S. Census of Business-1954, Vol V, Selected Service Trades-Summary Statistics, Table 6W, p 6-31
(3) U.S Census of Business-1958, Vol V, Selected Services-Summary Statistics, Table 6V, p 6-35
(4) U S Census of Business-1963, Vol VI, Selected Services-Summary Statistics, Table 17, p. 6-40

Table G-4.) The capital requirements of the large modern motel development and increased use of reservation systems are no doubt major reasons for this trend.

Along with the changes in size, function, and managerial structure, significant changes in access requirements for motels also have occurred. With its increased size, the modern motel must draw its patrons from a much larger area than did its predecessor.

Although the successful operation of the "Mom and Pop" motel was contingent on direct and convenient access to the through lanes of an arterial, the relative importance of such direct access has diminished with the newer and larger chain motels. A substantial segment of the clientele now relies on advance reservations, brand-name recognition, lead-in signs, and directories to determine where they will stay. To such clients, the location of direct access points would be expected to have little effect on their choice of lodging; however, the location and visibility of the motel itself is of major importance.

In an interview, the management of a major motel chain indicated that the prime locations are near major inter-

TABLE G-3

AVERAGE NUMBER OF UNITS IN MOTELS OPENED BY A MAJOR MOTEL CHAIN, 1958-1968

YEAR OPENED	NO. OF MOTELS OPENED	AVG. NO. OF UNITS PER MOTEL
1958	5	101
1959	7	160
1960	8	127
1961	12	124
1962	20	119
1963	8	104
1964	6	131
1965	14	200
1966	17	152
1967	23	165
1st half 1968	4	205

Source Interview with motel management

TABLE G-4

MOTEL OWNERSHIP PATTERNS, 1958 AND 1963

ITEM	1958[a]	1963[b]
Total number of motels reporting	41,332	41,584
Percent operated by:		
Individual proprietor	78.2	71 2
Partnership	15.9	16.0
Corporation	5.6	12.5

Sources [a] *U S Census of Business—1958,* Vol V, Selected Services Summary Statistics, Table 6CC, p. 6-54
[b] *U S Census of Business—1963,* Vol. VI, Selected Services Summary Statistics, Table 27, p. 6-103.

sections and freeway interchanges. (Locations within the city itself are not as desirable because of the higher land costs, difficulty in providing for adequate parking, signing regulations, and traffic congestion.) No objections to median dividers on major arterials were expressed. On the contrary, the desirability of nontraversable medians on high-volume arterials was indicated where access is available from the minor street. Frontage of at least 300 ft was reported as a desirable minimum.

It is also relevant to note that national motel chains maintain sizable professional staffs experienced in location, real estate, site layout, building design, and other areas to handle chain-owned developments and to assist franchised developers. Such changes in motel development management structures mean that the highway engineer can expect to deal with a smaller number of motel developers. It also means that much of this contact will be with other professionals who will be much more cognizant of long-term investment problems as related to highway design.

Shopping Centers

Shopping centers frequently have extremely large volumes entering and leaving the roadway along which they are located. Indeed, a large regional shopping center can generate traffic volumes which rival those on many major streets.

A shopping center also provides a single organization with which public agencies can deal on all matters—including access control. A number of the larger shopping center developers are making extensive use of traffic engineers in the evaluation of prospective locations and site layouts, so as to avoid potential access and internal circulation problems. At least one developer, who also operates a department store chain, has added a qualified traffic engineer to his staff for this purpose. His duties also include assisting in the alleviation of traffic problems at existing shopping centers in which the firm has retail stores.

The large regional centers often have a very limited number of access points. These main entrances and exits are of a very high design, capable of handling large traffic volumes. The inbound and outbound roadways of these centers are separated by a median, and access to the internal circulation system and parking areas is not permitted for some distance (often 200 ft or more) from the intersecting roadway. Separate right-turn lanes are, in many cases, provided for traffic entering and leaving the shopping center. With access points having such a high-type design, many centers of over 500,000 sq ft of floor area find it desirable to have only two primary entrances.

Because a large regional center must draw from a large trade area—at least 100,000 families (*1*)—it will be situated in close proximity to one or more major arterials; however, the size of the site for such a center is also very large. For example, a center having 1 million sq ft of Gross Leasable Area (GLA) will require some 2.2 million sq ft of parking based on the recommended 5.5 parking spaces per 1,000 sq ft of GLA. With parking on ground level and retailing on two levels, the site would contain upwards of 2.7 million sq ft, or nearly 1,700 ft on each side (for a square tract). Such extensive frontage, together with the preference for a limited number of high-capacity entry/exit points, is significant in reducing the number of access points along a roadway.

There has also been a trend toward increased office space in shopping centers. Although this is not likely to change the design of the entrances and exits, it may significantly affect the number of vehicles entering and leaving the center during the period of peak traffic flow on the arterial. This results from the fact that the peak office traffic generally will coincide with the AM and PM peak periods, whereas regional centers generally draw their peak shopping traffic at other times.

The type of shopping center that may be successful in the future also appears to be changing. At least one expert in the area, Homer Hoyt, has expressed the opinion that the neighborhood and super-regional centers will be successful but that the community shopping center may not be (*2*). The neighborhood center provides the convenience goods for which residents of the local trade area make frequent and repeated trips. This center characteristically includes a drug store, variety store, beauty and barber shops, one or more supermarkets, and, in some cases, specialty shops, a coin laundry, and a branch bank.

The large regional center characteristically contains two or more department stores, together with numerous specialty shops and other stores and may have a gross leasable area of 1 million sq ft or more. Except for a junior department store, the community center contains little more shopping opportunity than is found in a neighborhood center; however, it needs a larger trade area for successful operation.

There are also significant trends in the developers' interests in accessibility (not to be confused with direct access) to the shopping centers. The fact that developers are becoming more concerned with the traffic-carrying capability and permanence of the arterial(s) providing accessibility to their development is demonstrated by the fact that some developers are contributing toward improvements of the street system. Recent agreements between the developer and the local government in Madison, Wis., and in Indianapolis, Ind., are two examples. Developers of other shopping centers are also known to have contributed toward street improvements in the vicinity of the development; however, these two cases might illustrate the results that may be obtained where the traffic engineer of the local agency works closely with the developer and his staff.

In Madison, the developer of a proposed shopping center located in the southwest quadrant of Interstate 90/94 and East Washington Avenue (U.S. 151) agreed to contribute approximately $250,000 toward improvement of East Washington Avenue, with the improved section extending some distance to the west of the proposed center. Local traffic engineering personnel also worked closely with the developer's professional staff in locating median crossovers and a limited number of direct-access points. In all, three access points, one shared with another business establishment, are to be provided.

In Indianapolis, the shopping center developer agreed to a very sizable commitment in return for rezoning of a large tract on which he proposed to build an enclosed mall center.

This commitment included dedication of right-of-way, contribution of one-third of the cost of reconstruction of certain streets leading to the vicinity of the shopping center, and agreement to pay for the construction of acceleration and deceleration lanes at an intersection on a major arterial a considerable distance from the proposed center. The developer also agreed to pay the purchase and installation costs of traffic signals that may be specified by the responsible governmental agency within 4 years. Local officials estimate the value of these street improvements to be approximately $1 million.

OTHER TRENDS AND DEVELOPMENTS

There has been a general trend toward planned unit development of residential, commercial, and industrial complexes. This has occurred even though zoning ordinances commonly have not been designed to accommodate such development; however, under the pressures which have been developed, changes are beginning to take place in zoning law. Court decisions are making the law clearer and, with this judicial background, a number of local governments are beginning to update their zoning ordinances, permitting them to effectively deal with the problems of planned unit development. It is anticipated that application of planned unit developments will intensify in the years ahead.

There has also been a trend toward larger-scale development in retail commercial establishments such as supermarkets, variety stores, drug stores, and furniture stores. The size of supermarkets, for example, has increased from floor areas in the range of 4,000 to 6,000 sq ft in the early days of the supermarket to stores of over 40,000 sq ft today. The increased scale of development has been in direct response to the need to operate on lower profit margins in the face of increasing costs.

The larger scale of the development means a larger investment in the site and in the improvements and, therefore, a large base against which to write off costs of site evaluation and design—including studies concerning traffic circulation and access. Another important reason for increased use of professional traffic engineers in the layout of the site and consideration of potential traffic problems is that the developers are learning from previous mistakes. It is being recognized that the long-range traffic-carrying capability of the arterial and the adequacy of the internal circulation and parking arrangement are in the financial interest of the investor. This appears to be especially well recognized by the larger developers.

Strip Commercial

Strip commercial development characteristically is composed of businesses that have small site requirements and involve modest capital investments. Although these individual businesses do not generate large volumes of traffic, the owner/operator believes that he must be located along an arterial to have exposure to a large volume of traffic. This situation may be similar to the viewpoint commonly held by most merchants in smaller towns in the 1950's when numerous bypasses were being constructed. These merchants believed that their financial success depended on high volumes of through traffic passing their place of business. Subsequent findings (Appendix B) have shown this belief to be incorrect.

The construction of a bypass to serve the through traffic, however, often failed to accomplish its goal in the absence of access control. Numerous bypasses all over the U.S. have become sections of intense strip development. In many instances the resulting traffic problems have become as severe as those on original routes. In a few cases a more recent bypass has been constructed to bypass the original one.

The U S. 52 Bypass at Lafayette, Ind., and the Airline Highway (U.S. 190) at Baton Rouge, La., are two examples of the proliferation of direct-access points to the through-traffic lanes when no effective access control is exercised. The changes which have taken place on representative sections of these two facilities are obvious (see Figs. G-3 and G-4).

Both locations have had relatively high accident experience. Accident information for 1967 supplied by the Traffic Engineering Division of the Indiana State Highway Commission for four of the control sections on the Lafayette Bypass is given in Table G-5. The difference in the accident rates in the northbound and southbound roadways of the four-lane sections is a result of the larger number of high volume driveways along the southbound roadway.

Information previously assembled by the Louisiana Highway Department compared the Baton Rouge Bypass with that on the U.S. 71 Bypass at Alexandria which has partial control of access. Both of these bypasses are four-lane divided highways with 12-ft traffic lanes, are located in areas of suburban business development, and are in areas of flat terrain. The Alexandria Bypass has a 40-ft median and 10-ft shoulders, whereas the Baton Rouge Bypass has a 16-ft median with shoulders 8 to 10 ft wide. Other comparative information and accident experience are given in Table G-6

Extensions of existing arterials, as well as arterials on new locations in urban areas, have also experienced a general erosion in traffic-carrying capability in the absence of effective access control.

Table G-7 gives information on the number of access points by type of business establishment along sections of three typical urban arterials. The establishments found in strip developments might be classified as being in one of two general groups:

1. Highway oriented.—These establishments serve the highway user; although such establishments may have a substantial local trade, they depend on good visibility of the site from the street, together with an easily recognized path for reaching the site and returning to the arterial. Service stations, motels, and some restaurants are typically in this category.

2. Urban commercial.—This category includes those business types which rely on patronage by the residents of the urban area, but need the accessibility of the local market provided by the arterial. This category might be further divided into establishments that have indicated a tendency toward clustering and those that have not:

(a) Those that tend to cluster include supermarkets, drug stores, variety stores, clothing stores, barber and beauty shops, department stores, specialty shops, and other businesses commonly found in shopping centers.

(b) Examples of those that tend to locate in unorganized strip development along an arterial are: radio/TV sales and service, heating and air conditioning, auto repair and service, plumbing supply, and furniture stores.

The businesses that tend to locate in unorganized developments attract trips which have a purpose associated with a particular establishment. With the exception of radio/TV sales, auto sales, and furniture stores, there is very limited comparison shopping or complementary effect between establishments.

The tendency to cluster results from cumulative attraction of similar retail businesses in close proximity. This provides the customer with the opportunity for greater selection in price, quality, and style. The total aggregate business (and hence the business of each store) is greater than if the stores are scattered. Shoe stores and women's apparel shops are examples of establishments that appear to be particularly sensitive to clustering.

There is also a complementary effect between certain different types of establishments, such as department stores, women's apparel, children's clothing, shoes, variety, and men's clothing Clustering occurs as a result of customers' preference to shop from store to store on a single trip.

Although the linkages have not as yet been clearly (quantitatively) identified, smaller shopping centers also have shown a tendency to cluster. The cumulative attraction provided by their close proximity appears to be a primary factor in this clustering. The presence of this effect is demonstrated by interviews made at Congressional Plaza and Super Giant on the Rockville Pike (State Highway 355) in suburban Maryland in 1964, which indicated that some 20 percent of the shoppers at one shopping center came from another center.

As the trend of certain types of establishments to cluster continues, it should become easier to impose access regulations, as the needs and preference of the cluster development will be increasingly compatible with higher degrees of access control. Further, the developers can be expected to become more sophisticated in the planning of the site, with respect to internal circulation relative to the points of access and building location.

The more serious problem, then, is to reasonably accommodate the needs of the highway-oriented (serving the highway user) establishments and those commercial establishments which are situated in unorganized strip developments. A solution is to use all planning and implementation controls to encourage the organization of these activities in some functional manner. Service stations, motels, and restaurants (especially drive-in restaurants) might be formed into service clusters which would have convenient access to the arterials, but not direct access from each establishment to the through traffic lanes. This might be accomplished by the use of service (frontage) roads.

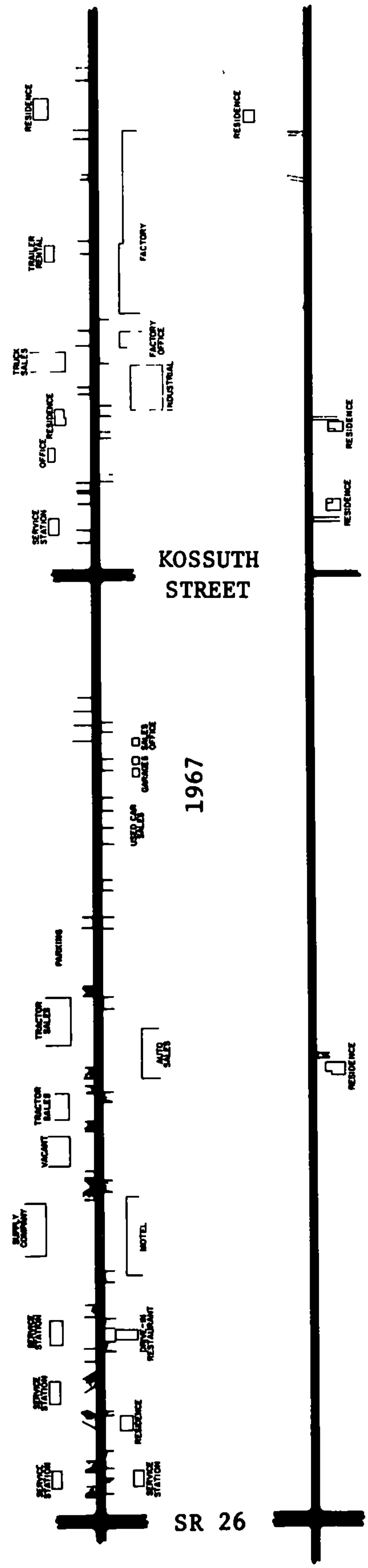
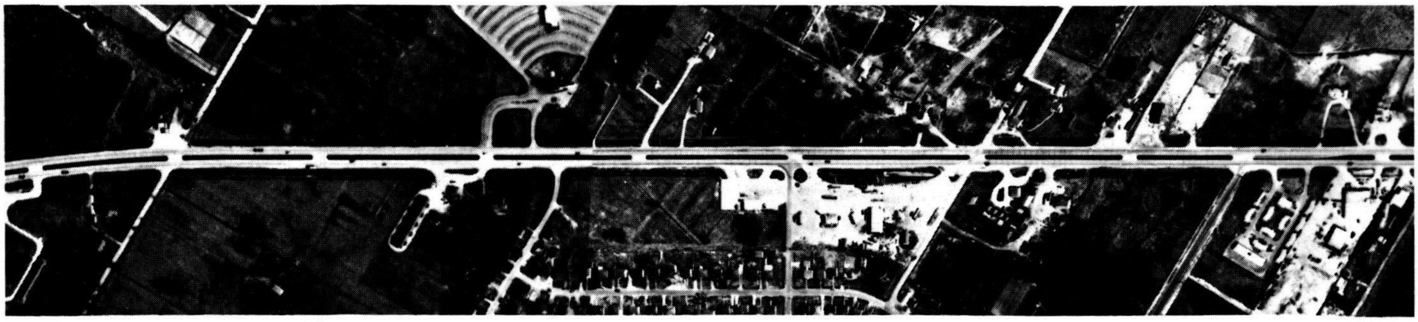
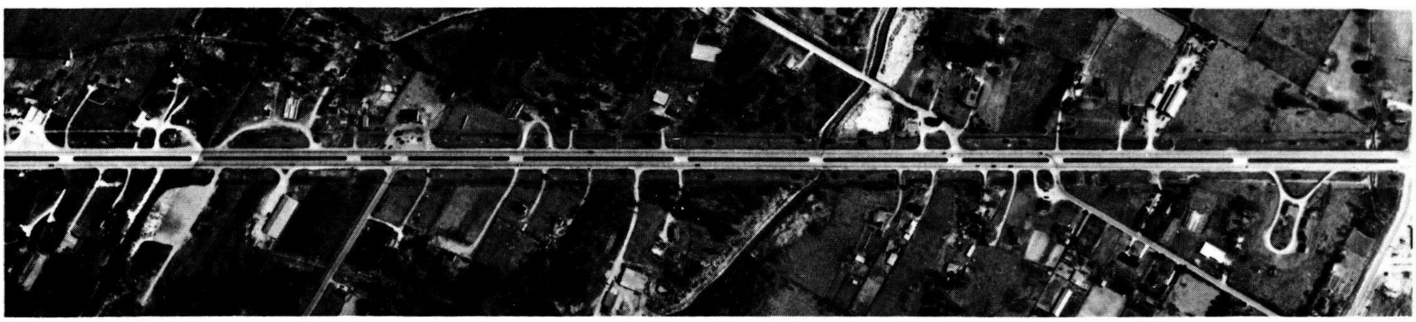


Figure G-3. Changes in direct access to a section of the U.S. 52 Bypass at Lafayette, Ind.



1954

1969



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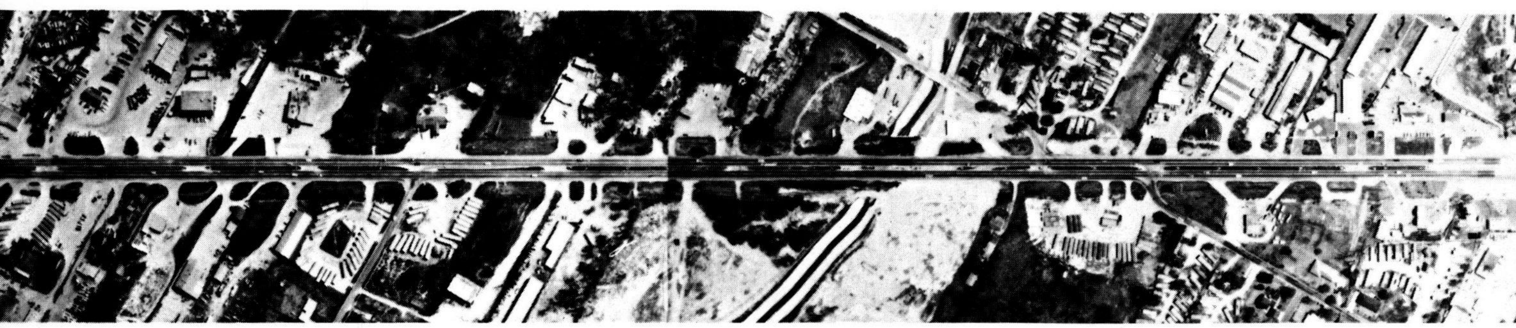

Figure G-4. Changes in direct access to Airline Highway (U.S. 190) at Baton Rouge, La.

TABLE G-5

ACCIDENTS EXPERIENCE ON SELECTED CONTROL SECTIONS OF THE U.S 52 BYPASS AT LAFAYETTE, INDIANA, 1967

ACCIDENTS BETWEEN CONTROL POINTS	SECTION LENGTH (MILES)	ADT	ACCIDENTS TOTAL NO.	ACCIDENTS PER 100 MILLION VEH.-MILES	ACCIDENTS PER MILE
SR 25 to SR 26	2.12	19,900	114	740	53.7
SR 26 to the 2-lane to 4-lane transition[a]	0.85	22,300	40	580	47.0
2-lane to 4-lane transition to SR 38	0.35				
Northbound roadway		10,800	10	720	28.5
Southbound roadway		10,800	33	2380	94 2
SR 38 to Lafayette city limits	0.33				
Northbound roadway		10,200	10	810	33 3
Southbound roadway		10,200	19	1540	57.5

Source Traffic Eng. Div., Ind State Highway Commission

[a] Corresponds to the road section shown in Figure 2-6.

Development on Rail Rights-of-Way

Highway engineers have generally held the opinion that there was little or no danger of direct-access driveways along the edge of the highway, where the railroad right-of-way coincides with the highway right-of-way. In the past, railroads have made little attempt to use or allow development on their rights-of-way, unless the development needed rail service.

In more recent years, however, there have been numerous instances where railroad rights-of-way have been used as sites for highway-oriented commercial developments. Such existing developments are primarily service stations, restaurants/bars, and convenience food stores. Examples of such developments are shown in Figure G-5.

With the increased interest in multiple use of rights-of-way, auto-traffic-generating land uses might be expected to make much more extensive use of railroad property. Many existing commercial land uses could find such locations quite satisfactory if a little ingenuity were used in the site layout and building design. The rearrangement of the service station, whereby the station building is situated at the end of (facing) the pump islands, rather than facing the side of the island, is an example. There would seem to be

TABLE G-6

COMPARISON OF TRAFFIC VOLUMES, ACCIDENTS, AND NUMBER OF ACCESS POINTS FOR THE ALEXANDRIA AND BATON ROUGE, LOUISIANA, BYPASSES, 1954-1961

Item	Partial Control (Alexandria) 1961	1960	1958	1954	No Control (Baton Rouge) 1961	1960	1958	1954
ADT	10,400	11,000	11,200	7,000	23,900	23,600	21,400	11,400
Annual Vehicle-Miles (thousand)	18,022	19,037	19,917	12,280	61,902	60,991	55,026	27,879
Average Running Speed	52	41	45	41	40	40	39	40
Number of Signalized Intersections	3	3	1	0	5	4	4	2
Number of Direct Access Driveways	———— none ————				427	325	338	293
Number of Crossovers·								
total	18	18	18		64	64	76	66
@ intersecting streets	8	8	8		29	19	26	--
Accidents Per 100 Million Vehicle-Miles	569.9	614.6	336.4	423.5	628.4	910.0	670.9	656.4

Source: Louisiana Highway Department.

TABLE G-7

BUSINESS TYPES LOCATED IN SELECTED STRIP DEVELOPMENTS

	Establishments						Access Points					
	Number			Percent(1)			Number			Percent(1)		
	Location			Location			Location			Location		
Type	A	B	C	A	B	C	A	B	C	A	B	C
Appliance store	1		2	.8		1.0	2		3	.9		1.3
Auto service station & car wash	29	17	28	22.7	37.7	13.6	56	31	49	24.2	40.3	20.2
Auto accessories	3		6	2.3		2.9	6		6	2.6		2.5
Auto repair	1		15	.8		7.3	1		15	.4		6.2
Auto sales - new	6	3		4.7	6.7		13	7		5.6	9.1	
Auto sales - used	4		23	3.1		11.2	5		24	2.2		9.9
Barber shop or beauty shop	1		1	.8		.5	2		1	.9		.4
Bank	1		2	.8		1.0	3		0	1.3		0
Bar	1		5	.8	2.2	2.4	1	1	5	.4	1.3	2.1
Convenience shopping												
Convenience food items	1			.8			1			.4		
Finance company	3			2.3			5			2.2		
Furniture store	3		5	2.3		2.4	5		5	2.2		2.1
Laundry - cleaners	3	1		2.3	2.2		7	2		3.0	2.6	
Lumber yard & builders supplies	3		22	2.3		10.7	4		25	1.7		10.3
Motel (only)	9	8	7	7.0	17.7	3.4	17	12	7	7.4	15.6	2.9
Motel & restaurant	4	1		3.1	2.2		6	3		2.6	3.9	
Office, medical-dental	1		4	.8		1.9	2		4	.9		1.6
Office, real estate	1	1	3	.8	2.2	1.[illegible]	2	1	3	.9	1.3	1.3
Office, other	6			4.7			6			2.6		
Restaurant	6	4	7	4.7	8.9	3.4	10	6	8	4.3	7.8	3.3
Restaurant, carry-out	1	1	4	.8	2.2	1.9	2	1	7	.9	1.3	2.9
Restaurant, drive-in	6	2	2	4.7	4.4	1.0	11	4	2	4.8	5.2	.5
Restaurant, specialty	4	2	4	3.1	4.4	1.9	7	3	5	3.0	3.9	2.1
Specialty food & meat market	4		5	3.1		2.4	7		5	3.0		2.1
Super market	1		4	.8		1.9	2		7	.9		2.9
Other retail sales	7		8	5.5			12		8	5.2		3.3
Other	9	1	17	7.0	2.2	8.3	16	2	19	6.9	2.6	7.8
Grouped development with common parking	9	3	32	7.0	6.7	15.5	20	4	35	8.7	5.2	14.4
Total	128	45	206				231	77	243			

Location A - S.H. #6 - Bryan-College Station, Texas.
Location B - U.S. #1 - Vero Beach, Florida From 17th Avenue, North 0.8 miles.
Location C - U.S. #441 - Broward County, Florida From Dade County Line, North 4.1 miles to SR #822.
(1) Percentages rounded to nearest 0.1 percent; sum may not add to exactly 100.0 percent.

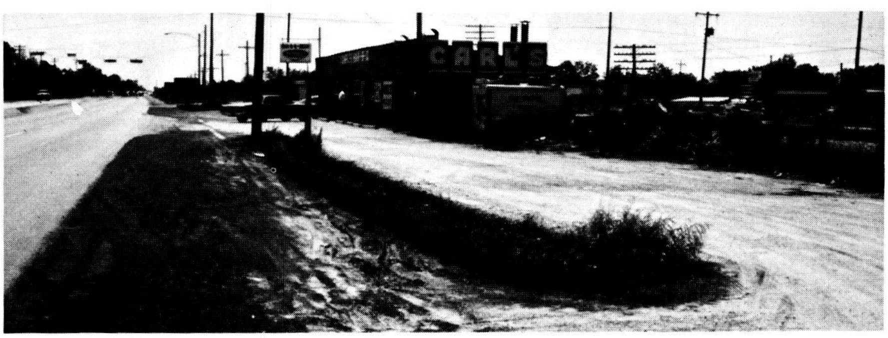

Figure G-5. Examples of commercial development on railroad rights-of-way. A combination service station and car wash (upper) uses the railroad right-of-way along U.S. 290. With relatively minor rearrangement of the building and pump islands, a service station can be located on a very narrow strip of land between the highway right-of-way and the railroad bed. A small cafe (lower) can be easily located on the narrow strip of otherwise unused railroad property between the highway right-of-way and the railroad bed. Such improvements generate land access traffic in locations which were formerly considered to be "safe" from such traffic.

nearly unlimited possibilities for highway-oriented development where the railroad right-of-way is exceptionally wide.

Further, the economics of highway-oriented development on rail right-of-way should be recognized. This development is a potentially high yield proposition to the railroad. All costs associated with ownership of the raw land are fixed and unavoidable. Any revenue over and above the increased taxes resulting from the site improvements and the cost of managing the leases is profit. With the financial difficulties which U.S. railroads have faced in recent years (and which are expected to continue in the future), any such revenues from the lease of rights-of-way for nonrailroad-oriented purposes may become increasingly attractive.

Local traffic to and from developments on railroad rights-of-way presents a potentially serious threat to the traffic-carrying capability of some arterials. It is believed that increased attention should be directed toward the planning for such development—including the application of access controls.

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APPENDIX H

AGENCIES AND INDIVIDUALS INTERVIEWED

STATE AND FEDERAL AGENCIES

1. Louisiana Department of Highways: Harry N. Theriot, Head Traffic Engineer.
2. Maryland State Road Commission. Walter J. Addison, Assistant Director of Planning.
3. Pennsylvania Department of Highways J. R. Hobbs, Location Engineer, Pittsburgh District Office.
4. Texas Highway Department: John N. Libscomp, Senior Traffic Engineer.
5. Washington State Department of Highways: W. M. Foster, Director of Highway Department; Val G. Rinehart, Roadway Development Engineer.
6. Wisconsin State Department of Transportation and Research: Douglas F. Haist, Deputy Director of Planning and Research; George Gunderson, State Planning Supervisor, N. M Margetis, Chief of Roadside Control; Jim Lowe; Bruce B. Wilson, Urban and Regional Planning Division; H. L. Myhre, Chief Planning and Design Engineer, District No. 1.
7. Indiana State Highway Commission· Donald F. Petty, Engineer of Traffic Research and Surveys.

CITY AND COUNTY AGENCIES

1. Dallas, Texas: John J. De Shazo, Jr., Director, Department of Traffic Control, City of Dallas.
2. Denver, Colorado James D. Braman, Jr., Director of Planning; Richard C. Thomas, Assistant Traffic Engineer, City and County of Denver.
3. Indianapolis, Indiana: Jacob B. Hall, Executive Director, Ronald R. Greiwe, Assistant Traffic Engineer, Mass Transportation Authority.
4. Kansas City, Missouri· Thomas G. Williams, Assistant Traffic Engineer, City of Kansas City.
5. Long Beach, California: Per Solberg, Traffic Engineering Associate, City of Long Beach
6. Los Angeles County, California: J. Marvin Blair, Assistant Chief Deputy, Los Angeles County Road Department.
7. Madison, Wisconsin: John H. Bunch, Traffic Engineer; W O. Somerfield, Traffic Planning Engineer, City of Madison
8. Memphis, Tennessee. Robert Fosnaugh, Traffic Engineer, City of Memphis.
9. New Orleans, Louisiana· John F. Exnicios, City Traffic Engineer, City of New Orleans
10. Olympia, Washington: Allan Kimbel, Assistant City Engineer, City of Olympia.
11. San Antonio, Texas: John Miller, Assistant to Director of Traffic and Transportation, City of San Antonio.
12. Seattle, Washington: Myron R. Mitchell, Traffic Engineer; William G. Van Gelder, Traffic Design Engineer; Richard J. Carlson, Senior Engineer—Traffic, City of Seattle.
13. Wichita Falls, Texas Roy L. Wilshire, Director of Planning and Traffic, City of Wichita Falls.

PRIVATE AGENCIES

1. Automotive Safety Foundation; James O. Granum, Deputy Chief Engineer, Highway Engineering Division.
2. Gulf Oil Corporation; Neale Engle, Director, Real Estate and Planning Representative; R. Velinder, Advisor, Real Estate; John Benecke, Advisor, Retail Outlets and Marketing Equipment, Paul J. Maddison, Real Estate Representative
3. Holiday Inns of America, Inc.; Warren E. Hallum, Real Estate Development; Newman R. Parker, Jr., Project Development.
4. Humble Oil and Refining Company; Guy V. Mallonee, Advertising Manager; I. H. Passel; Ted B. Miller; Rudy Cannon, James A. Fite, Jr.; Michael F. White, Marketing Analyst.

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* Highway Research Board Special Report 80

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34	Evaluation of Construction Control Procedures—Interim Report (Proj. 10-2), 117 p., $5.00
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62	Urban Travel Patterns for Hospitals, Universities, Office Buildings, and Capitols (Proj. 7-1), 144 p., $5.60
63	Economics of Design Standards for Low-Volume Rural Roads (Proj. 2-6), 93 p., $4.00
64	Motorists' Needs and Services on Interstate Highways (Proj. 7-7), 88 p, $3.60
65	One-Cycle Slow-Freeze Test for Evaluating Aggregate Performance in Frozen Concrete (Proj. 4-3(1)), 21 p., $1.40
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