NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM REPORT **121**

PROTECTION OF HIGHWAY UTILITY

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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM REPORT 121

PROTECTION OF HIGHWAY UTILITY

HAROLD MARKS
GRUEN ASSOCIATES
LOS ANGELES, CALIFORNIA

RESEARCH SPONSORED BY THE AMERICAN ASSOCIATION OF STATE HIGHWAY OFFICIALS IN COOPERATION WITH THE FEDERAL HIGHWAY ADMINISTRATION

AREAS OF INTEREST:
- HIGHWAY DESIGN
- TRAFFIC CONTROL AND OPERATIONS
- URBAN LAND USE

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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Systematic, well-designed research provides the most effective approach to the solution of many problems facing highway administrators and engineers. Often, highway problems are of local interest and can best be studied by highway departments individually or in cooperation with their state universities and others. However, the accelerating growth of highway transportation develops increasingly complex problems of wide interest to highway authorities. These problems are best studied through a coordinated program of cooperative research.

In recognition of these needs, the highway administrators of the American Association of State Highway Officials initiated in 1962 an objective national highway research program employing modern scientific techniques. This program is supported on a continuing basis by funds from participating member states of the Association and it receives the full cooperation and support of the Federal Highway Administration, United States Department of Transportation.

The Highway Research Board of the National Academy of Sciences-National Research Council was requested by the Association to administer the research program because of the Board's recognized objectivity and understanding of modern research practices. The Board is uniquely suited for this purpose as: it maintains an extensive committee structure from which authorities on any highway transportation subject may be drawn; it possesses avenues of communications and cooperation with federal, state, and local governmental agencies, universities, and industry; its relationship to its parent organization, the National Academy of Sciences, a private, nonprofit institution, is an insurance of objectivity; it maintains a full-time research correlation staff of specialists in highway transportation matters to bring the findings of research directly to those who are in a position to use them.

The program is developed on the basis of research needs identified by chief administrators of the highway departments and by committees of AASHO. Each year, specific areas of research needs to be included in the program are proposed to the Academy and the Board by the American Association of State Highway Officials. Research projects to fulfill these needs are defined by the Board, and qualified research agencies are selected from those that have submitted proposals. Administration and surveillance of research contracts are responsibilities of the Academy and its Highway Research Board.

The needs for highway research are many, and the National Cooperative Highway Research Program can make significant contributions to the solution of highway transportation problems of mutual concern to many responsible groups. The program, however, is intended to complement rather than to substitute for or duplicate other highway research programs.

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This report was prepared by the contracting research agency. It has been reviewed by the appropriate Advisory Panel for clarity, documentation, and fulfillment of the contract. It has been accepted by the Highway Research Board and published in the interest of effective dissemination of findings and their application in the formulation of policies, procedures, and practices in the subject problem area.

The opinions and conclusions expressed or implied in these reports are those of the research agencies that performed the research. They are not necessarily those of the Highway Research Board, the National Academy of Sciences, the Federal Highway Administration, the American Association of State Highway Officials, nor of the individual states participating in the Program.

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FOREWORD

By Staff
Highway Research Board

Although there has been full agreement as to the interdependence of land-use planning and transportation planning, there has been a general lack of information in the planning community as to the interrelationships between highway needs and land-use needs. The research presented in this report includes pragmatic guidelines for land-use control and intrinsic highway control design techniques that can be utilized to protect the public investment in the highway system against premature obsolescence or operational inefficiency. This report will be of special interest and use to urban transportation planners and engineers, land-use planners, traffic engineers, highway design engineers, and other professionals concerned with orderly development of the urban structure.

Good land-use controls, properly administered, can protect and enhance the public investment in transportation. If controls such as zoning and subdivision regulations are instituted without understanding and considering their effect on transportation, the results can be harmful to urban development patterns. The first phase of this research study, completed and published as *NCHRP Report 31,* "A Review of Transportation Aspects of Land-Use Controls," revealed a wide range of control practices in different states and brought to light deficiencies and alternate approaches for attaining the desired objective of optimizing the relationship between land-use development and transportation facilities.

This second phase of the research project has been conducted to study the range of factors besides land-use controls affecting the relationship between land-use development and the highway network transportation system. The objective has been to formulate general theory aimed at understanding the relationship between transportation and land use, and to develop practical criteria and guidelines that can be implemented to protect the enormous public investment in the transportation system from premature obsolescence or operational inefficiency.

In order to assure a broad-based approach to the study of this complex problem, the research agency, Gruen Associates, assembled a multidisciplinary team of related professionals. The study has attempted to concentrate on fundamental relationships, developed systematically as a basis for establishing general principles and guidelines. These principles and guidelines can be put to use by responsible agencies immediately in newly developing areas where full commitments for development and growth have not already been made. Opportunities for implementation are not as great in already built-up areas where major changes may be impractical. In such areas, existing practices may have to be continued, but corrective measures can be taken where feasible.

The report includes a discussion on the general land use-transportation relationships and the theory, design, and application of functional highway classification systems. In addition, the report presents a traffic generation vocabulary that classifies traffic generation by the various land-use categories. Application opportunities for this vocabulary are identified to help in the land-use decision-making process. The report treats in detail the intrinsic highway control measures that can be employed. This includes such matters as freeway and arterial access spacing; driveway spacing, design, and control; site design; service roads; and rear collector roads. Multiple use of public corridors, and their development and design, are treated in a separate chapter. Special attention is given to the problem of land-use controls for areas around freeway interchanges. The report discusses interchange characteristics, development, and problems, and how such problems can be handled through proper access design and interchange protection.

Although the sponsoring agencies for this project are highway agencies, the results of this research will be of interest to a wide audience beyond the highway engineering profession. The interrelationships between highways and land use are of great significance to a wide variety of administrative and technical personnel. Many of these professionals are relatively unfamiliar with the basic principles and concepts involved. The highway engineering profession alone cannot effectively protect the utility of the highway system without the support and understanding of related professionals. Their decisions, together with those of the highway administrator, planner, and engineer, will have a tremendous influence on highway service. The principles and guidelines discussed in this report should be of special help to arrive at decisions that will be of lasting benefit to the public.

CONTENTS

ACKNOWLEDGMENTS

The research reported herein was performed under NCHRP Project 8-5 by Gruen Associates. Primary responsibility for the research was assigned to the Traffic and Transportation Division, under Harold Marks, Director, who served as principal investigator for the project.

Particular acknowledgment is extended to the many public officials, engineers, planners, attorneys, and representatives of other disciplines who were consulted, and to the many public agencies, universities, private consultants, and other individuals and organizations who contributed their time and background of experience to further this research effort. Gratitude is also expressed to the many authors of reference sources from whose works relevant information and findings were extracted.

PROTECTION OF HIGHWAY UTILITY

SUMMARY

This report covers Phase 2 of a two-part effort that had the objective of identifying and analyzing the relationships between transportation facilities and land use. The purpose of the study was to recommend principles and guidelines for developing land-use controls and other techniques that would be stable and effective in the protection of highway utility.

The research effort was conceptual in nature and presents a variety of ideas and proposals by which the highway investment can be protected. Some of the guidelines are developed in considerable detail. These can be incorporated into the procedures and practices of land-use and highway administrators. In other instances the principles are developed as a base from which more detailed analysis can be undertaken.

The basic interrelationships between transportation facilities and land use can best be illustrated by the land use-transportation cycle: (1) Land-use activities generate vehicular trips; (2) The trips identify transportation needs; (3) Needs are met by transportation facilities; (4) These facilities provide additional access to land; (5) The provision of access enhances land value and affects the use of the land.

The urban environment is a system, each component of which has a measurable influence on other components. The analysis, by defining the mutual influences of the land-use and traffic-system components, sought to achieve control of the land use-transportation cycle so that the investment in highway facilities can be optimized. It has been concluded that control of the cycle is possible, and the study defines the elements of regulation and administration that can be used.

Major Problems.—The Phase 1 report, published as *NCHRP Report 31,* "A Review of Transportation Aspects of Land-Use Control," identified eight primary problem areas to be analyzed and treated. They were:

1. The problem of the all-purpose street that attempts to serve all movement, access, and service functions.
2. The problem of development so intense that it results in excessive traffic generation on the highway facilities available to serve it.
3. The problem of excessive conflicts between access demand and traffic movement requirements.
4. The problem of excessive marginal and medial conflicts on the arterial highway.
5. The problem of the intersectional bottlenecks created by inadequate intersection capacities.
6. The problem of excessive corridor traffic volumes.
7. The problem of interchange operation conflicts created by insufficiently controlled development in freeway interchange areas.
8. The problem of the instability of current land-use controls.

The present study, Phase 2, has generated a set of recommendations for actions

to solve these problems. Some of the recommendations deal with necessary advances in analysis and measurement of circulation factors. Some deal directly with the physical design of highways and private developments. Others are concerned with legal or administrative devices to ensure the implementation of good design and to control their subsequent operation. These recommendations are presented briefly as follows.

Recommendations

Traffic Generation.—Current land-use classification systems do not adequately reflect traffic generation characteristics. These systems were not intended for this purpose and cannot be used for traffic generation prediction.

A significant product of this study is a new traffic generation vocabulary and land-use classification system. These provide traffic generation guidelines for each land-use category, making it possible for alternative land uses to be compared. In addition they enable the planner to make evaluations of the interchangeability of land uses based on the characteristics of traffic generation. Guidelines are provided so that it will be possible to determine peak-hour generation characteristics directly affecting highway capacity.

Proposals are also developed for the balancing of land uses so that intermeshing of traffic peaks can take place. Land-use locational criteria are proposed that permit greater intensity of development without additional loads on the highway.

Functional Classification.—Increased use of the functional classification process is proposed for existing streets to achieve a greater specialization in functional use of streets and thus to correct the deficiencies of the all-purpose street. An expanded system of comprehensive functional classification is proposed that includes corollary functions as well as primary functions.

The study expands on the traditional classification system that groups highways into four categories: freeway, arterial, collector, and local access streets. A proposed system of design classification is recommended that would provide each category with well-defined demarcations, each classification being associated with specific design features and operational ranges in a clear hierarchical pattern. Further improvement is proposed through the raising of design standards to optimum levels for each classification.

The study also proposes that the principle of functional classification be extended in additional areas, such as the design of access to development sites and to the internal operation of parking facilities, so that the problems associated with direct access service can be minimized.

Access Design.—Land use directly affects the highway most immediately at the point where access is provided. The study concludes that controls need not imply serious restriction of either movement or access. Rather, the study proposes guidelines to mesh land-use needs and highway needs so that the location of access driveways, the design of the driveway, and internal site design are interrelated with traffic progression criteria and traffic controls.

Arterial Design.—Analyses of arterial traffic patterns following freeway installation have concluded that variations of traffic intensity take place along different routes and various sections of arterials. This study suggests possible reevaluation of arterial route spacing and design standards in some areas so as to retain a balanced volume-capacity relationship along each segment of arterial route.

Recommendations are presented for the application of intrinsic design controls that provide built-in protection for the highway. If this is done, detrimental external influences will have minimal effect on highway utility. Improved techniques for the use of traffic controls as a major highway-planning element are presented to regulate traffic flow more efficiently.

Intersection Design.—Analysis of new land subdivision design practices suggests that traffic patterns will change as new hierarchical street patterns eliminate alternative routings. Anticipated increases in intersectional turning movements caused by the changing character of arterials, plus the reduced flexibility in traffic routing, will tend to intensify intersection problems in the future and restrict arterial capacity. Proposals are presented for the use of more sophisticated intersection design techniques at critical intersections. Practices employed in freeway design are proposed as a source of new intersection design treatments that can be adapted to arterial use with little additional cost.

Transportation-Corridor Capacity.—Increased flexibility in highway-corridor capacity is considered a prime objective in providing for unpredictable future demands. The permanent transportation corridor concept is proposed for use in new areas where sufficient right-of-way can be reserved to provide for future needs. This concept can accommodate innovative new highway designs that will permit corridor capacity to be increased as required. The transportation corridor concept can be expanded to a multimodal corridor to incorporate both rapid modes of public transportation and slower modes of individual transport, in addition to the highway mode. A multiuse corridor could be sufficiently flexible to incorporate current and future transportation modes, and to provide for any required combination of corridor transportation capacities.

Freeway Interchanges.—The analysis of the interchange area problem concludes that the extension of access controls to the cross streets is an acceptable solution if applied so that it does not introduce a corollary traffic problem. Specific guidelines are provided for the application of various interchange designs and access designs within the interchange area. Particular design types are shown to have certain advantages in achieving access to land development and to cause a minimum of detrimental influence on interchange operations. The use of innovative land-use control techniques is proposed, including the interchange sector and the interchange zone concept, which can provide for better control of development in interchange areas.

Land-Use Controls.—Analysis of current land development practices shows a pronounced trend toward development of larger units in place of small individual parcels. Larger-sized sites and longer frontages permit a concentration of access at favorable points and allow a greater flexibility of internal circulation design.

Guidelines are proposed for land-use controls that will coordinate access needs with highway needs and provide proper site design relationships with the highway. Land subdivision regulations are recommended to provide for the collection of access traffic through a supplemental collector facility, thus avoiding numerous access conflict points. With such provision, strip development can be prevented from having a detrimental influence on highway facilities.

Stability in land-use controls is necessary to maintain balance between land use and highway design and to retain control over the land use-transportation cycle. Guidelines are presented for improving land-use control stability through the adherence of land-use controls to a general plan of development based on realistic goals of the community.

The ultimate objective, in both transportation and land-use planning, is to achieve a desirable community environment. Joint consideration of highway needs and land-use needs can be achieved through the use of multidisciplinary teams that are responsible for the planning of both the highway and the abutting land uses. Joint planning can be a protective tool that provides protection of highway utility as well as achievement of proper environmental relationships with abutting uses.

Conclusions

The study concludes that the opportunities for achieving long-lived highway utility are relatively favorable for the future. The basic tools and implementation techniques are already available in those areas where the problems are most severe. Effective implementation of current tools and of the new techniques proposed in this study can further enhance the opportunities available for the prevention of highway obsolescence. The principles and guidelines presented here provide the basis for sound decision making by land-use and highway administrators, which can assure maximum protection of highway utility.

CHAPTER ONE

INTRODUCTION AND RESEARCH APPROACH

The general field of inquiry of this study has been the relationship between transportation facilities and land-use development; more specifically the inquiry has been addressed to the mutual influence of transportation facilities design and development controls (land-use and others), with the objective of developing criteria and guidelines for the maximization of the beneficial aspects of such mutual influences.

Phase 1 of the study, already completed and published as *NCHRP Report 31,* "A Review of Transportation Aspects of Land-Use Control," focused on ". . . a better understanding of the effectiveness of existing land-use controls on the continuing utility of transportation systems." For this purpose Phase 1 included the findings of a thorough search of relevant literature on the subject as well as of extensive canvassing of highway departments and other agencies concerned with transportation planning.

The search of existing literature—encompassing the review of more than a hundred books, periodicals, and research papers—revealed that, in spite of the abundance of written material on specific aspects of the subject, little could be found in the form of comprehensive synthesis, and even less in the form of substantiated principles and guidelines useful for practical application.

The canvassing of public and private agencies directly or indirectly involved with the subject (highway departments, planning agencies, professional consultants, university research facilities, etc.) provided valuable contributions to the understanding of the problem, especially in the form of relevant case histories or specific experiences; the survey revealed a wide range of control practices in different states, and brought to light deficiencies and effectiveness of alternate approaches as well as suggestions for possible new techniques for attaining the desired objectives of optimization of the relationship between land-use development and transportation facilities.

The salient conclusions of Phase 1 were the following:

1. To achieve the general objective of the task, it would be essential that the scope of the study be expanded so as to consider other significant factors and techniques—besides land-use controls—affecting the stability and effectiveness of transportation systems.
2. The task—if carried on to cover all aspects and modes of the transportation systems and their relationship to urban structure and its control devices—would be monumental and well beyond the scope of the proposed study.

These findings were reviewed and discussed with the administrators of the Research Program and its advisory panel. It was concluded that the scope of the study during Phase 2 should be: (1) expanded to cover other factors besides land-use controls affecting the relationship between land-use development and transportation systems; and (2) limited to the single transportation mode represented by the highway system, both to reduce the scope of the study to manageable proportion and to reflect the areas of major concern to the sponsor.

The Phase 2 study has been conducted in accordance with the above specifications: other than for passing references of historical or comparative relevance, no transportation systems other than the highway network have been studied; conversely, the range of factors influencing the utility of the highway system has been expanded to cover other protective devices besides land-use controls. Although it is certainly appropriate to use land-use controls or other devices of urban growth guidance to protect public investment in the highway system against premature obsolescence or operational inefficiency, the primary objective of land-use and other urban growth controls is the encouragement of an optimum living environment. Indeed, only in the context of the quality of the urban environment that it serves can the utility of the highway system be measured. The value of the highway system is that of a component of the urban structure; on this basis it can be assessed, evaluated, corrected, or protected.

PROBLEM STATEMENT

The problem statement initiating this project expresses the underlying philosophy of the study as originally envisioned by the sponsor, as follows:

> Proper land-use controls, properly administered, protect and enhance the public investment in transportation. Zoning, subdivision regulations, and all other land-use controls are intended to shape the pattern of urban development; they thereby can affect the transportation system. If land-use control decisions are made without understanding and considering their effect on transportation, the results may be harmful to the community.
>
> Since transportation facilities have long development times, the stability of land-use controls and land-use plans is a key factor influencing the validity of transportation plans.

RESEARCH APPROACH

Phase 1 organized and categorized current procedures and practices and determined the current state of the art. The major effort during Phase 2 has been to comprehend and define the relationships between transportation and land use (as well as other factors) that have, in the past, been understood in only a vague or imprecise way. The experience of the writer in specific projects has provided a significant fund of information, and from such experience and from the research work specifically undertaken have been formulated a general theory and, as a corollary, practical criteria and guidelines.

In keeping with the broad and complex nature of the problem, the study has been conducted by a team of individuals proficient in related professional disciplines, including traffic and transportation engineers, highway designers, regional planners, land planners, urban designers, land economists, and civil engineers. Many of the concepts and conclusions have been reviewed with other professionals and practitioners; thus, the work has drawn on the combined experience and critique of numerous agencies, private firms, and individuals.

The study has attempted to concentrate on fundamental relationships. These have been developed systematically as a basis for the formulation of general principles and the development of pragmatic guidelines and design techniques. The principles and the guidelines are intended to be used by planning and highway administrators to assist in decision making, both in already built-up and in newly developing areas.

In areas already built up, land-use controls are well developed, firm commitments have generally been made, and major changes may be impractical, even though desirable. Theoretical considerations may have little effect in such areas; existing practices may have to be continued and only corrective measures taken where feasible.

In newly developing areas, the greatest opportunities are available and the greatest good can be achieved for the future. Current commitments in these areas can be readily modified if the agencies responsible for growth and development are convinced that new concepts have merit and that the end result will represent a community benefit.

OPPORTUNITY

The opportunities were emphasized in the Presidential message on cities delivered to Congress in March 1965. The message stated:

> In the remainder of this century urban population will double, city lands will double and we will have to build in our cities as much as all that we have built since the first colonist arrived on these shores. It is as if we had forty years to rebuild the entire urban United States. New suburban sprawl reaches out into the countryside, as the process of urbanization consumes a million acres a year. We are still only groping towards solution. The next decade should be a time of experimentation. We will seek new ways to structure our suburbs, and our transportation. This is an effort . . . . which must call upon administrators and officials to act with generosity of vision and spaciousness of imagination.

The engineer and planner have a great opportunity to "seek new ways to structure our suburbs and our transportation." When new development takes place, the exercise of "generosity of vision and spaciousness of imagination" need not be limited by commitments to previous practices.

Almost all new population growth in recent years has taken place within the suburban rings of large metropolitan areas. By 1980, 60 percent of the population in metropolitan areas will live in the fringes or in suburbs outside central areas (*18*), and the extent of suburban land use will double. The predicted pattern of urban growth indicates that the major areas of opportunity will be in the fringes of large metropolitan areas, where the bulk of population growth will take place, or, hopefully, in "new cities" encouraged into being through the formulation of a national policy on urbanization; in both instances correlation of land use with transportation investment can indeed be maximized. There is relatively little commitment with regard to land-use patterns and highway networks in areas that are yet undeveloped; thus there is opportunity to consider improved techniques for accommodating growth and enriching the quality and convenience of the environment.

Investment in highway transportation, as in many other engineering undertakings, has historically been guided by design criteria derived from maximization of benefit-cost ratios. The emphasis has been on those quantifiable economic factors that are usually associated with this kind of evaluation. Other factors that cannot be readily integrated into benefit-cost formulas have not been accounted for except in general qualitative terms.

Recently, increasing demand for higher levels of service is beginning to exert an influence on traditional practices. Considerations of environmental improvement, aesthetics, comfort, convenience, reduced anxiety, and many other nonquantifiable factors have recently been receiving significant emphasis. A public that is able to afford more expensive houses, better equipped automobiles, and other major luxury items is beginning to demand a higher level of service in transportation as well.

Furthermore, impatience is growing with the toll of death, injury, and property damage that results from traffic accidents, as well as with traffic congestion and delay that tend to rob the public of at least some of the benefits promised by greater affluence. The dangers and inconvenience of the transport system contrast sharply with the increased comforts that the public has been able to purchase in other aspects of daily life. Thus, increased expectations on the part of the public can constitute an opportunity for implementation of changes in many currently accepted norms, and design standards can be progressively raised to levels consistent with the demands of an affluent society.

CHAPTER TWO

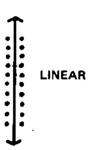
LAND USE–TRANSPORTATION RELATIONSHIPS

ROLE OF TRANSPORTATION

Historic Role of Transportation

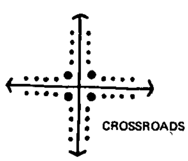
Throughout history there has been a close association between the use of land and the availability of transportation facilities. City sites were partially determined by preexisting transport features—waterways or trade routes. Numerous small communities sustained themselves in isolation because the transportation links between them were tenuous and slow. A city's outward growth was limited by the amount of time it took to travel from its center to its outskirts, and this in turn was limited by the rates of speed of prevailing modes of transport.

The growth of commerce and the advance of technology stimulated the development of improved transportation modes and culminated in the introduction of the canal, the railroad, and the improved highway. These higher-speed transportation media welded together widely distributed cities and initiated new cycles of urban growth. A variety of intense land uses began to locate at critical junctions and at the interface between different transport modes.



A general pattern of city growth that was evident in some cities illustrates the historical interaction between land use and the highway. In the early stages of growth, most land uses extended along the road in linear fashion, and in a small town all facilities fronted on the same road. If the community was formed at a crossroads, linear development extended along each of its four arms, and the junction formed the center of the community, where the most intense land uses were located. As the community continued to grow, area development began to replace linear development with the extension of new streets off the main roads.

A differentiation then became evident between major roads that provided connections with other communities and minor roads that provided access to land needed for development. At the same time, a distinction developed between the land uses adjacent to these two types of road facilities: major roads were valued for commercial development and other intensive land uses; low-density development tended to locate on minor roads.



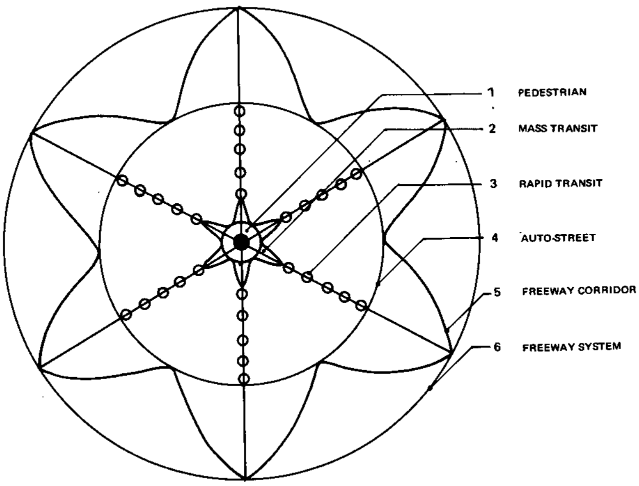
In this manner a natural separation began to take place between land uses along specific road facilities. A hierarchy tended to develop in both the road system and land uses. These relationships have continued to the present day, although they have grown more complex as the variety of highway categories and land uses has continued to proliferate.

Community Growth

The historical relationship between transportation and community development is also evident in patterns of community growth. Size, shape, and pattern of development have always been directly related to the transportation system. Technological improvements in transportation were followed by changes in patterns of land use, and several distinct stages in this process are notable.

Until little more than a century ago, pedestrian and equestrian transportation were the primary modes. Land-use development was concentric and more intensive development was located near the center. The relationship between land uses was determined by walking distances; this created a high-density development and a fine-grain mix of uses that were dependent on each other for interaction and mutual support.

The first major change in this pattern took place when systems of mass transportation were developed, generally in the form of radial systems of streetcars. Use of these



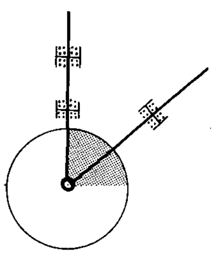
radial transit lines by commuters to the city center increased accessibility for a larger population and resulted in fairly concentrated strip development along the transit lines.

The growth of the city continued as faster forms of transportation were inaugurated. Development of elevated railroad, subway, and rail commuter systems were inaugurated in some cities at the turn of the century. Clusters of development took place around the transit stations.

Development patterns took an entirely different turn when automobile transportation became a major mode. The automobile freed the land-use development from the necessity of being located along fixed corridors. Extensions of the street system opened up vast areas for development. The gaps between transit corridors were rapidly filled in, forming a continuous urban pattern. A pattern of decentralization now extended to all types of land uses.

Highway Influences on Growth

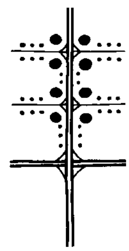
Development has historically clustered around the transportation facility as it has extended into the fringe areas. Intercity road networks frequently preceded growth and acted as the agent of growth. As new residential areas developed beyond previous perimeters of urban growth, it was logical to extend this new growth along a highway corridor that already existed, inasmuch as that highway provided an essential connection to the city center.



The highway acted as the main through-traffic carrier, the principal community circulation facility, and, as "Main Street," the site of intensive development. The highway soon lost its ability to accommodate through traffic because of the increasing demands imposed on it for access and local circulation. Frequently a continuous chain of strip development extended along the highway, and access demands proliferated with each added development increment.

Traffic demands along the corridor continued to mount. If there was no feasible means of restoring traffic capacity along the existing right-of-way, a new alignment was sometimes developed for through traffic, frequently with inadequate access controls. Within a few years, new development would be attracted to the new alignment, causing a reduction of capacity and, again, premature obsolescence.

To avoid a repetition of this cyclical relationship between the highway and abutting land uses, a new facility was developed with full control of access and grade separation—the freeway. The freeway provided built-in protection against the access demands of abutting properties by eliminating all direct access. The freeway became the prime transportation artery and its higher speeds permitted the commuter to move farther away from the city center. Radial freeways were supplemented by circumferential freeway routes that provided a web of freeway corridors to serve the principal transportation demands of large metropolitan areas. This further accelerated the decentralization of all types of development. The new hub of transportation activity was around the freeway interchange, and major development was now attracted to these areas.



LAND USE-TRANSPORTATION CYCLE

Urban Structure

Until recently, little information has been available that would permit quantification of the strong interrelationships between land use and transportation. In many cases even the qualitative relationships were not fully understood.

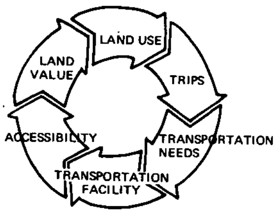
The community can be viewed as containing both structural and dynamic elements. The physical geography, topography, and land and water forms are basic controls of the urban structure. Other fundamental structural elements include the major public activity centers—parks, squares, government centers, cultural and recreational facilities, educational centers, and other community gathering places. These are not as permanent as are the land features.

Another element of the urban structural framework is the transportation system. The railroads, commuter railways, subways, and other fixed channels of transportation are usually permanent elements in the city's structural framework. The city streets, arterial highways, and modern freeways are also relatively fixed elements in the city's physical structure.

The transportation system usually survives several cycles of land use. The rights-of-way remain long after the original land uses have disappeared and have been replaced by other types of development. Frequently the transportation facility using the right-of-way remains the same, although the land uses that abut it undergo many changes. The long-term persistence of the transportation facility emphasizes that the highway plays a far more permanent role in the urban structure than do the land uses it is intended to serve.

Cycle Diagram

The basic interrelationships between land uses and the transportation facilities that serve them are illustrated by the land use-transportation cycle diagram (*15*), which offers a somewhat oversimplified explanation of interactions that frequently take place. This continuous cycle starts with land use; activities on the site generate trips; these trips, connecting points of origin and destination, identify transportation needs; transportation facilities meet these needs; the transportation facilities, in turn, provide additional access to land; with the provision of such access, land value is enhanced; land value completes the cycle by affecting the land use.



This cycle diagram also illustrates a primary cause of breakdown of a transportation facility: more intensive land use generates more trips; this increases transportation needs and causes the improvement of transportation facilities; additional facilities improve accessibility, which in turn tends to further increase land values; this results in more intensive land use to compensate for the increased land value—and the cycle begins again, frequently culminating in a breakdown of the transportation facility.

Alternative Approaches

The recurrent situation just described underlies the concern expressed in numerous publications that highway systems may not keep pace with travel demands in rapidly growing urban areas. Predictions of future highway transportation chaos and a breakdown of mobility are prevalent in many of the current discussions about transportation needs of the future.

One solution that has been proposed is to avoid excessive traffic concentrations by attacking the problem at its source —the land-use traffic generator. This viewpoint maintains that it is necessary to limit the amount of development that takes place in particular areas so that the highway system will not be overburdened. If large traffic generators were restricted from locating in critical areas, if the intensity of development were also limited, and if large concentrations of development were split up into several smaller concentrations in different locations, many of the problems associated with traffic concentration and highway facility breakdown could be avoided. This viewpoint proposes that controls over land use by governmental agencies be exercised more effectively to achieve these objectives.

Another viewpoint that expresses a contrary philosophy concerns itself with the function of the highway. This view stresses that transportation is one part of the urban environmental system that is intended primarily as a service function. Over-all community objectives are the principal determinants of land-use development. The land-use plan is intended to provide maximum opportunities for the organization of community life within a superior living environment. The highway is intended to serve the composite interests of the community, permitting the land-use plan to operate.

These two views are based on different premises, but both have some validity. The highway is a service facility intended to serve the circulation needs of the community as these are defined in the land-use plan. It is theoretically possible to design a circulation system to accommodate almost any demand. However, there are practical limitations and a balance must be maintained between the theoretical and the attainable. The urban environmental system is a flexible one whose components are interrelated and must be kept in balance. Changes in one component may have to be accompanied by changes in the others, to sustain a balanced system.

A full understanding of the interacting relationships between transportation and land use can be obtained by analyzing each of the component elements of the cycle and their relationships to the other elements. The study has therefore been expanded from the original problem definition, which concentrated primarily on land-use controls, to include the other elements as well.

These include the traffic generation resulting from land-use activities, the system of highways that is intended to satisfy the transportation needs of the land uses, the access needs of land development, the design of the highway to provide for access needs without detriment to highway utility, and, finally, the land-use controls that can provide effective regulation of land development and of site design to implement the planning and design objectives developed in the analysis of each of the other elements.

Available Controls

Controls to manage change can keep the land-use cycle within manageable bounds. Government regulates land use by various land-use controls. Highways are built with public funds, and public capital investment can be altered as required. Land value is affected by accessibility but it can also be controlled by tax policies, which are subject to modification. Thus, opportunities for controlling change are available through policies affecting the use of the land, the expenditure of public funds, the method of taxation, and many other governmental mechanisms.

The extent to which such controls are used depends on government philosophy. Which controls shall be exercised, for what purposes, and to what extent? Highways can be used to respond to needs as they develop, as a service function. They can also be used to shape the urban environment and development. Traditionally, highways have been built to respond to needs, but some communities are using public capital investments to shape land use as well as to serve it. The opportunities and the legal tools are available; it is a matter of policy whether a community wishes to use these devices for shaping the growth of the community according to long-range goals and objectives.

LAND USE-HIGHWAY INTERACTION

It is possible to detect several distinct areas of interaction between land use and the highway. The characteristics of land-use development that affect the highway are: type of development, development intensity, development location, access location, access design, and site design. The characteristics of the highway facility that affect and influence abutting land development include: access control, geometric design, traffic controls and restrictions, parking and loading controls, and other operational and design characteristics. The interrelationships must be fully defined and evaluated to determine how they can be meshed for the mutual benefit of both the land and the highway. The relationships briefly enumerated in the following are developed in detail in succeeding chapters.

Type of Development

The manner of use of land is a primary determinant of its effect on the abutting highway. Each land use has distinctive traffic generation characteristics that vary according to amount of traffic generated per unit of land area, time intervals of peak-traffic generation, intensity and distribution of traffic peaks, directional orientation of traffic movement, composition of traffic attracted, and other variables. Over-all daily traffic characteristics for specific land uses are of general interest, but the most critical effect on the highway system is the peak-loading condition at different times of the day as related to peak demands placed on the highway.

Existing land-use categories and their method of classification provide a basis for a modified grouping system that pertains more directly to traffic generation characteristics. To provide the necessary guidelines, traffic generation data that pertain to different land uses have been assembled.

Development Intensity

Traffic intensity varies with development intensity. Current land-use classifications are not necessarily related to traffic generation potential, and there is little consistent and reliable guidance available to the land-use administrator for evaluating the effects on the highway system of alternative land-use decisions. To provide an effective tool in relation to traffic intensity it is necessary to develop a new hierarchy of land use based on traffic generation intensity. Criteria have been developed for determining the effects of alternative land-use options on the highway system (Chapter Five).

Development Location

The proximity of land uses of different intensities and traffic generation characteristics to major traffic facilities can greatly affect the utility of the freeway and arterial system. The relationship of size of development to the type of highway facility it abuts can provide criteria for proper placement of different facilities (Chapter Twelve). Other locational criteria can be developed from the relationships of traffic characteristics for different types of land uses; different categories can be grouped together in such manner that their traffic characteristics complement rather than conflict with each other, and a balance between different uses can thus be achieved (Chapter Six).

Access Location

The specific relationship between a land use and an abutting highway is experienced primarily at that point where traffic transfers from one to the other. A large traffic generator located adjacent to a freeway has an effect on the freeway at the interchange where access is provided from one to the other. A land-use development located along an arterial has little effect on that arterial if there are no driveway access points; its influence is primarily felt at the point where traffic from the development reaches the highway. Consequently, the location of access rather than the location of the development is the most significant relationship that concerns the utility of the highway.

Specific criteria have been developed with regard to optimum locations for intersections and driveways along an arterial; these are related to the criteria for traffic signal location to maintain efficient traffic flow along the highway (Chapter Eight). Other access design criteria establish that fewer driveways of high-caliber design are preferable to a greater number of driveways with lesser capacities (Chapter Eight). Specific criteria for left-turn and right-turn access location provide guidelines for location of all types of access driveways along arterials (Chapter Eight).

Access Design

The design of the access driveway has a considerable influence on the abutting highway facility because it affects traffic operation on and off the highway and the efficiency of access. The design of the driveway is one determinant of how much interference occurs between the vehicle that slows down to enter the driveway and the remainder of the traffic stream. Similarly, the width of driveway determines how efficiently exiting vehicles from the development can merge with the through-traffic stream, and the degree of conflict encountered.

The types of controls exercised on entering and exiting vehicles also influence the effects on other traffic, especially with signalized control. Criteria for access design and driveway controls have been developed to minimize detrimental influences on the highway system (Chapter Eight).

In development of the criteria for access design, a theory of hierarchical movement has been worked out to explain some of the current failures. This leads to proposals for the use of a functional system of facilities to eliminate some of the current deficiencies (Chapter Eight).

Site Design

The internal design of the site, especially the manner of acceptance of the vehicle into the off-street terminal facility, determines whether a vehicle from the highway can enter the site at the speed of its arrival at the access point. If internal absorption capacity and conflicts impede in-flow rate, traffic will back up onto the highway and block through traffic movement. The design of the system of egress from the site also has an effect on the highway if the egress design does not permit traffic to flow efficiently into the highway. Lack of ingress capacity can result in serious congestion on the highway; lack of egress capacity is normally reflected in congestion on private property. Ingress deficiencies are far more serious in their effect on the highway and are of primary concern.

Criteria for site circulation design affecting ingress and egress capacity have been developed to provide the guidelines needed for effective internal circulation (Chapter Eight). Other elements of internal circulation design, including internal circulation roadways and even the design of parking aisles, also have some effect on the perimeter highway system.

HIGHWAY DESIGN RELATIONSHIPS

A highway is usually viewed as a specific design entity that varies only according to its function. Presently, however, the relationships between the arterial and abutting land uses are being recognized as modifying influences that can affect design.

Recognition of this concept is implied in the *National Highway Functional Classification Study Manual (330)*:

> The Transportation System is a major structural element of the community. It serves as a circulatory system providing travel mobility, and it serves equally as a skeletal system providing a relatively permanent framework which delineates and influences the pattern of land development, and within which residential neighborhoods and other land uses may develop and function. The preservation of neighborhoods, the stabilization of desirable land uses, and the encouragement of orderly development are among the basic considerations in the development of functional street systems. The concept of streets as a land use is also important in functional classification. In the same manner that industrial activities usually make undesirable neighbors for residential districts, but make suitable neighbors for railroads, so must streets and traffic be viewed in terms of their impact upon, as well as service to, adjacent land uses.

Design Coordination

This intrinsic relationship between the highway and the land uses abutting it has not previously been given much attention in the design of the highway, or, for that matter, in the design of the land uses that abut the highway. A basic consideration in the development of functional street systems is the preservation of neighborhoods and the stabilization of desirable land uses. The design of the highway is also related to the type and design of the land use that abuts it. The highway must accommodate its design to the needs of the abutting uses, and the land-use development must accommodate its design to the criteria for efficient traffic operation on the highway. Lack of coordination between these related needs can result in a severe restriction in the accessibility provided to abutting development and/or a serious reduction in highway efficiency and safety. There are also criteria governing the size, use, and operation of a development site that influence where such a development should be located (Chapter Twelve).

Dependent Relationships

In the current study each of the relationships was analyzed individually at first. But as the study developed and as the number of relationships was expanded, a high degree of dependence was detected between variables. Highway capacity, intersection control requirements, access spacing, turning-movement control, street design standards, arterial speeds, traffic signal phasing, and other elements of highway design and operation were found to be causally interconnected. This dependency was later extended to include some land-use controls, some aspects of internal site design, traffic generation variability, and other elements. The manipulation of each element has a derivative effect on other elements.

HIGHWAY FACILITY ROLES

Separators or Integrators

There is a distinct dichotomy influencing the role that highway facilities play in the community with regard to land uses; they can be considered either as separators or integrators. The community can be considered to be split by a highway, or the highway can be considered to be the community spine along which land-use development takes place. These are not necessarily contradictory because both are actually true. Each functional category of highway acts as a separator for one level of community unit and as an integrator for the next higher unit.

The smallest community unit is the individual residence, and the access street acts as a separator of residences on either side; however, the access street also acts as an integrator for the cluster of residences that surrounds the street. The collector street acts as a separator of clusters of residences on either side; but the collector street is also the central spine for the neighborhood that is composed of a number of clusters. The arterial highway separates neighborhoods lying on either side; yet it is also the principal integrator for the community composed of several neighborhoods. The freeway acts as a separator between communities located on either side; however, the freeway is also the principal regional facility that binds together the region composed of many communities. In this manner the highway acts in a dual role, as both separator and integrator, for different levels of community structure.

Separator Characteristics

The degree of separation represented by a highway is dependent on a number of physical and operational factors. Width is one obvious determinant: a narrow right-of-way is less of a separator than a wide one. Volume of traffic is another measure of separation: a collector street represents more of a separator than does an access street because of the heavier traffic using it. The arterial is wider than the collector and carries considerably more traffic. This width and intensity of use are frequently of such magnitude that crossings by both vehicles and pedestrians are unsafe except at signal-controlled intersections where arterial flow is stopped. The freeway is an extreme example of separation because it has a very wide right-of-way and continuous traffic flow. Crossings are allowed only at grade separations that are spaced quite widely, emphasizing the degree of separation. The freeway is frequently at a different grade than the surrounding land, and this provides an additional physical or structural separation.

Interaction across highway facilities is dependent on the degree of separation imposed. Vehicular interaction is not necessarily deterred across an arterial when crossings are limited to intervals of a quarter mile or even more. Freeway grade separations at one-mile intervals will deter interaction from one side of the freeway to the other, but intermediate half-mile grade separations will not seriously affect interaction.

The Freeway Role

The freeway can play a divisive role and separate one portion of a community from another, or the barrier effect can be minimized through design. The relative effect of the barrier varies with the method of construction and can constitute a physical, visual, or psychological barrier. The limiting of interaction is dependent on the frequency of cross connections. When projected through an existing community, the freeway is usually a disruptive element. This is emphasized by the interruption of many local streets. However, the freeway also offers new opportunities for modernizing the circulation pattern to improve traffic safety and environmental conditions. New residential developments usually maintain a wide spacing between arterials and make intermediate streets discontinuous. When a freeway is developed through an existing area, the continuity of major streets and arterials is retained across the freeway at about the same spacing as in new community design so that major interaction is not impeded. The separation effect of the freeway is more often a visual and psychological bar than a physical hindrance to interaction.

There are design methods of integrating the freeway into the community so that some of its divisive influences are minimized. The freeway can be woven into the texture of the community by joint highway and land-use development so that there is less disruption created and the community itself can extend across the freeway barrier.

The freeway can thus assume a number of different roles in the community, but its design must reflect the specific role assigned. As currently designed, many freeways constitute dividers, but this is not necessarily intrinsic or inherent in the freeway concept. It is simpler to use the freeway as a separator, and there are many applications in which this is beneficial. However, if separation must be minimized, the freeway can be integrated into the community design so that it constitutes one of the community's structural elements, to be anticipated in the initial design because of its effects on the location, profile, grade, and method of construction. Thus is emphasized the need to correlate the design of the freeway with the planning of adjacent land uses; if freeways are planned and designed separately, the opportunity for properly integrating the freeway into the community is lost.

Highways as Development Tools

It is now generally recognized that a new highway constitutes one of the principal active elements that controls and directs growth and shapes the community. This is particularly evident when construction of a freeway through virgin land promotes rapid development along its perimeter. A community general plan developed prior to the introduction of a freeway may be obsolete if it does not reflect the changing situation. New accessibility and exposure provided to undeveloped land imparts a previously nonexistent development potential. The new environment (freed from the blighting influences of older developments) and the improved accessibility from the regional highway system offer new opportunities.

In recognizing the potent influence of new highway location in directing growth, the community should seek to use this influence in a positive manner. Freeway location is a potent implementation tool to further community objectives. The community should take an active role in analyzing the effects of different freeway locations on the community and actively support the location that provides greatest benefit.

CHAPTER THREE

THE HIGHWAY PROBLEM

PROBLEM INTERPRETATION

Highway Functions

Highway transportation involves the movement of persons and goods along highways. A complete sequence of transportation service must also include access to the land. However, it is not necessary that the same facility provide both transportation service and land access service. In a functionally specialized highway system, several categories of facility are developed, each type designed to serve a specific function most efficiently. The composite system provides for both transportation and access, although these may be handled on different facilities.

Before the development of functionally specialized highways, problems arose from the lack of differentiation between the movement and access functions. The typical highway attempted to provide for both movement and access on the same facility. This led to a service breakdown, typified by congestion, delay, accidents, and other consequences of malfunction in both the transport function and the access function.

Urban Congestion

There are many explanations of the causes of highway service breakdown that, most frequently, tend to attribute the problem to too many automobiles, too much intense development, too much generation of traffic, too much urbanization, etc. All these interpretations have validity in that they partially explain the phenomenon, but they do not lead to a solution. These factors are all concomitants of economic growth, which affects many other aspects of urban life in addition to transportation facilities.

Urban transportation presently suffers from capacity limitations as expressed in congestion. Urban traffic congestion contrasts markedly with the situation in rural areas. Transportation facilities between cities frequently have the capability to handle vastly greater amounts of traffic, but as the traveler approaches an urban area, mobility decreases, speeds drop, and congestion appears. It is probably utopian to hope for completely congestion-free urban areas; we may never experience free and unimpeded peak-hour travel.

A program of future improvement in transportation will have two primary objectives; to expand capacity to meet growing demands and to make gains in relieving existing congestion. As quantity is expanded the quality of urban transportation will also be improved.

HIGHWAY DEFICIENCY

Transportation Facility Breakdown

Manifestations of highway deficiency are usually expressed in vague terms. A good method for measuring the symptoms of highway deficiency—traffic congestion, hazard, inconvenience, etc.—is needed to justify the controls and restrictions necessary to correct that deficiency.

Highway deficiency is sometimes expressed in terms of a "breakdown" in the transportation facility. Such a condition may range from total stoppage of vehicular movement over an extended period of time to occasional extra minutes of delay during peak periods. The problem of definition is compounded by the fact that service failures of one degree or another occur at some time in almost every system. There is usually little factual evidence about the type and intensity of the problem, and there usually is no measure of the seriousness of the situation. More seriously, the casual relationships are frequently masked. The effects are often ascribed to symptomatic causes rather than to basic causes. Relatively stringent control measures (including land-use controls) are frequently proposed to correct highway deficiencies; some criteria must be available to justify such controls.

Functional failure of a highway facility is evident in increased congestion, greater delays, excessive accidents, and other signs of deficiency. However, a condition considered to be a service failure in one community may be accepted as completely normal in another. In a large city the driver has generally become accustomed to frequent traffic delays of one kind or another; in smaller communities relatively minor delays are irritating because they are not expected. The definition of service failure therefore varies considerably between communities of different sizes, and different criteria must be applied.

Objective measurement of highway deficiency should be expressed in a form that is meaningful to the particular community affected. It is necessary to establish threshold values for each of the measurements of deficiency; from these appropriate measurements of deviation can be made. The principal symptoms—reduced safety, efficiency, and convenience—are subject to some form of measurement in relation to an average standard that can be established for a particular community.

Safety

A primary measure of service failure is accident history. It is necessary to define a level of accident experience beyond which the rate can be considered abnormal and excessive. The determination of this threshold value can be related to average current accident experience on the specific type of facility under consideration. This would provide a basis of comparison and an objective measure of service failure from the standpoint of safety.

Efficiency

One measure of inefficient highway operation is congestion. Traffic delay is closely related to congestion, and measurements of delay are frequently used as an indirect measure of efficiency. In a particular community it is possible to define reasonable levels of delay for that community and threshold values beyond which congestion can be said to exist. A quantification of delay might include frequency of deviation from the norm, in addition to quantitative measurements of deviation. Some guidance is provided by the *Highway Capacity Manual* in which various levels of service are defined (*151*); one of these can be selected as an acceptable norm for the particular community.

Convenience

Convenience is a characteristic especially difficult to measure for the purpose of defining a threshold value. One element of convenience is accessibility, whose opposite is circuity of travel. The degree of permissible inconvenience is related to motorists' tolerance. This degree of tolerance varies considerably by area and by the amount of restriction normally imposed in that area. Convenience thresholds can be established for different types of facilities in different areas. Some measures might include length of trip, circuity, and travel time.

Service Failure Relationships

The three aspects of service failure exhibit many relationships pointing toward their interdependence. When a change occurs in one, a change frequently occurs in one or both of the others. Frequently, increased freedom of movement and efficiency are achieved by reducing convenience and accessibility. Such restrictions then become acceptable to the motorist because he has learned to accept a moderate degree of inconvenience if it provides him with increased safety, improved traffic flow, reduced congestion, and other advantages that he values more highly. Modification of traffic signals at an intersection to incorporate an additional left-turn phase provides greater turning safety and convenience at the expense of intersection efficiency. These types of trade-off evaluations are constantly being made although objective measurement of the relative effects on each of the variables is seldom a basis for the decision. The difficulty of weighing one characteristic against another similarly discourages such comparisons.

EXCESSIVE TRAFFIC DEMAND

The causes of service failure are most commonly related to "excessive traffic demand." However, improper decisions can result from ambiguities in the meaning of this term.

Limitation of Traffic Control

Under normal conditions of field observation, a service failure implies that the traffic demand exceeds the capacity of the facility in its present condition. Frequently, however, the highway facility is not operating at peak efficiency and capacity for the width of pavement available. Numerous traffic control restrictions are still possible—parking prohibitions, turn restrictions, traffic signal improvements, and other operational improvements—that would increase the capacity of the facility through relatively modest expenditures. It is therefore inaccurate to conclude that an observed service failure shows the highway facility to be intrinsically deficient; it indicates rather that the traffic volume is excessive for the specific conditions under which the highway is operated. With changes in traffic control, the highway might be made adequate to handle the imposed traffic volumes.

Limitation of Highway Improvement

A second level of excessive traffic demand is the condition in which all appropriate traffic control measures have been instituted, but the highway has not been widened to planned design width. The facility is subjected to excessive traffic demand only in its present state. Improvement to the standard that has been planned may be necessary before additional traffic is imposed.

Limitation of Corridor Capacity

A third level of excessive traffic demand occurs when the facility has been widened to its ultimate right-of-way width and all of the applicable traffic control devices for providing maximum capacity have been installed. If the facility still cannot accommodate the traffic demand, a condition of excessive traffic demand exists that may require provision of a new facility to supplement the traffic capacity of that corridor.

Limitation of Land Use

In applying land-use controls as limitations on development densities, it is necessary to distinguish between these various levels of excessive traffic demand. Traffic generated because of a proposed land use may be excessive with respect to available highway capacity, but this may not in itself be sufficient justification for denial of the proposal. Modifications in traffic regulation or a widening of the highway to ultimate width could augment traffic capacity sufficiently to accommodate the demand. Such improvement could become a condition for approval of the proposal. However, if a particular land-use decision would create a traffic demand exceeding the capacity of the fully improved highway, only the addition of another facility would avoid the excessive traffic demand created.

TRAFFIC FRICTIONS

Obsolescence of the highway can be largely attributed to inadequate control over factors that cause conflicts, hazard, and frictional interference with traffic movement. To protect the traffic capabilities of new arterials, controls can be applied in the design and operation of the highway and controls can be exercised over the land uses that abut the highway. These controls are intended to reduce the four types of friction that account for highway deterioration—internal friction, medial friction, marginal friction, and intersectional friction (*221*).

Internal Friction

Internal friction is a lack of uniformity and smoothness of flow within a traffic stream that results in traffic turbulence and flow inefficiency. Merging, weaving, diverging, and other disruptive internal maneuvers contribute to traffic turbulence and internal friction. It is also caused by an excessive concentration of vehicles that results in a reduction in flow capability. Traffic flow concentration studies illustrate the importance of traffic flow density; the rate at which traffic is fed to a facility (concentration) is most important.

Internal friction caused by excessive merging and weaving results from close spacing of intersections and driveways; vehicles enter a traffic stream, weave over to the opposite lane, and leave the traffic stream, all within a length insufficient to accommodate these maneuvers properly. Weaving conflicts are particularly serious on a wide multilane highway carrying heavy traffic volumes.

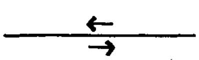
Critical traffic concentrations that inundate the highway, another major source of capacity reduction, can be reduced by metering entering flows to smooth out traffic peaks. Excess traffic can be held in reservoirs, be diverted to other routes, or be metered by traffic controls to limit the rate of entering flow and prevent it from exceeding the critical point.

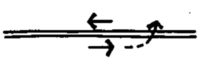
Medial Friction

Medial friction is the interference that occurs in the center of the roadway between traffic streams traveling in opposite directions. Such interference is affected by the degree of separation between opposing streams, the frequency and location of median openings, the number of left-turning movements, and the protection provided for turning vehicles.

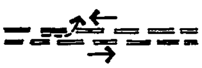
Many levels of median protection can be implemented by the highway agency to minimize the problems associated with medial friction and access. Some are very effective, especially those that are positive and permanent and not subject to external influences.

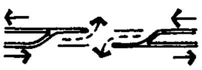
Medial friction is at a maximum when there is no center-line stripe to separate opposing traffic flows. The center-line stripe provides a visual guide to restrict the motorist to his own half of the roadway. The double center-line stripe is more positive than a single stripe, but the separation of opposing flows is still minimal. Vehicles waiting to turn left block the left fast lane, a major source of rear-end collisions and lane maneuvering.



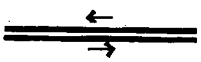


The two-way painted median has recently been introduced to eliminate left-lane blocking in situations where driveway access is irregular and continuous along the arterial. A separate lane in the median is enclosed by broken double center lines on either side, permitting left-turn vehicles to enter this center lane from either direction and wait for an opportunity to turn left. This device is useful in existing situations if more restrictive types of control are not feasible. The solid painted median with left-turn pocket lanes at selected intervals provides a higher level of protection. This permits left-turn access only at specific locations.

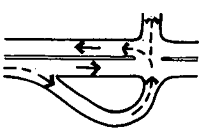


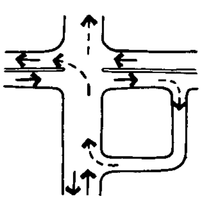


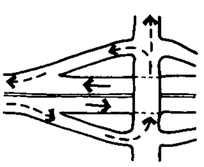
A raised curb median provides a more positive physical separation between opposing traffic streams. The raised median can be relatively narrow if its only purpose is to separate opposing flows. The median can be widened to permit the insertion of protected left-turn storage lanes at the approaches to intersections or driveways. A very wide median permits the insertion of U-turn roadways, which allow a vehicle to reverse direction for access to properties on the opposite side of the highway.



Maximum movement efficiency is provided by curtailing all median left turns, thus barring all slowing and stopping in the left lane. All turning vehicles exit from the right lane, using designs that permit turning movements only from the side of the highway. A jug-handle design permits a vehicle to cross the highway from the right side to negotiate a left turn or a U-turn. A cloverleaf-at-grade design provides a 270° right turn to negotiate a left turn or a U-turn. A grade separation design with approach ramps permits a vehicle to make a left turn or a U-turn without any through traffic stoppage.







Marginal Friction

Marginal friction is the impedance that a traffic stream encounters along the perimeter of the highway. The principal source of marginal friction is curb parking, which reduces the width of street available for moving vehicles and also seriously affects the efficiency of other lanes through the operations of parking and unparking. Marginal friction also results from acceleration and deceleration along the outside of the highway, generally for purposes of entering and leaving driveways. It is also caused by passenger loading of buses, taxis, and automobiles, and by commercial loading of trucks along the curb.

Marginal frictions are subject to correction by various levels of restriction and control, such as prohibiting parking and loading along the curb and prohibiting stopping in critical areas during peak periods. If these marginal activities cannot be prohibited, it is desirable to provide an additional lane for these functions outside the through traffic lane. A separate curb lane or shoulder can accommodate stopping, parking, and loading to the right of the through lane; however, the influence of these frictions is still experienced as vehicles maneuver in and out of the curb lanes.

Another major influence on marginal friction is the spacing and design of access driveways. Deceleration and acceleration interference at the approaches to the driveway can be minimized by providing an additional lane that permits access vehicles to leave the through lane before slowing and to pick up speed before reentering.

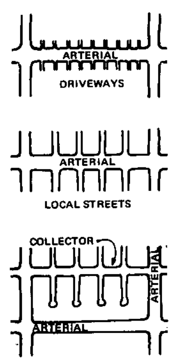
A higher level of marginal protection is provided by a separate roadway beside the arterial to accommodate marginal functions. A service road, separated from the arterial by a raised island, accommodates parking and unparking, deceleration and acceleration, merging and weaving, and all other marginal frictions without interfering with through traffic movement. An improvement over the front service road is a service or collector road along the rear, removed from direct proximity to the arterial. The rear collector road incorporates all the functions of the alley and adds the functions of the front service road, eliminating all marginal frictions.

Intersectional Friction

Intersectional friction is the loss of capacity caused by intersections, where traffic streams are required to stop to allow cross traffic to flow. The most significant losses occur at intersections with other major highways where traffic is stopped 50 percent of the time or more, depending on the number of signal phases. In addition to signal phase losses, there are losses due to turning movements and low acceleration rates of heavy vehicles. In concentrated urban areas, cross streets at too frequent and undesirable intervals may reduce progressive movement efficiency and add to capacity losses. When large numbers of left turns must be accommodated in separate signal phases, the resultant long signal cycles further reduce intersection capacity.

Functional intersections occur at any point where there are movements into and out of the traffic stream, whether the source of these movements is a street, alleyway, or private driveway. They all represent conflict points in their effect on the traffic stream.

The frequency of intersections is governed by the pattern of subdivision design and the controls exercised over access along the arterial. If there is unlimited access, driveways



can occur continuously. If there is no hierarchical pattern of subdivision design, each local street can intersect the arterial, often at intervals as close as 300 ft.

A higher level of intersection control is exercised in modern subdivision design, which uses a hierarchical pattern of collector streets that intersect with the arterial at infrequent intervals. Local access streets are served from the collector street and do not enter the arterial directly. This permits a reduction in the frequency of intersections and materially reduces intersectional friction. There are major intersections at junctions with other arterials and secondary intersections at collector streets. Arterial intersections accommodate through traffic while collector street intersections provide access to the land.

Some arterial highways may require a still higher level of operation, in which all access traffic is transferred to other facilities and the arterial handles only through traffic. Intersections are provided only with other arterials and there are no intersections with collector streets. To completely eliminate intersectional friction, all intersections are removed by the use of grade separations and interchange ramps, as with the freeway.

Intersectional friction is also influenced by the types of traffic control used at intersections. These range from no control to sophisticated traffic signal systems. The proportion of time that traffic moves through the intersection, as contrasted with waiting periods, is one measure of intersectional friction.

APPROACHES TO SOLUTION

There are several primary conditions that characterize different states of the transportation facility, each requiring a different approach. The first condition is exemplified by a highway facility already exhibiting signs of failure through an inability to provide efficient transportation service. The second case is that of the existing highway, perhaps in a less heavily developed portion of a community, that shows no current signs of service failure but exhibits all the characteristics of highways that have already failed; such a highway may be expected to fail when traffic demands reach a certain predictable level. The third case is that of the highway in a new community in which the highway system can still be designed to accommodate varied functions without risk of future breakdown. Each of these three basic cases represents a separate problem to be treated individually.

In the first case, where the highway already exhibits signs of failure, standard traffic engineering techniques will minimize the problem and improve service. In more serious cases the highway may be replaced by a parallel facility to accommodate the movement function, leaving the existing facility to accommodate primarily the access function. Where failure has already occurred, the objective is to alleviate symptoms and prolong the service life of the facility pending the replacement of the facility if this becomes necessary.

In many respects the most difficult and most frustrating case is the second—the currently adequate highway in an underdeveloped area. Here the greatest need exists to analyze the true nature of the problem with a view toward resolving the deficiencies before they are permitted to result in future service failure.

In the case of the new community whose highway system is designed according to the latest standards and functional concepts, the likelihood of future failure is vastly decreased; the objective here is to maintain high design standards that will ensure permanence of the facility. The design should include all of the current techniques, as well as new ones that are currently in the development stages. Design techniques that are adaptable to these various facility conditions are outlined in this study.

Temporary Solutions

There are many different types of solutions that can be applied once the problems have been identified. Solutions do not always have to be permanent; in some instances interim improvement can resolve the most pressing problems and provide time for developing a more permanent solution. Sometimes a particular problem does not ever have to be solved permanently, especially if a change in conditions is anticipated and if temporary short-range improvement will correct the critical nature of the problem until such time as conditions have changed and no additional improvements are needed. A problem of this type occurs most frequently in urban regions where a freeway network is in its development stages and has not proceeded sufficiently so that its over-all effects can yet be felt. In such instances, temporary short-range improvements on the existing street network may alleviate the existing condition for a period of time until the freeway network is completed.

In other cases urban renewal or revitalization programs may be under consideration that will drastically affect existing conditions and perhaps require different types of solutions. In such instances temporary improvements may resolve the problem until the more permanent improvements are installed. The case for temporary or intermediate solutions can be very persuasive in view of the fact that urban conditions do not necessarily worsen in a straight-line fashion. Even where conditions are constantly becoming worse each year, temporary solutions may have so stabilizing an influence that the improvement may become permanent. Furthermore, so unpredictable are many urban changes that last year's critical problem may no longer be critical next year. Thus, it is necessary to identify the specific type of condition for which solutions are being sought and the degree of permanence needed for the improvement; there is much to be said for interim solutions, which frequently prove to be permanent solutions.

Solution Through Control

Other solutions can be sought through controls. An example is the lightly developed area where the highway facility is serving its function adequately with existing controls and where no problems are yet in evidence. A problem begins to develop only when new land uses, particularly more intensive ones, are built abutting the highway and where additional points of access are created. If one or both of these factors could be controlled adequately, the highway could continue to function in a satisfactory manner.

The two aspects of control are control of land use and intensity of development, which affect traffic generation, and control of the degree of permitted interference with the highway, which is largely a function of the number and design of the access points. These factors are difficult to control or modify once the area has been extensively developed, but there is the possibility of effective control before the area has been developed. The critical element in seeking solution through control is the implementation of effective regulation at an early stage, so that development intensity and access location are established prior to development pressures.

CHAPTER FOUR

HIGHWAY CLASSIFICATION

DEVELOPMENT OF THE HIGHWAY SYSTEM

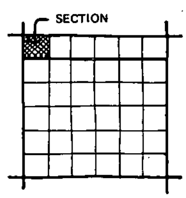
The functional specialization of highways evolved in stages as different systems were progressively developed to serve increasing travel demands. The efficiency of the highway system depends to some extent on the pattern of development of the system. Many communities have no discernible road pattern; current roads merely perpetuate earlier trails accepted through common use. Other communities started with a well-defined pattern of roads. The gridiron pattern is the most characteristic, offering the simplest method of subdividing land.

Local Grid System

Central area street systems usually consist of a small-scale grid pattern that was originally developed to provide many small lots with maximum street frontage. Streets are generally uniform in width, equally spaced, and equal in size, and all serve the same principal function of providing access to individual properties and circulation between properties. The principal design rationale was based on property marketability, and the major circulation criteria involved accessibility and desirable walking distances. The small-scale pattern of lot, block, and street sizes was consistent with the pedestrian scale of movement. In cities designed by these criteria, the proportion of land devoted to circulation averages about 25 percent, which is high according to modern standards, and the narrow rights-of-way provide a relatively low quality of service.

Arterial System

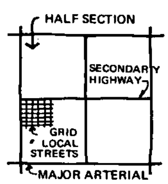
As time passed, it became apparent that the small-scale gridiron pattern was unsuitable to the modern automobile. Improved multilane arterial highways were developed, spaced at greater intervals, to accommodate heavier travel corridors. A major influence was the Land Ordinance of 1785, which prescribed that western lands beyond the Appalachian frontier were to be laid out in rectangular townships six miles square, with each township to be divided into 36 square sections of one square mile. This huge checkerboard pattern, modified only by severe topographic restrictions, established a giant rectangular gridiron over all land west of the Appalachians. Main roads were developed, where necessary, along the section lines, at one-mile intervals. Later federal legislation established half-section townships. This hierarchy of grid arterial highways served as the major web. The principal circulation system frequently consisted of a one-mile grid pattern of major arterial highways, supplemented by half-mile secondary highways where needed. Additional gridiron local streets were developed parallel and perpendicular to the section-line roads.



TOWNSHIP

Freeway System

The deterioration of the surface arterial system initiated another major phase in the development of the circulation system. Controlled-access freeways replaced arterials along important traffic corridors. Freeways were not originally conceived in terms of area-wide urban systems but rather as individual routes to replace existing congested surface highway routes.

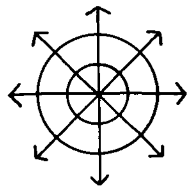


SECTION

The Interstate system was developed initially as a nationwide network oriented to intercity movement. This system was originally designed to accommodate long-distance travel, but it soon began to serve as the principal urban transportation network. In some regions the Interstate system was supplemented by a state freeway program to accommodate major intrastate travel corridors. The earlier interstate and intrastate freeways were conceived largely for point-to-point travel serving longer-distance trips.

The extensive use of interstate and intrastate freeways by urban traffic and the frequent overloading of these routes resulted in a reevaluation of urban transportation needs. Regional transportation studies generally revealed the need for an urban system of freeways and required an extension of the network to include many additional links not considered in the development of the Interstate and the intrastate systems.

The earlier freeway corridors form the backbone of the more complete urban freeway system. The complete system usually consists of radial freeway corridors, supplemented by circumferential corridors in larger cities. Some cities also provide an inner distributor loop circumscribing the central business district.

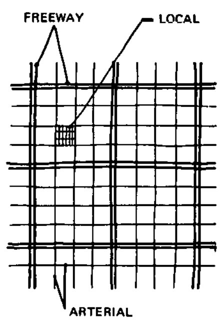

RADIAL RING

The urban freeway network thus represents a composite of several different systems that have been developed for different purposes. Recent regional transportation surveys have begun to develop a system rationale for the network of urban freeways, which was lacking during the inception of the freeway program. Most metropolitan freeway networks are committed in basic framework, particularly in central sections, although there is still some flexibility in outlying areas.

Composite Network

It is apparent that highways and freeways were not originally initiated with the concept of optimizing transportation patterns for the urban area. The system concept is of relatively recent origin, and the present system is a compromise encompassing many different considerations.

The over-all circulation network now consists of a composite of three separate systems developed at three different times to serve various stages in the evolution of the urban area. The fine-grained grid pattern of multipurpose streets was succeeded by a larger-grained pattern of arterial highways, which was succeeded again by a still larger-grained pattern of urban freeways. This trend was paralleled by the progression in many individual corridors from a two-lane roadway to a realigned multilane arterial highway, and then to a much wider, relocated freeway. Each new facility succeeded the previous one when it became obsolescent. In many areas all three stages still exist; the resulting network constitutes the urban circulation system.



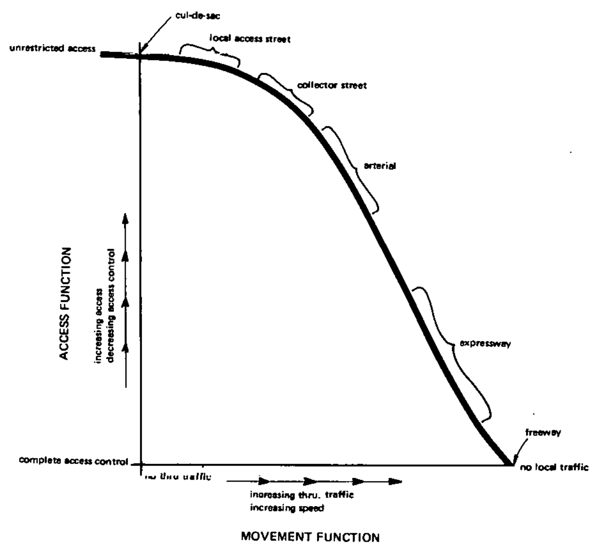
The composite network does not necessarily represent an ultimate network; the process may possibly be repeated in the future with still another system superimposed to permit even greater speeds for greater distances of travel. The automated-highway concept portends a trend in that direction.

THEORY OF FUNCTIONAL CLASSIFICATION

The principle of division of labor is basic not only to the economic use of men and machines but also to highway facilities. Achieving an efficient division of labor in industry first required that work be classified and the most effective means for its performance be identified. The highway application also requires classification of the functions to be performed and identification of the most effective facilities to perform them.

Functional efficiency is concerned with the specialization of traffic flow and the fineness of differentiation desired. Different types of movement can be most advantageously accommodated on facilities specially designed for those purposes. The advantages lie in the efficiency of homogeneous flow as provided by specialized design.

A functional system of highways can provide for a graduation of traffic flow from the movement function to the access function. The entire system can be schematically classified by relating the proportion of movement function to that of access function. The movement function is characterized by the proportion of through traffic; at one extreme is the expressway or freeway, which carries no

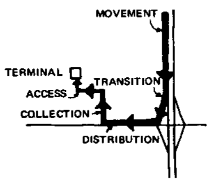


local traffic; at the other extreme is the cul-de-sac, which carries no through traffic. The access function is characterized by the degree of use of the street for access purposes and the decreasing degree of access control exercised. Access control ranges from "complete" in the case of the freeways to "unrestricted" in the case of the cul-de-sac.

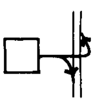
In each successive road classification occurs a step change in the type of service—from rapid movement and uninterrupted flow to slower movement subject to interruption wherever necessary. The specialization of design at the upper level strives for moving efficiency; at the lower level it strives for service efficiency and convenience. A vehicle originating at a local service street would progress upward to the level of flow that best accommodated its destination. On reaching its destination, it would then move down again along the scale.

Hierarchy of Movement

A complete functional design system must provide for a hierarchy of movement permitting individual stages to be defined. The six recognizable stages in most trip-making include movement, transition, distribution, collection, access, and termination. For example, the highest type of movement is on a freeway, where vehicles are permitted uninterrupted, high-speed flow. In approaching a destination the vehicle is required to reduce speed on a transition roadway or freeway ramp. The vehicle then enters a moderate speed arterial, the distributor facility, that brings the vehicle to the immediate vicinity of its destination. It next enters a collector road that penetrates a neighborhood. The vehicle then enters a local access road, and this provides direct accessibility to an individual residence. At its destination the vehicle comes to rest in a parking terminal. These six components of a typical trip are each handled by a separate facility designed specifically for that function.



Although many trips can be subdivided into six different types of functional movement, it is not always essential that six types of facilities be provided. The normal hierarchy of circulation facilities relates especially to conditions of low-density suburban development, where traffic flows are cumulative on successive elements of the system. However, in some instances it may be desirable to reduce the number of components in the chain. For instance, a very large traffic generator may fill one or more lanes of a freeway by itself during certain periods. It may then be desirable to lead traffic directly into a freeway ramp, without introducing intermediate facilities that will unnecessarily mix concentrated traffic flows with extraneous vehicles.



At first glance this might appear to abrogate the entire principle of movement hierarchy, rendering the six stages of trip-making applicable only in certain instances. However, the deletion of intermediate facilities has not eliminated the flow hierarchy, or even the functional design components, but has rather changed their physical character. The order of movement can still be identified, but in another form.

Internal Movement

The lack of recognition of the different components of trip-making and the need for providing specific design elements to accommodate each of these functions in turn is one of the most prominent causes of highway obsolescence. Many of the problems of the past have been experienced at the interface between public and private facilities because transitions from one function to another were inadequate. A major problem at the commercial driveway, as an example, is the typical design that leads directly from the relatively high-speed arterial into a parking aisle, with no intermediate provision for deceleration, distribution, circulation, and accumulation.

Even more serious problems can be encountered when freeway ramps lead directly into large traffic generators—if the intermediate functions are not adequately designed for. With inadequate acceptance capacity or internal circulation deficiencies, there is a danger that traffic may back up into the freeway. Successful internal design provides for the transitional functions between the high-speed freeway and the terminal parking facility, including appropriate facilities for deceleration, absorption, collection, distribution, and circulation.

Deceleration from the rapid movement on the freeway is handled by the exit ramp. Distribution to various parking areas may be provided by primary distribution roads within the parking facility that supplant the arterial function. Collector roads within the facility may then deliver segments of the entering flow to a series of parking bays. The parking aisle is the equivalent of an access street that leads to individual parking space terminals. Thus, all of the principal functions within the hierarchical movement system are recognizable, and each is characterized by a reduction of speed.

If all of these movement functions are accommodated properly, no greater difficulty should be experienced than where a freeway enters an arterial highway. Theoretically, a greater degree of control can be exercised within a predictable and controlled environment (such as a stadium) than with respect to the unpredictable conditions along an arterial.

The same principles of design are also related to a terminal facility adjoining an arterial highway or a collector street. The functional design of the facility must account for each of the movement stages, internal circulation being consciously designed to appropriately accommodate the order of movement.

The necessity of designing for all stages of the movement hierarchy varies with the size of the traffic generator. For relatively small generators, it is feasible to accommodate two or more stages on the same internal facility. For larger traffic generators it is necessary to respect each of the movement stages by providing a separate functional facility for each.

In determining the number of design components necessary, comparisons can be made with the customary volumes of traffic handled by different functional categories of public streets. The volume range on internal facilities can be related to the comparable range on public streets. These may not be directly comparable, inasmuch as the physical space available within a private facility is smaller and the standards of operation are necessarily quite different. However, the same principles of flow specialization and movement hierarchy can be applied.

Hierarchical Components

The principles of hierarchy of movement can lead to a logical system of classification that relates to traffic generation intensity. At the highest level of traffic generation it is conceivable that a single generator could fill an entire freeway, and for this condition there would be no need for intermediate public streets between the generator and the freeway; however, the various movement stages must be accommodated internally with appropriate design features. At the next level of traffic generation a single traffic generator could fill an entire freeway lane; it might then be appropriate to reserve a freeway ramp for the exclusive use of that generator, with no intervening public streets. At still lesser volumes it becomes desirable to combine the traffic from several generators with other traffic prior to the freeway entrance ramp. The arterial then acts as a collector facility, accumulating these lesser flows until they reach a volume that will fill a freeway ramp, and then directing this flow onto the ramp.

Similar principles can be applied at the arterial level of service. If a given traffic generator is of sufficient size, an exclusive intersection driveway for that generator is justified. In other cases, an intermediate collector street should combine smaller traffic flows until they reach a proportion that warrants an intersection along the arterial highway.

The same analogy can be applied to the collector street with regard to criteria for direct access to the collector. A moderate-sized traffic generator will usually warrant a direct connection to the collector without the use of an intermediate access street. However, in a district of single-family residences it is desirable that a local access street assemble the traffic from a group of residences and lead it into a collector street at a single point of access.

In short, each element of the functional hierarchy serves as a collecting facility for the next higher element, but only in those cases where intermediate collection is necessary to satisfy the spacing requirements or the volume requirements of the next higher facility. By defining these two requirements it is possible to establish where it is necessary to use the full system and where the system may be short-circuited by moving directly to a higher classification of facility.

Operating Ranges of Functional Units

The clearest definition of function and design characteristics can be provided in a strict functional hierarchy. Theoretically, there should then be no overlap of function or of operating ranges, and there should be a sharp differentiation between classifications. With each higher classification acting as a collector for a number of facilities of the lower classification, a substantial gap in operating volume would occur between each of the successive classifications.

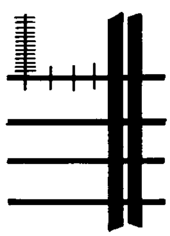


Table 1 gives one possible system of functional categories and indicates spacing of facilities and operating volume for a true hierarchical system. Each category would have a distinctive operating volume. In the case of the freeway and arterial, the ranges of operating volumes would approximate their capacity ranges. However, the collector and access street would have operating volumes based on other design criteria that involve environmental standards and functional intent. These operating volumes do not necessarily correspond to the capacity ranges of existing facilities, nor are they typical of current operation conditions.

TABLE 1

FUNCTIONAL CATEGORIES OF HIGHWAYS

FACILITY	SPACING (MI)	OPERATING VOLUME (VEH/DAY)	ACCESS SPACING (MI)
Freeway	4	60,000–200,000	1
Arterial	1	15,000–30,000	1/4
Collector	1/4	2,000–5,000	1/20
Access street	1/20	100–500	1/80

In this illustrative system each principal category has a well-defined scale of operation that is distinct from any other, and there is little opportunity for overlap of physical design characteristics or traffic operational ranges.

Within this over-all system of classification it would be possible to provide intermediate facilities to fill the gap between two highway classifications (in cases where such a facility might be needed). The intermediate facility would combine some of the characteristics of two adjoining categories.

Identification of Functional Units

For functional classification to have some relevance to the driver, the driver must recognize the type of facility he is using so that he may regulate his driving habits accordingly. There should be specific types of driver action associated with each functional category, and the driver must associate his driving characteristics with the type of facility he is traversing.

The motorist who mistakenly identifies a grade expressway as a full freeway will maintain a higher level of speed than safety requires, and will be taken by surprise when he encounters a grade crossing. This has resulted in the poor safety record of some expressways with infrequent grade crossings and traffic signals. Similar hazardous conditions exist on high-speed routes where there is an occasional access road or driveway. In an urban area a problem develops when a driver mistakes a local street for an arterial facility and proceeds at excessive speed without sufficient awareness of the many potential hazards to himself or others.

One objective of design classification is to correlate the design of the facility with its function through a sharp differentiation of design elements that are meaningful and explicit and that evolve normally from implementation of function. It may be desirable to associate intermediate facilities with the next lower classification type so that the driver will be influenced to exercise a higher degree of caution and greater restraint than on the higher facility.

Design features that can convey the level of functional classification include: width of roadway, continuity of alignment, spacing of intersections, frequency of driveways, building setbacks, alignment and grade standards, traffic controls, and other features that can become associated with the type of facility. The well-conceived functional classification system should attain a coherence and identification of design elements that are automatically conveyed to the user.

Utility of Functional Units

A distinction can be drawn between function and utility that is meaningful in relating the service aspects of a transportation system to the needs of its users. In the functional classification of streets and highways, a specific function is assigned to each category, and design characteristics are related to specific functions in a logical manner. Each category of highway can be described separately with regard to the functions it serves in isolation from other categories. However, the utility of the individual categories, and especially of a particular system, must also consider the connections of each category to the next, and these must be related in turn to the land-use system they are intended to serve. Thus, system utility is concerned with the method by which all of the interrelated elements serve the complete trip purpose—a somewhat different concept than highway function alone.

Measurement of utility is particularly difficult, although there are certain guidelines. A trip is generally related to land use, and the quality of connection with the land use is a measure of the utility of the system. The connection between trip and land use should be relatively simple and understandable to the user. Convenience is probably the most common characteristic. Reduced utility may be expressed in terms of travel circuity, absence of route orientation, excessive out-of-direction travel, or route incomprehensibility.

A logical routing pattern would normally proceed by a series of steps or thresholds from the highest classification of highway to the lowest, or in reverse order, depending on the trip segment. A hierarchical pattern of movement that proceeds in a definite sequence is clear and understandable to the user and provides good utility. The sequence of movement is not logical, for example, when the high-speed segment of a trip that is handled by the freeway system is broken in the middle by a short section of travel on an arterial that connects two freeways. A similar reduction in utility is created when the arterial segment of a trip is broken by intermediate travel on a lesser facility because of arterial discontinuity, or when short sections of local streets are used as short cuts or bypasses.

Residential access is a major example of poor utility. The usual symptom is lack of comprehensibility as to the route that must be followed to reach a destination within a residential development. Many of the current intricate patterns of residential design make it extremely difficult to locate a particular address. This is not a reflection on the new patterns of residential design, but rather on the manner of application of these new principles to the problem of route clarity. This condition is also symptomatic of the absence of a clear conception of the role and character of the residential collector street as an intermediate facility between the arterial and the access street. If the residential street system exhibits a hierarchical design pattern, with the driver proceeding logically from an arterial to a collector to an access street, then the pattern of movement is clear and direct.

Thus, the concept of highway utility is closely related to, but not synonymous with, highway function. Highway utility relates to the interaction of all of the elements of the functional highway system and also relates to the land-access service at the destination end of the trip. Even if there were a functional system of highways, the utility of the complete system would be inadequate unless the various components provided a logical sequence of movement that was direct, natural, comprehensible, and orderly. The concept of utility represents a benchmark against which the output of a transportation system can ultimately be gauged; the quality of transport is not measurable only in terms of transportation capacity provided, safety, speed of service, and other common measures of service quality. Rather, the concept of transportation utility in which a trip is viewed as a linkage between an origin and a destination, and in which the characteristics of land service and land access are equally significant, redefines the measure by which transportation quality can be evaluated.

FUNCTIONAL CLASSIFICATION SYSTEMS

As with many other basic theories, functional classification has been interpreted in many different ways. In some current systems the concept of "function" has almost been lost in semantic distinctions that have confused rather than clarified the basic concept. More significantly they have resulted in misapplications and misunderstandings that have not served to advance the objectives intended. This confusion of terminology is reflected in a comparable confusion in design standards that mirrors the ambiguities in the definition of terms. Improvements in design standards must be preceded by a clarification of function as expressed by each design classification term.

Because of the importance of this concept and its proper application, it is necessary to examine fully the derivation, development, current status, and potential applications of this principle. Then, after review of all of the current systems and applications, a system of classification will be proposed that corresponds generally to the categories in common use today but redefines the role and functional characteristics of these classifications.

Derivation of Terminology

One basic source of confusion is the term "functional classification," which is sometimes used for several different systems of classification that bear little relationship to one another. One system has to do with the purpose of the facility; another is an administrative category that designates administrative and financial responsibility; another refers to the specific design of the facility. As an example, the term "freeway" is a design classification; as a classification of purpose it may refer to a principal arterial highway; as an administrative classification it may refer to an Interstate route. Thus, a particular facility can be described correctly by three or more separate terms, each of which is considered to be a form of classification.

A second major source of confusion is the indiscriminate use of many different names to designate the same basic type of design classification. As an example, the terms "freeway," "expressway," "parkway," "throughway," "skyway," "turnpike," "tollway," and many others usually denote a facility of the same basic functional design. There is a similar proliferation of names used for other design classifications.

Another common practice is the opposite of that previously mentioned—the grouping together of several different design categories under a single classification. The all-inclusive term "arterial" sometimes includes freeways, expressways, major urban streets, and other facilities that serve the general purpose of moving traffic over relatively long distances on a continuous facility. There is similar confusion in the use of the term "access street." Any lesser street than a full freeway can be referred to as an access street if it provides some degree of access to adjoining properties. Frequently the major street through a business district is referred to as an access street, although it may be carrying the heaviest traffic volumes in the community, because one of its principal functions is access to adjoining properties. Similarly, using the literal definition, virtually any street or highway could fit the term "collector."

This imprecision in the use of terms provides a major source of confusion. Before a meaningful system of functional classification can be assembled, it is necessary for these literal definitions to be replaced by specific definitions so that terms in common use will convey a precise meaning.

Still another source of confusion is the common practice of combining an administrative and a functional term in the designation of a particular facility (e.g., Federal-aid primary). Although there is nothing intrinsically wrong with this practice, there has been a general lack of awareness that these two different systems of classification are being combined in the use of the particular term. The combination term is referred to as a particular functional classification rather than as a combination of terms from two systems of classification.

A further problem is the tendency to identify a specific highway classification with a particular standard of design. A distinction is frequently drawn between a two-lane and a four-lane facility or between a four-lane and a six-lane facility by using different terms for each, although their function and general design features may be the same.

A final source of confusion is the usual failure to differentiate among the specific intents of various methods of functional classification. Some current classification systems are intended as a means of classifying existing streets and highways for clarification of administrative and fiscal responsibility. The principal objective is the development of a sound system of financing of highway improvements—an objective that may have no relationship to the design of the facility.

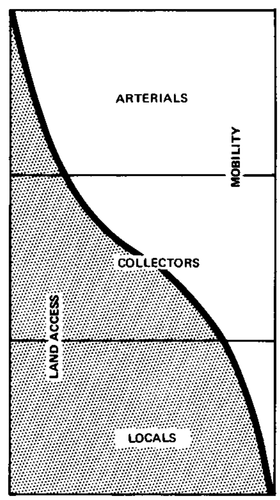
For purposes of clarification it is necessary to recognize the three different systems of classification presently in use and the specific objectives of each method of classification. The second step is to provide an adequate terminology within each system of classification so that all terms will have specific definitions that are clear and unambiguous. Each term must be clearly differentiated from other terms within that particular system of classification so that there is no overlap in a functional sense and so that the lines of demarcation are clear.

Classification Programs

Currently, there is substantial interest at various government levels in carrying out a program of functional classification of all highways and streets as a basis for improvement programs. This program, here defined as classification by purpose, would determine the type and extent of service performed by a particular section of road without regard to the administrative system within which it is presently located. Each road would be classified by its principal function; this type of classification sorts out existing facilities according to the type of linkage service that they currently provide and is not necessarily related to design characteristics or design type. This classification program would make possible the integration of all highways, roads, and streets into complete systems, and these systems into a comprehensive network. The systems would then be subject to further classification by administrative responsibility according to the level of government having prime responsibility.

There are a number of methods of classifying existing highways according to their present functions. These are generally differentiated according to traffic composition and traffic utilization, identifying primary functional characteristics. Most of these systems retain separate classifications for urban and rural highways and are applied primarily by state highway departments for the state highway system.

The network shown in the Mobility-Access Diagram indicates the three principal classifications used most widely in highway planning. The diagram provides a relative impression of the concept of network function and does not reflect the proportions of the road network devoted to the three systems, nor does it depict accurately the ratio of mobility to access.



MOBILITY–ACCESS DIAGRAM

Urban System

For classification of the existing urban circulation network, the National Committee on Urban Transportation has suggested criteria based on current standards in common use in many communities (*239*). They suggest a fundamental four-element hierarchy that includes the expressway (freeway), arterial, collector, and access street. Each classification accommodates movement and/or access to a varying but distinctly different degree. The purpose of each category governs the structural features, the dimensions, and the use of control devices or measures. These criteria provide a sound basis for the development of a functional system of urban streets for existing communities.

DOT Functional System

In a new national highway classification manual the U.S. Department of Transportation (DOT) defines functional highway classes in urban areas. The functional system classifications most significant to this study are those proposed for urbanized areas of 50,000 population or more. The criteria considered in determining classification of existing facilities include average trip length, traffic volume, volume-trip length index, system continuity, and service to travel generation centers. A second group of criteria includes neighborhood identification, spacing between routes, control of access, and travel time or speed. All of these characteristics are applied in the classification process *(330)*.

This system provides for the classification of all existing roads and streets into a limited number of functional classes on the basis of the most logical use of facilities to serve present travel and land use. The hierarchy of functional systems for urban areas includes major categories of principal arterials, minor arterial streets, collector streets, and local streets. The arterial systems include a wide variety of roadway designs ranging from freeways to standard arterial streets. The classification system does not relate directly to facility design.

The principal arterial system serves major centers of activity, the highest traffic volume corridors, and the longest trip desires. It carries the major portion of trips entering and leaving the urban area, as well as the majority of through movements. The principal arterial system is stratified into controlled-access facilities (including the Interstate system and other freeways and expressways) and uncontrolled-access facilities (including all other principal arterials).

The minor arterial street system interconnects with and augments the principal arterial system and provides service to trips of moderate length at a somewhat lower level of travel mobility. It contains facilities that place more emphasis on land access; it provides intracommunity continuity, but it is not to penetrate identifiable neighborhoods.

The collector street system penetrates neighborhoods, distributing trips from arterials through an area to their ultimate destinations, which may be on a local or collector street. Conversely, the collector street also collects traffic from local streets in the neighborhood and channels it into the arterial system. It is not intended that through traffic be carried by collector streets, although a minor amount of such traffic is sometimes unavoidable in the design of the system. The collector system provides for both land access service and local traffic movements within residential neighborhoods, commercial areas, and industrial areas.

The local street system comprises all facilities that primarily offer direct access to abutting land. It offers the lowest level of mobility. Through traffic movement is deliberately discouraged.

Table 2 gives typical mileage proportions for each system in current use and travel volume ranges for urban systems.

This program of functional classification is intended to be applied to present streets and highways; the definitions and criteria have been developed for the purpose of categorizing facilities as they are currently operated. The DOT system of classification is compatible with that formerly proposed by the National Committee on Urban Transportation (with some changes in terminology).

The system proposed in this report is intended to standardize what is currently a tremendous variety of design and operation standards. This system of categorizing existing facilities is not intended to be an optimum system for design classification of new facilities, nor should it be so considered.

TABLE 2

TYPICAL MILEAGE AND TRAVEL ON URBAN HIGHWAY SYSTEMS

SYSTEM	TRAVEL VOLUME (%) [a]	MILEAGE (%) [b]
Principal arterial	40–55	5–10
Principal arterial and minor arterial	65–75	15–25
Collector street	5–10	5–10
Local street	15–30	65–80

[a] Of total vehicle-miles of travel. [b] Of total highway mileage.

DESIGN CLASSIFICATION

Criteria

Most classification systems currently in use and proposed are intended as administrative and as purpose classifications relating primarily to existing highway systems. The intent of design classification is quite different. It does not conflict with current systems of classification but is intended as a method of classifying new facilities by design category.

The proposed system of design classification is based partly on current practices and definition, but it represents an extension of these practices into a more logical pattern that can be applied in a consistent and uniform manner. Use of these classification definitions could eliminate much of the current ambiguity surrounding each of the commonly used designations.

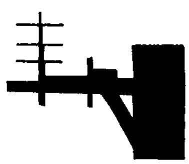
One principal criterion that can be used for distinguishing between different classifications of highways is that of access. In the case of the freeway, access to abutting lands is provided at approximately one-mile intervals in urban areas. Such access is usually provided indirectly by means of connecting ramps, arterials, collectors, and access streets, in a hierarchical flow of movement from one facility to another. In special instances employing the same spacing criteria, it may be justifiable to provide direct access for a single land use.

The arterial highway can also be designed to provide access service to abutting lands at a particular spacing interval. In this case the interval corresponds to the spacing that is desirable for progressive signalization—a quarter mile, for example. Like the freeway, the arterial can also serve single generators of sufficient size to justify a separate access intersection, using a spacing and design that is functionally identical with the collector street intersection. Thus, the service provided to abutting lands by the freeway and the arterial is different in scale, in access spacing, and in the design techniques used to provide access.

To provide an intermediate level of access service the collector must be distinguishable from the arterial. If the arterial provides access at quarter-mile intervals to collector streets, the collector should provide access at closer intervals, and the residential collector street should collect the traffic from a group of residential lots and not from each lot directly. The spacing of driveway access could correspond to the spacing of access streets—that is, at approximately 300-foot intervals. Because the access driveway would be functionally similar to an access street, it should be designed in the same manner. The collector street thus constitutes a third level of service in a logical progression or hierarchy. Two categories of access are provided for, as in the case of the arterial and the freeway. Direct access driveways are provided to generators of requisite size, and a comparable level of service is provided for access streets that serve single-family private residences.

At the fourth level, the access street allows for continuous service to abutting properties where driveways can be spaced at intervals of about 60 feet (depending on lot frontage). Within a strict hierarchy, only the access street would provide direct accessibility to single-family residences.

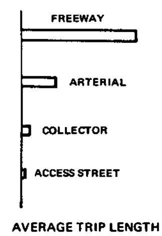
In the hierarchy of movement, groups of vehicles from a number of individual residences would be directed to the collector street. The collector street would accumulate the traffic from a number of access streets and from a few individual larger generators and carry this traffic to the arterial. The arterial assembles the traffic from all of the individual collectors and from larger traffic generators with access driveways into the arterial and leads this traffic to the freeway. The freeway collects all the traffic from the arterials and from very large traffic generators that have direct access to the freeway and carries this traffic to the vicinity of its destination, where the process is repeated in reverse.



The highway system can thus be viewed as a hierarchy of elements; each performs similar functions, but in a different manner and on a different scale. The level of gradation for access service is approximately equal for each successive level: the freeway services the arterials and very large traffic generators at access spacings of about one mile; the arterial services the collector streets and relatively large traffic generators at intervals of about a quarter mile; the collector services the access streets and intermediate-level generators at intervals of about 300 feet; the access street services the individual residences at spacings of about 60 feet. At each level the spacing of access is changed by a factor of about four. This sequence appears to be logical and consistent and can provide the basis for a system of highway design classification that can be readily comprehended and codified.

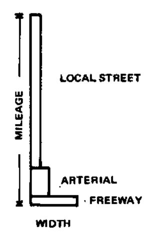
Single System

The ultimate objective of design classification is to institute a single classification system that serves all needs for new facilities. The proposed system of design classification clearly differentiates one classification from another; the purpose and function of each facility are apparent from its design characteristics. Administrative responsibility over each system can also be easily established, because the definition of users of each system is specific; responsibility for financing can then be readily determined.



Terminology

The terms suggested for purposes of design classification are the same as those commonly employed today. The continued use of the same terms with a more specific definition has both advantages and disadvantages. An obvious disadvantage is that the precisely used terms will be confused with the same terms in their current ambiguous usage. This semantic problem can be overcome if the particular system of classification being employed is understood and the conditions of use of the term are well defined.



Although the terminology and number of categories in design classification include the same four basic classifications as existing systems, their operational ranges and design characteristics may be quite different. Existing classifications cover a wide range of access and movement functions; they frequently overlap and offer unclear functional and visual distinctions, with ambiguity between categories and indistinct demarcations. Design classification must be initiated with a clear definition of terms, which can then be translated into physical design features.

Freeway

In some classification systems the freeway is grouped with arterials as the highest classification of facility, and no clear distinction is shown between them. In other systems the freeway and expressway are grouped together as a category of facility having full or partial access control and complete or partial separation of grades.

A specific facility may be legally designated a freeway because the right-of-way has been acquired with full control of access; however, in the interim stage of development, it may retain some access conditions and grade crossings. This legal freeway facility is obviously not a freeway in actuality until it is fully developed as such.

In the classification system proposed, the freeway design classification is explicitly a full freeway with full control of access and full grade separation. All lesser types of facilities are included in lower design classifications.

Arterial

In a design classification the arterial includes all designs below a full freeway and above a collector. Although the upper limit is well defined because the freeway designation is quite specific, the lower limit is indistinct and must be made far more explicit before the arterial designation will have specific significance.

For purposes of defining this lower level, the criteria assembled by DOT with regard to arterial classifications provide some valuable guidelines. The constituent elements that differentiate the arterial are: trip length, continuity, traffic volume, neighborhood identification, spacing between routes, and other indices normally associated with the arterial function. One significant difference between the arterial and lower classifications is that arterials surround neighborhoods and are continuous, and collectors penetrate neighborhoods and serve primarily as connectors leading to the arterial. Thus, the arterial system generally forms a continuous network providing service for trips of moderate length at relatively high speeds and accommodates relatively heavy traffic volumes. In contrast the collector street primarily collects traffic from local steets within a neighborhood and channels it into the arterial system. To accomplish this function the collector street need have only limited continuity, from the arterial into the neighborhood interior. It will generally carry only locally generated traffic and little or no through traffic, trip lengths will be short and at slow speeds, and traffic volumes will be relatively low.

This comparison between the characteristics of the arterial and the collector provides sufficient distinction for the design criteria for the arterial to be well defined at the lower limits. With the upper and lower limits thus explicitly defined, the arterial can become a specific design classification for which design criteria can be developed.

Arterials serve a portion of the land-access function through an intermediate facility, preferably meeting the arterial at specific points of intersection that are consciously chosen to minimize any interference or conflict between the access function and the through movement function. The intersections can be public streets or major driveways functionally designed to be indistinguishable from public street connections.

Collector

A definition of the collector design classification can be developed by referring to its upper and lower limits—the arterial and the access street. The functional criteria specified by DOT are helpful in defining the upper limit. The residential collector street provides for intraneighborhood movement by furnishing system continuity within the neighborhood, but it should tend to discourage external through movement. It acts as a collector for local access streets and channels the traffic into the perimeter arterial system. These criteria clearly separate the collector from the arterial so that there should be no ambiguity at the upper limit.

Clarification is needed in the delineation of the lower limit of the collector and its differentiation from the local access street. In many cases there may be no discernible difference between the collector and the access street within a neighborhood. The access street, from a design classification standpoint, is a local street that provides direct access to lower-density residential lots and is intended to serve this purpose alone. The collector street is intended to serve the collection function for a group of access streets and not the immediate access needs of individual residences. However, the collector street does serve the access function for higher-density residential development and for other neighborhood facilities.

The access street is restricted to a particular, well-defined function; the collector street is specifically excluded from that function but includes other access functions for higher-intensity neighborhood developments, and also serves the collection function for the access street system. Given these specific definitions, it becomes possible to draw a clear design distinction between the collector street and the access street, and to develop design criteria that specifically implement the intended functional classifications.

Access driveways on collectors serve group parking rather than individual homes, signifying a major change of character. There should also be some degree of buffering between adjoining land uses and the collector street so that the street is not immediately next to abutting properties but is separated from them. This psychological as well as physical separation of the collector street from abutting properties implies that there can be different operating conditions along the collector than along an access street.

The collector street is a traffic street of moderate volume and should be so designed. The separation between the traffic on the collector and the abutting properties must be instilled in practice as well as in theory. Thus the design of the collector, if it is to establish its own individuality, should reflect its specific status and should not be conceived of nor developed simply as a continuous access street. Ideally, the collector street should have no fronting single-family residences. However, this ideal is not always attainable and compromises are sometimes necessary.

Access Street

The access street provides immediate access to residential parking. It is not intended to provide traffic mobility and serves its function best when it is discontinuous. Through movement without a terminal destination along the access street should be discouraged from using it. The normal access street is a short residential street that is little more than the extension of a group of private driveways. Thus current residential design has established a new type of access street devoted exclusively to land service, a function that was not previously well defined.

Intermediate Facilities

In some cases it may be necessary to provide intermediate facilities that overlap two classifications. At the local street level, for example, a facility may be a compromise between a collector and an access street, collecting traffic from individual access streets and also providing direct access to some residences. In the case of arterial highways, it may not always be feasible to maintain intersection and driveway spacings at minimum quarter-mile intervals; intermediate driveways may be required by specific land uses. In the case of freeways, it may not always be possible to adhere to the minimum one-mile spacing intervals between interchanges, particularly in some urban situations. In these instances, exceptions should be justified so that they are recognized as exceptions and do not weaken the generality of the basic principle.

One common intermediate facility is the expressway, which combines some of the characteristics of the arterial and of the freeway. In many cases, the expressway is selected because the freeway, which might have been more desirable, was not practicable to implement. Sometimes the plan is to convert an expressway to a freeway at a later time, and the design must provide the flexibility for such conversion. In some instances, particularly in rural areas or underdeveloped urban areas, the expressway appears to offer the proper level of service for the conditions that will exist in the foreseeable future.

Most facilities that are currently designated "expressways" are merely arterials that have been developed to somewhat higher standards. The arterial definition suggested in the design classification system assumes a design standard considerably higher than that of current arterials, and is almost comparable to the "expressway" as that term is currently employed.

For most purposes the four-level classification system will be adequate in providing a well-defined hierarchy of highway categories. Intermediate categories can be used where necessary, but they should be recognized as intermediate facilities rather than as distinctive entities that are different from the principal categories.

APPLICATIONS OF FUNCTIONAL CLASSIFICATION

When the specific function of each highway facility has been clearly defined, the highway can then be designed and operated to accommodate that function most efficiently; the facility can also be prevented from attempting to serve other conflicting functions. Functional classification alone is only a first step; an obvious corollary is the establishment of design standards and operational guidelines for each classification, and active adherence to these principles.

Application to System Components

New Facilities

Many of the major principles of design classification are being applied currently to new facilities, although, perhaps, in a less rigorous fashion and with fewer specific guidelines than are proposed in the system suggested here. The proposed system of design classification is intended to redefine each of the principal categories and associate each type of facility with a set of design principles to eliminate current ambiguities and functional overlaps.

The proposed system of design classification will tend to raise the standards for each classification to a higher level than is currently maintained. Major traffic corridors can then be served by a smaller number of facilities of a superior type.

The success of the freeway, accommodating large volumes of traffic with increased safety, is a prime example of this trend. The extension of freeway design principles to arterials, together with the general upgrading of standards for arterial highways to attain greater efficiency and safety, is a natural extension of this trend.

The primary opportunities for raising standards exist in new areas that are currently becoming urbanized, where there are few commitments at present. The proposed system of design classification is intended to carry out the intent of the recommended DOT functional classification criteria by extending the general guidelines provided to the next stage of implementation—design standards that can be applied to new facilities in a uniform fashion. Implementation of these design guidelines provides the highest level of intrinsic protection for each type of facility.

The proposed upgrading of design standards will affect the various highway classifications in different ways. The freeway is currently well defined functionally, although there is considerable variation in design practices. The federal standards for Interstate routes are being used increasingly for other freeway routes; this is upgrading the general level of freeway design so that there will be greater uniformity of design and operation in the future. The arterial highway, especially, requires upgrading of design standards and operation. The collector, the most ambiguous of current facilities, can benefit most by the functional classification process. The greatest current deficiency of the access street is its lack of differentiation from the collector. The DOT recommendations provide a sound basis for consistent definition by clearly defining demarcation lines between facilities. Design standards can then correlate the functional distinctions with design criteria that can elevate the facility to the highest standard consistent with its primary function.

Existing Facilities

The DOT functional classification system was developed primarily for application to existing facilities. This program of classification, presently being implemented, will categorize existing facilities into logical classes of administrative responsibility and will help to establish priorities for improvement.

The DOT classification system is a necessary prerequisite for any future program that aims to correct the urgent deficiencies of current highway networks. The designation of a facility as an arterial or as a collector is only a first step in assigning responsibility for the facility to a particular agency and making available certain funds for its improvement. The types of improvements applicable to each facility and the types of restrictions that can be imposed to protect that facility more fully against encroaching obsolescence can be developed as design guidelines applicable to existing facilities and comparable to those suggested for new facilities.

The new TOPICS program (Traffic Operations Programs to Increase Capacity and Safety) is intended to apply traffic engineering techniques to improvement of existing facilities. Design guidelines for the optimum application of known techniques for the intrinsic protection of existing facilities can be developed; these would provide a model framework to which actual improvement programs could aspire. A starting point in this effort could be the suggested design standards for new facilities as proposed in the system of design classification. These standards would represent a theoretical optimum, inasmuch as they have been developed for new facilities for which there are no precommitments.

Optimum design for each class of facility could then be scaled down in accordance with the constraints imposed by existing conditions. This process could be carried out by setting up a list of existing conditions commonly encountered; design guidelines would illustrate how a theoretically optimum design could be developed within each of these constraining conditions to maximize the utility of the highway and protect the current rights of abutting properties.

This effort would require a detailed study of the many conditions normally encountered on existing facilities, a categorization of these conditions into groupings that are subject to similar solutions, and the development of design solutions for each of these typical situations. To start from a common base, it would be desirable to establish a set of optimum solutions and then consider various levels of downscaling, dependent on the degree of compromise necessary under particular circumstances. In this manner a systematic application of theoretical principles to field conditions could be undertaken, with prior recognition of the optimum solution for most of the conditions encountered and the variations possible to fit particular circumstances in a community. Because there will be a major effort to upgrade existing facilities in the near future, there appears to be a high priority for these types of guidelines.

Highway System Optimization

Optimum Mix

The process of design classification, associated with a raising of design standards to their highest levels, could ultimately lead to an optimum highway system. However, a theoretical analysis would be necessary to define an optimum highway system and the criteria to use in measuring optimization.

It is possible that an optimum highway system would be different from the highway system currently being developed. It is safer and more efficient to handle a trip on a freeway than on a surface street. An optimum highway system might include a higher proportion of freeways and a lower proportion of surface arterials than is customary in present systems. The optimum system might also include a different mix of surface streets. The collector might be used more frequently and effectively; the use of access streets might be minimized.

Pattern and Design

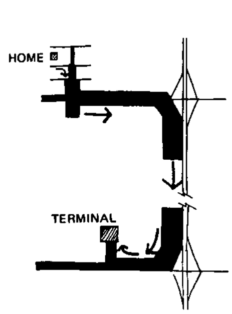
Changes in proportional use of different types of facilities might also be accompanied by a change in their pattern. With the specific functions of each facility clearly defined, it might be found that a different geometric form for that facility would better serve the community's needs. Drastic changes have already taken place in the pattern and geometry of streets. New subdivisions have introduced many innovative design patterns for access and collector streets. Detailed analyses of community circulation functions might result in other optimum geometric patterns for arterials and other highway categories.

Studies of highway optimization might consider new highway categories and concepts that could emerge as optimum design types superior to current categories in some areas of application. Another step in optimization would be to develop an optimum design for each type of highway. Optimum design would embody the highest level of design capability consistent with its function. Design features and specifications would cover various capacity levels and operational performance standards.

A complete theoretical analysis would define an optimum highway transportation system, the functional components that make up the system, the optimum mix of component elements, the geometric pattern of the system that will best serve community needs, and the design features and specifications for each component. Such an analysis would have both a theoretical and a practical value. The concept of an optimum system would permit comparisons to determine where current systems may be deficient. The criteria for such an optimum system, unrestricted by past choices and prevailing practices, could provide principles applicable to new areas where few commitments presently exist.

User Goals

The concept of optimization can be initiated by considering the user of the highway and his criteria for an optimum system. Most motorists measure driving quality more in terms of travel time and ease than in terms of physical distance. Freedom of movement—flow continuity and the absence of congestion—are prized most highly. The freeway usually provides for most efficient travel and greatest safety. From the driver's standpoint, an optimum highway system would permit him to enter a freeway after the shortest possible travel on surface streets. Minimum travel would be required along access streets and collectors, and the objective would be to reach the arterial highway as quickly as possible. For longer trips the arterial is just an intermediate facility leading to a freeway on which the major portion of the trip is conducted. The amount of travel on lesser facilities provides the major determinant of the quality of service provided by the over-all system. The optimum system from the driver's point of view would permit maximum trip mileage to be conducted on a freeway and minimum trip mileage on surface streets.



In traveling from home to freeway on an optimum system, the motorist would be required to stop only at the interface between different facilities and would travel with minimum interruption or conflict on each. His speed would increase as he reached each higher type of facility.

The anticipation of conflicts would progressively decrease, because the frequency of conflict points is reduced in proceeding from a lower to a higher type of facility.

Operational Objectives

Optimum operation can be translated into design features for each type of facility. The access street should be very short and designed for minimum continuity. The motorist proceeds cautiously at slow speeds on the residential access street because of the frequency of driveway and pedestrian conflicts. When the motorist leaves the access street and enters the collector street he expects a higher level of service. The collector street should be designed to provide fewer points of conflict so that the motorist is not subjected to the same types of hazards. If access to individual residences is eliminated and intersections are spaced at regular intervals along the collector street, the motorist can exercise appropriate caution while traveling at a reasonable speed.

On an arterial highway the motorist anticipates a high quality of traffic service. Potential conflict points should be spaced far apart and at uniform intervals, preferably controlled by a progressive system of traffic signal control. The motorist can then continue in uninterrupted fashion at constant speed, experiencing no conflicts with cross traffic.

When the motorist enters a freeway he expects the highest quality of traffic service. Crossing conflicts are eliminated by grade separation, and access conflicts are minimized through infrequent spacing and high-caliber merging design. The motorist travels at very high speeds at the highest level of safety.

Design Elements

The difference between circulation facilities should be emphasized by design distinctions that are easily recognized. These details include spacing of intersections and driveways, width of roadway, curb parking practices, pavement striping, types of traffic control, median dividers, and other geometric design features.

Driving accidents are frequently caused by surprises. The design objective is to eliminate the unexpected to the greatest degree possible by providing a consistent pattern of driving experiences with well-designed control points that the driver can learn to negotiate effectively.

Consistency of design within classes is not necessarily synonymous with uniformity and monotony. Operational elements necessary to achieve operational consistency and driver recognition are but a few of the design features. Other elements of facility design have little effect on street operation and considerable variability is possible in these features. Design criteria are needed, rather than rigid standards, to permit the use of ingenuity and innovation without affecting operational efficiency.

Extension of Functional Classification

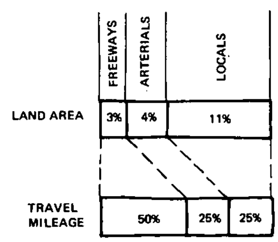
The process of functional classification has until now been confined to the conventional elements of highway and street systems and has generally recognized a four-element functional hierarchy of traffic movement components. In the future there may be a further categorization of circulation functions to include elements not included in current classifications. These could provide for corollary functions such as parking, loading, pedestrian movement, transit movement, and new forms of transportation and circulation that are beginning to play a prominent part in over-all transportation. The concept of functional classification could have greater significance if it were extended to include all elements.

The principles of comprehensive functional classification are applied in the same manner as the more limited applications of the four-element hierarchy. A primary function is assigned to each right-of-way, and the facility is then designed to assure that it is best equipped to perform that function properly. With the higher degree of specialization achieved through separation of conflicting modes and operations, a more efficient facility can be provided that is better protected than a mixed-mode facility.

Land Use for Highways

Land-Use Reduction

A reduction in street area is one product of physical implementation of functional classification. In new metropolitan fringe communities, the amount of land devoted to public streets is usually reduced by at least a third, as compared with older street patterns. The effective channelization of the movement function onto a smaller portion of the land area is dramatically illustrated by the proportions of land devoted to the movement function in such communities. It has been estimated that approximately 3 percent of the land in future urban areas will be occupied by freeways and their appurtenant facilities, but that these freeways will account for approximately 50 percent of the total travel mileage. An additional 4 percent of the total land area will be occupied by arterials having an average one-mile spacing, and these will handle about 25 percent of the future travel mileage. Thus, the combination of the freeway and arterial systems, occupying a total of 7 percent of the land area, will accommodate more than 75 percent of the total travel mileage.



Approximately 11 percent of the total land area will be occupied by collector and access streets constituting the local street system; this system will handle less than 25 percent of the total travel mileage. Thus, even in newer communities, 60 percent of all land devoted to circulation is primarily associated with local access and distribution rather than principal movement functions.

Circulation Efficiency

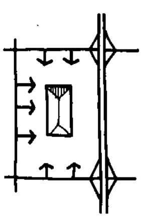
The reduction in land used for circulation is largely accounted for by increased efficiency resulting from specialization and improved design. One freeway lane can accommodate three times as many vehicles as a surface street lane operating under normal traffic controls. A lane on a new arterial highway with effective geometric design, access control, and efficient signalization can accommodate almost twice as many vehicles as an older surface street lane with poor operation and obsolete design. Thus, a substantial decrease in the land devoted to the movement function is made possible by the greater capacity and efficiency achievable with new circulation designs.

The reduction in land used for the movement function has been accompanied by a reduction in street area devoted to the access function. Local access streets now reflect automobile-scale mobility, which permits longer blocks and a lesser need for local street continuity. Larger-scale development has created an entirely new set of design criteria that are no longer dependent on direct street access to numerous small parcels.

Relocation of Function

Another major cause of the reduction of land devoted to public streets is the increasing proportion of land devoted to private internal circulation and terminal facilities. In the past, the public street served all auxiliary functions, including access, parking, and loading. As sophistication in the design of circulation facilities increased, it became necessary for many of these auxiliary functions to be removed from the public right-of-way. The increased scale of development also made it apparent that the required volume of loading and parking could not be accommodated on the public street. In many new large-scale developments, the land occupied by buildings represents a minor portion of the total, the major portion being used for parking, loading, and circulation functions. Thus, the reduction in the amount of public land dedicated to streets is accounted for by the increase in the amount of land devoted to internal circulation, parking, and loading on private property.

The decrease in land area devoted to public local streets is evident in all current large-scale developments. The residential superblock surrounded by arterial highways, with large interior blocks served by a minimum of discontinuous internal streets, is one example of this trend. Regional shopping centers use large sites surrounded by freeways and arterial highways and are frequently devoid of internal public streets. Large industrial sites are often developed as superblocks with few interior public streets. Urban renewal projects frequently create large superblocks, and these drastically reduce the area devoted to public thoroughfares.



In all these instances there is also a discernible trend toward relocating the major circulation facilities to the periphery of the activity area. These new living, working, and shopping environments are created in relatively large superblock units. Automobile access is provided to parking facilities around the periphery, and a minimum of circulation facilities penetrates into the development. It is not coincidental that both circulation and land use have adopted a larger unit of design, for both reflect the dominance of the automobile. The design objective is to retain the pedestrian scale of design within the interior while facilitating the automobile scale around the periphery.

Channel Specialization

Incompatibility Between Modes

The process of functional classification has been confined in the previous discussions to facilities for the accommodation of the automobile. The most serious incompatibilities between different types of movement take place between dissimilar modes, which greatly influence highway efficiency. Functional classification must therefore be extended to a specialization of channels or corridors to accommodate the passage of different modes.

The trend toward specialization of roadways for various types of movement was given official sanction in a Presidential message in 1966; the President urged that studies be made of the potential of separate roadways for different classes of vehicles. Such separate roadways can accommodate the vastly different classes of vehicles and different operating conditions within the same mode.

The incompatibility between different circulation modes that use the same right-of-way has been recognized for some time. Serious problems result when modes exhibiting wide differentials of size and speed of movement are required to share the same roadway. This conflict was resolved initially by separating the pedestrian and the vehicle, providing a raised sidewalk for the pedestrian outside the vehicular roadway. Street railways formerly constructed in the center of roadways resulted in serious delays and congestion for both the streetcar and the automobile; these have been replaced by motor buses in recent years.

More recently there has been a recognition that incompatibility involves more than dissimilar modes sharing the same right-of-way. There is also incompatibility between vehicles of the same type when operating under different conditions. The freeway serves the same vehicles as the surface street, but they maintain completely different operating speeds for different types of service. Specialization of right-of-way has become more widespread to accommodate different modes, different speeds, and different conditions of operation.

Measures of incompatibility are usually defined by extreme differentials in characteristics. The principal variables include speed, size, vulnerability, and other physical characteristics. Relative hazards are measured by the degree of difference, and the problem involves safety, capacity, and efficiency. Compatibility is largely associated with homogeneity of flow.

Warrants for Channel Specialization

When the quantity of a specific character of flow becomes significant within a particular corridor it becomes feasible to channelize that flow. Specialization of circulation channels is justified primarily on the basis of intensity of use. In the case of the freeway, there are enough motor vehicles desiring high-speed movement over considerable distance to justify a specialized facility to handle only that type of movement. At the other extreme, heavy pedestrian flows within a single corridor may justify the reservation of a special channel for the sole use of pedestrians. If there is a heavy flow of bicycles the development of a separate bikeway may be justified. Thus, the predominance of a particular vehicular mode or type of movement justifies the reservation of a specialized channel exclusively for that mode.

Channel specialization does not necessarily mean completely separate rights-of-way for each mode of movement. Three or more modes of transportation can be located alongside each other, providing, for example, a vehicular roadway, a pedestrian sidewalk, and a railroad right-of-way. Adjoining channels may not be the most efficient or safest means of separation but they can work satisfactorily in many cases. Complete separation of rights-of-way is usually more effective but not as easily achievable.

Specialization of rights-of-way and the increased partitioning of rights-of-way for the separation of different modes is expected to accelerate in the future as such increased specialization becomes justified. This is one method by which the efficiency of traffic movement can be improved. Functional classification of streets, which accounts for different operating conditions by providing for different design characteristics of each type of facility, is one major aspect of channel specialization.

CHAPTER FIVE

TRAFFIC GENERATION VOCABULARY

TRIP CHARACTERISTICS

There are many ways to measure travel and to describe the general patterns of movement in an area. However, it is far more difficult to discern the cause and effect relationship by which all of the sources and determinants of travel can be related and connected. The key to the prediction of travel patterns is an understanding of the interactions between travel characteristics and the surrounding environment.

Among the determinants of that environment are the uses of the land itself. The movement of people and goods embodies the functional interrelationships between land uses. Land use is a direct mirror of the activities of people, and the variety and intensity of land uses reflect the vast range of human activities. The amount of travel and its distribution is functionally related to land use; the feedback is direct, and any modification of one results in changes in the other. Thus, a solution to the highway problem may be sought along two complementary lines: one is the regulation and control of traffic and the improvement of the physical channels that accommodate traffic movement; the other is the planning and control of land uses and their changing patterns, which create the demand for travel.

Trip Generation

Trip characteristics that facilitate an understanding of trip generation include trip purpose, time distribution, trip length, trip distribution, and mode of travel. Other factors may influence trip generation—family income and vehicle ownership, car occupancy, ages of persons affected, quality of transportation system, etc. These variables have some influence on trip generation and should be given consideration. However, for the purposes of the current study, only the primary influences are considered in the development of traffic generation guidelines, of which land use is the major influencing factor.

By far the most common purposes of trips are to go to places of work and to go home. Work and home trips not only constitute the bulk of all trips, they are also the most repetitive. They occur on a daily cycle, primarily during peak hours.

Each type of trip is distinguished by a particular time distribution. Work trips occur daily during peak hours; recreation trips occur primarily on weekends and are spread over a longer period of time; shopping trips occur generally during off-peak periods. Traffic is usually expressed in 24-hour daily volumes and a particular percentage is used to represent the peak-hour travel demand. Such over-all evaluation may be appropriate for certain purposes, but specific land uses materially affect transportation demands in localized areas. It is therefore necessary to analyze more precisely the time distribution of travel for particular land uses.

Trip length varies with the type of land use. Residents in outlying areas tend to make more trips over longer distances because of the dispersed nature of suburban development.

Available modes of travel exert an important effect on trip generation. Each mode has a particular function in the metropolitan transportation system. Generally, smaller cities depend almost exclusively on the automobile and larger cities use mixed modes of transport, or the larger the city, the higher the proportion of public transit use. This is especially true in older cities that developed prior to the automobile age.

Trip Distribution

The largest generator of travel is the residence, because about 80 percent of all trips start or end at home. Thus, the density and spatial distribution of residential areas have a profound influence on urban travel patterns.

The second major generator of trips is the place of work, where 40 percent of all trips begin or end. The existing spatial distribution of employment centers as well as trends of change in job locations are key determinants of an area's travel patterns.

In most of the larger central areas the number of jobs is not increasing, but the composition of the work force is changing. Manufacturing, retailing, household services, and wholesaling seem to be moving out of the central business district; financing, business services, central office administration, and other professional offices are growing in central areas.

These trends result in increased transportation loads over longer distances. Higher-income white-collar workers travel to the central areas from distant suburban residential areas, which are becoming more distant each year. Blue-collar workers, who frequently reside in or near the central area and who could formerly find employment near their residences, are now being forced to travel long distances to decentralized plants and other suburban work destinations. This cross current of white-collar and blue-collar commuting constitutes a serious transportation paradox.

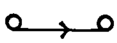
Future increases in travel will take place mainly in the suburbs, where population, jobs, retail sales, and average income are all on the upgrade. Travel to the central business districts will not decline, however, because of the continuing growth of certain types of jobs in central areas.

The newly developing areas are those in which most current decisions have to be reached with regard to alternative land uses and their effects on the transportation network. In most of these newer areas the predominant transportation mode is the automobile; other modes of travel have little influence at this time. In such areas, traffic generation characteristics tend to be surprisingly uniform and vary little from one area to another and even from one region or part of the country to another. For such areas it is possible to develop fairly reliable traffic generation guidelines for different types of land use.

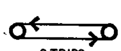
TRAFFIC GENERATION CLASSIFICATION

Traffic Generation Terminology

A trip refers to the act of traveling between an origin and a destination without respect to length or distance. Travel combines a trip as an event with the property of length or distance between an origin and a destination. A trip may be referenced to either the movement of a person or the movement of a vehicle. The term "trip" refers to a single movement having either an origin or a destination at a particular point (sometimes referred to as a "trip end" or a "trip origin"). A "two-way round trip" is considered, in traffic terminology, as two trips.

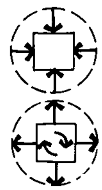


1 TRIP



2 TRIPS

The term "traffic generation" refers to the total number of trips that start or end in a particular area within a given period of time. This implies that the subject area has boundaries, and only those vehicles crossing the boundaries are counted. There may also be a substantial number of trips conducted within the area that are not interpreted as generated trips with respect to external origins. In a fairly large area, such as a central business district, the number of internal trips may be appreciable, but these would not be included in trip generation for the district as a whole. The same is true of a residential neighborhood where trips would not be counted so long as they did not cross the boundary lines.



Traffic Generation Base

In categorizing traffic generation in relation to particular types of land uses, it is necessary to express the trips in terms of some common denominator for comparative purposes. This common denominator should reflect some common characteristic of the land use being considered. Traffic generation in trips per acre may be a reliable measure for certain types of land use, whereas trips per thousand square feet of floor area may be a more reliable measure for other types. Sometimes other related indicators are more applicable—the number of dwelling units for residential areas, number of employees for industrial plants, or other common denominators—and some of these may be highly specialized, such as the number of beds in a hospital or the number of students in a school.

Traffic generation figures are normally obtained by dividing the total number of trips entering and leaving a particular area across an imaginary cordon line by the common basis of measurement for that particular land use. The measurement unit normally sought is the one that provides the best key indicator of site activity. Sometimes it is necessary to use a combination of indicators, producing multiple regression predictive equations. Trip generation can become quite complex if an attempt is made to reach a high level of accuracy. In most cases, however, the variability typical within a particular land use does not warrant this high level of analytical accuracy. It is usually more appropriate to choose a trip generation approach that is simple to apply and yet acceptably accurate.

To develop a basis for comparing different types of land use with regard to their traffic generation capabilities, it would be desirable to have some means to express traffic generation rates for all land uses on some common base, with recognition for the limited accuracy of such generalizations. The most general measure of trip making is one based on units of area, such as number of trips per acre. When land-use controls are being considered, the only known factor may be the acreage involved. More refined measurements of traffic generation, such as square feet of building, population density, or number of employees, are unknown factors at this stage. The decision-making process can be based on a common factor that is measurable and known at the time the decision must be made; this, typically, is the land area involved. Therefore, the ratio of trips to acreage has been selected as the common bridge by which the traffic generation intensity of different types of land uses can be directly compared and connected, especially in those cases where greater refinement is not possible at any early stage.

Traffic Generation Studies

Review of the literature on traffic generation reveals a wide range of reported rates for each land-use classification. This generally indicates the differing conditions under which field studies or interviews are conducted and the variation in classifications and specific uses. The ways of reporting traffic generation are also not uniform. The variations include "person trips" and "vehicle trips," "trip origins" and "trip destinations," "trips" and "trip ends," and other terms generally not well defined. Furthermore, traffic generation is related to different base units of measurement—square miles, acres, square feet of floor area, dwelling units, employees, theater seats, hospital beds, pupils, etc.

Traffic generation rates have generally been reported in two principal forms. Transportation studies for urban areas usually describe traffic generation by such generalized land-use categories as commercial, industrial, or residential use. Other special planning and traffic generation studies report traffic rates by the type of facility, such as a supermarket, hospital, school, or office building. Between these two extremes are many intermediate categories. This lack of consistent reporting of traffic generation rates is one of the major difficulties in attempting to categorize existing data into a meaningful classification system.

Traffic Generation Categories

In current land-use classification systems, there are the three major categories of land use—residential, commercial and industrial—and other such categories as public buildings, public open space, and transportation. In relating traffic generation to land use it would be convenient if each land-use classification also constituted a specific traffic generation classification. Unfortunately, an extremely wide range of traffic generation potential for different uses is included under each major category, and the major category cannot be regarded as a traffic generation classification. To obtain anything significant, it is necessary to examine the specific uses within each category.

Still, it is desirable to retain a basic classification system that can be related in some manner to the generally accepted land-use classifications. This will facilitate the administration of the guidelines that are developed. The objective is to develop an ordering of specific land uses within each major classification with respect to traffic generation potential.

Over-All Traffic Generation

To obtain an undistorted picture of over-all traffic generation for an urban area, it is necessary to examine not only the trip-making potential of each type of land use but also the quantity of land in each category. Table 3 gives typical proportions of urban land in various land-use classifications, which vary with the size and character of the city.

TABLE 3

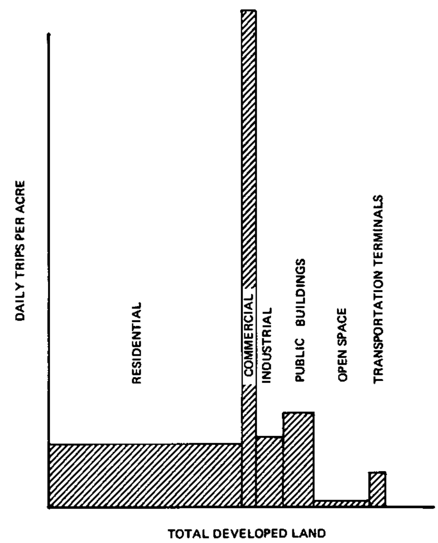
TYPICAL LAND-USE DISTRIBUTION

LAND USE [a]	PERCENTAGE
Residential	56
Commercial	5
Industrial	7
Public buildings	8
Open space	17
Transportation terminals	7
Total	100

[a] Excluding roads.

The figure shows the average traffic generation of various land uses in an urban area, indicating the effect of each type of land use on total traffic generation. It shows that residential uses, which make up the majority of all productive land uses, account for the greatest proportion of total traffic generation. Even though commercial land has a much higher traffic generation rate per unit of land, the relatively low percentage of commercial land reduces its proportion of total traffic generation. Similarly, industrial land constitutes a relatively small proportion of total developed land, reducing its proportion of total traffic generation in an urban area. Although the over-all traffic generation contributed by these intense land uses is low in comparison to residential traffic generation, their effects on individual routes and in localized areas are far more severe.

TOTAL LAND USE TRAFFIC GENERATION



RESIDENTIAL TRAFFIC GENERATION

Daily Traffic

There is an extremely wide range in the rates of residential traffic generation. These rates may be as low as five daily trips per acre for low-density development with less than

TABLE 4

RESIDENTIAL TRAFFIC GENERATION

DENSITY			PERSONS/ DWELLING UNIT	DAILY TRAFFIC GENERATION (VEH-TRIPS PER)					
				ACRE		PERSON		DWELLING UNIT	
TYPE	DWELLING UNITS/ACRE	HOUSING TYPE		RANGE	TYPICAL	RANGE	TYPICAL	RANGE	TYPICAL
Low	1–5	Single family	4.0	5–50	40	2.3–3.0	2.5	7–12	9
	4–5	Single-family cluster		30–65	50				
Medium	5–7	Patio houses		40–75	55				
	6–8	Duplexes		45–85	65			5–8	7
	8–15	Town houses		60–150	85				
High	15–25	Garden apts.		85–220	150				
	20–30	Multifamily (4- to 5-story apts.)		110–240	175			3–7	5
	30–60	High-rise apts.		160–400	240	2.3–3.0	2.5		

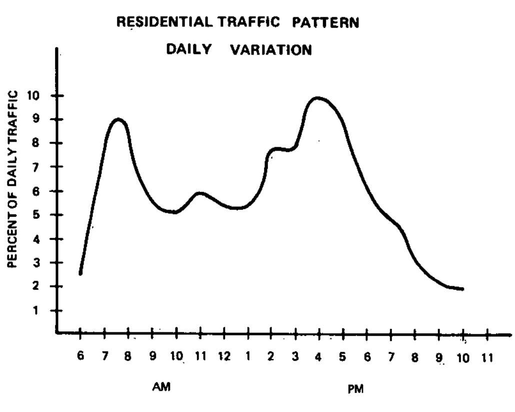
Source: California studies.

one dwelling unit per acre. As many as 400 daily trips per acre may be generated by high-rise apartment housing.

The number of vehicle-trips per person is almost independent of density or size of dwelling units. Thus, traffic generation varies directly with the number of persons living within a particular unit of area. Although the number of vehicle-trips per person tends to remain fairly constant, the number of persons per dwelling unit generally decreases in higher-density housing, so that the number of vehicle-trips per dwelling unit tends to decrease with higher densities. Table 4 gives these variations with density in comparing trips per acre and trips per dwelling unit. Residential trips are expressed in average daily vehicle-trips per acre to provide a basis of comparison with other land uses.

Peak Traffic

With specific regard to the effects of traffic operation on the highway system, figures on daily traffic generation provide only a general indication of influence; peak-hour traffic generation is more pertinent. The figure shows a typical distribution of average weekday residential traffic. Peak-hour characteristics generally occur between 7 and 8 AM and 4 and 5 PM. The evening peak is slightly higher than the morning peak; the peak-hour rate is approximately 10 percent of the average daily volume. Typical studies (*58*) of single-family residential areas have found average



weekday peak-hour generation as follows: AM peak: range 5 to 15 percent, mean 8 percent. PM peak: range 8 to 19 percent, mean 12 percent.

Another significant measure in relation to the highway system is the directional split of peak-hour generation into inbound and outbound components. Some studies (*202*) indicate a very pronounced outbound peak leaving residential areas in the morning; 75 percent are outbound and 25 percent are inbound during the AM peak hour. However, the evening peak is far less pronounced, with 60 percent inbound and 40 percent outbound. There thus appears to be a more varied mix of traffic during the evening peak in residential areas. These directional splits vary considerably between areas; in some cases the directional proportions are much higher and more heavily unbalanced.

The actual intensity of the peak hours may vary considerably. The range of vehicle-trips per dwelling unit during the morning peak hour (*201*) extended from 0.5 to 1.4, with a mean of 0.8. The afternoon peak hour ranged from 0.8 to 1.8, with a mean of 1.1 vehicle-trips per dwelling unit. Although the afternoon peak tends to be more pronounced, the directional split may be more nearly equal, so that the actual volume in the peak direction may not be much greater in the afternoon than in the morning.

Most empirical studies have taken place in single-family neighborhoods; there are fewer studies of medium- and high-density residential areas. As additional data become available, predictive equations can be developed by means of multiple regression techniques that could give proper weight to variables most importantly affecting traffic generation rates.

COMMERCIAL TRAFFIC GENERATION

Daily Traffic

Commercial land, constituting about 3 to 5 percent of urban land, is normally devoted to various types of retail, wholesale, and service establishments. The central business district has until recently been the dominant commercial center for the urban region and the most intensive commercial trip attractor. But recently a major reorientation of commercial land use has taken place; a considerable amount of new commercial development is locating in outlying areas. Retail shopping is only one of several types of commercial land use. Business, personal services, wholesalers, etc., are also classified as commercial activities, so that office buildings and other types of structures are also included in this category.

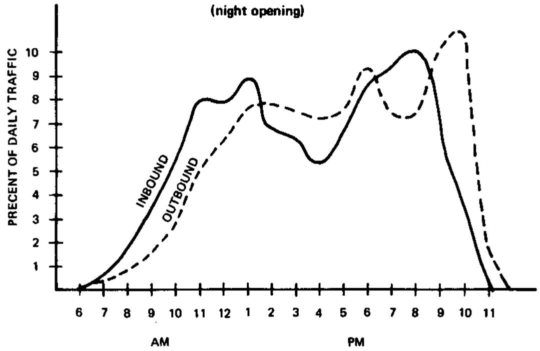
Because of the numerous types of establishments that are included in the commercial land-use category, reported traffic generation rates range widely from supermarkets to wholesalers. Office buildings have completely different traffic generation characteristics than do wholesale distribution and warehousing facilities. Land values also influence the intensity of land use, so that traffic generation rates expressed in terms of acreage can have very wide variations, depending on the vertical concentration of uses of the land. Traffic generation rates thus will vary according to the amount of floor area and the intensity of use of that floor area.

On the basis of some 50 transportation studies and smaller surveys conducted within the last decade, traffic generation data for many different types of commercial land uses have been sorted out. The relevant data were translated into the common base of vehicle-trips per acre and per thousand square feet of floor area. Traffic generation rates for various commercial types were then ordered and ranked according to their traffic generation potential. There is a considerable range even within individual categories.

Peak Traffic

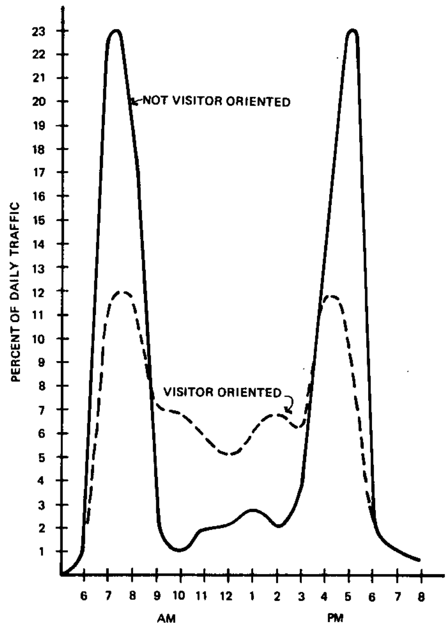
Peak periods are especially critical in commercial areas where there are concentrations of office buildings or where shopping centers attract large groups of people. A typical hourly distribution curve for a regional shopping center shows the daily variations for inbound and outbound traffic for centers that stay open late in the evening. The peaks of entering and existing vehicles do not coincide with the road-traffic peak between 4 and 6 PM. However, the road-traffic peak on the adjacent street system, together with the traffic generated by the shopping center at that time, may result in the most severe condition to be accommodated. In most cases Friday and Saturday are the highest shopping-peak days. There are also severe seasonal peaks before Christmas, Easter, and other major holidays.

SHOPPING CENTER TRAFFIC PATTERN
DAILY VARIATION
(night opening)



At office buildings most of the traffic is generated by employees who observe normal working hours. For offices that attract relatively few visitors, 80 percent of the daily trips may be work trips, with sharp inbound peaks in the morning and outbound peaks in the evening. Some studies indicate that more than 50 percent of daily inbound trips arrive during a 1-hour period, and about 75 percent arrive within a 2-hour period in the morning (*180*). Departures have similar peaking characteristics—about 50 percent departing during a 1-hour and 75 percent during a 2-hour afternoon period. The figure shows a typical daily travel pattern for an office building that attracts few visitors.

OFFICE BUILDING TRAFFIC PATTERN
DAILY VARIATION



The same figure also illustrates the hourly variation of traffic for an office building that attracts a substantial number of visitors. This type of public-oriented (service) office building has a more evenly distributed traffic pattern and the proportion of employees' trips is significantly lower. Service offices have more nonpeak activity. However, 50 percent of all persons may still enter such buildings between 7 and 9 AM, and leave between 4 and 6 PM (*181*).

A comparison of these two types of office buildings illustrates how important the peak distribution pattern is in its effect on the highway system. In the first case the peak-hour figure is about 23 percent; in the second case it is only 12 percent—a ratio of 2 to 1. Since the peak-hour generation rate governs the design of the adjacent street system, it is necessary to take into account both daily traffic generation and peak-hour generation when making any significant decisions based on traffic generation.

INDUSTRIAL TRAFFIC GENERATION

Daily Traffic

There is relatively little comprehensive data available concerning traffic generation by different industrial land uses. Acreage is not the best measure of industrial traffic generation because of the variable amounts of vacant and inactive acreage associated with certain types of plants. Floor space, which sometimes reflects the number and type of workers employed, is a somewhat better indicator. Four types of floor space can be distinguished (*181*)—production, storage, office, and service. Each of these has a different function and a variable number of employees per unit area. Generally office space generates more traffic per unit of floor area than do production or storage areas.

Peak Traffic

Of particular significance are the shortness and sharpness of industrial peak periods and the very high directional orientation. Industrial peak-traffic generation frequently constitutes a much more serious problem to the adjoining highway than do other land uses.

For suburban industries, peak-hour traffic generation rates can be best correlated with employment. In one study (*4*) the peak hour had a mean generation of 0.34 vehicle-trips per employee, and about 17 vehicle-trips per acre of developed land. The peak-hour proportion of total daily automobile traffic ranged from 36 to 45 percent. Directional tendency (the proportion of total trips in the dominant direction of travel during the peak hour) was very high, ranging from 79 to 94 percent.

Of even greater consequence for industrial development is the concentrated peak that occurs within the highest 15-minute period. The quarter-hour leaving peak, for instance, might represent half of all peak-hour leaving vehicles. Thus, the intensity of the concentrated peak period usually represents the most serious problem at an industrial plant, unlike other principal land-use types where peaks extend over longer periods of time and are distributed more gradually. The industrial peak is thus exaggerated in its effect on the highway system by the extreme concentration of leaving traffic within a very short period of time and the intensive directional orientation.

MISCELLANEOUS USE TRAFFIC GENERATION

Between 80 and 90 percent of all person trips originate in residential, commercial, and industrial areas. The remaining 10 to 20 percent originate in areas devoted to other land uses, such as public and quasi-public buildings (hospitals, churches, etc.), transportation facilities (terminals, harbors, and warehouses), and public open spaces (parks and stadia).

Public Buildings

Public buildings, such as government and administration buildings, are primarily work places and exhibit traffic patterns similar to those of private office buildings. Daily traffic generation of government buildings has been found to be similar to that in private office buildings. More than 50 percent of the daily trips arrive between 7 and 9 AM and depart between 4 and 6 PM. In the intermediate hours there is a fairly constant percentage of in- and outbound activity, with no hour exceeding 7 percent of daily trips.

Universities and Colleges

Large schools are major centers of activity and are therefore prime traffic generators. The growth trends of recent years portend an increasing significance of college campuses as major sites of traffic concentration. Transportation studies reveal that up to 90 percent of commuting students, faculty, and staff members arrive by automobile. Because of the variable sizes of campuses, the number of trips per acre ranges widely. The most reliable indicator of campus trip-making is number of students.

Traffic flow to and from the campus changes considerably throughout the day and shows variable peaking characteristics. Students, faculty, staff, and visitors follow different traffic patterns, and total traffic flow is an aggregate of the needs of all these components. The hour immediately preceding the first period is generally the most intense, inasmuch as students, faculty, and staff go to school and work at about the same time in the morning. Thus, the hour around 8 AM may account for 20 percent of all vehicle trips to the campus. Students leave school throughout the day, but faculty and staff leave after a normal working day, so that the peak leaving hour, at around 5 PM, accounts for about 15 percent of total trips.

Campuses also attract a substantial number of visitors and numerous night students. Universities do not exhibit the sharp morning and evening peaks that are typical of private office buildings. The travel impact on the surrounding highway network is related largely to the size of the university and the community.

Hospitals

The impact of hospital travel on adjacent streets depends mainly on the size of the facility, because hospitals maintain a relatively high level of travel activity throughout the day and night. Doctors and visitors come and go all day long, and nurses generally work in three shifts. Most other employees work a normal daytime shift whose traffic pattern coincides with general traffic peak hours. The most reliable indicator of hospital traffic generation is the number of beds. Studies reveal that about 20 percent of all inbound vehicle trips arrive during the morning highway peak hour between 7 and 8 AM; fewer than 20 percent leave the hospital between 4 and 5 PM. During the day and late evening, about 5 percent of all cars arrive and leave each hour.

Public Open Spaces

Traffic generation rates for public open spaces can vary over an extreme range. There are some facilities, such as beaches, stadia, and other major public facilities, that are extremely high traffic generators. Other public recreation facilities may also attract a very high number of visitors, especially on weekends. Parks and golf courses have lower visitation rates per acre. Some open-space facilities, such as stadia, may have very heavy peak conditions if their attractions terminate at a particular time.

Transportation Terminals

The major portion of the generalized category of land use known as "transportation" is the urban highway network. About 28 percent of the developed land of an urban area may be devoted to highway rights-of-way. The streets and highways are obviously not traffic generators themselves; they are the channels over which the traffic generated by other land uses is carried.

The remainder of the transportation category consists of terminal facilities, such as bus, railroad, and airport terminals, harbors, warehouses, and other facilities where an interchange of persons and goods between different modes of transport occurs. Terminals are operational points of origin or destination where freight and passengers are transferred to automotive vehicles; they may be considered as traffic generators insofar as they attract highway traffic.

Airports have become one of the largest traffic generators in many urban areas and their role will continue to grow in the future. The terminal can be considered among the largest single traffic generators in the metropolitan area. In addition to passengers, there are numerous visitors, flight and maintenance personnel, and service employees. There may also be a sizable amount of subsidiary industry around the periphery of the airport. More than 75 percent of all passengers arrive by automobile; additional access is gained by motor bus, airport limousines, taxicabs, etc. Traffic generation related to land area is generally too crude a measure of the diverse activities of an airport. A more accurate determination of traffic generation can be related to the number of enplaning and deplaning passengers (*186*).

LAND-USE TRAFFIC GENERATION

Classification System

If traffic generation is to be used as a major criterion in land-use control decisions, it will be necessary to provide some means by which land-use categories will reflect traffic generation intensity. The usual categories of land use by type and performance characteristics may correlate positively with density, but sometimes they do not. In the case of residential uses, the different zoning categories generally correspond to density classes and are usable in comparing traffic generation. However, in the case of industrial and commercial land uses, this correlation is frequently not possible with existing classifications.

For maximum utility, the land-use classification system needed for a traffic generation vocabulary should comply as closely as possible with existing zoning classifications, but traffic generation intensity should also be reflected. Traffic generation intensity would then be obtained by multiplying the rate of traffic generation by the land-use density. A traffic generation vocabulary system to accomplish this objective has been developed that uses both a common base of acreage, by means of which all land uses can be compared, and a specific base for each land use that more accurately reflects traffic generation density for that land use. The following table illustrates an initial system of land-use classification in which the major land uses are divided into four principal categories and each category is subdivided into several density classes. This table is based on all available sources of traffic generation data correlated to land-use types.

Residential Category

Residential classification uses the density measure of dwelling units per acre (Table 5). Three separate density classes are used. Low density is defined as fewer than 5 dwelling units per acre; medium density has 5 to 20 dwelling units per acre; high density has more than 20 units per acre. Each density class specifies the types of development that would normally be included within these classes. Typical traffic generation rates are indicated in vehicle-trips per acre and in vehicle-trips per dwelling unit.

Commercial Category

The commercial category has two principal classes, retail-commercial development and office buildings, which have completely different traffic characteristics. Retail-commercial development is divided into five subclasses, including three typical scales of shopping center development. The smallest type of retail commercial development is the neighborhood shopping center of less than 10 acres. Next is the community shopping center development, which occupies a site of 10 to 30 acres. The largest suburban type of retail development is the regional shopping center, occupying a site in excess of 30 acres. The most intense retail area is the central business district, which has specialized traffic generation characteristics. A final subclass is highway-oriented commercial development, which may include individual parcels, clusters, or strip development. These five general subclasses include almost every variety of retail-commercial development. Traffic generation rates are indicated in vehicle-trips per acre and in vehicle-trips per thousand square feet of floor area.

The density measure for office buildings is the ratio of floor area to land area. Density of development is reflected in a five-step subclassification for office buildings. Single-story buildings with surface parking that have a floor area ratio of less than 0.5 are in the lowest density category. More intense development categories include a two-story building with surface parking and a floor-area ratio of about 1.0, a three- to four-story building with structure parking and a floor-area ratio of about 2.0, a three- to six-story building with structure parking and a floor-area ratio of about 5.0, and high-rise office buildings with structure parking and a floor-area ratio of 10 or more. These five subclasses of density are generally illustrative of most existing office building types and provide a gradation of traffic generation within the office building classification scheme. Traffic generation rates are indicated in vehicle-trips per acre and in vehicle-trips per thousand square feet of floor area.

TABLE 5

TRAFFIC GENERATION VOCABULARY

LAND USE	DENSITY UNIT	DENSITY NUMBER	TRAFFIC GENERATION RATE (VEH TRIP ENDS PER DAY): NUMBER PER ACRE RANGE	NUMBER PER ACRE TYPICAL	NUMBER PER UNIT UNIT	NUMBER PER UNIT RANGE	NUMBER PER UNIT TYPICAL
Residential	Dwelling units/acre				Dwelling unit		
Low density (single-family homes)		1–5	5–65	40		7–12	9
Medium density (patio houses, duplexes, townhouses)		5–15	40–150	75		5–8	7
High density (apartments)		15–60	85–400	180		3–7	5
Commercial							
Retail commercial	Acres				1,000 Sq ft F.A.		
Neighborhood retail (supermarket)		10	800–1,400	1,000		70–240	130
Community retail (junior department store)		10–30	700–1,000	900		60–140	80
Regional retail (regional shopping center)		30	400–700	600		30–50	40
Central area retail	High density		600–1,300	900		10–50	40
Highway-oriented commercial (motels, service stations)	Low density		100–300	240		4–12	10
Service commercial (office buildings)	FAR [a]				1,000 Sq ft F.A.		
Single-story bldg. with surface parking		0.5:1	120–1,200	300		6–60	14
Two-story bldg. with surface parking		1:1	240–2,400	600		6–60	14
Three- to four-story bldg. with deck parking		2:1	360–6,000	1,200		6–60	14
Three- to six-story bldg. with surface parking		5:1	1,200–12,000	2,600		6–60	14
High-rise office bldg. (more than 10 stories) with structure parking		10:1	2,400–20,000			6–60	14
Industrial	Employees/acre				1,000 Sq ft F.A.		
Highly automated industry; low employee density (refinery, warehouse)		5	2–8	4		0.2–1.0	0.6
Light service industry single-lot industry (lumber yard)		5–20	6–30	16		0.4–1.2	0.8
Industrial tract (5 acres) (machinery factory)		20–100	30–160	70		0.6–4.0	2.0
Office campus: research and development (research industry)		100	150–200	170		3–8	4
Mixed central industry; small industrial plants		Varies	10–100			1–4	
Public and semi-public uses		Varies					
Schools and colleges	No. of students		7–600 (colleges)	60	Student	0.4–1.0	0.8
Places of public assembly (theater, stadium, convention center)	No. attending				4 Seats (stadia)		2
Administration facilities (city hall, state offices, post offices)	FAR [a]		70–600	200	1,000 sq ft F.A.	10–60	20
Recreation facilities (park, zoo, beach, golf course)			1–10 (parks)	4	Acre (golf course)	2–10	8
Terminals (bus terminal, airport)			3–30	15	Based aircraft [b]	6–12	8
Hospitals	No. of beds		16–70	40	Bed [c]	6–16	10

[a] Floor area ratio. [b] Local airport. [c] Person-trip ends.

Industrial Category

Industrial development also may be divided into five classes. The principal measure of density is employees per acre, which best reflects traffic generation intensities. The operations with lowest employee density are highly automated industries supporting fewer than five employees per acre. A second class is light service industry, generally located on small parcels and having 5 to 20 employees per acre. An industrial tract is a larger development with more intensive employment ranging from 20 to 100 employees per acre. One of the most intensive industrial classes is office industry (research and development); an industrial "campus" of this type may support more than 100 employees per acre. A fifth class is mixed central industrial development, having a variable employee density. Traffic generation rates are indicated in vehicle-trips per acre and in vehicle-trips per thousand square feet of floor area.

Public and Semi-Public Category

The fourth major category of land use is public and semi-public uses, which include a wide variety of facilities with no common density measures. Density components include area of land used and number of persons affected: for schools—number of students; places of public assembly—number of persons accommodated; governmental administrative facilities—number of employees and visitors, or floor-area ratio; open-space recreation facilities—people in attendance; terminals for various transportation models—acreage, people handled, or number of operations; hospitals—number of beds. For other types of facilities that do not fit the suggested classifications, separate designations may be necessary. The density measure is different for each type of use. Traffic generation rates are indicated in vehicle-trips per acre and in other base measurements that most typically describe the intensity of use for that facility.

This tabulation of traffic generation relationships uses the common base of trips per acre, a base that permits comparability among all land uses. The daily traffic generation rates indicated provide one basis for comparison. Another relevant base of comparison would be peak-hour traffic generation rates, which directly affect the utility of the highway during the most critical period. The peak-hour rates developed previously provide some measure of this variable.

Future Categorization

The traffic generation guidelines given in Table 5 are based on available data that have been sorted out and translated into a single compatible system. The data have been compiled from numerous sources having different levels of reliability and subject to variable interpretation. The table illustrates the method of classification proposed and provides some rough guidelines to the achievable results.

This system can be developed to a higher level by using a greater number of categories and classes and a greater variety of traffic generation rate comparisons. Relevant factors of comparison include person and vehicle-trip generation rates by day, peak hour, and peak 15-minute period; by direction; and by other significant variables that affect the highway system. Traffic generation data should ultimately be compiled to this higher level of accuracy and detail so that a reliable table of comparisons can be provided for use by planning administrators in the decision-making process.

The standard land-use coding system (*324*) can be effectively applied to develop a detailed categorization that is adaptable to the needs of the traffic generation vocabulary. With the standard coding system, traffic generation data can be directly related to the specific land-use category to which they apply. All traffic generation data should ultimately conform to the same reporting base. The major effort would be to compile all reliable and detailed traffic generation data so that they can be adequately categorized. Additional traffic generation studies will be needed to fill numerous gaps where insufficient data are available. This effort could become one of the most valuable tools in relating land use to transportation needs.

TRAFFIC GENERATION VOCABULARY APPLICATIONS

Factual Evaluation

The development of a land-use traffic generation vocabulary provides the necessary tool to obtain a quantitative correlation between land use and highway capability. With it, all types of land use can be compared with respect to traffic generation potential and characteristics. Most significantly, they can also be compared with the capacity constraints of the highway network intended to serve them.

Quantitative Comparison

A traffic generation vocabulary should inform an administrator about the amount of traffic that would be generated by a proposed land-use development and should facilitate comparisons with the traffic generated by alternative types of development. These quantitative comparisons should be possible with respect to total generation, peak-hour generation rates, general orientations of traffic flow, and other pertinent aspects of the traffic situation. Furthermore, it should be possible to relate these traffic generation characteristics to other traffic in the vicinity to determine whether they are compatible and interlocking, or cumulative and concentration-prone.

Traffic generation has significance only in relation to the capabilities of the adjacent transportation system. Thus, the most significant comparison to be made is that between the traffic generated by the facility and the traffic capacity of the nearby highways. Available techniques permit a fairly accurate determination of highway capacities and of spare capacity available to accommodate the traffic that will be generated by the proposed development. Traffic absorption potential—the rate at which traffic from the generator can flow into the highway system—may have some influence on such significant considerations as work-hour staggering, metering of exit traffic flow, driveway design capabilities, and other aspects of traffic operation for the proposed facility.

Traffic generation analysis can thus affect judgments about the feasibility of different types of land use and about the intensity and concentration of particular land uses. It can affect site design requirements and operational provisions. Land-use control should not be visualized as purely a restrictive device with narrow connotations. It can become an extremely valuable tool to be exercised with great sophistication when the proper evaluation techniques and guidelines are provided. At the very least, the new tools will permit land-use decisions to be made on the basis of factual evidence instead of varying shades of opinion.

In the past, a lack of necessary guidelines and analytical techniques may have influenced the community to make certain decisions without considering the full implications. As new guidelines become available, allowing administrators to make the correlative analyses needed to determine the transportation concomitants of their land-use decisions, a higher level of responsibility will be imposed on governmental agencies. Significant decisions affecting highway adequacy will be subject to analytical testing; authoritative data can be presented to influence the decision-making process. The administrator will be able to relate the required improvements in highway construction and traffic control with the land-use decision itself.

The political process of decision making is subject to the greatest variability and influence when the matters under consideration cannot be well defined and are most subject to opinion, interpretation, and prejudice. Land-use control decisions have not previously been subject to precise definition or quantification. Guidelines that systematize the process of decision making can materially influence land-use control procedures.

Future Considerations

The control of land-use development in relation to the highway system is made more complicated because any single decision is one element in an indeterminate time stream. A highway may be able to accommodate the traffic generated by the development currently under consideration, but it must also accommodate future developments along that highway as well. The immediate decision cannot be divorced from the effects of other developments that will take place later.

Inasmuch as the ultimate development of the area is not subject to definition, particular cases are frequently examined in a vacuum. In the absence of an over-all picture, the microscopic examination of one particular development has questionable validity. Limited analyses of this type are valid only with respect to the effects on the immediate environs and are applicable primarily to the immediate future.

To examine a particular development within the context of ultimate area-wide development, it is desirable to refer to the area-wide transportation study, which offers a new tool for land-use decision making. The transportation study is intended primarily to determine corridor travel demands in the future, for which it is necessary to make certain assumptions about anticipated development in particular areas based on existing and anticipated land-use controls, development trends, area growth potentials, economic determinants, and other factors that influence development. These predictions of area growth, combined with travel growth trends and other future travel determinants, result in traffic volume estimates for particular travel corridors and arterial facilities. Thus, the area-wide transportation surveys use the best available predictions to provide the means for estimating future corridor travel demands. Because these travel estimates are intended to be maintained up to date at periodic intervals, corridor traffic volumes will be available on a continuing basis and can provide the basis input data for analytical studies of particular areas.

The assumptions used in the area-wide transportation study provide the necessary linkage between the effects of a specific land-use proposal under consideration and future area-wide development. If the current proposal generally corresponds with the assumptions originally made in the transportation study with regard to future development, then the findings of the over-all study with regard to needs for highway improvement continue to be valid. The effects on the specific travel corridor under consideration can be predicted by relating the traffic generation characteristics of the proposed development to existing highway volume-capacity relationships. The need for the highway improvement predicted in the area-wide transportation study can then be related to the specific proposal; if such improvement is required it becomes a concomitant of the land-use decision to be implemented in conjunction with that decision.

For the development proposal to differ materially from the assumptions made in the transportation survey is an indication that the land development trends in that area may be considerably different from those anticipated, not only for the land parcel under consideration but also for other land around it. It is then appropriate to examine the full ramifications of such a change, considering the effects of such development on other land uses in the vicinity, for each proposal affects the use of other land around it.

To test the complete effect of the land-use proposal on the highway network, new input information with regard to development potential and traffic generation must be entered in the transportation survey analysis as revised input. A new analysis will then determine what effect the development would have on the over-all transportation system, and particularly on the corridors immediately affected. The resulting traffic corridor volumes are translated to highway improvement requirements, permitting the proposal to be realistically evaluated.

Application Opportunities

The combined tools of the area-wide transportation survey and the traffic generation vocabulary provide the necessary instruments by which land-use decisions can be more fully evaluated. In addition to permitting a system overview, these new tools can be employed at the subsystem level for a variety of applications. It will be possible to evaluate the effects of different land uses on the highway system, both generally and specifically in a particular location. The effects of increasing density will be subject to analytical evaluation with regard to an adjoining highway. It will be possible to determine how large a concentration of a particular land use is possible without overburdening an adjacent highway. The comparative effects of one larger concentration as contrasted with several smaller concentrations can be evaluated with regard to specific locations and various separation distances.

It will be possible to determine optimum mixes for different land uses within a specific area and for an entire community, to minimize traffic load concentrations on the highway system. To minimize traffic concentration, the relationships between employee working hours and visitor traffic characteristics can be determined. Also, many of the design and operational elements for a development can be optimized, such as parking location, driveway location and spacing, internal circulation needs, and other aspects of operation that will reduce congestion and facilitate patronage.

CHAPTER SIX

TRAFFIC GENERATION CONTROL

TRAFFIC GENERATION PREDICTABILITY

Historical Unreliability

Early attempts at predicting traffic generation and consequent facility needs proved to be unreliable owing to the lack of adequate analytical techniques. New facility designs were usually based on estimates of traffic generation that proved to be too low, and facilities quickly became overloaded. The tendency to underdesign has led to a prevailing attitude that traffic estimates are always too low, and that whatever is built will be filled to capacity before long.

However, there are cases where attempts at being farsighted have resulted in unnecessary construction. Some communities have major investments in facilities that are used to only a fraction of their capacity. There are therefore dangers in both overestimating and underestimating. The deficiencies of circulation planning in the past must not affect judgments about the future.

Another factor contributing to poor predictions in the past was the absence of land-use controls in many areas and the ineffectiveness of those controls in other areas. The location and the effects of new development were truly unpredictable. Also, there was little knowledge about the types of traffic generation that might be anticipated for each land use. In short, none of the elements necessary for predictive planning was previously available.

Although much remains to be done, many of these prediction factors are now available. Land-use controls are tighter; cities have master plans that illustrate future development intent; fairly large amounts of data are available concerning the traffic generation potential of different land uses. Therefore, the planning of the circulation system can be based on more accurate land-use and traffic generation data.

Future Predictability

The transportation planning techniques currently being applied have a scientific rigor that was not typical of past methods. The continuing transportation planning programs developed for all large urban areas have inaugurated a methodology that allows the planning of the transportation system to be based on specific, detailed knowledge of current traffic patterns and projections of future travel trends. The continual updating of this program assures that the developing transportation system is coordinated with changes in land use and reflects the most reasonable estimates of future demand.

Obviously, much remains to be done in this field; the current study represents one attempt to improve the available techniques. With a concerted effort, the predictive tools will be further improved and new control techniques will make it possible to implement programs that will ensure further reliability.

Predictability of Area-Wide Traffic Generation

One technique for the prediction of transportation needs (*84*) distributed trips among expressways and arterials, using various combinations of local street spacing, arterial spacing, expressway spacing, and mean trip lengths. Trip distribution was converted to volume by applying a factor based on the over-all trip density per square mile.

It has been found that total trip generation for the typical square mile of developed urban land is surprisingly similar throughout a particular area. As the size of the total area under consideration is increased, the trip generation range becomes smaller. In the typical suburban freeway grid pattern of four by four miles, it is unlikely that significant differences in total traffic generation will be observed from one freeway cell to another.

Some analysts have concluded that the large zones commonly employed in most transportation planning programs tend to have an average density that is comparable from one zone to another. The gross generation of traffic is hardly affected by the types of development within the zone, or the intensity of such development, because differences tend to average out within a large general area. Even in the absence of a land-use plan, it is possible to estimate total gross acreages for various land uses that will probably occur in a typical area. The gross traffic generation from such a land-use mix will be fairly consistent, whatever the assumptions may be. It is only the localized distribution of land use that may affect the transportation network.

Other researchers strongly support this approach by indicating that, on a gross basis, population, commercial centers, and industrial employment will be found to be consistently distributed in large areas. Only major concentrations of development will have an appreciable effect on the network, and then only in a localized fashion. The absolute quantity of jobs, commercial development, residential population, etc., will be relatively fixed for the typical total community. The only significant variable is where facilities locate, and in what form and concentration. The similarities that have developed from one community to another, and between segments of a community, have become more pronounced than their differences, and this finding has profound implications for the stabilization of transportation facility planning.

It has been generally believed that changes in land-use configuration and distribution have a substantial effect on the transportation network. This is true to a lesser degree than has been generally supposed. In one particular regional transportation study (Hartford area), five alternative land-use configurations were analyzed to determine the relative transportation requirements for each. It was concluded that the total transportation network requirements were basically the same for each pattern studied. There were few instances in which any particular highway facility was significantly more affected under one pattern than under another. The only real variability appeared to be in specific sections of facilities, where local concentrations affected highway operation.

In a few high-density metropolitan areas, this uniformity is less pronounced, and these generalizations may not apply. The spacing formulas developed for some transportation studies can be used for large areas to develop broad general estimates of transportation needs—estimates that are almost as satisfactory as assignment results. This technique is most satisfactory when one is dealing with undeveloped areas where there is no clear definition of land uses from which to make a more refined analysis.

Traffic generation predictability on a regional basis is thus fairly high, even in the absence of specific land-use distribution information. A fairly realistic estimate of network needs can be made from the results of the many transportation surveys that have already been conducted.

HIERARCHICAL SYSTEM PREDICTABILITY

Route Assignment Predictability

In most U.S. cities until very recent years, continuous grid patterns were used to construct a continuous, open-ended system of streets. It is difficult to assign traffic to such a system, for innumerable choices are available to the motorist. Communities currently being developed often use a hierarchical circulation system pattern, which provides built-in controls on the amount of traffic that will be generated on each element of the system. This pattern permits relatively accurate assignment of traffic to each element.

A strict hierarchical system permits few travel options between specific origins and destinations. The driver uses a specific access street to reach a particular collector, which then leads to an arterial. The driver may then have the choice of staying on the arterial or entering a freeway to reach his destination, but this is usually his only real choice. It can be fairly accurately determined what proportion of drivers will choose each option. Thus, the hierarchical system of circulation permits the rational assignment of trips to available routes and further improves the predictability of traffic generation for individual elements of the system.

Functional System Predictability

The most reliable traffic estimation is achievable in planned communities where master plans and effective land-use controls assure stability. There will continue to be many areas where definitive and reliable planning cannot be assumed and where allowances must be made for some unpredictability, but even in older communities an attempt is now being made to develop a functional system of highways by categorizing the existing circulation system and developing improvement programs that will cause the system to operate in a more hierarchical fashion. A general framework is thus being prepared to improve the opportunities for traffic generation predictability.

Current programs of functional classification are intended to establish a general pattern of arterial highways that will carry the principal traffic loads within the community. Within the bounds of the arterial network, smaller community units are being identified as neighborhoods or other subcommunity elements. Within these neighborhoods most of the street system will serve internal circulation needs; external traffic will be routed along the perimeter arterials. This functional distribution of traffic will make it possible to predict the amount of locally generated traffic that will use the internal street network.

In most cases the volumes of locally generated traffic within the neighborhood will be low. Access and service are the principal functions of these internal streets and traffic volumes will not usually be the determinants of design. Thus, it will be increasingly possible to predict accurately the amount of traffic that uses the local and collector street system and these volumes will normally not present a capacity problem.

At the other extreme of the highway transportation spectrum, the freeways are spaced at relatively distant intervals and are not particularly sensitive to local variations in land use. The predictability of freeway system needs is based on regional transportation surveys and over-all metropolitan area growth trends. The relatively large changes that would affect freeway network configurations and capacities can be detected and adjustments can be made as necessary. The major scale of change that can affect a freeway is relatively infrequent.

The freeway system is therefore subject to a relatively high degree of predictability based on continuing regional transportation surveys. Only very large installations will have an appreciable effect on the freeway network. Most of the effects will be felt locally around a particular interchange.

Arterial Traffic Predictability

Formerly, a major problem in traffic prediction was the continuity of the arterial and its use for virtually all through traffic. The amount of traffic that built up along a section of arterial depended largely on how far into the suburbs the metropolitan area grew. Each additional increment of growth added additional traffic to the arterial, for this was the only route available for suburban traffic to reach the central city.

The development of the freeway system has changed this situation. Longer-distance travel from the suburbs is no longer added to the arterial, but is handled by the freeways. Given a complete network of freeways, including radial and circumferential routes, it is possible to make a more accurate prediction of the total amount of traffic that will be using the arterial system. With the major through traffic component rerouted to the freeways, the arterials are required to distribute traffic from the freeway interchanges to the community, to handle a certain proportion of through travel, and to serve intracommunity travel. All of these functions are subject to a fair degree of predictability.

However, the arterial is quite sensitive to localized concentrations and new land developments. In the typical situation, segments of the community are planned at different times by many individual entrepreneurs, and it is difficult to predict where various land uses may locate. It is possible, however, to predict the general number and scale of facilities needed to serve an area of a particular size.

Long-range predictability is less certain because the highway system will generally outlast many of the land uses that currently exist or are planned for the immediate future. New cycles of land use in the more distant future may have different traffic generation characteristics but must be served by the same highway framework. Predictive planning, though better than in the past, still encompasses only a limited interval of time.

Considering all components of the highway transportation network, the arterial appears to be most affected by unknown factors that can determine its viability and long-range utility. The low degree of predictability with regard to the specific location of particular land uses, together with the arterial's sensitivity to localized traffic concentrations and its long life, represent critical controls on the accuracy of long-range traffic prediction. The techniques available to counteract these influences include design flexibility permitting the arterial to respond to future change, built-in design controls that protect the highway from deteriorating influences, controls on land use and access that correct some of the problems at their source, and other precautions that safeguard the future utility of the arterial.

Accuracy of Traffic Prediction

Although accuracy of traffic prediction is obviously desirable, there are many instances in which a high degree of accuracy is unnecessary for the specific purposes intended. In such cases generalized guidelines may be sufficient; frequently a rough estimate based on general traffic guidelines will reveal whether a more detailed evaluation is necessary.

One reason that refinements may not be needed is that broad parameters generally control design adequacy. Highways are designed by number of lines, and there are huge capacity increments involved in proceeding from a two-lane to a four-lane highway, from a four-lane to a six-lane highway, and from a six-lane highway to a freeway. Similarly, there are large steps in traffic capacity from a four-lane freeway to a six-lane freeway, and up to a fourteen-lane freeway.

Frequently, approximate methods of traffic estimation can determine which range of facility is needed under specific conditions. A two-lane highway, for instance, is adequate for a very wide range of traffic volumes. Without undertaking sophisticated analysis, the designer may determine whether the upper capacity limit will ever be exceeded. The traffic generated along a local access street is usually quite low—well beneath the capacity of the street—so that the designer needs no refinement of traffic estimation to know that a two-lane street will be sufficient. In most cases the same is true of a neighborhood collector street that handles only traffic generated internally.

Traffic generation becomes an important determinant for the arterial. In most urban areas it is common for an arterial highway to have at least four through lanes; six through lanes are common in large urban areas. The volumes that can be handled by such arterials extend over a considerable spectrum. In smaller urban areas it is generally apparent that the capacity provided by a four-lane arterial highway should be satisfactory for the conditions normally encountered in an area of that size. In larger urban areas served by six-lane arterials it is only when the projected volumes fall close to the capacity limits of a facility that estimating refinement may be necessary.

When traffic volumes exceed the capacity of the normal arterial highway there are several alternatives available. The jump from the arterial to the freeway is a large one and it is generally obvious when corridor traffic volumes are enough greater than arterial volumes to justify consideration of a freeway. When the volumes that require a full freeway are approached, traffic predictions are generally developed from a regional transportation study, so that localized prediction inaccuracies are no longer of great consequence. In the case of the freeway the tremendous range of traffic capacities that can be accommodated, extending from the four-lane to the fourteen-lane facility, provides a flexibility that can accommodate almost any traffic corridor condition if sufficient rights-of-way are acquired.

Applications of Traffic Prediction

One of the products of a regional transportation study is a compilation of corridor traffic volumes. These are first applied to analyze the adequacy of the freeway network. There are also derivative corridor volumes for the arterial network. Inasmuch as traffic generation is determined for each land use in the community and each route assignment made in the course of the transportation study, the results can also yield anticipated traffic volumes for each arterial corridor.

The regional survey is generally based on gross area traffic generation and uses large unit areas, sometimes a square mile in size. The survey therefore yields over-all corridor flows rather than traffic flows along individual thoroughfares. These gross volumes can be further manipulated to yield traffic volume estimates for individual arterials.

These methods are thus generally applicable to the design of major components of the arterial system where broad corridor volumes can be applied. In designing the details of the system, more specific traffic generation characteristics are necessary. On a gross basis, individual errors in land-use generation factors and predictions are balanced out over a large area.

The principal applications for detailed traffic generation data are in arterial highway and freeway design. Lesser types of streets, such as local access and residential collector streets, rarely develop enough traffic to require more than two lanes, so that traffic generation data are not significant in their design.

TRAFFIC GENERATION POTENTIAL

Measured Generation Limitations

There are two basic measures of traffic generation—traffic generation potential and traffic generation intensity. A parking facility for example, would have a traffic potential equal to the number of parking spaces provided; its traffic intensity would be the number of vehicle trips generated per hour per space.

The number of spaces in a parking facility is only an indirect indicator of the traffic generation capabilities of the land-use development it presumably serves. Not all the persons who use the development may make use of the associated parking facility; moreover, persons whose destination is some other development may park there. Most important, the parking facility may be underdesigned, in which case there exists a hidden demand for parking that cannot be detected by measuring the intensity of traffic generation within the parking facility itself. Traffic generation might have been considerably higher had an adequate number of parking spaces been provided. To establish a true picture, traffic generation must consider real demand as well as measurable demand.

Current empirical data that relate traffic generation to specific land uses are usually based on measured intensity of use. These may be deficient if there are constraints that do not permit traffic generation to reach its full potential, such as insufficient parking during periods of maximum demand. However, current empirical data are the only information available; they can be used judiciously as long as it is recognized that actual traffic generation potential may be somewhat higher than the measured use.

Unsatisfied Demand

Another limitation of measured use is the unsatisfied demand resulting from a lower than optimum level of car ownership. Trip making is somewhat limited by vehicle availability; an increase in trip rates would result if there were a saturated level of car ownership (*349*). For households in which automobile ownership equals the number of adult members of the household, an optimum level of trip making can take place. This condition is maximized when income constraints are also removed and potential trip rates are at a maximum. The resulting increase in trip rates is mostly related to nonwork trips. Because most urban peak travel demands relate to the work trip time period, it is unlikely that this situation of full mobility will have a profound effect on peak travel demands. To account for the future when there may be a saturated level of car ownership that eliminates any unsatisfied demand caused by vehicle unavailability, some allowance can be made for a somewhat greater trip rate than is currently experienced.

In translating current trip rate data from one community to another, the factor of number of automobiles per 100 employed residents can be used to account for variable automobile ownership. (Data are available in publications of the U. S. Census Bureau.) Although comparisons of data between communities are invalid if those communities are vastly dissimilar, the differences in traffic generation characteristics for typical suburban automobile-oriented communities located in different sections of the country are very slight.

TRAFFIC FLOW METERING

The metering of traffic flow may be defined as the supply of traffic in a measured or regulated amount, as contrasted with the free flow of traffic with no restraints. Traffic flow metering has both positive and negative connotations. The method by which metering takes place and its effects on the traffic stream determine whether metering is beneficial or harmful.

Every bottleneck situation is a form of metering. A roadway constriction, a narrow driveway, or an intersection bottleneck are metering devices that restrict flow, usually to the detriment of traffic. However, a traffic signal is a positive form of metering that controls traffic flow for the purpose of regulating conflict. The most recent example of traffic flow metering is the control of traffic entering a freeway by the metering of entrance ramps during peak periods to prevent overloading of the freeway.

Traffic Concentrations

Serious problems occur when large concentrations of traffic seek entry into a highway at a time when the facility is unable to absorb it at the rate of traffic accumulation. An excessive concentration of traffic causes congestion and delay; traffic flow metering reduces the concentration by spreading the load out over a longer period of time.

In the case of a large traffic generator, the metering system that regulates the flow of exiting traffic includes a number of metering components. The number and design of exit driveways limit the number of vehicles that can enter the abutting highway within a particular interval of time by limiting egress capacity. The perimeter highway system that accepts the exiting traffic controls its rate of entering flow by the limit of its capacity to accommodate additional traffic. The first signal-controlled intersection beyond the driveway further meters the volume that passes through the intersection.

The process of equalizing traffic flow to reduce concentration is assisted by the availability of choices at each junction. The motorist initially has a choice of several exit driveways. Excessive loading at a particular driveway results in a redistribution of traffic to other driveways. In exiting onto the perimeter highway the motorist has the choice of going right or left; his decision is frequently based on the congestion encountered in a particular direction. At each succeeding intersection the motorist is presented with three choices of direction and his decision is frequently based on the relative degree of congestion encountered. Thus, the metering and balancing out of traffic flow continues all along the route through the controls exercised by the physical design and operation of the system.

Before freeways were introduced, traffic flow concentrations were distributed to numerous arterial facilities in various directions. On the freeway, traffic from large generators tends to flow in the same direction—toward the freeway interchange. The concentration that takes place as traffic converges on the freeway interchange has intensified the problem because traffic has become cumulative as it approaches the freeway. The former metering influences that caused a distribution and dissipation of traffic to many arterials no longer apply.

Instantaneous Traffic Demands

Traffic flow metering takes place most frequently in the control of instantaneous traffic load situations where it is physically infeasible to design an access system and highway facilities to accommodate instantaneous demands. The most notable examples are at stadia, auditoriums, and other huge generators where exiting demands occur instantaneously at the termination of the event. It is obviously impossible for everyone to leave at the same time because it is infeasible to improve access facilities sufficiently to satisfy the demand within a short interval of time. The metering of exit flows spreads the load over a reasonable period of time.

Traffic flow metering also takes place at large industrial developments when the termination of the work day results in an instantaneous demand for exiting. For large developments this instantaneous demand cannot be satisfied by any reasonable system of adjoining highways, and some delays are anticipated and expected. The tolerable limits of delay are far lower under work conditions than those experienced at a major public attraction because of the daily nature of the occurrence. One solution to reduce the level of congestion is to stagger work hours so that the leaving rate is reduced. This method of metering exit flow makes it possible for the highway to absorb leaving peaks more readily.

At shopping centers there is also an instantaneous exit demand when the stores close in the evening. The patron learns to adjust his shopping habits so that he leaves before the final closing of the stores to avoid major delays. During peak shopping seasons, the patron learns to avoid the peak shopping hours, and the traffic load is spread more uniformly throughout the day. Personal adjustment to shopping habits is a form of traffic flow metering that makes it possible for shopping centers to accommodate a much greater volume of business during peak seasons than they handle at other times of the year.

This kind of informal self-regulation of travel habits affects many other transportation peaks. The staggering of travel peaks during weekend periods allows the existing transportation system to handle heavy vacation and resort travel demands. Some commuters adjust their working hours so that they avoid peak-travel periods whenever possible. Women shoppers frequently schedule their shopping trips so that they can return home before the afternoon travel peaks.

This self-metering phenomenon explains to some extent what happens when a new high-capacity facility is placed in service. A new subway system may be subjected to a far greater peak load than the previous system, although total daily use may be only slightly greater. Patrons concentrate their trips within a shorter period of time because the new system is able to accommodate a higher peak load. The readjustment of travel habits is a form of metering in which a constant balancing is taking place between flow and capacity.

Tolerance Levels

The constant balancing between traffic flow and capacity maintains a certain degree of equilibrium that is achieved partly by the factor of tolerance for congestion. This implies that adjustments in travel habits are made only after conditions are considered intolerable by some users. This is certainly not a desirable condition and the objective is rather to create a situation in which such a state of congestion will not prevail.

Ideally, the objective would be to permit every driver to travel at whatever time and by whatever facility he might wish, guaranteeing that he would not be subjected to congestion or delay at any point along his way. In large urban areas, this ideal is usually not attainable. Overload conditions during seasonal peaks and delays around major public attractions are tolerated within certain limits. However, conditions of severe congestion and delay that occur every day cannot be considered acceptable.

Tolerance and acceptability are subjective matters. The level of tolerance varies according to the frequency of the occurrence and the particular circumstances. Although a certain degree of inconvenience is tolerated, the design objective should always be to reduce this to a minimum.

Restrictive Traffic Metering

Metering controls that are exercised by public agencies tend to be restrictive in nature. They include restrictions on the number of driveway access points, restrictions on the width of individual driveways, restrictions on the direction of travel permitted from individual driveways, and restrictions on the rate of exit flow from a driveway, through traffic signal timing. These devices can be detrimental to a development if they are overly restrictive, particularly when they inhibit exiting capabilities arbitrarily or unnecessarily, or are not related to the capacity of available facilities that serve the development.

Under the conditions normally encountered, in which most driveways are of the same type and driveway location is not correlated with traffic signal progression, the regulation of driveway frequency represents a regulatory form of metering. The rate at which traffic can leave the development is proportional to the number of driveways. Proper location and spacing of driveways can increase access capacity with no detriment to highway traffic flow.

Adherence to a uniform driveway design permitting a single entrance and exit lane is a form of metering because it treats small generators and large generators alike. The driveway exit capacity from a large generator is reduced to the same rate as that from a smaller generator, which is a safety device for the arterial but may constitute an injustice to the development. The driveway design restriction is an unnecessary impediment when the abutting highway can absorb a higher rate of traffic access. Multilane driveway designs are desirable for large generators when located at appropriate points along the arterial where multiple lanes can be accommodated within the pattern of progressive traffic movement.

Driveway restrictions are especially inappropriate when peak flow conditions from the generator occur at times when the abutting highways are carrying relatively light normal traffic loads. There is no reason to meter the rate of exit flow with narrow driveways during such periods, for the abutting highway system is capable of absorbing a high rate of flow.

Variable peak conditions can be adjusted more effectively through traffic signalization controls that are responsive to variable traffic loadings of this nature. During periods when normal traffic along the arterial is low, the proportion of time allotted to exiting flows can be at a maximum to permit peak exiting. When arterial traffic is heavy, the proportion of time allotted to exiting traffic can be adjusted to whatever amount the arterial can accommodate without overload. This opportunity to adjust the rate of exiting flow to the capabilities of the abutting highway system permits a highly selective operation that is far more effective than artificial restraints on the number and width of driveways, which are not responsive to variable loading conditions. Sophisticated applications of metering techniques are intended as instruments for expediting traffic flow and improving traffic access as well as for controlling highway overloads. They provide built-in safeguards that should be acceptable to those being restricted so long as the controls are legitimate and applied discriminately.

Operational Controls

Traffic flow metering can also be effectively applied through operational controls that influence the rates of traffic concentration. The rates of inbound and outbound flow can be regulated through such internal operational controls as staggering of working hours. Through adjustments in working hours an industrial plant can reduce the outbound traffic flow demand by letting out only a portion of the employees at one time. When these have been absorbed by the highway system, another portion can be let out. The traffic effects of an industrial plant on an adjoining highway system can thus be changed drastically by this expedient and the rate of traffic flow can be made compatible with the capacity of the facilities available to receive it.

Traffic flow metering through operational controls can be exercised by a single company or through agreement among a group of companies. Mutual benefits are achieved by distributing traffic loads more uniformly and reducing traffic delays. Similar operational controls can be used with other types of development where some means of spreading the traffic load over a longer interval of time can be implemented. Such controls should be given first consideration in resolving problems of traffic concentration and overload.

TRAFFIC LOAD BALANCING

Land-Use Mixtures

A corollary to traffic flow metering is traffic load balancing, whose objective is to spread the load uniformly among all available facilities and provide balanced use of all elements of the highway system. It is known, for instance, that residential and industrial land uses frequently have opposite and complementary traffic flow characteristics. Knowledge of specific peak-hour and directional characteristics for particular types of land use makes it possible to assemble certain mixtures of land uses that distribute traffic demands more uniformly and lower the peak traffic loads.

These techniques are particularly useful for industrial communities and high-density commercial areas. Through the balancing and dovetailing of different traffic generation characteristics it is possible to increase the intensity of development without materially affecting peak-hour traffic loadings. This has the same effect as the staggering of work hours in permitting more intensive development without detrimental effects on the highway system. Balancing of travel directions through an appropriate distribution of land uses also makes it possible to provide an equal loading of the highway system in all directions, so that the full capacity of the system can be employed during peak hours.

Interchange Balance

One specific application of the theory of traffic load balancing is in the freeway interchange area. Various studies have suggested the possibility of locating complementary types of land use in different parts of the interchange area so that the traffic loads imposed on the freeway interchange are more uniformly distributed and are not cumulative (*312*). There are many advantages in a conscious balancing of land uses around interchanges to achieve complementary traffic flow patterns. Land-use mixtures in the four quadrants of a freeway interchange can effectively balance traffic generation characteristics to avoid intense peak loads, eliminating overlaps of traffic concentrations. The quantitative and time distribution factors for different land uses make it possible to determine an optimum mix of facilities that would provide the greatest balance of traffic load.

The balancing of loads around the freeway interchange is only a first step in over-all traffic load balancing. The traffic generated locally around the interchange may represent only a small proportion of the total load using the interchange. In a complete program it should be possible to extend the principle of load balancing to the entire tributary area of a particular interchange. It would be theoretically possible to exercise fuller controls over land use to provide an area-wide balance of traffic loadings in both time distribution and directional orientation. For freeway interchanges that are subjected to very intense, brief peak loadings, this type of area-wide balancing may be very beneficial. In many other cases, however, where the traffic loadings are composed of numerous small increments from many different sources, there may already be a natural load distribution resulting from the different habits of numerous smaller developments; the traffic characteristics may be balanced naturally by the variety of uses involved.

CHAPTER SEVEN

ACCESS CONTROL

LEGAL DEFINITIONS

Highway Access Rights

A highway, in legal terms, is a public way over which all people have a common and equal right to travel and in which they have a general interest to keep unobstructed (*243*). This concept of the highway deals with rights—privileges and powers to act in a certain manner—rather than with physical characteristics. There are actually two sets of rights involved: the rights of the public to travel on the strip of land, and the rights relating to those whose land abuts the highway.

The highway thus establishes two sets of rights that can and often do conflict. This conflict between the abutting property owner and the traveling public often involves the general public welfare and the entire community. Reconciliation must be achieved within the constitutional limitations that define the public's power to appropriate or regulate private property for the benefit of the public welfare.

The constitutional concepts are far from precise and the whole process of this reconciliation is in continual evolution. Reduction of any of the rights involved, even when the public welfare is concerned, requires adequate demonstration of its value and necessity before it can be applied under the constitutional guarantees. The questions are thus of relative importance to the community: Is the action important enough to warrant restriction or purchase of individual rights? And is the action sufficient to give reasonable assurance that further limitations of rights will not be required for the public welfare?

In developing a definition of right of access, real property law customarily states that ownership or occupancy of premises abutting on a highway carries with it certain rights in the use thereof, distinct from the general easement of passage (*243*). These rights are the right of access to and from the highway, the right to have air and light come into abutting property and across the highway, the right to see and be seen from the highway, and the right to lateral support of abutting land during construction.

Further definition of the right of access and its limitation has been formulated (*346*): complete deprivation of access is compensable; restriction of access leaving the property owner with reasonable remaining access under all circumstances is not compensable. The right of access is subject to the fullest exercise of the public's primary right of travel on the street or road; reasonable traffic regulations, such as weight restrictions, no left turns, and one-way street regulations, are not compensable. An abutting owner has no right to a continuation of the full traffic in front of his property; diversion of traffic with or without a taking is not compensable. An abutting owner has no right to travel from his property to his destination in the most direct route possible; circuity of travel because of one-way streets, median strips, culs-de-sac, frontage roads, etc., is not compensable. When a street or highway is created on a new location and access is restricted, limited, or controlled, no right of access arises in the now abutting owner. The right of access is not damaged by reasonable traffic regulations that make access more difficult or less useful, such as no-left-turn and one-way-street restrictions. Reasonable regulation of access through driveway permits is not a compensable damage if there is no arbitrary refusal to issue such permits.

Control of Access

Control of access may be defined as a condition in which the right of owners or occupants of abutting land to access, light, air, or view, in connection with the highway, is fully or partially controlled by public authority. Full control of access exists if there is no direct property access to the through traffic lanes of the highway. Partial control of access permits some access to abutting property, controlled with respect to spacing, location, design, and use.

To implement the concept of access control, a wide range of legal powers is available, including the public power to regulate private use of property, referred to as the police power; the power to appropriate private property for public use upon compensation, known as eminent domain; the power to spend public monies in aid of public purposes, or the power to make contracts; the power to tax and license; and the planning function of public agencies.

The regulatory legislation dealing with use of the highway and roadside access (*243*) includes acts intended to protect the integrity of access control established in the original design and construction of the highway; acts intended to introduce control of access into the design or operation of a highway originally designed as a land-service road but now unable to accommodate traffic demands adequately or safely; and acts intended to exercise control over the traffic-generating capacity of roadside land and thus forestall the development of conditions jeopardizing the safety, efficiency, and convenience of the adjacent highway.

Techniques that have primary eminent domain characteristics include the acquisition of access rights or acquisition of development rights. One approach to the control of development involves public acquisition of all or part of an abutting owner's right to highway access. This form of eminent domain has been widely used to protect highway facilities from congesting influences. Acquisition of access rights can only regulate traffic generated from land that actually abuts the highway, controlling only a portion of the land in the approach zone of influence. Acquisition of development rights can affect a much larger area, regulating the total traffic generated from the zone of influence.

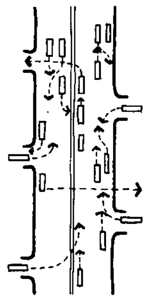
Control of the abutting land is an oblique but potentially effective way of controlling roadside access by regulating the number, spacing, location, and use of access driveways. Devices that restrict or control access by fixing the location of access points along the highway are official mapping and subdivision control. There are also other control devices available to regulate the type of use made of access, including restricted-use roads, roadside zoning, and general planning. Restricted-use roads control access by excluding certain kinds of traffic from the highway or from the use of access to it. Roadside zoning and general planning control access by controlling land use to specific areas along the highway.

Access control can be exercised under the police power so long as such controls are reasonable. This application of the police power is similar to the intent in zoning—for the protection of health, safety, and welfare. The exercise of design and geometric control over access privileges protects the public interest just as much as land-use zoning.

ACCESS PROBLEMS

Uncontrolled Access

The lack of access control along arterial highways has been the largest single factor contributing to obsolescence of highway facilities. Each driveway creates an intersection with the major street and is subject to all the accidents common to intersections. Moreover, because these are unrecognized intersections, they create unexpected traffic hazards for which the motorist is not prepared, as he would be for the hazards of a normal intersection.



Inadequate access control has resulted in the functional obsolescence of an entire generation of new arterial facilities built only a short while ago. Most of these arterials are structurally adequate but operationally deficient as arterial routes. In most cases, the cost of improving these facilities to regenerate their traffic utility is so great that it is less expensive to build a new facility than to salvage the old one. In the development of new facilities it is necessary to avoid a repetition of the same problems that caused the demise of existing facilities.

Serious impedances are caused by vehicles entering and leaving streets and driveways along any arterial without access control (*151*). The effect of different access control measures on the transportation function of the street has not been fully developed in the past because the collection of field data for the many parameters involved is complex and the analysis and correlation are difficult. The casual relationships are generally accepted, so detailed field corroboration might be considered unnecessary. However, it would be useful to be able to predict the amount by which highway capacity is reduced by various types of land service.

A simulation of actual conditions could be accomplished by mathematical models. A vehicle entering a traffic stream causes following vehicles within that stream or opposing vehicles in the other stream to reduce speed and/or change lanes. The magnitude of interference may be interrelated with various factors, including road and access point characteristics, traffic density of opposing traffic streams, access point frequency and location, proportions of vehicles exiting the main stream, and volumes entering the main stream via right and left turns. A multiple regression analysis on the basis of simplified concepts that interrelate these factors could yield valuable results and serve as a basis for design guidelines.

Access Friction

A close spacing of driveways creates excessive access friction under conditions of random flow or platoon flow. In the case of random flow, one study (*208*) found that vehicles using adjacent driveways then interfere with each other excessively and reduce the ability of traffic to enter the highway rather than enhance access opportunities. When driveways are adequately separated this mutual interference does not occur and a maximum number of vehicles can discharge into the highway with a minimum of interference to each other and with other vehicles traveling along the highway. If there are at least 600 ft between driveways, vehicles can be absorbed into the through traffic stream under random flow conditions with little interference.

Access Accidents

Traffic conflict is affected by the number and spacing of driveways, and also by their design. With poor driveway design, slow-moving vehicles block or slow the major traffic stream. In the absence of signals to regulate traffic flow into and out of major driveways, heavy traffic volumes along the arterial may prevent exiting vehicles from entering or crossing the through traffic stream for considerable periods of time. Impatient drivers then tend to accept smaller gaps between vehicles on the highway within which to negotiate their entering maneuver, and this may result in an unsafe condition of ingress.

These potential hazards and risks affect both the entering vehicles and the through traffic in the main stream. Frequently, they result in rear-end and sideswipe accidents as well as right-angle and left-turn collisions.

The effectiveness of access control in reducing accidents is illustrated by numerous accident studies. A composite of studies concerning the rural highway (*21*) shows an accident reduction equal to 36 percent with partial control and 55 percent with full control. One study (California) reports a successive decline in accident rates as control is applied to multilane highways—first by median, then partial control of access, then full control. On urban highways the reduction in accidents with full access control is almost 65 percent, although the effect of partial control is much lower.

A study of the effects of service road access control (*215*) shows that highways through residential areas with numerous direct driveways have six times the average accident rate of highways equipped with service roads preventing direct driveway access into the highway. Driveway accidents constitute a considerable proportion of major street accidents—a proportion reaching 12 percent in one study (*50*). All of the available studies thus tend to support the premise that a driveway is merely a low-volume intersection having a significant accident potential. The frequency of accidents also reflects the intensity of use to which the driveway is subjected.

Analysis of driveway accidents (*51*) indicates that almost 70 percent involve left turns; the remainder involve right-turning movements. Inbound movements into the driveway cause more accidents than do outbound movements. Left-turn movements into driveways are especially dangerous because of the pressures from behind in conflict with opposing vehicles in front.

A median barrier is an effective method of controlling such accidents. The annual accident frequency for driveways along routes with median barriers was only one-third the rate for driveways along routes without a median (*21*). Comparing accident characteristics over long routes with and without median barriers, the study found that there were 11 times as many accidents along routes without a median barrier as along routes so equipped.

ACCESS CONTROL PRACTICES

State Practices

New facilities offer the best opportunities for instituting effective access control and limitation. State highway departments have found that the purchase of full access rights in conjunction with new rights-of-way may be only slightly more expensive than purchase without such access controls. Some highway departments have established a policy of purchasing access rights whenever new rights-of-way are acquired. This has been particularly common in rural areas, where the low additional cost makes the policy economically feasible. In more urbanized areas, the purchase of access rights along new highways can be prohibitively expensive.

Reasonable control of access is usually exercised under the police power. Design and geometric controls that restrict access protect the public interest in the same manner that land-use zoning safeguards the public. However, unreasonable controls are compensable; the principal area to be resolved is what constitutes reasonable access control.

Some highway departments have developed planning guides for access control and spacing along state routes. Access control policy in one state (Washington) calls for prohibition of direct access to property along new principal highways in rural sections and allows public road grade intersections at a minimum spacing of one mile. Existing rural properties are limited to two access points per mile, including public roads. The policy for new major highways calls for prohibition of direct property access and allows public road intersections at a minimum spacing of one-half mile. Full access control is proposed for principal and major highways with four or more lanes. For existing roads, not more than four direct access points per mile are allowed.

Another state (Wisconsin) permits the highway commission to control access on the state trunk highway system. The commission is required to review all land subdivision plats abutting state trunk highways and connecting streets. The purpose is to minimize the number of direct entrances to the highway, ensuring that development of adjacent lands will be accomplished by means of frontage roads or alternative means. Rural portions of the state trunk system on which average traffic is in excess of 2,000 vehicles per day may be designated as controlled-access highways. No direct access is allowed between the state trunk highway and individual lots without express permission. A minimum number of street connections with state trunk highways is provided, with a distance of at least 1,000 ft between intersections. Access points along opposite sides of the highway either are located directly opposite each other or are separated from each other by at least 300 ft to prevent traffic jogs across the highway. Subdivision layouts may not provide direct vehicular access to the highway from individual lots; subdivision streets may not open directly into a state highway whenever existing streets provide reasonable access.

A controlled-access facility is declared after a public hearing that results in a freeze of existing access conditions. The hearing takes into consideration the requests of adjoining property owners for additional access. After the hearing, no additional intersections are authorized unless they can be individually justified and fit the state's policies with regard to access along the particular route.

In Wisconsin the controlled-access highway law is even extended to cover county trunk highways. The county board holds hearings at which access locations are fixed; maps are prepared showing the official locations of highway entrances. Such access restrictions cannot be removed without another public hearing.

New access controls cannot be imposed on an existing highway if the restrictions would be equivalent to a total denial of access. However, in many instances it is possible to impose some degree of access limitation without materially affecting accessibility to fronting properties.

To achieve a functional and long-lived system, access restrictions must be stable and permanent. In the case of freeways, the acquisition of all access rights provides protection that is not subject to deterioration over the years. In the case of arterial highways, however, there is the danger that, over time, the restrictions may be diminished for various reasons. Eventually, the road's built-in capacity and safety may be seriously curtailed as the pressure for additional access is increased. The fixing of access locations by law is a useful method to establish controls that are not readily subject to local pressures and to assure that political expediency has minimum effect on the highway. There is the concurrent danger, however, that the fixing of access control by legal means will introduce inflexibility. A built-in mechanism that permits accommodation to new situations is necessary.

The most effective access control policies have been established by state highway departments in areas that are primarily rural. Most of the current guidelines and established criteria are specifically designed for rural highways outside major population concentrations. These are the areas where the application of access control is most readily obtained and where the fewest objections are raised.

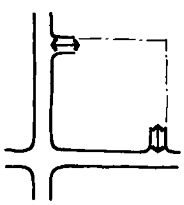
Obviously, it would be desirable to extend access control for rural highways to other states where such policies have not yet been adopted. However, the most critical need for access controls is in urban areas where land development intensity, congestion, and accident potential are greatest.

City Practices

Most of the larger cities in the United States and Canada and many smaller cities were surveyed to determine current practices in cities with regard to access control (*133*). Few cities have effective access control restrictions along surface arterial streets; almost all permit access to abutting properties, except where access rights have been acquired. Many new arterials are still planned and constructed with little or no access restriction. These uncontrolled access facilities are subject to the same deteriorating influences that have caused the obsolescence of most of the arterial facilities constructed in the last 50 years.

One encouraging sign is the considerable interest at federal and state levels in developing more effective access controls for new facilities. Implementation is being stimulated by administrative requirements that encourage the adoption of more effective access control techniques.

The only effective regulation normally practiced in most cities is the control over driveway location and design, which exhibits a wide range of effectiveness. In some communities the degree of control is minimal and access is virtually unrestricted. In other communities, relatively restrictive regulations and driveway policies are in effect. The general trend is toward greater restriction in driveway access practices. Some communities currently restrict abutting properties to a single driveway for each property. For a corner property a single driveway is permitted along each abutting highway. Some cities also specify the location of the driveway, particularly in the vicinity of intersections where driveway location is most critical. Recently, a few communities have limited service stations at major intersections to a single driveway entering each arterial at the farthest corners of the property; this mode of access interferes least with intersectional operations.



There is wide variety in current practices, and broad generalizations cannot be readily made. Any standardization of driveway frequency and location must permit some flexibility to account for special conditions and circumstances. Obviously, the treatment accorded a large regional shopping center should be different than that for a corner service station, even though each is a single property. Consideration must be given to the size of the development and its traffic generation potential in establishing access controls and restrictions.

Raised median dividers, channelizing islands, and similar traffic devices minimize the detrimental consequences of frequent access driveways by restricting such drives to right turns only. These physical design restrictions may be used to supplement other forms of access control but cannot be considered a substitute for them. With appropriate access control design and effective driveway restriction there should be little need to depend on barriers as an access control device. They may be considered primarily as ameliorative devices to correct existing situations where other forms of access control cannot be provided.

Access Closure

The most difficult applications of access control are the regulation and change of existing conditions. Sometimes attempts are made to close existing driveways or local streets in order to limit the number of access points. This is very difficult, because drivers and abutting property owners have become accustomed to the existing access, and its physical closure is especially unacceptable. Closure is resorted to only in critical situations where no lesser methods will suffice.

Driveway closure involves legal questions. Under what conditions can a community close a driveway, and what legal rights of access does a property owner have in an abutting highway? Complete deprivation of access is compensable, whereas reasonable traffic regulations that accomplish similar objectives are not compensable. If a piece of property has multiple points of access, it may be possible to close some driveways and leave others open. The factors to be weighed include amount of access taken away, amount of access remaining, resultant loss to the property owner, and resultant gain to highway users and the general public. A detailed analysis of the situation requires traffic counts, examination of accident records, interference observations, and other engineering techniques to show the amount of interference with through traffic that results from use of the driveway. From this information an estimate can be made of the benefits accruing from closure.

Control of the driveway function by restriction of turning movements can prevent the driveway from becoming an extreme point of interference without necessitating complete closure. The police power available to the community to restrict the use of driveways through noncompensable controls can be potent. To avoid such restriction a development may choose voluntary access control, including redesign of existing driveways and the elimination of excessive driveways, if the development is assured that the resulting access system will serve its needs adequately. In some cases accessibility can be improved in this manner rather than diminished.

The closure of minor side streets into an arterial is an equally difficult task; use of the street is difficult to eliminate without serious complaints. When street closures are one element of a complete neighborhood rehabilitation program —where relatively drastic measures are expected—they can be carried through successfully. Closure of a single street is far more difficult, even though the community may have the legal power to do so without compensation to the users. It is usually sufficient to diminish the detrimental consequences of frequent minor street crossings by traffic control devices, such as median barriers and channelization.

ACCESS OBJECTIVES

Control Levels

The basic objective of access control is to protect the utility of the highway. This general goal covers more specific goals—to preserve or improve highway capacity and expedite traffic flow; to reduce traffic hazards and accident causes; to achieve the best possible balance of benefits among the roadside landowner, the highway user, and the community at large; to protect the public investment by preventing premature functional obsolescence; and to improve the appearance of the highway and roadside areas.

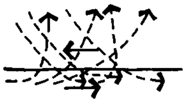
One measure of the utility of the highway is its capacity. The usual modifying factors for calculation of capacity do not normally take into account the number and type of conflict points; however, it is only too apparent that a series of access points devalues the transportation function of the highway. Because most highways also serve abutting land, it is necessary to establish a degree of restraint on the access function to ensure that the predominant movement function can be performed effectively.

Access control warrants may be based on the function of the highway, on traffic volumes, and on the land-use patterns adjoining. There are various levels of access control combining different proportions of movement and land access. At one extreme the cul-de-sac provides unrestricted land access but no service for through traffic; at the other extreme the freeway provides the highest level of service for traffic movement but no direct land access.

Land Service Levels

The range of land service along existing highways extends from unlimited access, where the entire frontage of the property is in continual contact with the highway, to no direct access at all, where all access is provided through such intermediate facilities as access ramps or collectors. Between these extremes there is a wide variety of access arrangements, representing different stages in the control of access.

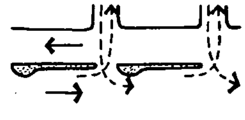
Under rural conditions there is frequently no distinguishable demarcation between the highway and private land. The highway pavement is frequently extended into the site, and access between the two is completely uncontrolled. Vehicles can travel between the highway and the site along the entire frontage of the property, all of which constitutes a potential area of conflict. They can enter or leave the highway at any point, and conflicts, both on the site and along the highway, can be serious if traffic volumes are substantial. This type of uncontrolled situation is not acceptable in an urban situation; a greater degree of control is necessary.



A greater level of control is provided by designating particular widths along the frontage as driveways and extending the pavement into the site only at those points. A more effective separation between the highway and the site is achieved by constructing curbs along the highway to further define the demarcation. The degree of improvement is dependent on the spacing between driveways and the widths of driveways. In some cases there is only a minimum separation between adjoining drives, and this creates a continuous series of intersectional conflicts along the highway. A vehicle waiting to turn into one driveway blocks an outbound vehicle from another driveway, and there are no storage opportunities for vehicles waiting to make a left turn.

Some communities have advanced a step farther and now require a minimum separation between adjoining driveways, frequently the length of one car, which is intended to provide space for parking along the curb between driveways. This reduces the frequency of intersectional conflict points and the interference with other vehicles and with pedestrians. However, there is still no protected storage for vehicles waiting to make left turns from the highway and these block others attempting to exit into the highway.

A further improvement limits the number and spacing of driveways permitted to serve particular sites. This type of limitation further decreases the number of intersectional conflict points along the arterial and lessens friction with pedestrians and other vehicles along the site frontage. If there is adequate separation between driveways, vehicles waiting to turn left off the highway do not block other vehicles waiting to leave an adjacent driveway. An opportunity is also presented to introduce a separate left-turn storage lane. This is generally about the highest level



of control achieved in communities today; in most areas the degree of control is far less.

Optimum Access Control

Current access control practices do not represent optimum control of access for the benefit of either the land or the highway. Higher levels of control are achievable.

A major deficiency of current control techniques is exemplified by the term that is used—"control." Control implies restriction, a term that has a negative connotation associated with a limitation of freedom of action. Controls, as such, can only minimize a problem and reduce conflict. Their intent is to minimize the detrimental consequences of access. No guidance is provided as to where driveways should locate. Driveway locations are chosen arbitrarily without recognizing that certain locations provide optimum access opportunities, whereas other locations penalize access traffic because they are inherently in conflict with traffic movement. The arbitrary selection of driveway location frequently bars traffic signals because the location does not meet the criteria for progressive signalization. The controls make no provision for avoiding the staggering of driveways on opposite sides of the highway, for advance storage of left-turning vehicles, or for coordination between driveways that serve adjoining parcels.

The concept of access control must be complemented by a concept of access design. Fundamentally, the problem must be restated as one of expediting movement into and out of properties rather than one of restricting movement. Restriction implies curtailment of privileges and is a negative way to view the objectives of controls. Expediting movement, on the other hand, implies a mutual desire to eliminate delays to accessibility.

The difference is far more than a semantic one. It reveals a completely different attitude and approach to solutions. It requires a comprehensive approach to the problem of circulation and access, in which both are considered as indispensable links in the total system and are mutually interdependent.

When the objective is to expedite traffic access there are many additional criteria for which guidelines are necessary. These include the minimizing of conflict points, adequate storage for all turning movements, minimum conflict with pedestrians, coordination of driveways serving adjoining properties and opposite properties, locational criteria to meet signal progression needs, efficient site circulation for adequate ingress and egress capacity, etc. By use of these design criteria an optimum system of access can be developed.

CHAPTER EIGHT

ACCESS DESIGN

FREEWAY ACCESS

Freeways serve through movement exclusively. Their limited access points handle mass entry and exit of traffic under full guidance and control, permanently preserving the freeways' functional utility. The design requirements for full access control establish specific restrictive criteria with regard to spacing and design of access. The point of access is a ramp that merges tangentially into the main roadway; vehicles merge with the through traffic stream after accelerating to the speed of freeway traffic. Exiting vehicles leave the through traffic lanes and decelerate on an exit ramp that is separated from the main traffic stream. These modes of entry and exit cause little conflict with through movement and preserve the integrity of the through traffic lanes.

ARTERIAL ACCESS

Levels of Control

A trend is developing for permanent protection of the utility of the arterial highway by the extension of access control to new arterials. Sometimes accessibility to the highway is permitted only at intersecting public highway facilities. On freeways, connections are effected through interchange ramps; on arterials, signalized intersections permit traffic interchange.

Although access control commonly refers to the prohibition of access from abutting properties to the highway facility, it can also be interpreted in a wider context as the control of accessibility to a highway facility from either private driveways or public streets. Whether access is achieved from a public or private facility has little effect on the consequences of such access to the highway affected.

The principal control variable is the spacing of access, inasmuch as this affects the highway most directly. Under maximum control, access may be allowed only at intersections with other arterials; this is severaly restrictive and rarely practiced. More commonly, access may be restricted to collector street and arterial intersections. The signalized intersection can be either a public collector street or a private driveway, so long as the required spacing and operational design criteria are satisfied.

Lower levels of access control allow additional points of access to the arterial, preferably governed by traffic criteria that determine where such points can best be accommodated. In some instances these criteria cannot be followed because of the intensity of access movements or the specific conditions of property ownership that require more frequent access opportunities. The utility of the arterial can then be preserved by the use of a service road or a raised median divider restricting access to right-turn ingress and egress. Even with lesser degrees of access control, the utility of the highway can still be well protected.

The most effective control is achieved by acquiring all access rights. The abutting property owner may dedicate these rights, a practice that is becoming common in land subdivisions where residential lots back up to an arterial highway without direct access to it.

Access Control Techniques

The access function of streets includes pedestrian access, vehicle access to abutting land, and vehicle access to intersecting streets. Access to abutting land can be subclassified as access of vehicles via driveways, access from occupants' vehicles parked on the street, access by unloading of passengers from vehicles that continue their trips, and access of goods from vehicles loading on the street.

The two direct methods for achieving a desired degree of access control are on-street control and off-street control. On-street control methods are easier to apply than off-street controls because they are of a corrective nature within the power of the administrative agency to regulate. They include parking regulations, channelization, traffic regulation by signing and signalization, left-turn control, median control, and curb-cut control. Off-street controls include the purchase, acquisition, or dedication of abutting rights of access, access point location and design, and site circulation design controls.

Large developments with extensive frontage along arterials can be designed to adhere to specific access spacing intervals. For smaller developments, the preselected access intervals can be maintained by using some supplemental facility in the form of a service or collector road that connects all the individual properties and delivers the combined traffic to the arterial at the preselected points.

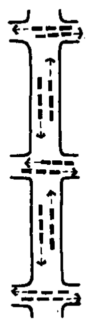
ACCESS SPACING

Intersection Spacing

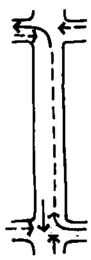
The highest quality of flow for through traffic on an arterial highway would be achieved if there were no driveways and few intersections. These ideal traffic conditions are seldom attainable. A reasonable compromise between conflicting requirements is achieved by providing the maximum degree of accessibility that does not materially interfere with quality of traffic flow. This is theoretically reached with an optimum spacing of intersections that permits movement in both directions without interruption at desirable speed levels. Closer spacing between intersections would make it impossible to provide progressive movement. Wider spacing would reduce the degree of accessibility and increase circuity to interior destinations with little advantage to arterial flow. There are distinct advantages to this optimum spacing, for it permits effective control of speed (Chapter Nine).

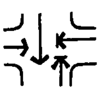
Intersection Safety

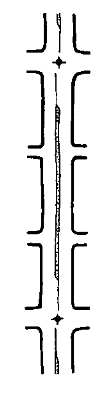
The advantages of controlled spacing of arterial intersections are further emphasized by safety considerations. An improvement of intersection safety in urban areas can be achieved by concentrating cross traffic of vehicles and pedestrians at controlled intersections of major highways. Where a progressive signal system is in operation, analysis of time-space relationships for platoon traffic flow shows that it is difficult to cross at any point other than at the signal. The signalized intersection is so located that through traffic will not be passing through that intersection for a given safe period. The signals bunch the main traffic stream into platoons, enabling cross traffic to move between platoons. Most of the time, when the street is operating at capacity, intermediate points are occupied by platoons of vehicles traveling in one direction or another. Crossing at an intermediate point is hazardous because the traffic gaps are minimal.



On most major highways operating at capacity, the continuous flow of vehicles presents such a formidable barrier to cross traffic at intermediate uncontrolled locations that lengthy waiting periods are the rule. The cautious motorist will not attempt to break through such a barrier and will turn right instead, weaving across to the left lane for a left turn beyond. However, the more daring driver will dart across, forcing the platoon to stop for him, or he will wedge himself into the intersection and block one traffic stream while waiting for the other to clear. For safety reasons, crossings of major highways should preferably be provided at proper signalized intersections. Intermediate highway crossings can be prohibited by the installation of continuous median dividers with openings provided only at signalized intersections.



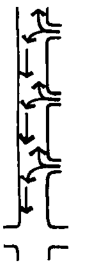




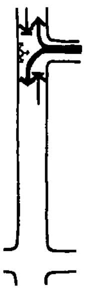
The public has learned to accept the necessity of infrequent vehicular crossings of rivers, railroads, and freeways for reasons of economy and safety. If arterials are to become as safe and efficient as current technology permits, additional attention should be directed to controlling the frequency of grade crossings of major streets.

The implications of these concepts can have a profound effect on arterial design techniques. Permitting intersectional crossings and left turns only at signalized intersections establishes a basic control on the spacing of intersections and driveway locations. The spacing pattern of traffic signals along the arterial then establishes the basic criteria for the location of cross streets and major driveway access points.

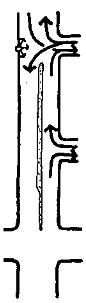
Driveway Access Criteria



The limitation of access to the public highway is based on the premise that greater accessibility will result in a deterioration in quality of traffic flow. Quality of accessibility depends on concentrating traffic conflicts at specific points that can be efficiently controlled and regulated. If there are many driveways, no single driveway will collect sufficient traffic to justify the installation of a traffic signal. If, instead, all the smaller flows are collected at a single point, the resultant traffic is of sufficient intensity to warrant specialized traffic control that will interrupt the flow on the arterial highway and permit traffic to enter the arterial safely.



For large developments, the design objective is to provide driveways that can be signalized. The provisions of additional driveways that cannot be protected with signal control is permissible if left turns and cross movements are prohibited at these locations. However, the use of right-turn-only driveways is somewhat undesirable, for the driver normally wishes to return in the direction from which he came; a person turning right into a development will normally expect to turn left when leaving. It may be confusing if some driveways permit left-turn movements and others do not.



Access Spacing Variations

Although there is a theoretical optimum spacing of intersections and driveways along arterials to maintain continuous progressive through traffic flow, this criterion does not always govern. In some urban situations the through traffic component is minimal; the majority of vehicles on the arterial may consist of access traffic having destinations in the area or at a particular large development. In such cases the primary traffic objective is to facilitate the movement of the majority of the vehicles using the street. If a preponderance of the traffic is destination traffic rather than through traffic, the maintenance of progressive traffic flow for through vehicles has less significance than does the expeditious flow of access vehicles to their destination.

With heavy concentrations of access traffic, it may be very difficult, if not impossible, to accommodate all of the desired turning movements at widely spaced intersections. Concentrated turning movements usually require multiphase signal operation, but this reduces the capacity of the intersection. It is sometimes more efficient to accommodate the turning movements at more frequent intervals, so that the signal time allotment at intersections for turning movements can be reduced. It may thus be possible to achieve greater highway capacity by providing additional intersections where turning movements can take place, instead of concentrating all intersectional movements at greater intervals.

Limitation of access means that the access movements that would have been made if an access drive were available at a particular location either will not be made at all or will be made in another location or in a different way. If access is restricted without consideration of the alternatives by which the desired movement can be made, a disservice to the community may result. The movement desired may be transferred to another location where the effect on the highway may also be detrimental—possibly even more so than at the original location.

In most cases, the prohibition of a driveway access point will shift to the next intersection the turning movements that would have occurred there. If that intersection is a major signalized cross street that already has a heavy burden of left-turn movement, additional left turns may have a serious effect on the capacity and safety of the intersection.

There is thus an apparent conflict between excessive concentration of turning movements at few intersections and excessive distribution of intersections at too many locations. The conflict can be resolved analytically in a particular situation by comparing the levels of arterial capacity that can be maintained under two sets of conditions; by concentrating all turning movements at widely spaced intersection intervals, or by permitting additional turning movements at intermediate points. The insertion of additional intersections is not necessarily a compromise with access requirements; it may be a method that achieves greater arterial capacity.

ACCESS DESIGN CONTROLS

Responsibility

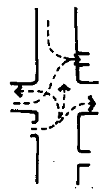
Access design is commonly considered to be the responsibility of the developer. Governmental agencies usually exercise control by specifying driveway design standards and providing curb break permits. Governmental restrictions on driveway location and spacing are frequently minimal and the loose criteria result in a laxity of control. Theoretically, the governmental agency has the power to exercise full control over where driveways will be permitted and over the design of those driveways. A tremendous improvement could be achieved in highway utility and much premature obsolescence could be prevented if these powers were used more effectively.

The objective of access design is to minimize the severity of the conflicts between vehicles using the driveway and through traffic. Although preferential treatment must be given to through traffic movement on the arterial, access service to abutting properties need not be of inferior quality.

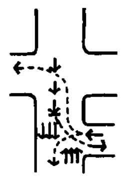
Access Location

Basic solutions to the problems of property access require that the intrinsic problems be distinguished from the more apparent manifestations of those problems that are commonly cited. The location of a large development in a high-exposure location is not in itself objectionable or harmful as far as the highway is concerned. The intrinsic conflict inheres in access location, frequency, and design rather than in the development itself.

The location of access is contingent on a number of factors, including the locations of individual property lines and highway frontages available, requirements of internal site design, numbers of vehicles to be accommodated, required spacing of traffic signals along the arterial, and other factors. The number and spacing of driveways should logically be associated with the use of those driveways. Some criteria could be developed to relate the number of driveways serving individual properties to the use that will be made of those driveways, by means of volumetric warrants just as they are used to justify installation of traffic signals. By this means, the number of driveways could be limited without resorting to some arbitrary, nonfunctional method of determination.

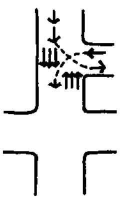


Driveways located in proximity to a major intersection have an especially adverse influence. The most serious problems are created at such driveways by left-turn movements, which frequently interfere with intersection movements. Various types of hazardous situations may be created; these vary according to whether the driveway is along the approach lanes or the leaving lanes of an intersection. The left-turn maneuvers require a vehicle to force its way across opposing traffic in a very disruptive manner. These movements are legal, and the occasional foolhardy driver, by attempting to save a fraction of a minute, places himself and other drivers in a precarious position.



APPROACH DRIVE

Any traffic movements that incur serious risks should be effectively prohibited by a raised median or other self-enforcing technique. If driveways in the proximity of intersections cannot be avoided, then appropriate design measures should be instituted to minimize their disruptive effects. As a general rule, the farther from an intersection a driveway can be located, the less it will affect arterial traffic.



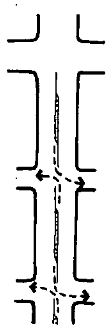
LEAVING DRIVE

Coordinated Spacing

Varying degrees of control of access spacing can be exercised, in accordance with the type of development. In the case of residential development, which does not require direct access to the arterial, it is possible to maintain a fairly rigorous spacing of access with collector streets at appropriately spaced intervals.

In the case of commercial developments, restrictions are harder to maintain, although the same principles of optimum design apply. It is generally possible to concentrate access at relatively few locations. But rigid rules of access spacing do not apply in all circumstances. Each case must be evaluated according to its own special requirements to achieve the maximum degree of control feasible under the particular circumstances.

For corner properties with limited highway frontage, the least detrimental driveway access point is generally at the corner of the property farthest from the intersection. However, there are a number of related conditions that may affect this access location. It is necessary to coordinate the location of access for properties on opposite sides of the highway so that they do not interfere with each other. Driveways directly opposite each other are generally beneficial, for they share a single access location. If this is not possible, it is necessary to provide adequate left-turn storage capacity in advance of each driveway and to avoid the overlap of left-turn lanes.



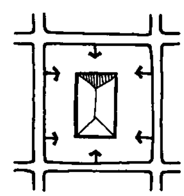
COORDINATION

In most cases, proper driveway location benefits both the community and the developer because it combines the best opportunities for accessibility with minimum detrimental consequences on the highway. This coincidence of interests will foster cooperation instead of conflict in many cases. A lack of correlation between access drive location and signal progression requirements may bar a specific property from obtaining left-turn accessibility and traffic signal controls.

OVERLAP BLOCKING

Large Generator Access

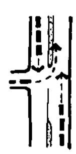
For a large traffic generator, the number and spacing of driveways is established by the approach volumes that must be accommodated along each route. If the development site is surrounded by perimeter highways and if there is an equal distribution of parking facilities around the perimeter, uniformity of parking use is achieved by distributing access driveways around the site.



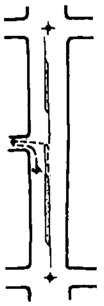
Because of the severe access loads and the unique operational characteristics of large traffic generators, a specially tailored design of access that is interrelated with the signalization system along the arterial becomes necessary. Primary access can be provided at the customary signal spacing locations, where both right- and left-turn access are provided. In addition, supplemental access can be provided at other points by use of the natural time separation of platoon traffic flows to facilitate turning movements.

With a progressive signal system, platoon movement on the arterial introduces relatively large gaps between platoons. It is possible to use these gaps productively by permitting traffic to turn left into adjoining property at preselected points, through the gaps in opposing traffic, with minimum hazard or interference (Chapter Nine). Left-turn entering vehicles require a gap in one direction of opposing traffic flow to negotiate the left turn, and left-turn leaving vehicles usually require a gap in both directions of travel to safely negotiate an exiting left turn with conventional designs. It is frequently possible to provide for left-turn entering while prohibiting the left-turn leaving movement. The most appropriate location for a supplemental left-turn entrance is at the midpoint between signals. At this intermediate location the traffic gap in the opposing stream is at its maximum, and there is usually ample space for a left-turn refuge lane that does not interfere with other left-turn

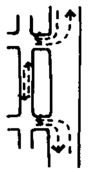
ENTERING



LEAVING



MULTI-DIRECTIONAL



DIRECTIONAL

lanes at the approaches to signalized intersections.

When capacity is a consideration, as in the case of very large generators, the typical two-way driveway may not be the most effective type of access design. Directional driveways handle traffic movements to and from a single direction rather than to and from both directions. A pair of such driveways can sometimes be incorporated into the arterial traffic control system, offering greater capacity and efficiency than does a single driveway with multiphase control. A left-turn ingress driveway that does not permit left-turn egress at the same point is a form of directional driveway. Paired directional driveway design usually requires an internal cross connection to permit directional choice and operational flexibility. It can also be used without internal connection if parking facilities are segregated by directional orientation.

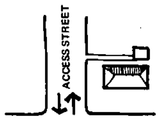
DRIVEWAY DESIGN CONTROLS

Design Standards

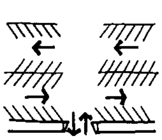
The criteria for driveway design follow a hierarchy corresponding to the hierarchy of functional classifications. The variable operational factors that control design include speed, traffic volume, volume of pedestrian traffic, and access spacing.

The community usually establishes uniform driveway standards for ease of administrative application. Such uniformity sometimes has the effect of imposing a rigid design mold to which all types of access needs must adhere. It may fail to recognize the need for variable standards dependent on the type and magnitude of access requirements. Some types of design can facilitate ingress and egress and expedite traffic movement; others impede access and substantially interfere with traffic movement along the street.

There has always existed a separation in administrative practices based on notions of "public" versus "private" access, rather than on functional characteristics that should govern design. Some city policies require a major regional shopping center serving 20,000 cars a day to use the same type of driveway design as a single-family residence serving six cars a day. For a short cul-de-sac generating 100 car-trips a day, administrative policy may require a minimum right-of-way of 50 or 60 ft with intersection-type curb returns at the juncture with the collector street. The same administrative body may restrict large traffic generators serving 20,000 vehicle-trips per day to 30-ft-wide dustpan-type driveways. These administrative practices can be improved by establishing functional requirements and standards for driveways.



COLLECTOR



ARTERIAL

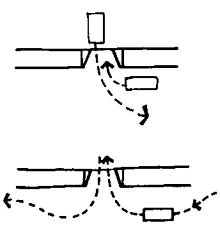
Driveway Types

In urban areas where curbs are provided, a roll curb and gutter design can provide access at any point, for a vehicle can mount the curb. Vertical curbs restrict access to those locations where driveways are constructed.

The most common type of vertical curb driveway design takes the form of a "dustpan"; the curb is depressed and slopes up toward the sidewalk. Another common type of driveway resembles an intersection; the curb is curved toward the property like a typical intersection curb return. The radius of curvature is variable, ranging from a very nominal radius to a radius of 35 ft or more. At some driveways the roadway pavement is continued into private property without interruption and the pedestrian steps down into the driveway. In other designs the driveway slopes up toward a sidewalk that is on a constant grade.

The dustpan driveway is usually adequate on local access streets where traffic is minimal and there are no particular objections to vehicles swinging wide into and out of a driveway. However, for arterial highways and for driveways serving large numbers of vehicles this design has many deficiencies.

Although most nonresidential driveways are intended to allow vehicles to enter and leave at the same time, they are frequently not wide enough to permit this with any ease. Motorists frequently wait in the roadway to enter a facility while an exiting vehicle is waiting in the middle of the driveway for a gap in traffic so that he can leave. In many instances the vehicle will use the entire driveway width for entering or exiting to avoid jumping the curb, because the tracking of the rear wheel bears no relationship to the configuration of the curb cut. The driver invariably swings wide on entering or leaving to make up for the deficiencies of the driveway design, thus encroaching on adjoining traffic lanes. The design intent may be to use the right-hand lane for acceleration and deceleration at the approaches to a driveway, but often the design of the driveway virtually prohibits a curb lane vehicle from entering properly.

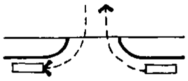


Functional Driveways

Just as functional specialization has become necessary in the classification of different types of highway facilities, another form of functional classification is necessary for access facilities. Design criteria for driveways that serve large volumes of access traffic should be different from design criteria for residential driveways serving a few car movements a day. The geometrics of driveway design for a major commercial or industrial development along an arterial highway where there is minimal pedestrian movement can differ substantially from the geometrics of a residential driveway on a local access street with pedestrian traffic.

On the local access street the usual dustpan driveway is adequate to serve individual single-family dwelling units. The speed and volume are low and pedestrians are numerous; turning vehicles virtually come to a stop before turning into a driveway, and encroachment on other lanes is not serious. On a collector street with moderate travel speeds and volumes, intersection curb returns can be used to serve group parking facilities so that vehicles can start their turn from the curb lane without encroaching on other lanes.

Along arterial highways, volumes and speeds are high, and driveway design should correspond to vehicular capabilities to facilitate free flow on and off the highway. The rounded curb return driveway should permit a vehicle to follow the path outlined by the curb. The entering vehicle should be able to turn right from the curb lane without slowing too suddenly or encroaching on other travel lanes to its left. Likewise, a leaving vehicle should be able to turn into the right-hand lane without encroaching on the adjacent lane.



Although pedestrian movements along the sidewalk are a major consideration in many areas today, it is likely that fewer pedestrians will be walking along the arterial highway in the future if the design of the community is introverted to facilitate internal pedestrian movement. Most designs for new, planned communities purposefully avoid the need for pedestrians to walk along the arterial.

In the future there will be a greater need to facilitate the movement of automobiles into and out of driveways without interfering with through movement. At those locations where crossing between automobiles and pedestrians is inevitable, it would be advantageous to emphasize that conflict does exist whenever the pedestrian steps from sidewalk to roadway as he does at any other intersection. In the future there will be fewer driveways along the arterial and each one will be used by more vehicles. It will be important to emphasize that each driveway is an intersection, and the design should call this to the attention of the pedestrian so that he may exercise extra care.

Driveway Traffic Control

Where access is provided to relatively large generators along the arterial, the magnitude of driveway traffic is very often equal to or greater than that from a collector street intersection. This traffic frequently cannot enter or cross the highway safely without the aid of traffic signal interruption of arterial flow. In such locations the need for signalization should depend on the intensity of the conflicts to be controlled, regardless of whether the intersecting facility is classed as public or private.

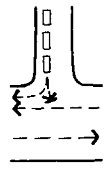
There is frequently an administrative fear that installation of a signal at a private drive will expose the community to a proliferation of similar requests. There are solutions available to this potential problem (Chapter Nine). The operation of a large driveway is no different functionally from any other important intersection.

DRIVEWAY CAPACITY

The capacity of a single driveway can be substantial if it is supported by appropriate internal geometric design. An optimal driveway design can absorb inbound flow at the same rate at which the abutting highway can deliver traffic to the site. Similarly, a maximum leaving capacity can be provided to achieve exit flow equivalent to the acceptance capacity of the abutting highway. Special internal design techniques make it theoretically possible (although not necessarily desirable) to achieve this high capacity at a single access point. If highway access capacity were the sole criterion and considerable control could be exercised on internal design, driveway frequency could be quite limited.

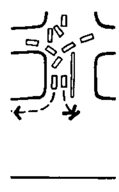
Single Exit Lane

The basic controls that govern capacity of a driveway are the number of lanes available, the proportion of time that these lanes are moving, and the acceptance capacity of the street. In the normal two-lane driveway, there is a single outbound lane from which vehicles turn either right or left. This lane can move only when there is an adequate traffic gap on the arterial highway. The right turn merges with the right-hand traffic lane. A left-turn maneuver requires the exiting vehicle to cross all the lanes moving toward his right and then to enter the left lane of opposing traffic. Traffic gaps on a busy arterial are frequently of insufficient length to permit this type of crossing and merging maneuver in one step. The left-turn vehicle waiting in the driveway will frequently block all outbound traffic, both left- and right-exiting vehicles, until an acceptable gap occurs.



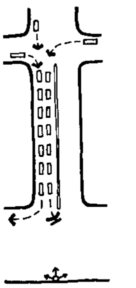
Double Exit Lane

If the volume of egress traffic justifies additional driveway width, two exit lanes can be provided for outbound flow, thus separating right and left turners. This solution introduces other problems, for exiting vehicles must choose the proper lane sufficiently in advance of the exit to weave over safely. To operate well it requires a certain length of clear approach to the exit driveway to permit sorting out of exiting traffic. Insufficient distance provided in most internal designs results in considerable cross-weaving and maneuvering confusion at the exit, and this disrupts exit flow capacity.



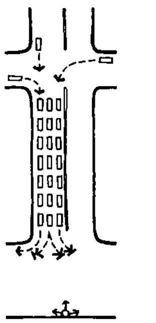
Under favorable circumstances vehicles can be sorted out by direction: the right turner can merge easily with curb lane vehicles on the arterial, and left turners can wait for gaps in traffic so that they can safely cross and merge into the opposite left lane. The additional exit lane increases exit capacity substantially because a single waiting vehicle does not obstruct all exit flow. On heavily traveled arterials, however, it is extremely difficult for a left turner to break out into the main traffic stream unless traffic signal control is provided at the driveway.

If the exit driveway is located so that traffic signal control is feasible, its internal design should provide sufficient exit storage capacity to maintain continuous exit flow for the full green signal interval without interruption by weaving vehicles and internal conflicts by vehicles turning from the wrong lane. Together, proper internal design and traffic signal control can achieve a high level of exit capacity.



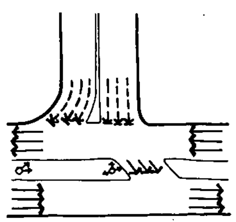
Triple Exit Lane

A signalized driveway will usually have one or two egress lanes, depending on volumes. In the event that capacity is still inadequate, it may be feasible to provide a third exit lane. Internal design is especially critical in this case, for the middle lane is permitted to turn either right or left (unless there is a preponderant directional flow so that the middle lane can be assigned to one direction). A considerable length of internal exit storage must be provided so that vehicles can sort themselves out by direction well in advance of the driveway intersection. Directional instructions must be so clearly marked that all vehicles in the right lane will turn right and all in the left lane will turn left, thus giving the middle lane the safe option of turning either way.

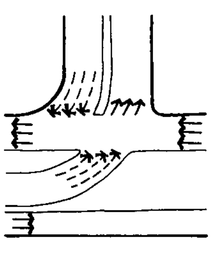


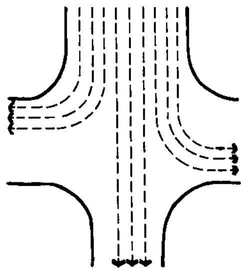
High-Capacity Designs

For unusual situations, an exceptionally high capacity can be achieved through the principle of internal separation by directional orientation. If the internal approaches are sufficiently long to handle the sorting out of traffic by directional orientation, it is possible to design an exit having as many lanes as there are on the arterial highway leading away from the exit. In one installation, an arterial highway with three lanes in each direction is fed by two parallel three-lane exit driveways. This high-capacity driveway system replaced seven normal driveways along an arterial and cut the exiting time in half. This type of design requires a highly controlled operation for adequate internal sorting. It is best adapted to extremely large generators, such as major industrial plants, where drivers use the facility often and have learned to organize their exiting flow systematically.



A similar system with high exit capacity can be achieved by an internal sorting out of vehicles by directional orientation, channeled to separate exit driveways. At one driveway there may be three or more lanes of right-turning vehicles, and at another driveway three or more lanes of left-turning vehicles. In the case of extremely heavy generators, such as stadia or other major recreational attractions, there may be a great number of parallel driveways exiting in a single direction into several abutting highway facilities. To maintain a high exiting flow, no choice of direction is provided at the exit, because choice implies an opportunity for weaving from one side to another in order to go in a specific direction.



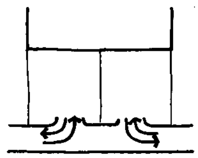


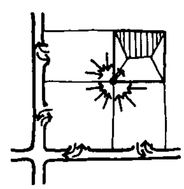
The capacity of a single driveway can thus be almost limitless. The major constraints on the traffic volume that can be handled at a single access point are the ability of adjoining highway facilities to absorb that volume and the control of internal design to feed it.

Directional Choice

One key to maximum capacity is restriction of the motorists' options. When all vehicles are required to move in the same direction, there is no need for cross weaving, the principal deterrent to effective capacity. Wherever the element of directional choice can be eliminated, capacity levels can be raised. It therefore becomes especially pertinent to examine methods for minimizing the need for choice.

In most instances a vehicle approaching from a specific direction will choose to return in the same direction. If the facility can be designed so that vehicles entering from a particular direction park in a particular area and then return in that same direction without mixing or merging with traffic from other directions, the element of choice becomes unnecessary. It is then possible to maintain a separation of directional components of traffic and to segregate parking facilities in accordance with directional orientation so that traffic from various origins need never cross or mingle. Such internal segregation can reduce the conflicts and confusion that normally develop at large traffic generators. This is possible only when the design pattern for a large development can locate the principal destinations at the center of the complex, approximately equidistant from all peripheral parking facilities, so that there is no special advantage to parking in one area as opposed to another. Specific traffic with common origins can be assigned to particular parking areas, achieving more uniform distribution among access driveways and parking facilities.

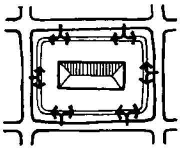




The principle of segregation by orientation has a number of theoretical advantages, but it can be practically applied only at certain large generators whose patrons will tolerate restriction of choice. It is intended to resolve serious traffic problems, not to supplant conventional design methods where freedom of choice can be readily permitted. Drivers must not be seriously handicapped or restricted by parking in one area rather than another. This limitation can sometimes be overcome if a supplemental internal transportation system is available to provide access from any parking area to all points of destination.

Interconnected Design

In developments having multiple points of destination, the motorist expects interconnection that provides free internal circulation to let him reach a point immediately opposite his destination. In these more conventional situations, the design has an objective opposite to that of segregation. Efficient internal circulation facilities are provided to connect all the distributed parking facilities and to permit appropriate opportunities for recirculation within. The internal circulation roadway provides good accessibility from all external access points to all internal parking destinations.

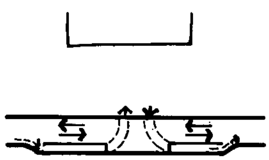


There are thus two opposite and seemingly contrary approaches to access design. It is necessary to choose the better approach for any specific situation.

Grade Separation

In theory, a specially designed access driveway can accommodate almost any desired volume of traffic. Proper internal design for such a driveway requires substantial area and depth and a highly controlled operation. There are some types of development where this degree of restriction is not feasible, and the internal site plan may not permit it.

At some locations it may be desirable to resort to grade separation, especially where topographic and other physical restrictions limit accessibility. Although grade separation for private access has been used only rarely until now, it is anticipated that the current trend to larger developments may increasingly resort to grade separation and other sophisticated design techniques to provide the accessibility required.



GRADE SEPARATION

LAND-USE ACCESS

Residential Access

The variables that affect residential access design include type and intensity of residential development and the classification of the street along which the development is located. Single-family dwellings should be located along the access street, with a direct driveway provided to each individual unit at a driveway spacing equal to the lot width. Medium-density residential development should preferably be located along collector streets and be served by group parking facilities, with access provided at more widely spaced intervals. The spacing of driveways should be compatible with access street intersection spacing; intersections and driveways should be located opposite each other to minimize the number of intersections and conflict points along the collector. Large, high-density residential development can locate along arterial highways with access drives preferably at locations that permit the platooning of traffic from adjoining signals to provide a gap that will allow vehicles to enter the arterial without excessive delay.

Commercial Access

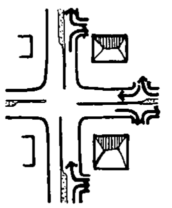
A major objective of commercial access design is to achieve permanent, stable access that is not subject to deterioration over time. It is inappropriate to permit development to take place in potentially critical areas without adequate controls to guard against the problems that may arise. The growing needs of moving traffic and the access requirements of adjoining development may meet head on. Congestion and hazards mount, limiting accessibility and discouraging patronage. In most cases, severe restrictive measures are then taken to minimize the detrimental consequences on moving traffic. Restrictions are imposed on traffic and access, including the installation of median dividers, turn restrictions, and driveway controls that lessen traffic conflicts only by severely curtailing accessibility to abutting development.

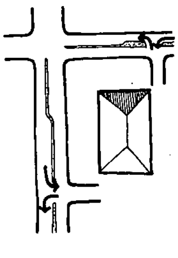
It is frequently difficult for the developer to foresee that a critical traffic situation will develop at a new shopping center site in a presently undeveloped, isolated area. Frequently the site is designed on the assumption that unlimited access will always be available; no restrictions are anticipated. When a conflict begins to develop, moving traffic is given precedence, and accessibility suffers. If the community imposes restrictive controls for which the site was not designed, the results can be extremely detrimental to the development. If no action is taken, the results may be equally detrimental, for extreme congestion and hazard drive customers away. Appropriate steps should be taken to forestall such a crisis in the initial planning stages.

Unless his initial design anticipates the possibility of more restrictive controls in the future, the developer is faced with a situation in which his requirements for accessibility are subject to constant reevaluation as the traffic exposure to his property increases. A gain in exposure, which would normally result in increased patronage, is frequently accompanied by a reduction in accessibility. The developer wants stable access that is not subject to constant erosion. The public wants its own interests to be safeguarded, so that movement on the highway is not subject to constant deterioration from a proliferation of access openings to adjacent properties. The current tendency to react to crises can only minimize the results of conflict through increased restriction and control; it cannot resolve the basic causes of conflict.

The design of optimum access opportunities as an integral part of the highway plan is ultimately to the maximum advantage of both the highway user and the developer. It guarantees the perpetuation of a sound access system, one that will not be subject to deteriorating influences and that will serve the access requirements of the development for its expected life. The broader objectives of access control can thus be directly related to the enlightened self-interest of the developer.

From an access design standpoint, the most desirable practice for commercial design at intersections is to concentrate development in one corner of the intersection rather than to spread the development uniformly between corners. This arrangement concentrates development in a

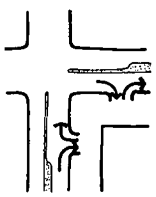




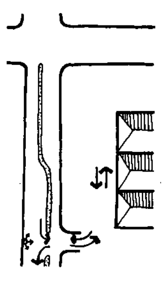
contiguous area not bisected by arterial barriers. Optimally, pedestrian interaction and safety calls for a single pedestrian area, uninterrupted by vehicular traffic, that provides access to all shopping activities. The ideal one-stop shopping trip should not require the shopper to move his automobile or walk across an arterial.

A large, single center in one intersection quadrant offers better opportunities for good traffic access than do smaller centers in each quadrant, and the size of the development site is the most significant determinant of whether good access can be provided. Good access design should provide an opportunity for left-turn ingress and egress; the site requirement most critical to this objective is a length of frontage that allows a driveway to be located at an appropriate distance from the major intersection. A large site located in one quadrant is more likely to meet this requirement, because smaller sites with inadequate frontage may not provide appropriate driveway locations where left-turn access can be permitted. A large site in one quadrant also provides room for entrance and exit reservoirs sufficiently deep to accommodate vehicles yet not disrupt traffic flow on the highway. At smaller and shallower sites it is often difficult to provide proper storage and circulation facilities.

The strength of a development, as well as the image it creates in the community, is frequently a function of its size. The single large development is a bigger magnet that attracts more patronage from a larger area than do two or more smaller developments split by an arterial highway. However, there will always be some individual commercial developments on isolated sites to which reasonable access will have to be provided. Frequently, access will take the form of unidirectional driveways permitting right turns in and out only. If the frequency of driveways is limited, the relatively low volumes of traffic serving these small generators will not materially impede traffic on the arterial.



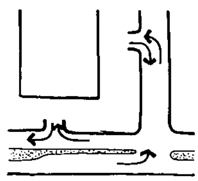
Wherever possible, it would be preferable for individual retail activities to locate collectively on adjoining sites, so that their parking and access facilities can be operated as a single functional unit. Common access can then be provided to all off-street parking at a controlled location where traffic signals may be installed when necessary. Developers of individual sites will benefit if they are not restricted to right-turn ingress and egress. A joint access driveway permitting left-turn accessibility materially advances the developers' common interests without detrimental consequences to the highway. What would normally become a series of uncoordinated strip commercial developments can be integrated into a common functional facility. With adequate internal circulation through a common connecting drive, optimum accessibility can be provided to everybody's advantage.



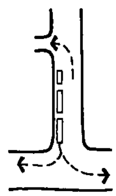
Industrial Access

Driveway location and design are especially critical to industrial access because of the types of vehicles attracted by industry and the heavy peak loads generated by it. As in the case of commercial frontage, a few well-designed driveways can provide optimum service, and the number of driveways is not a measure of capacity.

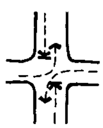
The criteria for location of industrial driveways along arterials are not materially different from those for commercial driveways. Wherever possible, the driveway should be located at an appropriate point for left-turn accessibility so that a median opening, and possibly signalization, can be provided. If a driveway must be located at some point where a median opening would harm traffic flow, it may be necessary to restrict access to right turns at that driveway. In such cases, secondary left-turn access from an internal collector street becomes desirable. Developments on either side of the highway should so coordinate their access locations that a single median opening can serve the access needs of both, increasing the likelihood of meeting the required signal warrants at the earliest time.



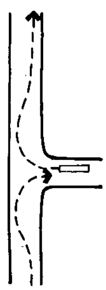
For driveways located along collector streets, the most critical access locations are in the vicinity of arterial intersections. Driveways should be kept far enough from arterials so that vehicles waiting at the approach to an arterial do not block driveway entrances.



If property frontages along the collector are sufficiently wide, driveways serving properties on opposite sides of the street can act independently as isolated T intersections. If opposite driveways must be located near each other, they should be directly opposite each other rather than staggered, to avoid potential blockage.



Driveway configuration should conform to the performance characteristics of vehicles using the facility. For trucks, this requires a large-radius curb return and a relatively wide driveway.



SITE DESIGN

Site Access Deficiencies

The reluctance of public agencies to provide direct connections between major highways and large traffic generators is caused by a justifiable fear that inadequate internal design and operation may result in delay and congestion at the entrance, and that this might extend into the highway. Restriction of direct access has the advantage of providing an additional, publicly controlled buffer and safety valve to

guard against the circulation design deficiencies of private property. There is frequently no effective administrative machinery available to control and regulate internal circulation on private property. In the absence of appropriate implementation techniques to assure proper internal operation of private parking facilities, public agencies have resorted to greater restrictions to protect the highway.

In earlier days the automobile remained outside the property line and parked in the street. Only the pedestrian crossed the property line, so the highway and the land use were clearly separated. This all changed when the automobile was admitted into private property by provision of off-street parking facilities. The vehicular trip does not terminate until the vehicle comes to rest in a parking space. The driver is constantly moving from public property to private property and back again; he sometimes has difficulty in recognizing whether he is traveling on public or private rights-of-way. This lack of distinction emphasizes that the requirements of transportation cannot be bounded by a strict demarcation between the public and private sectors of interest. Control of the vehicle overlaps the property line in both directions.

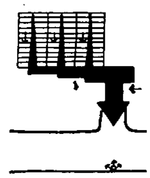
The community's prime responsibility is to assure that the public right of passage on the highway is not interfered with; it is also the responsibility of the community to permit appropriate access that will minimize detrimental consequences to the highway. The developer's responsibility is to assure that the site is so designed that the access and circulation system, both internal and external, does not harm the utility of the highway.

The entire circulation and access system must be viewed as a single functional entity. The efficiency of movement of the automobile is of concern to the community beyond the point where it enters private property. Any breakdown in this movement evokes a chain reaction that extends far beyond the point of immediate congestion. If entering vehicles cannot be accepted as rapidly as the highway delivers them to the facility, the result is a backup of traffic onto the highway that can block all movement in both directions. Thus, even built-in protection for the highway, through advanced design techniques, cannot prevent breakdowns stemming from design deficiencies on private property.

Site Design Functional Classification

Arterial obsolescence is largely caused, not by the inherent access requirements of abutting developments, but by a breakdown in the functional hierarchy of circulation inside the property line. An orderly hierarchical system is commonly accepted in residential development, but the circulation organization inside commercial and industrial sites is frequently deficient. Intermediate linkages are required to effect a transition between high-speed arterial movement and very low-speed terminal movement. If frequent driveways are provided from the arterial to the adjoining parking lot, the arterial is reduced to an access street.

There is usually a notable absence of intermediate facilities to handle the functions of speed transition, distribution and collection, internal circulation, and termination. To be consistent, all of the small streams of parking lot traffic should be assembled and delivered to an internal collector facility that combines these small individual streams in a few concentrated streams. These can then be delivered to the arterial at a few access locations susceptible to effective traffic control.

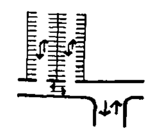


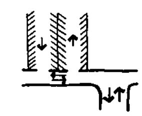
If the principle of functional classification is valid, it should certainly be applied to the most critical segments of the arterial system to control the most intense traffic generators. The internal design elements needed may take a form vastly different from the access and collector street pattern of residential development and may be either public or private. The only significant criterion is the efficiency with which these elements accomplish their assigned function.

Internal circulation within the development site is subject to design criteria similar to those governing vehicular circulation elsewhere. A hierarchical pattern of circulation within a parking facility can be differentiated. The significance of the hierarchical pattern is dependent on the size of the facility. A small parking facility may be inconsequential in its effect on the external circulation network. However, in a large parking facility, the efficiency of internal design has a significant effect on the adjacent external network. Thus, the importance of adhering to an internal design hierarchy increases greatly with the size of parking facility.

Internal Design Elements

The specific design elements used in site circulation are comparable in function to their residential counterparts. Individual parking stalls are arranged either perpendicular to the aisles or at an oblique angle that facilitates parking and unparking. The aisles leading to individual parking spaces serve a function comparable to that of the residential access street. The aisles should be sufficiently wide to allow for comfortable one- or two-way movement, according to the design used, and should permit a vehicle to enter a parking space in a single maneuver whenever possible. The parking aisle pattern should provide adequate opportunities for internal recirculation; if the stalls are angled, this can be facilitated by reversing the direction of flow in alternate parking aisles.





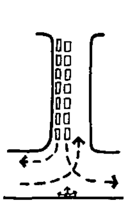
Individual parking bays can lead to an internal collector that combines the traffic from the aisles and carries it to the arterial access driveway. In larger parking facilities there may also be a major interior circulation road around the perimeter to combine the traffic from several collectors, provide general circulation opportunities to all parking areas, and equalize parking area use. This circulation road leads directly to the principal access driveways from the arterial, connecting the access driveways to permit maximum internal recirculation opportunities and directional distribution.

These principal definable elements compose the circulation system hierarchy within a typical large parking facility. In smaller parking lots some of these functions may be combined. There are also specialized designs that accommodate these functions in different form, the only important criterion being effectiveness.

Entrance Design

The most critical portion of the site circulation system is the immediate area around the arterial driveway; this area includes the acceptance or reservoir area, where vehicles are received from the street. The entrance must be designed to absorb the maximum rate of inbound flow. This implies an entrance wide enough and deep enough for traffic to enter the facility without interruption and clear of disruptive marginal interference. The internal design must facilitate the prompt distribution of entering vehicles and must provide clearly defined alternative choices so that there is a minimum of hesitation and confusion at the entrance to distract the driver and reduce the continuity of entering flow. There should also be minimal interference from cross conflicts, and no marginal interference from parking or loading vehicles and other disruptive influences.

Egress is usually handled at the same driveway with a storage area provided where exiting vehicles accumulate. Exit flow is generally subject to more intensive peaks than is entrance flow; the exit reservoir must be adequate to assure that vehicles will emerge into the arterial highway at a continuous, uninterrupted rate during the time interval provided by external traffic controls. If there is signalized exit control a specific time period of the traffic signal cycle is assigned to the driveway; this time must be used efficiently to move a maximum number of vehicles from the driveway through the intersection. The same principles apply as at any other signal-controlled intersection. A queue of vehicles waits in each approach lane while the light is red; when the light turns green, this queue of vehicles flows into the intersection. Efficiency is achieved when each approach lane is filled with waiting vehicles that can proceed with minimum headway between vehicles.



The queue of waiting vehicles should be of sufficient length to use the full time interval allotted to the driveway by the traffic signal, and should not be interrupted by other vehicles entering or crossing the collection area. Any marginal friction would introduce interruptions or gaps in the exiting stream so that fewer vehicles would negotiate the intersection during each green-light interval. Unfortunately, few driveways are designed to achieve this level of operation.

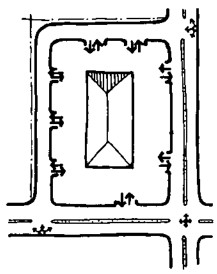
Site Parking

Although site parking is not normally considered to be an element of the circulation network, the adequacy of parking can vitally affect the operation of the entire system. If parking is inadequate, adverse effects extend out to other elements of the system and cause them to break down. Motorists continue to enter the parking facility even when it is filled and no spaces are available. They circle endlessly in seeking a parking space and, if not successful, merely stand in an aisle and wait for someone to leave. The line of waiting vehicles then extends beyond the parking aisles and into the circulation roadways; ultimately it may reach out into the street or arterial highway.

Internal Perimeter Circulation

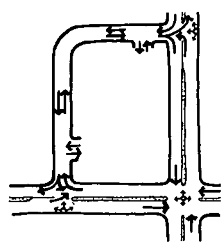
Conventional internal design should provide flexible and continuous interior circulation so that vehicles can reach any portion of the development and any parking space without reentering the highway. This requires that the internal circulation system be highly interconnected. Minimum conflicts should be encountered between pedestrian and vehicular circulation. This is facilitated when vehicular circulation is along the outside perimeter where pedestrian activity is minimal. The major internal circulation roads should also connect directly with the major external driveways.

The requirements for the various elements of internal design usually converge in a common facility located on the perimeter of the property. A roadway around the rear of the development, joining the arterials at the farthest corners of the property, frequently provides optimum accessibility. If left-turn access is provided to the encircling roadway from each of the arterial highways, then access traffic can distribute itself to every portion of the site. The rear circumferential road serves the function of a collector, with primary access to parking from this road.



Cloverleaf Perimeter Road

A circumferential road around the rear of a corner property can be viewed primarily as a means of facilitating safe ingress and egress to the property. But this road also offers an opportunity to facilitate intersectional traffic movement by providing a cloverleaf at grade to eliminate left turns at the intersection (Chapter Nine).



In the event that the cloverleaf road were used for through, turning traffic as well as for access traffic to a corner property, the road would have to be a public facility and designed to higher standards than would be necessary for an internal perimeter circulation road. Access to the property from the perimeter road would require some minimum restrictions to function properly with the additional traffic load imposed.

With a circumferential road the site would be exposed to traffic on all four sides instead of only from the arterial itself, possibly resulting in increased value of the corner property. Some entrepreneurs might be willing to build and dedicate a public roadway around the rear of their property to attain this additional exposure. Thus, the cloverleaf perimeter road concept appears to hold benefits for the developer, the community, and the motorist, and has considerable potential for the future.

CHAPTER NINE

ARTERIAL DESIGN CONTROL

ARTERIAL CHARACTERISTICS

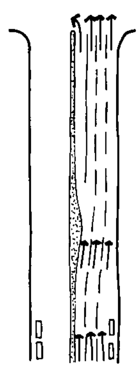
Arterial Operation

Until recently the conventional arterial highway had undergone relatively little change since its inception. The principal differentiation from other streets had been its greater width and continuity, but other design features were similar to those of local streets. Abutting properties were provided access at virtually any point. Spacing of intersections was subject to little control; every local street could intersect the arterial, and crossings of the arterial could occur anywhere. The relationships between streets intersecting the arterial from opposite sides of the highway were frequently uncoordinated. Curb parking was usually permitted with few restrictions. In many areas there was little lane striping to make effective use of available pavement. The use of traffic signals was frequently uncoordinated and haphazard. In many areas these conditions are still prevalent, but now there is a renewed emphasis on improving the traffic operation of arterial highways.

A great deal can be done to improve the operation of existing arterial facilities. But the greatest benefits can be achieved in the planning and design of new arterials. Tremendous strides have been made in recent years in the introduction of new design features, including access limitations, parking restrictions, center medians, left-turn refuge lanes, coordinated traffic signals, effective lane striping, improved signing, and many other measures. These techniques have made an impressive record in the improvement of arterial operation. Newer arterials endowed with all these design features have demonstrated lane capacities as much as double those on poorly controlled and designed arterials. However, there is still a great gap between current practices and potentials for improvement. To assure intrinsic protection for the arterial, built-in design features must be provided that are not subject to erosion and creeping obsolescence as development takes place.

Arterial Spacing

A high-caliber urban arterial for use in large cities will normally be of multilane design to provide ample passing opportunities, to permit acceleration and deceleration at access points, to permit left turns without blocking through movement, and to maintain a high quality of flow. A four-lane arterial would be a minimal facility satisfying these criteria. An arterial with six through lanes is common in larger urban areas.

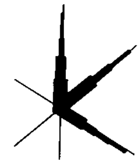


Using minimum cost criteria, the smallest number of arterials having the highest design capacities will generally result in maximum efficiency of both land use and capital expenditure. A typical maximum spacing of arterials in large urban areas that have fully developed freeway systems (*84*) is a mile apart in low-density suburban areas and at half-mile intervals in higher-density areas.

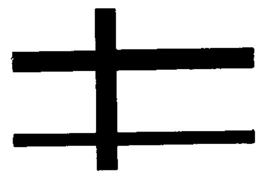
ARTERIAL TRAFFIC PATTERNS

Freeway Traffic Reorientation

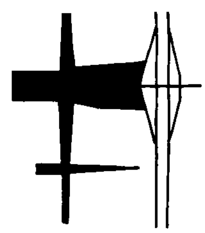
The patterns of arterial traffic movement are subject to major reorientation following completion of the freeway system. In the past, arterial movement was largely linear in character. Radial arterials carried traffic over long distances from the suburbs into the central city on a continuous route with traffic volumes gradually increasing as the arterial neared the central area.



When the freeway network has been completed, these new facilities will assume the long-distance travel function. The new role of the arterial highway will become primarily that of a distributor for the freeway; this will create an entirely different pattern of use whose major traffic orientation is no longer linear and radial. Arterial streets parallel to the freeway and in close proximity to it will sustain a substantial loss of volume. Arterials leading to freeway ramps will experience a considerable gain in traffic. The effects will be most pronounced in the vicinity of the freeway and will diminish with distance from the freeway (*308*).



BEFORE FREEWAY



AFTER FREEWAY

The net effect of superimposing a freeway system over an arterial pattern is a substantial redirection of traffic on the arterial system. An abrupt 90° change in direction occurs in some major traffic flows. The principal radial arterials that formerly carried the heaviest traffic loads are relieved of some of their traffic by the new radial freeways. Circumferential or nonradial arterials, which formerly carried lighter traffic loads, are required to sustain the principal burden of collecting freeway-oriented traffic, resulting in a substantial increase of circumferential traffic load.

Another major change occurs along cross streets as the restriction of cross-freeway movements redirects traffic to major streets that have grade separations. The traffic flow that was formerly distributed over all streets that crossed the freeway right-of-way is now restricted to a few streets.

Major streets with grade separation carry larger traffic loads whereas other streets are confined to minor local traffic.

Substantial changes also occur in concentrations of traffic flows along arterials, especially variations in intensity. Previous traffic volumes along arterials were fairly uniform, with changes occurring gradually as the arterial neared areas of higher density. The new function of the arterial as a freeway distributor results in high concentrations of traffic in the immediate vicinity of the interchange. Lower volumes are experienced a few miles away on the same arterial. This variation in demand on different portions of the same arterial illustrates a possible need for variable design standards that are consistent with traffic demands.

There is also a pronounced difference in traffic intensity along different arterials in the same area. Arterials that parallel the freeway in close proximity will experience lesser volumes than others farther away. Cross-arterial routes having an interchange with the freeway will have far greater volumes than others that do not have an interchange. These variable traffic demands on different arterial routes illustrate the possibility that a nonuniform spacing of arterial routes may be more in accord with traffic demands. The location of an arterial with respect to freeway corridor locations, and also with respect to freeway interchange locations, should be evaluated in establishing arterial spacing and design.

The development of an optimum system of arterials is largely dependent on relationships with the freeway system, which have not been fully analyzed in studies to date. An optimum system of arterials could well involve a variable spacing of routes and the use of variable cross sections and standards. The current practice of uniform arterial spacing and uniform design standards does not appear to match the variable loadings that will be experienced when the freeway network is completed. Some sections of arterial can probably be upgraded to much higher standards in accord with the higher traffic volumes anticipated, while other sections of arterial can probably be reduced in anticipation of lower traffic demands.

Arterial Traffic Components

The composition of traffic using the arterial largely depends on whether the highway is used for regional circulation or whether longer-distance regional traffic has been preempted by the freeway system. In large urban areas with a freeway system, the community arterial serves three different traffic components. The through component comprises those vehicles that have no specific destination within the community and are passing through to reach some other destination beyond. The freeway access traffic component originates within the community and has a destination beyond, for which the freeway system provides the most direct connection. The community traffic component includes vehicles traveling from one point to another within the community.

These three separate traffic components have individual needs, although they are customarily considered together. In new communities a system of arterials could be devised that provides a specialized functional arterial for each of these three traffic components. However, in most instances a single arterial facility will serve all three traffic components without differentiation.

The proportions of the different traffic components carried by a particular facility will vary with its location. Even in communities served by a freeway system, surface arterials will continue to carry some through traffic, especially moderate-length trips for which the use of the freeway will not result in substantial time savings. The proportion of through trips depends on the distance of the arterial from a parallel freeway. As the distance from the freeway increases, the proportion of longer-distance trips on the arterial becomes greater.

In the case of the second major component of arterial traffic, freeway access traffic, most freeway-oriented trips will be of a relatively short duration if there is a fully developed freeway network, so that the arterial connection provides a collection and distribution function.

Intracommunity traffic, the third major component, is composed of numerous short trips between origins and destinations within the community. The arterial provides the principal circulation backbone that ties together various community elements, and most of the trips are relatively short.

Changing Trip Characteristics

The change in arterial travel patterns resulting from completion of the freeway network will greatly affect movement characteristics and design criteria on the community arterial. On the regional arterial, through traffic movement is given primary consideration in geometric design and traffic engineering controls. On the community arterial, a vehicle is much more likely to be close to its origin or destination point, for the arterial portions of trips will be of shorter duration. There will be a greater proportion of turning movements at intersections, requiring more consideration of turning lane needs and multiphase traffic signal controls. These require more efficient methods of intersectional control.

This changing role has significant implications about how the community arterial must be viewed in relation to abutting land developments. The principal function of the arterial is to serve intracommunity travel of medium trip lengths. It brings traffic from the freeway into the community; it connects one neighborhood with another; it brings patrons and visitors from the neighborhood to community facilities. The typical trip is a few miles in length, takes several minutes, and passes through a number of signalized intersections. The arterial must be designed primarily for its predominant users, who desire to travel at a reasonable speed without stopping unnecessarily, and with minimum conflicts.

If the predominant trip is properly accommodated, the longer-distance trip will also receive satisfactory service, and the short trip can likewise be appropriately handled without reducing the efficiency of the facility for other users. The access trip requires relatively convenient and safe access to abutting land uses; this can be obtained by well-designed and well-spaced access points. Good arterial design with built-in protection can satisfy the primary user without penalizing other users.

CIRCULATION CONTROL

Traffic Control

Traffic control is usually viewed as a tool to regulate traffic in conflict situations. Within a broader context of meaning, full control of traffic could be defined as the regulation of all circulation movement, much of which is intrinsic in the design of the circulation facility. If it is viewed only as a regulatory system superimposed on the circulation system after it has been built, to make it operate more efficiently or safely, the full significance and value of control is lost.

There is a significant semantic distinction. The term "traffic control" has specific connotations that relate directly to the regulation of vehicular traffic by control techniques and devices. A different term to encompass the full meaning and intent of the broader control suggested would be "circulation control," which signifies the control of all circulatory movement by physical or regulatory means. This term encompasses all of the design elements of the circulation system that control or regulate the movement of vehicles and pedestrians, either by intrinsic design or through imposed external regulations. Traffic control then becomes one component element that is concerned specifically with movement control through regulatory devices and techniques. The importance of the concept of circulation control is that the techniques for effecting control should be considered as an intrinsic element of circulation design and not as an adjunct to be added later.

Expediting of Traffic

Most aspects of traffic control are viewed from the standpoint of restriction of traffic, which is basically a negative concept. Too frequently, restriction alone does not resolve the problem but merely relocates it elsewhere; in its relocated form the problem may be even more serious. Traffic restriction is appropriate for certain types of problems, but in many others the objective should be rephrased as "traffic expedition." The object is not to restrain the motorist from going where he wants to go, but rather to channelize his movements so that he reaches his destination in a more efficient manner.

This semantic distinction also reveals a difference of attitude in the design of the circulation system. Most commonly, traffic control is viewed from the standpoint of prohibition; the more constructive attitude is that of redirection by provision of an alternative. Prohibition alone has resulted in negative reactions from both the public and the landowner, who may feel that they have been treated harshly or discriminated against unnecessarily. Frequently the restriction can be redefined so that it becomes a positive rather than a negative constraint. The approach and solutions tend to be more comprehensive and involve all elements of the system rather than confining attention to a localized trouble spot alone. This positive approach can achieve support when the action is taken to expedite rather than to restrict.

Control Forms

All elements of highway design embody some aspects of circulation control. The highway pavement inherently controls the movement of vehicles by restricting them within a specific area. Vertical curbs along the edge or at the center median further confine the movement of the vehicle. Other physical design controls include channelizing curbs and islands that restrict the movement of vehicles according to a predetermined pattern. The curb radius of an intersection, the design of a driveway, separate acceleration and deceleration lanes, raised bars, and other physical components of the roadway channelize the movements of vehicles and exercise control over traffic. The design of specific features should communicate operational intent and be self-enforcing and self-regulating.

In addition to the physical forms of circulation control, there are other degrees of control exercised over circulation movement by paint striping and markings, painted channelization, traffic signals, traffic signs, and traffic regulations and restrictions.

Built-In Safety Features

Dangerous and undesirable movements should be made physically impossible through built-in design features that are self-enforcing. The best circulation control is achieved by a design that requires no auxiliary devices to supplement its effectiveness. If a particular driving maneuver is physically possible, it will be done regardless of its potential hazard. The rash driver will take many chances, and even the cautious driver will be tempted occasionally.

Legal restrictions and prohibitions alone are too often ineffective, and total dependence on the driver's prudence and caution is unreliable. The most effective means is to make a wrong move physically impossible through positive design techniques that guide the motorist into correct paths and leave him no option to make potentially hazardous moves, either accidentally or purposefully.

The increasing sophistication of design requires that controls constitute one of the design elements, not palliatives to correct operational deficiencies. The successful operation of circulation facilities is becoming increasingly dependent on the types of control used and the criteria governing their use. The capacity of the arterial highway is largely governed by the types of channelization, lane striping, and signalization phasing used at the intersection. The optimum locations of intersections and driveways along an arterial are largely derived from the spacing of traffic signals, their phasing, and the operational speed on the highway. The capacities of interchanges are dependent on the geometric design and the capabilities of the traffic signal system. In many cases the control system is subject to such rigid requirements and criteria that these controls may dictate certain elements of the circulation plan.

Speed Control

High speeds are normally associated with driving hazard. A common cure for many traffic ills is to impose lower speed limits and to apply rigid enforcement and restrictive design controls that slow down the motorist. This negative approach is frequently used to minimize the effects of current poor designs. Travel speeds higher than can be safely handled under existing conditions are certainly to be avoided. However, proper design sets its own safe speeds and establishes built-in controls that permit reasonable travel speeds without undue restriction. The upgrading of design standards for arterials will permit higher speeds with increased safety.

Parking Control

There are many valid reasons for prohibiting parking along arterial highways. The marginal friction created by parking operations adjacent to traffic lanes severely disrupts operational efficiency, reduces capacity, and represents a distinct hazard to fast traffic. In most cases the quantity of parking that can be provided along the curb can satisfy only a small portion of the parking demands, especially of large developments. Because off-street parking is usually essential, the entire parking demand should be accommodated off-street so that the arterial may be free of the frictions and hazards of curb parking. Elimination of curb parking along the arterial also tends to discourage strip commercial development and stimulates the development of commercial clusters, which accommodate their own parking needs in large facilities.

Where total parking prohibition cannot be achieved, a minimum parking prohibition should extend along the approaches to and departures from major intersections for a distance of about 400 ft. This would provide the maximum number of approach lanes to the intersection and permit the unhindered flow of traffic along the most critical section of the arterial. Midblock parallel parking does not materially reduce the capacity of the arterial, although it does introduce some friction and hazard and should be unnecessary if proper off-street parking is provided.

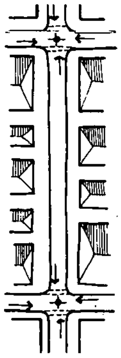
In existing areas, the prohibition of parking on the street should be accompanied by provision of off-street parking facilities. Regulations limiting curb parking can provide control when it is most critically needed, during peak traffic hours. Time-limit parking does not necessarily benefit traffic flow, and, in fact, the consequent increase in parking turnover and parking maneuvers increases the frequency of conflicts to through traffic.

PEDESTRIAN CONTROL

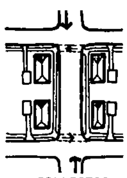
Pedestrian Separation

There are two different scales of movement in modern urban areas. One is the small, relatively slow, pedestrian scale and the other is the larger, more rapid, vehicular scale. One of the principal problems that has affected arterial operation is the conflict between the pedestrian and vehicular modes. The basic incompatibility between these modes must be resolved in some manner to maximize the utility of the arterial.

The functional separation of pedestrian circulation from vehicular circulation is one approach that has been effective in some areas. This is a logical extension of the theory of specialization of traffic flows. Pedestrian circulation is obviously of a different scale and governed by completely separate design criteria. Separate facilities for pedestrians can be justified where pedestrian concentrations warrant separate systems or where the degree of incompatibility is so severe that separation is essential. The separation of vehicle and pedestrian is accommodated in ascending order in accordance with the intensity of conflict between the two. Freeway design recognizes that pedestrian functions are absolutely incompatible on this facility, and provides complete separation. Arterial design assumes traffic movement along the arterial to be the primary function, and strictly controls pedestrian movement. On neighborhood collector streets, greater equality can be accorded to the vehicle and pedestrian; the pedestrian is given somewhat greater latitude and freedom although he is still restricted to sidewalk areas except at specific points of intersectional crossing. On the local access street, the pedestrian assumes special privileges and freedom of movement; vehicular traffic is minimized to reduce the likelihood of conflict, and the driver must control his vehicular movement to a much greater degree. The conflicts between vehicle and pedestrian are thus controlled in different degrees on each type of facility, depending on the function of street, relative proportions of pedestrians and vehicles, and characteristics of traffic operation.



ARTERIAL



COLLECTOR

Arterial Protection

The most serious area of conflict between pedestrian and vehicle is along the arterial highway. The design objective is to reduce the frequency of pedestrian exposure and to concentrate such exposure at a few well-controlled locations, eliminating conflicts at all intermediate points. This can be done by limiting the number of intersections along the arterial, thus reducing the number of points at which pedestrians can cross. The degree of control of the pedestrian must be quite high to account for the greater severity of conflicts at points of crossing. With high travel speeds and volumes, the degree of control that can be exercised by the driver over the automobile is limited. The greatest opportunity to improve pedestrian safety is to provide greater restriction and control over the pedestrian, especially avoiding midblock crossings.

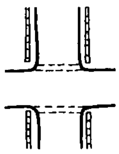
A higher degree of pedestrian control along the arterial can be achieved if attention is directed toward land-use placement patterns that will make such control possible. In the past, arterials were continuously bordered with all types of residential, commercial, and industrial developments, and each development had individual access to the arterial. There was virtually no control possible of either vehicular or pedestrian access.

In newer arterial designs, intersections are spaced more widely and are controlled by traffic signals, so that a higher degree of pedestrian control is possible. In newer patterns of development, large clusters of interrelated land uses are combined on one side of the arterial. Pedestrian movement is concentrated within the complex and there is little need for pedestrian crossings of the arterial. The pedestrian, as well as the vehicle, reaches the arterial at a signalized intersection; he crosses with the protection of the signal and has no need to cross at intermediate points.

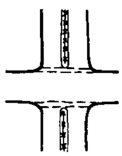
The greatest protection that can be achieved for the arterial with regard to pedestrian conflicts is to encourage inward orientation of neighborhoods, internally oriented shopping center development, and other forms of cluster growth that remove the pedestrian from the arterial perimeter. Land-use controls can further this objective by encouraging this type of development so that the conflict between the pedestrian and the vehicle on the arterial highway is minimized.

The design of the arterial should emphasize the specific right-of-way assignment inherent in arterial operation. The heavy volumes and fast speeds emphasize that the vehicle must have privileged status and be given priority of movement. At potential points of conflict the pedestrian must yield right-of-way, and the design should emphasize this condition. To dispel any illusion or false sense of security on the part of the pedestrian, all of the design features should clarify this operational intent.

The only certain way to assure that pedestrians will cross only at signalized intersections is to effectively restrict the pedestrian from making an unsafe crossing. One method is to restrict access to the arterial for both vehicles and pedestrians at all points except at signalized intersections. In some areas the use of reverse frontage design is accompanied by construction of a wall along the arterial property line, which restricts pedestrians from entering the arterial between intersections. Another method is to install a fence in the median to prevent pedestrians from crossing at midblock. All other types of arterial frontage design are less restrictive and do not permit the most effective control of midblock pedestrian crossings.



WALL



MEDIAN FENCE

GEOMETRIC DESIGN CONTROL

Control Types

The objective of geometric design is to provide permanent protection for the highway. Some geometric design controls are of a positive, barrier type, such as walls, fences, raised curbs, channelization islands and other physical devices, which the motorist respects and observes because he has no option to do otherwise. Raised channelization restricts the flow of vehicular traffic in accordance with a predetermined pattern. Other control devices are less positive, such as striping, painted markings, buttons, and reflectors; these inhibit the motorist but do not necessarily prohibit him.

Positive forms of regulation to make violation impossible are desirable if even occasional violations would impair operation; in less critical situations a lesser type of restriction may be feasible. Hard physical construction is less likely to be modified than are lesser types of control, for these can be easily obliterated and require constant maintenance and surveillance.

Median Applications

The median is a primary form of channelization that is effective in correcting many of the deficiencies of existing highways. Its most obvious application is as a divider that separates opposing traffic flows and prevents head-on collisions. The raised median divider, broken only at infrequent intervals, eliminates most of the primary disruptions caused by indiscriminate left turns. Restricted right-turn access enforced by an unbroken median usually has far less effect on arterial operation than left turns.

The median is effective in eliminating the problems associated with close spacing of intersections along an arterial. Ideally, intersections along arterials should be located only where signal controls can be provided. When intermediate unsignalized intersections are necessary, the most suitable device for protecting the arterial is the continuation of the median without a break through the intersection, restricting the intermediate street to right turns only.

The median provides a pedestrian refuge area that is particularly useful on a wide arterial; the pedestrian may have difficulty in negotiating the entire crossing in a single continuous movement. The median also provides room for traffic signals, traffic signs, directional signs, etc. The median should be designed to achieve all the benefits of which it is capable. It should preferably be wide enough to provide for left-turn pocket lanes at intersections; a narrow median has relinquished one of its principal advantages. Median openings should be correlated with traffic signal progression and with the access needs of abutting properties.

In developed areas where the pattern of access is relatively fixed, the design of the median can attempt to achieve correlation with existing access locations that meet the design criteria for access openings. At other access driveways, which do not meet these criteria, access may be restricted to right turns only.

In newly developing areas the correlation of median openings, signalization, and access should be one of the primary determinants of access design for abutting properties. If coordination of driveway access with these criteria is not achieved, abutting access will be detrimentally affected, for median design must primarily adhere to criteria that safeguard highway utility.

Median Opening Warrants

An explicit policy governing the opening of a median for the purpose of serving a private driveway may be difficult to define, but without such definition there is the danger that median openings will be demanded at all private driveways, ultimately devaluing the median. To avoid this dilemma it is essential that warrants be established defining the conditions under which median openings are permitted. One important criterion is that an opening in the median correspond with a potential signal timing point, or with a point at which a restricted turning movement can take place without interference with opposing traffic.

A second criterion is the anticipated use of the driveway. Major traffic generators will justify a median opening if access to the generator is concentrated and access demands are in the same range as traffic from a comparable intersection where the median is broken. The same general criteria would apply in determining whether a median should be broken for a cross street. If the cross street occurs at a logical signal timing point, and if the volume of traffic entering the arterial at the cross street is sufficiently large, a median opening can be justified.

In this manner a set of warrants should be established for median openings that will apply to both cross streets and access driveways, with regard to location and volume of use. Volume use may be subject to interpretation in different ways for the intersection and the driveway, for the characteristics of traffic operation may be considerably different for these two intersection types. The normal street intersection will usually follow the typical hourly traffic variations and the warrant can be based on the use during a group of peak hours or on total daily use. For driveway access locations, however, the conditions of use may be considerably different. Intense peak periods may occur only during short periods of the day. Therefore, the warrants that are established for driveways must be based on somewhat different considerations than those for street intersections.

Some guidance about median opening warrants can be inferred from the typical warrants used for traffic signals (*322*). Although it may be inappropriate to use exactly the same warrants, a consistent approach should be used in both cases.

The use of locational warrants and volumetric warrants for median openings illustrates the method most appropriate to avoid the usual administrative problem of determining where certain privileges can be permitted and where they must be prohibited. Because a good warrant policy has not been defined, the current tendency is to have a blanket policy that permits median openings in certain locations and prohibits them in others. Frequently, this involves permitting median openings at all street intersections and prohibiting them at all private driveways. This type of warrant is not defensible, because it bases the policy on administrative ease rather than functional need. If the objective is to protect the highway and still provide reasonable access to abutting property, a general policy of this nature does not serve the need and does not do justice to either the highway or abutting land uses.

Left-Turn Pockets

A separate left-turn pocket lane within the median provides a refuge area for left-turning vehicles, effectively reduces many types of accidents, and expedites traffic movement. If there is no pocket lane, a left-turning driver knows that he is holding up the entire lane of traffic behind him as he waits for a safe gap in the oncoming traffic. Frequently, the psychological pressures of this situation cause the driver to force a left turn against opposing traffic under unsafe conditions. The provision of a refuge lane eliminates this pressure. Stopping in the fast left lane to make a left turn is also a primary cause of rear-end collisions. Many sideswipe accidents are caused by vehicles changing lanes to avoid a traffic queue waiting in a blocked left lane. Both of these problems are minimized by a pocket lane in the median.

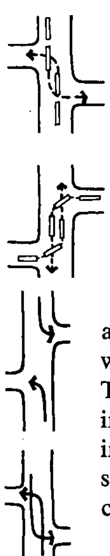
By concentrating left-turn access at a few well-designed left-turn pockets, the median reduces and controls the points of conflict and turbulence at which accidents may occur. The greater physical separation between streams of opposing traffic also prevents many head-on collisions. In addition to improving safety, left-turn pocket lanes also improve efficiency by fostering fuller use of all traffic lanes.

Without a pocket lane at the approach to an intersection, a left-turning vehicle usually blocks the left lane until the end of the signal phase, when one or two vehicles can negotiate a left turn. Even an occasional left-turning vehicle reduces highway capacity. With higher proportions of left turns, the left lane blockage becomes continuous during peak travel periods. If a separate left-turn signal phase is provided, the additional pocket lane is essential to permit left-turning vehicles to accumulate separately from through vehicles; each can then move freely during a separate time interval. At major intersections separate left-turn lanes are desirable in almost all circumstances.

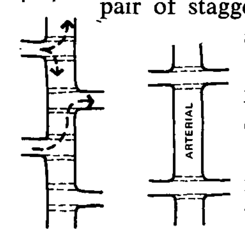
At lesser intersections left-turn lanes are not as essential for capacity because there is usually excess capacity available, and left lane blockage will not seriously reduce route capacity. The major consideration here is safety; left-turn pocket lanes provide greater safety in almost every situation. With greater proportions of left turns in the future, the justifications for providing left-turn lanes will increase.

Jog Intersections

To avoid objectionable jog intersections, street entrances on either side of an arterial highway should be located either immediately opposite one another or at a substantial distance from one another. The distance between adjacent T intersections should be large enough so that the motorist makes a definite turn into the arterial, weaves across safely to the inner or outer lane as required, and then turns into the next cross street. Diagonal movements across the arterial should be eliminated.



The minimum spacing between T intersections is determined by the distance required to negotiate the weaving maneuver safely. If intersections are too close together, problems are created by the overlapping of left-turn lanes and the blocking of some movements by vehicles waiting at the approach to another intersection. The direction of staggering of two adjoining T intersections can make a considerable difference in operation. Some designs facilitate left-turn storage whereas others create an interlocking conflict.



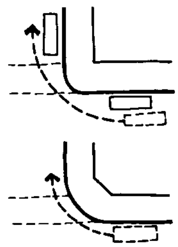
STAGGERED 3 LEG FOUR LEG

There is sometimes a choice between using a pair of staggered, three-legged intersections or a single four-legged intersection along an arterial. The T intersections have fewer conflict points and simpler control requirements but there are a greater number of intersections required and a closer spacing between intersections. Also introduced are jog traffic movement and more frequent pedestrian crossing locations. For purposes of efficient signalization the less frequent four-legged intersections are more likely to meet spacing criteria and avoid the problems of jogs, overlapping turn lanes, and frequent crossings.

Curb Radius

The determination of appropriate curb radii at intersections is subject to a number of opposing criteria. At the arterial intersection primary attention must be directed to expediting vehicular flow through the intersection. Right-turn vehicles should be restricted to the curb lane so that they do not encroach on neighboring lanes. At intersections of major arterials, the amount of pedestrian flow can be expected to diminish in the future, so that the needs of vehicles can be the principal determinant.

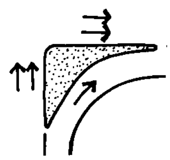
In the past it was normal to use relatively short curb radii to avoid encroaching on property corners, to retain wide sidewalks at intersections, to control speed for turning vehicles, and to reduce intersectional areas. The recent trend has been to increase corner curb radii to keep vehicles from encroaching on other lanes and to improve intersection capacity. When curb parking is practiced, the corner curb radius is not critical because the vehicle normally turns right from and to the second lane, avoiding the parking lane. In new highway planning it is becoming common to eliminate parking along arterials. The right turn must then be negotiated from the right lane and the curb radius is far more critical. The need to restrain right-turning vehicles to the curb lane thus necessitates an increase of curb radius. Although use of a longer curb radius creates a larger intersection pavement area for the pedestrian to cross, the anticipated reduction of pedestrian crossings along arterials will minimize this problem.



One problem in increasing curb radii is to determine where to limit such increases. Passenger vehicles have a relatively short turning radius and can easily be accommodated with a moderate radius increase. Large trucks and buses cannot turn right without encroaching on other lanes unless large curb radii are provided.

Long curb radii should be provided at least on those routes that can be identified as significant bus or truck routes. On other routes it is reasonable to accommodate primarily passenger vehicles and small trucks, recognizing, however, that larger vehicles will occasionally extend into other lanes.

At locations where there is a particularly heavy right-turn movement, it becomes desirable to provide a separate channelized right-turn lane. This provides for a free-moving right turn that need not be stopped by the intersection traffic signal.



Acceleration Lanes

All driveways constitute some impediment to through traffic flow along the arterial, owing to the acceleration and deceleration that occurs in their vicinity and the general turbulence of traffic flow that accompanies any reduction or addition of traffic, however well designed. Normally, the right lane is most affected, because it directly accommodates the accelerating and decelerating maneuvers. In the case of freeways this problem has been resolved by adding an additional lane for acceleration and deceleration. This method can also be applied to the arterial by adding an additional lane near the driveway. A supplemental lane can also reduce such other disruptive interferences along the arterial highway as bus transit stops.

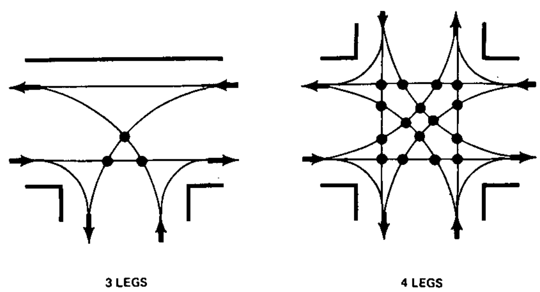
TRAFFIC SIGNAL CONTROL

Conflict Control

A basic principle of effective traffic control is to concentrate conflict situations at specific points where appropriate traffic control devices can be installed to regulate movement with order. The intersection, the principal point of traffic conflict concentration, may be defined as any point where conflicting traffic streams cross each other.

Traffic signals control traffic conflict at an intersection by systematically apportioning the time allotments for each movement. Right-of-way is assigned to conflicting vehicle streams in a sequential order. Maximum safety is achieved when each conflicting traffic stream is provided with its own separate signal phase, so that there is no conflict with other movements during that interval. Common practice in the past has been to regulate only the principal conflicts, permitting minor conflicting movements to occur during gaps in opposing traffic, rather than assigning every movement a separate signal phase. In normal two-phase control only the major through movements are positively controlled.

The number of conflict points to be controlled varies with the configuration of the intersection. At a simple T intersection with three legs there are three conflict points; a normal two-phase signal controls two of these. At a four-legged intersection there are 16 conflict points and the

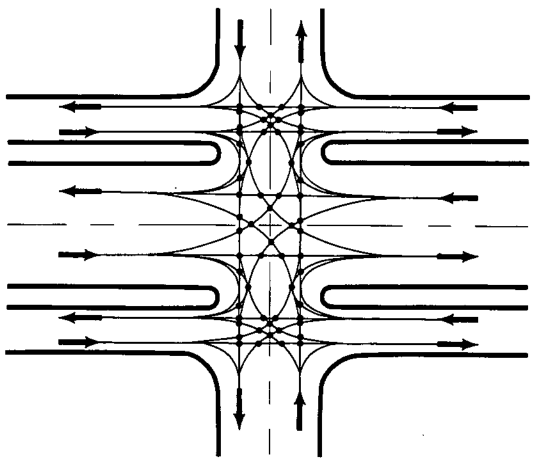


3 LEGS
3 CONFLICT POINTS

4 LEGS
16 CONFLICT POINTS

normal two-phase signal controls 12 of these, leaving uncontrolled the 4 that involve left-turn movements. To control all conflicts it would be necessary to incorporate two additional signal phases into the signal cycle; this illustrates the reduced efficiency obtained from additional phasing.

The number of conflict points at an intersection multiplies in geometric progression with the number of approach legs. At a six-legged intersection (for instance, where a service road is provided on one side of an arterial highway), there are 38 conflict points. At an eight-legged intersection, where a service road is added to both sides of an arterial highway, there is a total of 60 conflict points.



8 LEGS
60 CONFLICT POINTS

These conflict situations result from the numerous lines of travel and the intricate turning movement patterns that must cross each other within the large intersectional area.

The complexity of conflicting movements illustrates the basic inefficiency of multilegged intersections, which are virtually impossible to control effectively. The normal two-phase signal at an eight-legged intersection can control only the major conflicts on the two principal intersecting streets, or 12 of the 60 potential conflict points. To provide maximum built-in highway efficiency, it is desirable to limit intersections along the arterial to no more than four intersecting legs. This applies to any combination of intersectional conflicts that can take place in the vicinity of a specific intersection, whether from a street or a driveway.

Flow Regulation

Signals are usually considered as a control device installed in response to a specific warrant involving conflicting traffic streams, and constituting a corrective device to resolve a problem at a particular location. However, traffic signals have recently taken on a more comprehensive function. Signals are no longer considered as a purely negative restrictive device but rather as a positive metering system, which regulates the flow of traffic in a predetermined pattern. Sophisticated systems of traffic signal control applied in a sequential pattern according to specific spacing criteria can optimize traffic efficiency along an arterial highway.

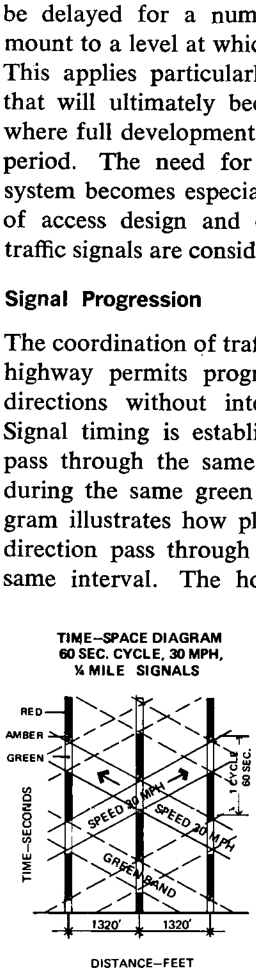
This positive application of signal control is possible when signals are viewed as an integral element of highway design. In fact, the highway and its intersections are designed in accordance with traffic signal requirements and criteria; the spacings of intersections and driveway access may be dictated by the need for maintaining progressive traffic movement in accordance with a predetermined pattern of signal control. Optimization of traffic flow as controlled by traffic signals can exert a considerable influence on the design of the entire facility, thus becoming an intrinsic design element rather than purely a control device.

Traffic signals can no longer be viewed as a device to be added independently in the future as the need develops. A design for the future system of signalization of the arterial should be provided initially. Estimates of the relative proportions of through traffic and turning traffic at each major intersection determine the number of through lanes and turn lanes needed; the actual installation of signals may be delayed for a number of years until traffic volumes mount to a level at which signal control becomes necessary. This applies particularly in suburban and exurban areas that will ultimately become part of a metropolitan area, where full development will take place within a foreseeable period. The need for early design of the traffic signal system becomes especially apparent when the relationships of access design and control to the locations of future traffic signals are considered.

Signal Progression

The coordination of traffic signal operation along an arterial highway permits progressive platoon movement in both directions without interruption to through traffic flow. Signal timing is established so that vehicle platoons will pass through the same intersection in opposite directions during the same green signal phase. The time-space diagram illustrates how platoon traffic flow bands from each direction pass through successive intersections during the same interval. The horizontal dimension represents distance; the vertical dimension, elapsed time. The passage of time is illustrated by the vertical dimension in seconds. The green signal phase band represents the traffic platoon movement and the vacant area between bands depicts the interval of traffic gap.

TIME–SPACE DIAGRAM
60 SEC. CYCLE, 30 MPH,
¼ MILE SIGNALS

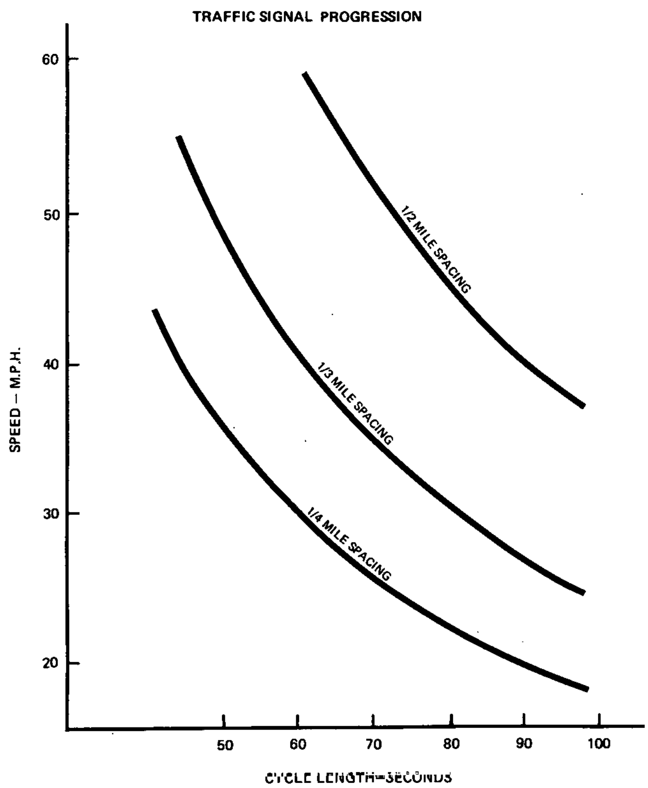


Traffic signal progression depends on a fixed relationship between three variable factors. If any two of these factors are fixed, vehicles traveling in opposite directions can gain the advantages of progression only with one value of the third variable. The time-space diagram shows a typical combination of a 60-sec cycle length, 30-mph speed, and ¼-mile signal spacing. The traffic signal progression diagram shows the necessary signal spacings for various combinations of cycle length and travel speed.

Traffic Signal Warrants

To avoid the indiscriminate application of traffic signals at all intersections, it has been necessary to establish warrants that determine when there is justification for a traffic signal. These signal warrants have been extremely useful in limiting the placement of signals to those public street intersections where they are justified (*172*).

More recently the heavy concentration of vehicles at the driveways of large traffic generators has created a demand



for improved methods of traffic control at such driveways. Many communities have surmounted this problem by permitting traffic signals at private driveways when the volumes are of such magnitude that they are justified.

Some cities have established numerical warrants to determine where traffic signals can be placed and where the justification does not exist. These warrants are not the same as those used for public street intersections because the traffic characteristics at a private driveway are different. The peaks may be far more concentrated and there may be little use of the driveway at other times. Thus, the warrants for traffic signals at private driveways are based on different premises than those at intersections. In addition to a volume warrant it is also desirable that a location warrant be used, as with other traffic signals, to permit traffic progression along the arterial.

A desirable warrant for traffic signals thus involves both locational and volumetric warrants. There should be no distinction drawn between the needs for traffic signal control at a public street intersection or a private driveway. The justification is the degree of conflict that requires control. Warrants should prevent the indiscriminate application of signals where they are not needed.

Future Warrant Estimates

The absence of techniques for directly correlating quantitative traffic generation with different types of land use has until now limited the opportunity for using traffic volumetric warrants for future conditions. The traffic generation vocabulary, one of the new tools developed in the current study, is now available for these purposes. As a preliminary estimate, tentative correlations have been proposed between specific types and intensities of land use and the ranges of traffic that will be generated.

As a basis for traffic volume warrants, some measure of the anticipated trips that will be attracted to specific land areas devoted to a particular type of use can be made. These traffic generation figures can be used tentatively in establishing the appropriateness of various types of traffic and access controls for preliminary design purposes. In the event that a substantially greater traffic volume is generated by a particular installation after development, a review of the warrant determination can then be made that might result in an adjustment at that time. However, the basic tool is available by which traffic volume warrants can be estimated for future development.

DRIVEWAY CONTROL

The principle of using traffic signals for private driveways as well as for public intersections has direct relevance to driveway access control methods. To obtain voluntary compliance by abutting developments with the principle of access control, it would be especially convincing to tie together the abutting developer's desire for good accessibility with the highway administrator's desire for control of access. Good access has as its prerequisite that the access driveway be treated in the same manner as a major intersection handling a comparable volume of traffic. This means that all turning movements into and out of the driveway should be allowed, including both left and right turns, that the approaches to the driveway intersection should be equipped with left-turn pocket lanes and possibly a right-turn lane, that access to and from the driveway should be expedited by traffic signal controls that are responsive to the demands of traffic to and from the driveway, that the driveway should be designed much like any other major intersection with long-radius curb returns and multilane approaches into and out of the driveway, and that driveway traffic should be given equal consideration with arterial traffic in the adjustment of the signal timing, just as for the intersection of two public streets.

The highway administrator would like to impose other requirements on abutting land development. These include a minimization of access driveways, preferably to a single location along the arterial; situation of the access driveway at a location that will best fit the pattern of traffic signal spacing, so that access traffic has the least detrimental effect on through traffic flow; design of the access driveway and of the internal site layout so that entering vehicles will be readily accepted, without internal conflicts and friction; appropriate internal reservoir areas, exiting storage areas, internal circulation roadways, and other site design requirements that will assure the efficient handling of traffic within the site to avoid spreading internal problems out into the highway.

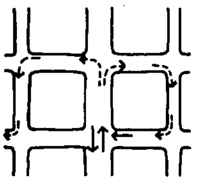
Each party has certain desires and certain rights and privileges. The needs of the property owner for reasonably good accessibility can usually be granted so long as the primary needs of the highway are not compromised. The driveway location must meet not only locational criteria but also volumetric criteria much like any other intersection that warrants signalization. The volumetric warrant requirement acts to control the number of driveways. This illustrates the intimate relationship that can be developed between access control, traffic signalization, and site design. Cooperation is essential to achieve a mutually agreeable solution to a common problem.

INTERSECTION DESIGN CONTROL

Arterial Capacity Control

The capacity of the arterial highway is primarily controlled by the capacity of its signalized intersections. Arterial capacity is determined by the limitations imposed at the worst intersection, where the actual operating capacity of the highway is fixed. Inasmuch as the arterial is most fragile at the high-volume intersection, any increase in efficiency that could be achieved at that intersection would accrue to the benefit of the entire arterial.

The major arterial intersection will probably become even more critical in the future. Under the continuous grid system for both arterial and local streets, innumerable alternate routes are available. If a major intersection is congested, vehicles find other routes. Numerous overflow valves are thus provided so that movement does not come to a standstill if one key element breaks down.



Under the new hierarchical pattern of circulation facilities, alternate routes are frequently not provided. This is typically illustrated by the freeway system in which an accident or temporary overload creates a stoppage of the entire freeway because of the infrequency of egress opportunities.

In the future the arterial system will provide the only continuous surface linkages for the community. Alternate routes of a lower classification will not be available, for neighborhood collector and access streets are now being specifically designed to discourage their use by through traffic. The new hierarchical design patterns usually concentrate all major surface traffic on the arterial system, with no provision for overflow in the event that a major intersection becomes blocked.

This does not imply that the all-purpose grid system is superior to the hierarchical system, because there are many other considerations involved. However, it does emphasize that new potential dangers and problems have been introduced that require new solutions.

Balanced Design

Balanced design provides the most economical system of highways with consistent capacity in all linkages of the network. The objective of intersection design is to provide a balanced design capacity at each intersection along an arterial route so that a constant ratio of volume to capacity is maintained for each segment. With balanced capacity there are no weak linkages. Similarly, there are no advantages in providing excess capacity on certain linkages, for this capacity can never be effectively used.

In developing a balanced design for future arterials, the most significant consideration is the probable variability of traffic flow along the arterial. Before the inception of the freeway system arterial volumes changed only gradually; it was customary to maintain relatively uniform intersection designs that were consistent with the uniformity of traffic characteristics.

Given the greater variations in traffic intensity along the arterial and higher volumes of turning movements in the future, uniformity of intersection design and capacity will not be consistent with variable loadings. The highway planner must determine probable intersection loadings along different sections of the route and provide designs that are in balance with capacity needs.

A considerable range of intersectional capacities can be provided by using different combinations of traffic elements. The variables include number of through lanes, number of left-turn lanes, number of right-turn lanes, number of signal phases, signal cycle length, access controls, parking and marginal friction controls, intersectional spacings, and other variables that affect capacity at the approach to an intersection.

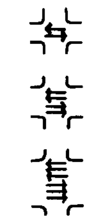
Intersection Efficiency

The efficiency of a highway is ultimately dependent on the proportion of time that the traffic lanes are occupied by vehicles moving at a normal rate. A freeway is very efficient because the traffic stream is constantly in motion and vehicles occupy the traffic lanes continuously. On an arterial operating at a high level of efficiency with progressive signalized traffic movement, platoons of vehicles occupy the traffic lanes continuously for only a specific period; the lanes are relatively vacant between platoons. Traffic signals regulate the periods of movement and standing at intersections; the efficiency of arterial operation is dependent on the proportion of time that the traffic stream on that facility is in motion.

At an intersection of two equal arterials with two-phase signal control, each traffic stream is permitted to flow approximately half the time. Left turns move only when a safe gap appears in opposing traffic. As left turns increase it becomes necessary to provide a separate signal phase so that left-turning vehicles may enter the intersection without conflict from other movements. The time allotted to left-turn movements must necessarily be taken away from through traffic. This reduces the proportion of total intersection signal time allocated to arterial through traffic, automatically decreasing the efficiency of movement for the entire arterial facility with respect to capacity. It may be anticipated that there will be a continuing trend toward reduced efficiency of movement along arterials, and this must be compensated for by increasing the efficiency of movement by other means.

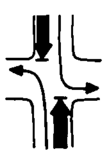
The capacity obtainable at an intersection is determined by the efficiency of use of the intersectional area by various conflicting traffic streams. Maximum intersection flow is dependent on maintaining continuity of movement through the intersection, unimpeded by conflicts and disruptions that create traffic gaps.

The most efficient type of movement consists of through traffic streams, where there are no frictions created by turning movements. Efficiency of flow is determined by the number of lanes moving through the intersection within a given time interval. Four moving lanes are twice as efficient as two moving lanes; six moving lanes are theoretically three times as efficient, because that many more vehicles are occupying the intersection during an equivalent time interval.

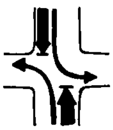


Efficiency of intersection operation is also dependent on directional distribution of traffic flows. Maximum use is achieved when there is an equal flow in both directions so that all moving lanes are fully occupied for the entire period.

Left turns materially diminish intersection capacity, the reduction depending on the number of left-turn lanes provided. A single left-turn lane fully occupies the intersection, as do three through lanes, but it is carrying only a third of the volume during that interval. If the volume of left-turn movements warrants it, a double left-turn lane is more efficient, permitting two left-turn lanes to occupy the intersection instead of a single left-turn lane and using a lesser proportion of intersection time. A basic principle of intersection design for optimum efficiency is to provide the greatest number of moving lanes feasible to occupy the intersection during each signal phase.



SINGLE LEFT



DOUBLE LEFT

Intersection Capacity Improvement

The most generally applicable ways to alleviate the intersection problem are to extend design methods to a higher level than currently practiced and to expand intersectional control techniques. These can be illustrated by analyzing the basic causes for the weakness of the arterial intersection.

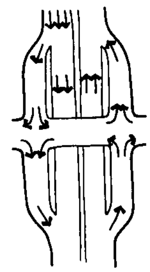
First is the inherent defect of conflicting traffic streams. Because each stream is permitted to flow through the intersection only part of the time, each traffic lane is productively used for only a fraction of its free-flowing capacity. One solution is to increase the number of lanes at the approaches to major intersections so that the greater number of lanes compensates for the shorter proportion of time they are permitted to flow. However, there is a practical and safe limit to the width of an intersection approach. Additional approach widths introduce problems of traffic weaving, but a moderate widening of intersection approaches is feasible and constitutes a basic technique for increasing intersectional capacity.

A second major cause of intersectional inefficiency is the need to accommodate turning movements. To avoid blocking through traffic lanes, auxiliary left-turn pocket lanes are provided, and occasionally right-turn lanes as well. The increased use of multiphase signal operation to provide separate phases for left-turn movements has reduced intersectional efficiency. To overcome this deficiency, two or more left-turn lanes can be used to handle heavy turning movements, or the direct left turn can be eliminated within the intersection by providing an alternative way for this movement to be made.

Another basic cause of intersectional inefficiency is the lack of control of external influences and marginal frictions. These include such elements as curb parking, bus and truck loading, driveway access, and other influences. These marginal frictions should be eliminated or minimized at the approaches to major intersections. The feasibility of accomplishing this depends on the land-use controls exercised on the properties that abut these intersection approaches. If appropriate off-street parking and loading are provided and if driveway access is controlled, many of these marginal frictions can be eliminated.

One major change in arterial design could involve variable rights-of-way. Most current designs maintain the same number of lanes through intersections and between intersections; this practice is inconsistent with the differential capacities required. Variations in arterial roadway widths were not practicable in the past when street intersections were spaced closer together. In the future, there will be greater distances between intersections, providing more space for transitions between narrower and wider sections as needed. Additional pavement widths will normally be needed only at the intersections with major arterials, not at intersections with collector streets.

A commonly proposed solution to resolve the arterial intersection bottleneck is to construct a grade separation, so that through traffic movements are handled at separate grades and turning movements are accommodated at a grade crossing through the use of ramps. Grade separation is a very tempting solution to many intersection problems and is frequently advocated. However, an attempt should first be made to resolve these problems in a more economical manner. At most locations a more sophisticated type of grade intersection design will usually suffice.

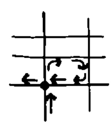


Turn Restrictions

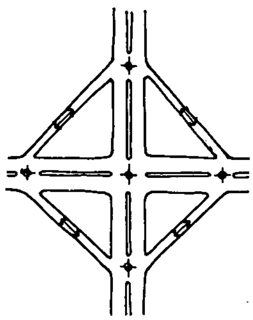
Turn restrictions are normally considered a rather drastic form of control that is applied at critical intersections. When traffic congestion is severe and additional capacity is needed, especially during peak hours, turn restrictions are considered as a corrective measure to relieve intolerable traffic delays.

The restriction of turning movements could also be viewed as a method of increasing traffic capacity for new facilities. Serious consideration should be given to the possibility of using alternative methods for negotiating left-turn movements at critical arterial intersections.

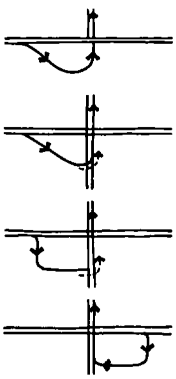
The ideal intersection would have only a single cross-conflict, the two through movements crossing each other during alternate time periods. Some guidance can be found in current practices. At present, if left turns are prohibited at an intersection, the driver can circle right around the next gridiron block beyond the intersection to accomplish his left turn, negotiating an informal cloverleaf at grade. In designs of the future, this principle can be instituted purposefully instead of accidentally.



There are several current installations where the difficulty of handling extremely heavy left-turn movements through a single intersection has resulted in the development of new designs. In some cases, turning movements have been removed from the immediate vicinity of the intersection and directed to use an auxiliary roadway designed to handle those movements separately. The basic principle involved is a separation of traffic conflicts, so that fewer conflicts need be controlled at the prime intersection. The single intersectional conflict area is subdivided into three or more separate conflict areas that are individually controlled; the conflicting turning movements are rerouted via auxiliary roadways. This principle is also applicable to a major high-volume intersection for the purpose of increasing capacity. It requires the development of auxiliary roadways and other special design features specifically planned for that purpose.

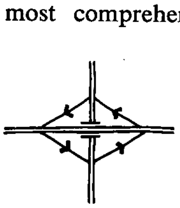


The provision of supplemental roadways for such purposes has been practiced for many years in some states where "jug handle" and "cloverleaf at grade" designs have been used at intersections where left-turn movements are prohibited. The principle represented by these techniques can be extended as a standard design practice to cope with intensified intersectional problems. The possibility of using turn controls should be considered in the initial design of the facility so that the alternative roadways can be provided as part of the initial installation.

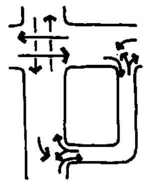


Cloverleaf Roads

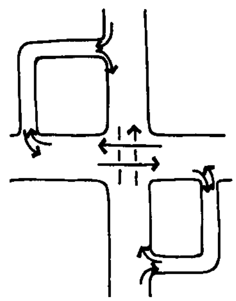
The increased vulnerability of the arterial intersection requires reappraisal of current intersection designs and a wider application of recent innovations to eliminate the intersection bottleneck. The design techniques employed for freeway interchanges provide the most comprehensive application of innovative methods that may be applied to arterial intersections. Direct conflict between the arterial roadway and the freeway roadway is eliminated by grade separation. All turning movements are accommodated by auxiliary roadways outside the major intersection that separate the points of conflict.



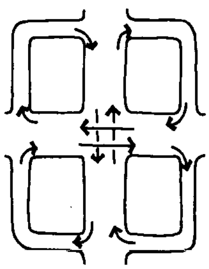
These freeway design techniques can be adapted to arterials. The major design element is the auxiliary roadway by which the desired turn can be negotiated. A cloverleaf roadway at the far side of the intersection can accommodate a left turn by permitting a 270° right turn. A similar cloverleaf roadway at the near side of an intersection permits the left turn to be negotiated via a right turn and then a left turn into the cross street. Auxiliary roadways can thus be provided either at the near or far side of the intersection to accommodate turning movements.



Cloverleaf roadways can be installed in four quadrants, three quadrants, two quadrants, or even one quadrant of an intersection and still permit all movements to take place outside the principal arterial intersection. Complete four-quadrant design achieves minimum conflict, but lesser designs using fewer cloverleafs can be coupled with various combinations of right and left turns to accommodate all movements. The auxiliary roadways are merely freeway interchange ramp designs located on grade, or a formalization of current cloverleaf movements around grid blocks. Although the primary objective is to provide a means to accommodate turning movements outside the prime intersection, a secondary use is an emergency route to bypass the prime intersection when necessary.



The land circumscribed by the cloverleaf-type roadways has a particular value for certain types of uses and the auxiliary roadway can also be used effectively to provide increased accessibility to corner developments. These devices therefore have greater implications than simply as techniques for improving intersectional efficiency, although this objective alone would justify their extensive application.



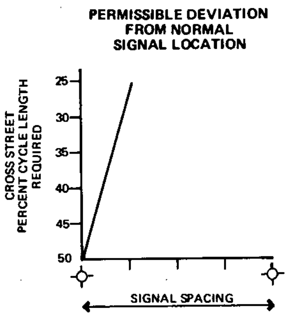
Minor Cross Streets

The most critical intersection and the one that is the determinant of over-all arterial capacity is the crossing of major arterials. The signal cycle length is established by the needs of this major intersection and all other intersections are generally operated with the same cycle length if progression is maintained. At the intersection of an arterial with a lesser cross street, surplus capacity is then usually available.

This surplus time will be accentuated in the future as increased proportions of turning movements at major intersections necessitate a longer signal cycle; through movement will be allocated less than 50 percent of the signal time. At minor intersections, cross-street movements and pedestrian crossings will require a still lesser proportion of signal time than arterial through movement. The remainder of the time, a considerable portion of the signal cycle, will not be used productively and will be wasted unless effective use can be made of it to accomplish other objectives.

As signal cycles become longer in the future and minor intersections have even more excess capacity than they do at present, a new opportunity is provided to gain greater design flexibility. The principal use that can be made of the excess signal time is to provide greater latitude in intersectional location and driveway location. It becomes possible to deviate from rigid locational criteria without interfering with continuous progressive traffic movement along the arterial. In this manner the excess capacity is used for an entirely different purpose—to provide a flexibility of access spacing that would not be possible if capacity controls were more rigid at minor intersections.

The graph shows the allowable deviation from normal signal progression locational criteria as related to the proportion of signal cycle time required at a particular minor intersection. The required relationships between signal cycle length, travel speed, and signal spacing normally fix the location of major intersections where capacity is critical. At less important intersections such as collector streets or driveways, where excess capacity is available, a lesser proportion of the signal cycle time is required for cross-street traffic. This permits some latitude in the location of that intersection without interfering with progressive traffic movement. In the illustration, for instance, if only 25 percent of the total signal cycle were required for cross-street traffic, there would be a permissible deviation of one-fourth of the normally required distance between signalized intersections.



THE SERVICE ROAD

Functional Types

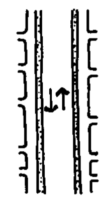
A service road is an auxiliary road that parallels a major traffic facility such as an arterial or a freeway for the purpose of providing service and access to abutting properties. The service road concept was evolved for the purpose of separating the access from the traffic function by inserting a buffer roadway alongside the arterial. The arterial itself could then be reserved for through traffic movement. With the advent of the freeway, the service road concept was expanded to parallel the freeway as a frontage road. It serves the same function as the service road along the arterial and has the additional function of collecting and distributing freeway traffic.

In the case of freeway frontage roads, access to and from the freeway is carefully controlled with regard to traffic operational elements such as weaving, merging, cross conflicts, parking and loading. This degree of control is generally not exercised on the normal service road abutting an arterial. The arterial service road is frequently viewed as an adjunct of adjoining properties and a minimum of control is exercised.

Different types of service roads are intended to serve different functions. The minor residential service road is basically an access street for individual small lots. The service road adjacent to commercial frontage and multifamily development is primarily a collector street—an intermediate facility inserted between the traffic function of the arterial and the access function performed by the driveway. The frontage road paralleling a freeway serves as a collector and distributor for freeway traffic and serves the function of an arterial or a collector street. Each service road has a different function and is subject to different design requirements. Each may be considered comparable to the functional facility that it most closely resembles.

Service Road Advantages

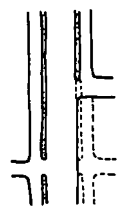
The value of service roads as access control devices has a special appeal to administrative officials; these roads can be administered easily and they provide complete control. The public agency exercises full control over the service road and all its openings into the arterial highway. It is less concerned with the number and location of driveways, the location of fronting properties, or the conditions of parking that prevail. In effect, a buffer is inserted between the private property and the arterial highway. Whatever access problems are created take place on the service road and, hopefully, do not extend out into the arterial.



The service road eliminates the need for parking along the arterial and all the marginal friction that accompanies it; it eliminates the acceleration and deceleration to individual driveways along the arterial; and it provides the aesthetic quality and spaciousness normally associated with such design. The service road concept thus offers many advantages that the public agency values highly The service road has been put to frequent use along arterials in serving residential frontage and other small ownerships and narrow frontages that require individual access to each holding.

Stage Development

In stage development along highway frontage, service road access control can be achieved by requiring a section of service road to be constructed by each developer along his own highway frontage. Access openings to the arterial can be permanent installations if they are well located, or they may be temporary openings to provide access until the service road is extended in conjunction with adjoining development. The value of this method lies in the proper location of permanent access openings after all parcels are developed.



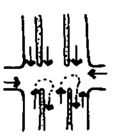
Stage construction of service road segments obviates difficulties by maintaining a fluid situation in regard to access openings. An over-all pattern of access control can be more easily administered, and access openings are subject to adjustment if this becomes necessary. Continuity and uniformity of access control are important factors favoring service roads for small parcel development.

Service Road Disadvantages

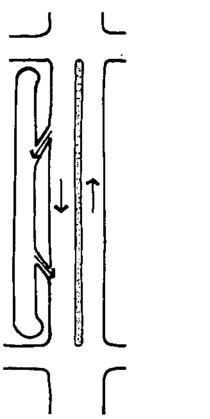
The basic concept of removing the conflicts of access from the arterial highway is fundamentally sound and the provision of separate roadways to serve the two distinctly different functions is consistent with the principles of functional specialization. The principal disadvantages of the service road are operational and economic. For many applications, there may be other design solutions that offer greater advantages and fewer problems, and these should always be considered as alternatives.

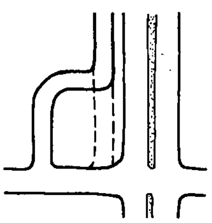
One serious disadvantage is the additional land used by the service road, which represents a considerable cost. Another frequent objection is that the service road is inherently inefficient because it serves only one side of the street.

The most serious problem with service roads is operational in nature. It concerns the complex multilegged intersection where the service road joins the cross street at its intersection with the arterial. If there are service roads on both sides of the arterial, there are eight separate approach legs to the intersection. The complex intersectional turning movements that must be accommodated within the common intersectional area result in an operational problem that is difficult to resolve when significant volumes of traffic are involved. Traffic signals are inadequate to control the great variety of turning movements and conflict situations inherent in this design.

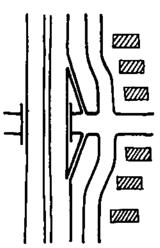


There are some design solutions that reduce the inherent conflict at the multilegged intersection, but these do not resolve the basic problem. The most effective design solution is to avoid the creation of the multilegged intersection by other designs that have fewer operational problems. One improved design introduces breaks in the parkway panel at midblock locations where interchange between the main roadway and the service road can be effected with fewer problems. With appropriate channelization design, these openings can be directional in nature and permit entrance at one point and exit at another. Another effective design technique is the realignment of the service road at the approach to the cross street so that the service road intersection is some distance away from the arterial intersection.



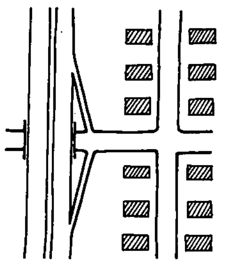


An extremely difficult problem is presented when a paralleling frontage road enters a cross arterial adjacent to a freeway interchange where the ramps also enter the cross arterial. There is insufficient room between the frontage road intersection and the interchange ramp intersections, so that mutual conflicts are created between the two. With back-up design these intersections can be spaced farther apart.



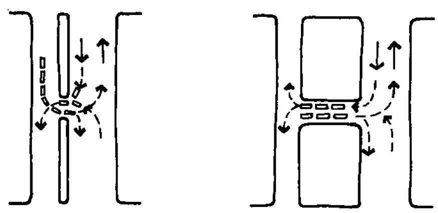
THE REAR COLLECTOR ROAD

The service road has aroused considerable opposition, and alternative types of design are frequently preferred. A service roadway can be located away from the arterial or freeway in the form of a rear collector road. Properties adjoining the arterial or freeway can have either the rear or front of the property adjacent to the highway. Reverse frontage (backup) design is being increasingly used for residential and industrial properties; highway frontage is normally preferred for commercial properties. Rear collector road designs frequently use less acreage for streets than front service roads, especially where they service properties on both sides of the street. They also provide greater flexibility of design, improved intersection control, more effective access control, and superior pedestrian protection.



Requirements

The front service road does not normally operate effectively as a collector street. The design elements that a collector facility requires for proper operation include proper intersectional spacing along the arterial, right-angle entry and exit for visibility and safety, unobstructed ingress to absorb entering traffic without blocking, unobstructed egress storage to permit continuous exiting when a traffic gap is provided, signalization opportunities if volumes warrant such control, and continuous interior circulation. These desirable features cannot be provided on the typical front service road.



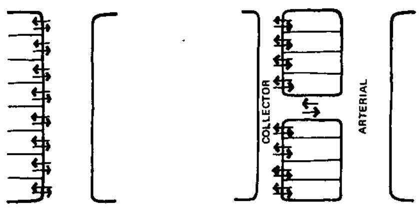
SERVICE ROAD COLLECTOR   REAR COLLECTOR

In the rear collector road that circumscribes the rear of arterial properties, all of the auxiliary functions normally concentrated along the arterial or along the front service road are transferred to the rear. It is possible to make small-parcel development no more detrimental to arterials than larger parcels if special provision is made for access requirements. The rear collector road eliminates the individual access requirements of small parcels by combining all of their access along the rear. Access to the arterial is provided only at intersections that meet traffic progression criteria.

The rear collector road is applicable for all types of development and land uses. It is not vastly different in concept than current requirements for rear alleys. It replaces both the rear alley and the front service road, which are the most common practices in many areas today.

Advantages

Strip commercial development is detrimental to arterials largely because of the access demands and marginal frictions that it imposes on the arterial. If these problems are transferred from the front of the property to the rear, they have no significant influence on the operation of the arterial. It is usually too late when the arterial frontage has already been subdivided into many small parcels; there are then legal obligations to provide access to these individual parcels. The problem can be resolved in the initial subdivision process by adding the requirement that a rear collector road be installed.



DIRECT ARTERIAL ACCESS REAR COLLECTOR ACCESS

The rear collector connects all of the individual parcels to be subdivided. It can have access to cross collectors that intersect the arterial, or can have separate connections to the arterial at appropriate locations for more direct service. The rear collector can provide high-quality rear access as a substitute for lower-quality front access.

The rear service road concept can have a significant influence on the design and operation of commercial facilities and provide many new opportunities. Currently, commercial development along highways is oriented toward and exposed to traffic only on the highway side. Major parking and access are in front; rear facilities are not well used. All the usual problems of driveway access, parking circulation, pedestrian circulation, etc., are concentrated along the highway frontage and interfere with highway operation.

In contrast, the rear collector road extends the exposure of the property around its entire perimeter. Principal access is not from the front but from the rear, so that rear locations become just as desirable as front locations. A double depth of development can take place if desired. Locations of desirable parking are equally distributed around the site instead of being concentrated in front. Most of the frictions are transferred from the arterial highway to other locations where they are not significant. A new fluidity of design is made possible.

THE OPTIMUM ARTERIAL

Design Criteria

Quality of traffic flow is a measure of level of service to the driver. It is related to average running speed and the ability to maintain continuous movement with a minimum of interruptions, distracting influences, and conflict situations. Quality of traffic flow is facilitated by the separation of opposing traffic, refuge for turning vehicles, elimination of parking and marginal frictions, and other operational controls.

The optimum arterial would be the highest level-of-surface arterial highway—one that embodies the highest quality of traffic service, highest capacity, maximum efficiency, maximum safety, and other desirable goals. It would have all the built-in safeguards that provide maximum protection of its utility and efficiency. Although such an optimum facility might be impractical in many areas and would have limited application, it would be valuable to have a prototype facility in mind, against which new arterials can be compared.

There would be no technical problems involved in constructing such an optimum highway; rather, the problems would involve the effects that it would have on the use of land along its perimeter. This evaluation must therefore determine whether there is some method of achieving design compatibility so that adjoining land uses can coexist with optimum arterial development and whether such a highway can be practicably accommodated within a community. The implications for land use along the periphery of the arterial will determine the frequency with which optimum design can be applied.

Innovative Design Concepts

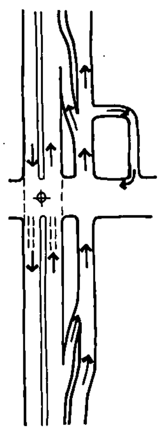
The most obvious source of new ideas for arterial design can be found in the innovative design concepts developed for the freeway; many of these may be applied to the arterial. They include access control, turn controls, channelized access, special turn facilities, greater access spacing, new types of intersection design, and other features.

Selective application of these design elements makes it possible to develop a very high level of arterial facility that has many of the design features of the freeway at a fraction of the expense. The cost of an optimally designed arterial need not be much greater than that of a conventional arterial.

The use of freeway design features has the effect of providing a greater isolation of the circulation facility from the peripheral lands abutting it. The intimate association that has historically existed between the arterial and its abutting lands induces a psychological association that has been a principal deterrent to the development of improved arterial design. In the case of the freeway the public has learned to accept the complete isolation of the circulation facility from the lands that abut it. If greater control and restriction were imposed on the arterial, the result would be a semi-isolation of the arterial that is intermediate between the full isolation of the freeway and the full association of the conventional arterial. Semi-isolation does not necessarily imply a reduction of accessibility with respect to abutting properties, although this might appear to be a direct consequence of greater restriction. It involves instead a control of access, so that accessibility is provided by some alternative design method, frequently resulting in improved accessibility rather than in a reduced opportunity for access. Accessibility may be somewhat more indirect, but the quality of access can frequently be improved.

Operational Design

From an operational standpoint, optimum arterial design should achieve maximum intersectional capacities, minimum interference with continuous movement, higher arterial speeds with progressive uninterrupted movement, minimization of crossing and turning conflicts, and a high level of traffic safety—all with minimum additional expense. The optimum arterial would include all the innovative design features, controls, and restrictions that typify the freeway, but it would delete those design elements that account for the major expense of the freeway—full grade separation, acquisition of full access rights, wide rights-of-way, and changes of grade. Arterial crossings would be widely spaced to promote relatively high travel speeds with maximum safety; intersections would be controlled by traffic signals that are interconnected to maintain uninterrupted progressive traffic movement; access to and from the arterial roadway would be by means of directional ingress and egress lanes comparable to the designs used for freeway ramps, and turning movements to and from the arterial roadways would be prohibited at the intersection; parking and marginal friction would be eliminated by requiring all stopping, parking, and loading to take place off the street. The design could function with one-way or two-way frontage roads, or with no frontage roads, depending on the access requirements of abutting properties.



Traffic operation would be continuous and uninterrupted, much like that on a freeway but at lower speeds. Speed would be strictly controlled by progressively timed traffic signals, so there would be no advantage gained by traveling at a faster rate. After entering the main traffic stream the motorist would proceed without interruption and with a minimum of the usual marginal frictions and crossing and turning conflicts encountered on the conventional arterial. Traffic would be strictly controlled in tight platoons and capacity would be very high. The driver would leave the arterial roadway by a channelized egress lane and would enter via a channelized ingress lane similar to the operation of freeway ramps at interchanges. Turns at intersections would be executed only from the auxiliary roadways and never from the main arterial roadway. Because the average driver is most interested in maintaining continuous movement, this type of facility would provide him with most of the advantages of the freeway with only a minor differential of total travel time.

There is considerable flexibility possible in the design of this facility. It is possible to add grade separations where necessary at critical points, to acquire access rights where feasible, and to eliminate some design features by substituting others. Auxiliary cloverleaf roadways could be provided at intersections to eliminate all turns in critical areas. Such cloverleafs could occupy from one to four intersection quadrants.

Design Applications

Optimum arterial design can have a number of different applications. In developed urban areas this described facility could be considered as the ideal for arterial design. In many instances only some of these features could be applied, as determined by local conditions. In other areas, where anticipated development densities will not reach the levels necessary to justify full freeway construction within the foreseeable future, this type of design can provide an alternative to the full freeway. In still other locations this design can be used as an interim condition prior to development of a full freeway. Many of the freeway design features can be incorporated initially, designing for the addition at a later date of full grade separation and full access control.

This design is especially useful in areas where a freeway cannot be justified, but where the typical surface arterial could become obsolete as development increases. The built-in safeguards against obsolescence make this facility especially applicable in intermediate areas of this type. With the cost only a fraction of freeway cost, these facilities can be developed at more frequent intervals to provide maximum service at minimum expense, with assurance that utility will not progressively deteriorate.

CHAPTER TEN

MULTIPLE-USE PUBLIC CORRIDOR

THE FREEWAY CORRIDOR

Freeway Characteristics

The freeway is a corridor dedicated to movement; it is insulated from surrounding areas to minimize external interferences and influences. It permits free flow of vehicles with no interruption by cross traffic or turning movements and a minimum of marginal interference. The design features that make this possible include full control of access, full grade separation, elimination of parking and all other marginal frictions, separation of opposing traffic flows, auxiliary shoulders for emergency stopping, and other design features that implement free flow. Ingress and egress are provided at widely spaced intervals so that traffic can merge into and out of through traffic lanes without excessive interference with through traffic movement.

The freeway corridor is insulated from the community, but it is also intended to serve the community. Ramps are provided at reasonable intervals and the junction between the freeway ramp and the arterial is the interface between the freeway and the community it serves.

Freeway Spacing

In determining optimum freeway spacing, opposing criteria are balanced against each other. From the standpoint of economics it is desirable to develop a minimum number of freeway corridors with each designed to a maximum number of lanes. Opposed to this is the desire to provide optimum freeway accessibility, which suggests a closer spacing of freeways having fewer lanes. Most current criteria for spacing have been developed from the transportation surveys of larger cities that are based on the cost-benefit ratio method of evaluation rather than the more elusive convenience-accessibility criteria.

One method for determining the optimum spacing of freeways and arterial streets on the basis of the user-benefit rationale was developed through traffic simulation and assignment techniques (*84*). By this method, a means of minimizing community transportation costs was developed in which freeway spacing varied with population densities, ranging from three to five miles for suburban areas.

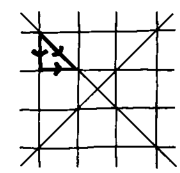
Another study (*261*) determined volumes and capacities based on typical suburban densities and trip generation rates. Trips were assigned to an assumed network of freeways and arterials using an average one-mile spacing of interchanges and a four-mile spacing of freeways. The analysis concluded that adequate traffic service could be provided by such a network, within the operating range of an eight-lane freeway system, with a one-mile spacing of interchanges and with ramps operating at capacity.

Another study of freeway-spacing criteria based on population density (*290*) concluded that an average spacing of 4 miles with eight-lane design would accommodate a density of as many as 10,000 persons per square mile, recognizing capacity as the principal criterion. These studies suggest that an average freeway spacing of four miles (with a range of three to five miles) appears to satisfy most of the criteria for fully developed suburban areas.

Freeway Traffic

The traffic characteristics of a freeway system reflect the sequence in which system components were developed. The first routes generally served intensive traffic corridors where the needs were most obvious. They were usually developed to lower standards with fewer lanes and narrower widths than current designs. It is frequently impossible to upgrade older freeways, and this has resulted in severe overloads on earlier routes. Newer routes subsequently developed to serve other corridors were built to higher design standards and have a greater number of lanes.

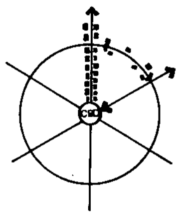
In some areas new gridiron patterns have been superimposed over earlier radial freeway patterns to better accommodate the travel demands in very widespread metropolitan regions. However, the diagonal radial routes initially developed frequently continue to be overloaded because they offer the shorter travel distances.



The central area usually represents the single largest destination point, through which much of the metropolitan traffic flows. The approaches to the central area are the most critical segments of the freeways systems and carry the highest traffic loads. These inner radial segments of the freeway system will continue to be the most critical elements in the future. The development of inner distributor routes around the central areas of many cities has helped to reduce the traffic load and distribute it more uniformly, easing the problem of central area concentrations.

Circumferential Freeways

Circumferential freeway routes that divert traffic around the perimeter of metropolitan areas have vastly improved freeway system service. Circumferential freeway routes are somewhat different in character from radial routes, which influences the types of land-use development that tend to congregate around them. Radial routes are usually located in the established corridors that have historically connected cities. These routes handle the majority of the longer-distance trips of an intercity nature. The radial routes also provide the direct connection with the city center, and much of the centrally oriented suburban development tends to congregate along radial routes.



In contrast, the circumferential freeway route does not follow a historical transportation corridor and carries a lesser proportion of longer-distance and intercity traffic. The circumferential route is a peripheral facility, providing the principal linkage among all of the newer suburban communities around the periphery of the metropolitan area. It attracts high-caliber, prestigious employers who cater to the labor market represented by the suburban dweller. The circumferential route connects all of suburbia and provides primary access between suburban residential developments and suburban industry. By avoiding the intense concentrations normally encountered along the inner portions of radial routes, the circumferential freeway is a strong attractor of many types of land use that cater to the suburbanite, including places of employment, residence, recreation, shopping, and other activities that can readily be reached from any point on the perimeter without combatting serious traffic congestion.

Circumferential commuting is a new travel pattern; the outer portions of radial routes, which would usually have lower traffic concentrations than the inner portions, are now used for reverse commuting—the resident traveling outward toward the circumferential freeway for purposes of employment.

The concentration of new development around the circumferential freeway encourages many commuters to travel inordinate distances to work because of the greater ease of commuting around the perimeter of the area. Also, the circumferential route may not have been designed with the idea of acting as an attractor of intensive industrial development; the resulting loads may be in excess of what was anticipated.

FREEWAY DEVELOPMENT

Stage Development

In current stage development programs for freeways, rights-of-way are usually acquired for an ultimate multilane freeway corridor. In presently undeveloped areas the facility may be initially constructed as a four-lane surface road with a wide median. As traffic continues to increase, temporary grade crossings are converted to grade separations and temporary access is eliminated, with all access to the facility concentrated at new freeway ramps. When the capacity of a four-lane freeway is exceeded, an additional lane is added in each direction. In urbanized areas the freeway can be further widened to eight or more lanes.

The upgrading of the freeway in gradual stages involves not only the through lanes but the interchanges. Initially the simplest type of diamond ramps will suffice for low traffic volumes, and the interchanges are spaced at relatively wide intervals. As the areas around the freeway develop, additional interchanges are constructed to provide ramps at closer intervals. When the area tributary to an interchange becomes fully developed, more complex interchange designs, including cloverleaf and direct ramp designs, may replace the simpler diamond ramp patterns.

Each stage of upgrading interchange service for the freeway necessitates additional right-of-way and reconstruction. Additional grade separation structures must cross the freeway and extend for some distance on either side. The more complex interchange ramp systems use large land areas and extend some distance on either side of the freeway corridor. If the freeway right-of-way is insufficient to accommodate the new design, additional right-of-way must be acquired.

Many urban freeways constructed only a decade ago are already deficient and are undergoing major reconstruction. In the interim the lands that abut the freeway have been developed, and widening of the freeway now involves acquisition of expensive developed properties. Earlier acquisition of a wider right-of-way when development along the route was minimal would have cost a small fraction of the sums involved in widening the freeway. The initial acquisition of additional undeveloped right-of-way to maintain flexibility in the capacity of the transportation corridor would therefore be justifiable on economic grounds.

It is difficult and expensive to obtain a wide corridor through an existing highly developed urban area because doing so causes a major disruption of the community. Current experiences in obtaining freeway corridor rights-of-way are indicative of the much greater problems that would arise from the attempt to acquire even wider rights-of-way for future needs yet to be determined. Principal applications would therefore be in relatively undeveloped suburban and exurban areas that will develop in the decades ahead where acquisition of additional land would not be prohibitive.

Freeway Overload

The upgrading of freeways has not always been able to keep up with constantly increasing traffic loads. A common cause of overload of the freeway system is the build-up of long-distance commuting that results from continued extension of the urban perimeter as the metropolitan area grows. This problem is similar to the one that resulted in the breakdown of the arterial system before it. Surface arterials were extended outward from the central area. With each new increment of extension, traffic loads grew and eventually overloaded the facility. Freeways were then developed to attract long-distance travel from the outer suburbs; arterials were allowed to resume their previous function of moderate-distance travel.

Currently, the freeway system is being extended, making possible the growth of the urban area far beyond its previous limits. These extensions of the urban perimeter and the greater ease of travel by freeway have encouraged commuting from greater distances. The freeway has also attracted many short trips from surface arterials. The combination of these short trips and a growing number of long trips has resulted in the overloading of freeways.

This trend may result in still another stage in the evolution of the highway system. A higher form of freeway may be developed that will accommodate long-distance express travel, as contrasted with shorter-distance freeway travel. The present overload of primary freeway corridors in areas where it is unlikely that additional corridors can be developed is stimulating new ideas to expand freeway corridor capacities.

Freeway Corridor Capacity

One of the most serious charges against the freeway system is that the capacity of the system is inadequate to handle the transportation demands of the future. Current experiences with overloaded freeway corridors attest, in the public mind, to the validity of this claim. A transportation corridor can, in fact, have a very high capacity if the initial system is conceived in terms of a flexible transportation corridor to be developed to whatever capacity is ultimately needed, with a sufficiently wide right-of-way to accommodate such an eventuality without encroaching further on the community.

To achieve very high capacities it is necessary to deviate from the standard freeway design concept. A freeway corridor today can have a capacity up to about 200,000 vehicles per day. For the corridor to handle higher capacities, one concept envisions an automated freeway in which lane capacities would be increased several fold; automated operation of the automobile would permit closer headways to be maintained safely. To provide for future automated freeway operation, a major prerequisite will be additional right-of-way for the new facilities needed.

Other proposals of more immediate relevance are various solutions for the relief of existing overloaded freeway corridors. These include construction of a parallel freeway adjoining a current freeway, development of collector-distributor roadways on both sides of a current freeway, double-decking of an existing freeway, and other similar proposals.

In many of these concepts, the freeway corridor would be redeveloped as a higher-capacity dual freeway. Separate freeway roadways would be provided for localized service and for express service. One freeway roadway would accommodate the usual spacing of freeway ramps at approximately one-mile intervals in urban areas. The express roadway would be insulated from these individual service ramps and provide primarily for long-distance travel. Entrance and exit to the express roadway would be at wider intervals, such as at spacings of about four miles.

A complete freeway network of this type could be developed so that express freeways would interchange only at crossing points with other freeways. At those points, vehicles would have the option of continuing along the express freeway or transferring to the local freeway. To develop a system of express and local freeways, which would vastly increase freeway corridor capacities, the basic prerequisite is sufficient right-of-way to be reserved for this eventuality.

Flexible Capacity

The fact that highway facilities have a life that extends through several cycles of land use emphasizes the difficulty of correlating the highway with future land uses that will have to be served. Even if it were possible to predict highway needs correctly during the first cycle of land use, subsequent land-use cycles are probably unpredictable. The capacity needs in the more distance future are not subject to definition at the time the highway is being designed.

This lack can be accommodated only by providing a flexibility in the design of the highway so that it can be adjusted to accommodate future needs as they develop. Just as future land uses cannot be predicted, it is impossible to predict what forms future transportation may take. Although there is no assurance that transportation will continue to remain on the ground, it is likely that the investment in a wide right-of-way corridor in areas that are currently relatively undeveloped is a wise one.

If transportation is viewed as a service function, whose objective is to serve the needs imposed by the urban community in whatever form they take in the future, the best assurance that the transportation system will be able to serve this mission is to provide the transportation system with the highest degree of flexibility that it is possible to anticipate. Ultimately, the transportation system must have the ability to renew itself and supplement its capacity to whatever level the future demands.

Permanent Corridor Concept

The permanent transportation corridor concept is an appropriate solution to the problems of stage development, freeway overload, expandable corridor capacity, future innovative designs, and land-use unpredictability (*190*). A network of permanent, continuous corridors superimposed over an entire metropolitan area could serve all of its future transportation needs. A permanent corridor of sufficient width to accommodate any future needs offers the most logical device to assure the highest degree of flexibility. With the right-of-way available, the highway can be reconstructed to meet any future technological innovations that arise. The community also can develop to whatever potential the future may hold with reasonable assurance that the transportation corridor will be able to service it satisfactorily. The transportation facility will not continue to encroach on the community but will regenerate itself within the permanent corridor to which it has been assigned.

If the general spacing of highway corridors for a particular urban area is determined, it is appropriate to designate those future corridors and protect them from encroachment. This is particularly pertinent in fringe areas where development has not yet taken place but is imminent. Early acquisition of wide corridors through these undeveloped regions can be accomplished at minimum cost before development takes place and costs escalate.

The basic premise in this program is that a corridor can be developed to almost any capacity and for any facilities that may be necessary in the future. Wide rights-of-way can be acquired at the predetermined spacing; the particular uses and designs to be incorporated into these rights-of-way can be left for later determination. The corridor has a variable capacity depending on the facilities provided; it can be developed according to a staging program, which is reevaluated periodically.

Because right-of-way acquisition is the most time-consuming element in freeway improvement programs, the availability of sufficient right-of-way to handle almost any eventuality would permit a prompt response by the highway administrator to approaching traffic overloads. The improvement of the corridor would be totally within the control of the highway administration, subject to the availability of funds, without requiring new right-of-way acquisitions and further disruptions of the community.

CORRIDOR LAND-USE PLANNING

Influences of Freeways on Development

The development of a new highway facility represents a major change in the area through which it passes. A major change in transportation service and accessibility is frequently followed by a resultant change in land use. A new highway creates new economic values that are reflected in new development, which follows rather strict laws of supply and demand. Unless controls are planned in advance, development will take place on an *ad hoc* basis as a result of entrepreneurial pressures.

The phenomenon of induced development, in which the freeways act as a magnet for new development, should be fully evaluated in developing the highway plan. The patterns of land-use development that will probably follow the installation of a freeway should be analyzed during the planning process. The land-use development aspects of freeway location are so significant that the usual considerations of user benefit-cost ratios may have less consequence than the economic impact on the community as a whole.

The freeway has an influence on the community that extends far beyond the limits of its own right-of-way. These influences can be either negative or positive, depending on whether the abutting uses benefit from, or are penalized by, their proximity to the freeway.

Until now the freeway and its abutting land uses have been planned independently of each other. Little relationship was developed between them because the intent of the freeway was to divorce the highway facility from abutting development. The highway designer was not concerned with land uses abutting the right-of-way when the basic intent was complete separation.

In practice, the theoretical separation of the freeway from abutting lands has not eliminated the influence of one upon the other. The freeway, by virtue of its size, separates one part of the community from another. Various designs of the freeway affect adjacent properties differently. Development that takes place around freeway interchanges can have a substantial effect on freeway operation. These and other relationships have become especially significant in urban areas.

Multidisciplinary Team Planning

A recent trend is to combine the planning efforts for the freeway and the abutting land uses so that they complement each other to the greatest degree possible. The multidisciplinary team concept of freeway corridor design and the joint development of highway rights-of-way are new trends that are receiving increasing support. These new approaches leading toward the integration of planning efforts provide major new tools to achieve compatibility between the freeway and the land uses that it serves. Separate planning has led to many of the current problems; these can now be overcome by joint planning and development of the entire corridor as a single interrelated unit. Land uses around interchange areas can be designed for compability with interchange operation and appropriate controls can be exercised to assure compatible operation.

The process of multidisciplinary team planning is intended as a means of protecting adjoining communities by minimizing disruptions created by new highway facilities. This tool is viewed largely as an urban planning device where new highway facilities are required to penetrate existing developed communities. It is an extremely valuable procedure and should ultimately become the established practice for location of new highway facilities in existing communities.

Although this approach has generally been viewed as a means of protecting the community, it is equally valid to consider this concept as a valuable tool to protect the highway by joint planning of the highway corridor and the land uses around it. Multidisciplinary team planning of the highway corridor through an urban area has many obvious advantages. It may not be as clear that joint planning of the highway corridor in suburban and exurban areas has similar advantages in protecting the future utility of the highway by avoiding development practices that will cause obsolescence.

New transportation facilities are perhaps the single largest determinant of growth patterns of the community. However, this tremendous influence has rarely been effectively used as an implementation tool to encourage desirable practices of community growth and design. Because the highway is such a tremendous influence, it can become the primary tool for guiding community growth.

It should theoretically be possible to initiate the process of area-wide planning by determining the type of community pattern desired. Then the highway location and design would serve as the primary implementation device to achieve the desired pattern. In most cases today the opposite process is at work. The highway is planned largely on the basis of engineering considerations, which are not concerned with land-use development or community patterns. The community then grows up around the highway and the entire shape of the community is governed by highway location and design.

This process can be reversed. The pattern of the community should be considered primary and the highway should then be used as the tool to achieve that objective. This type of advance planning would result in a far better community than one that happens accidentally or incidentally. It would also greatly enhance the opportunity for protecting the highway if the land uses around it were anticipated and planned for minimum interference with the utility of the highway. Current *ad hoc* procedures serve neither purpose beneficially. If the highway is integrated into the community in a preplanned manner, the community can accept the highway without suffering disruptive influences and the highway can accept the community that grows up around it without losing its initial built-in service capabilities.

Community Separation

In new areas, the wide freeway corridors have a significant influence on the pattern of the region. The wide rights-of-way act as major dividers of the metropolitan area into a series of separate entities. This huge subdivision of the urban region permits each entity to be planned as a separate identifiable community unit. In effect, each unit is surrounded by a belt of open space that restrains it from growing together with its neighbors. The separation is as positive as any such physical control as a river, ravine, or mountain.

Until now, urban development has continued to expand indefinitely with no separation or division between one community and another. The attempt to provide artificial community separations by green belts and open areas has generally been unsuccessful because there was no permanent protection of the green belt separations. The wide freeway corridor can establish the permanent divider necessary to fix the boundaries of identifiable community units. These new types of community elements can be planned as unified entities with guaranteed boundaries.

MULTIPLE-USE SYSTEMS

Shared Right-of-Way

The multiple-use public corridor expands on the concept of the permanent highway transportation corridor. It envisions a network of continuous corridors that would serve all transportation modes, as well as provide rights-of-way for many other public uses and facilities.

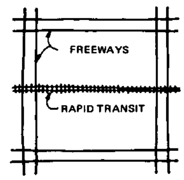
The basic premise for the multimodal corridor concept is that the common denominator for all forms of ground transportation is a controlled-access, grade-separated right-of-way. The freeways, railroads, and rapid transit lines of today, or the automated freeways, high-speed trains, or other innovative modes of the future, have protected corridors as their primary requisite. The type of vehicle, roadbed, or hardware used does not affect the need for a protected right-of-way.

The spacing of permanent multiple-use corridors depends on the spacing criteria for the various facilities contained in these corridors. Because the freeway is probably the most important single element in the corridor, freeway-spacing criteria will usually govern. Freeway spacings for urban areas have been fairly well established by previous studies, averaging about four miles in suburban areas. Freeway corridor locations are the most likely areas around which the multiple-use corridor concept can be developed, for the development of the freeway system will be the major implementing force.

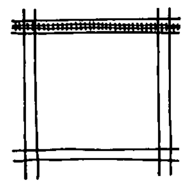
Transportation Mode Accommodation

A major criticism in the past has been that insufficient attention has been given to the potentials of other modes of transportation. Each transportation agency usually develops its own individual right-of-way independently of others, with the result that several different corridors disrupt the community in different places and at different times. The permanent multiuse corridor could provide sufficient right-of-way to accommodate all current and future modes, whether fixed-rail rapid transit, freeway bus, monorail, dual-mode vehicles, or automated individual transport. The combination of all transportation rights-of-way in a common corridor would reduce disruptions to the community and result in considerable cost savings.

From the standpoint of community planning there are often advantages in providing separate corridors for public transportation and for freeways. In areas where the community can be designed initially to incorporate all of the separate circulation corridors that will ultimately be needed, a more effective pattern may thus be achieved. However, in the normal pattern of diverse development, the multiple-use corridor concept offers a unifying influence. Inasmuch as the freeway corridor will probably be reserved in advance, the reservation of a wider corridor to accommodate other eventualities is a more likely prospect than the reservation of an additional corridor elsewhere to cover the possibility that a future public transportation system may ultimately be needed. Although not the ideal arrangement, the multiple-use corridor has many pragmatic advantages for implementation.

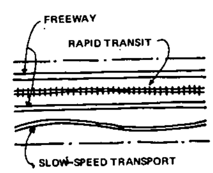


SEPARATE CORRIDORS


MULTIMODAL CORRIDOR

The combination of transportation capacities obtainable within the combined transportation rights-of-way would probably be adequate for future transportation needs. The rights-of-way could be modified and altered as necessary to keep abreast of future innovative modes by substituting one form of conveyance for another as obsolescence sets in. The primary components for most transportation systems will continue to be about the same; a roadbed, a station platform, pedestrian escalators, parking facilities, waiting rooms, etc., are common elements that will serve present and potential systems, and these will not change materially; a permanent transportation corridor with all necessary facilities would be subject to minimum obsolescence in the future.

Transportation in an urban context is normally limited to the conventional highway modes and bus and rail transit modes. It is anticipated that there will be a greater diversity of transportation modes in the future. These will include low-speed modes that until now have been unable to develop because there has been no safe right-of-way on which they could operate. Slower-speed modes could include small electric vehicles, bicycles, and other mechanical forms of transportation that could be used by younger people and elderly people who currently have no suitable means of self-mobility. There are also many recreational forms of transportation (such as horses, boats, and hiking) that could be materially promoted if appropriate continuous rights-of-way were available through an urban area.

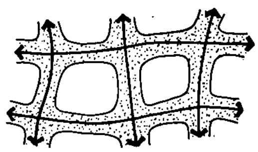


The multiple-use public corridor provides the opportunity to incorporate paved pathways, bicycle ways, equestrian trails, hiking trails, waterways and other continuous routes alongside, but buffered from, the more rapid continuous routes provided for high-speed transportation. These continuous routes could penetrate through the entire metropolitan area and provide the opportunity for low-speed mobility throughout the region for both transportation and recreational purposes which would add a new dimension to urban living.

The area immediately adjacent to the freeway may not be the ideal location for such facilities. Preferably, they should be in the interior of the community, not along the periphery. In planned communities these facilities might be located differently. However, in the usual situation where such facilities would probably not be provided at all, the continuity of the freeway right-of-way with minimum crossings offers an opportunity to incorporate these additional facilities at minimum cost, even though the location is not ideal.

Open Space and Recreation

In many urban areas today the landscaped freeway corridor is one of the very few areas that provide permanent open space through the community. The multiple-use public corridor would expand this opportunity to provide a network of open space and of recreational play and sports facilities to serve the community more effectively. The permanent corridor could vary in width to incorporate rivers, streambeds, forests, parks, playgrounds, golf courses, lakes, swimming pools, bridle trails, bikeways, hiking trails, and other facilities for sports and recreation.


REGIONAL OPEN SPACE

Utility Corridor

A common urban area problem is the need to provide utility rights-of-way for water, sewerage, drainage, gas, electricity, communications, etc. In the future there may be additional forms of communication and transportation to be accommodated, including pipelines for materials transmission and conveyers for transport of goods and commodities. The multiple-use public corridor can provide the right-of-way to accommodate some of the appurtenances needed for utilities, communication, and goods transportation where it is appropriate, minimizing the disruption of the community with other rights-of-way. The public-use corridor could incorporate some trunk line networks for utilities, reducing the number of major utility swaths cutting up communities.

Excess Land Acquisition

A new concept that has been proposed in public transportation legislation is that the excess values that accrue to land located along the perimeter of a new transportation facility should become a public asset. The appreciation of land values that accompanies a new transportation system is of such magnitude that it could pay a major portion of the cost of that transportation system.

Legislation recently under consideration for mass transportation financing provided for the transportation corridor right-of-way to include sizable amounts of excess land along the corridor, particularly around station stops, which would permit controlled development around the transportation corridor and around station stops. The increased value of such land would revert to the transportation funding system; this would pay a major share of the cost of the project. Excess land not immediately needed for transportation purposes would be developed for other uses; the increased land values would accrue to the benefit of the transportation facility that created those values.

If the concept of excess right-of-way acquisition became an accepted principle for other transportation systems, it could have great significance for highway protection. The acquisition of rights-of-way for highways could include excess property along the corridor and especially around interchanges. The ultimate purpose would be to retain control over lands that might ultimately become necessary for highway purposes. In the interim and before this land is needed for highway purposes, it could be leased back to private development with stipulations regarding land-use types, intensities, design, and other controls to protect the highway from encroachment, excessive traffic generation, inadequate access provision, and other detrimental aspects of uncontrolled development along the perimeter of the highway.

The corridor would be widened considerably in the vicinity of interchange areas because these would be prime locations for a number of facilities that would seek to locate there. The crossing with a major arterial highway would be the logical location for freeway interchange ramps, transportation stations, parking facilities, transfer areas, and many types of land use that would prefer to locate in this prime area. To accommodate the need, these interchange and interface areas would be of considerable size.

The large area that would be placed under public control at interchanges would provide the highest degree of protection for the freeway and its appurtenances. All of the facilities and uses within this area would be under public control, which would assure that the highway facility could be permanently protected from encroachment and unnecessary conflicts.

CHAPTER ELEVEN

FREEWAY INTERCHANGE CONTROL

INTERCHANGE CHARACTERISTICS

Interchange Spacing

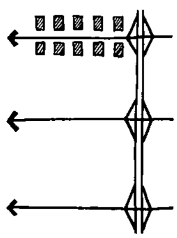
A basic characteristic of the freeway is that access is limited to infrequent locations so that there is minimum interference with high-speed traffic. To maintain the high quality of traffic flow, access opportunities are provided where sufficient traffic has been collected from tributary areas to justify the construction of access ramps. In urban areas, the capacity limitations of ramps generally determine the frequency of their spacing.

With freeways spaced at approximately four-mile intervals and with a one-mile spacing of access ramps, the arterial system will deliver to the ramps a vehicular volume that approaches the maximum limit that can be absorbed at a conventional interchange (*261*). If unusually large traffic generators are located in an area tributary to the freeway, the one-mile spacing may not be sufficient. It is then necessary to reduce the spacing between interchanges or provide specially designed interchanges that can accommodate the anticipated load.

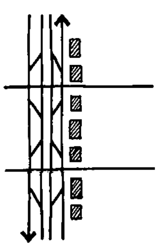
Types of Distribution

There are two primary types of distribution from a freeway to the community. One is the arterial interchange, which connects directly with a cross arterial. All freeway traffic exits into the arterial, which then distributes it to the community. A second type of distribution is provided by frontage road interchanges with ramps exiting at intervals into parallel frontage roads. Freeway traffic is thus distributed to an intermediate facility parallel to the freeway prior to its distribution perpendicular to the freeway.

The most common interchanges connect directly with cross arterials. In such interchange areas the major proportion of traffic on the arterial may constitute interchange traffic turning to or from the ramps. Other traffic components include through traffic and intercommunity traffic with no freeway destination. The concentration of traffic conflicts within the interchange area frequently makes it the most critical element of the circulation system.

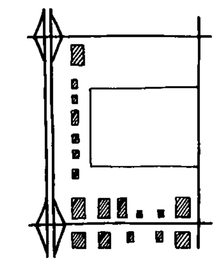


Frontage roads generally permit a wider distribution of freeway traffic than does the arterial interchange, which concentrates all freeway traffic onto the single cross arterial. The frontage road acts as a distributor that spreads the freeway traffic laterally along the freeway corridor, connecting with a number of perpendicular facilities. Distribution service is provided by all the streets that join the frontage road. There is a greater flexibility and uniformity of traffic distribution to adjoining areas.



The Arterial Interchange

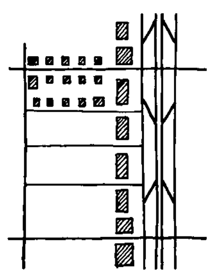
The type of freeway distribution and interchange service has a pronounced effect on land-use development patterns. Interchanges with arterial highways tend to foster ribbon development along the arterials extending out from the interchange area. The more valuable parcels are close to the interchange; this provides a relatively narrow corridor of high-value land along the arterial. The land along the freeway corridor between arterials is generally not prime property for intensive development because of indirect freeway access. Principal nodes of traffic generator concentration take place near the interchange itself, with lower-density development between interchanges.



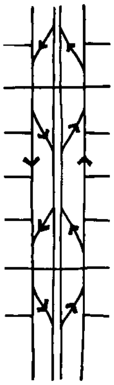
The principal pattern of development consists of a series of penetrating limbs along arterial spines perpendicular to the freeway. All traffic to and from the freeway is funneled along the arterial through the concentrated interchange areas. The arterial is required to handle freeway interchange and distribution traffic, some through traffic, access traffic to abutting high-density developments, and intracommunity traffic generated by the community around it. All of the demands for through movement, turning movement, and access movement are concentrated along the same section of arterial highway in the vicinity of the interchange.

The Frontage Road Interchange

Where there are parallel frontage roads for freeway ramp distribution, relatively equal accessibility is provided to all freeway frontage. This encourages the more uniform development of high-density land use along the freeway perimeter. Commercial, industrial, and multifamily residential development tend to be distributed along the freeway corridor rather than being concentrated along the arterials perpendicular to the freeway. With the more intense traffic generators located along the freeway perimeter, the internal areas between freeways tend to be of lower-density development. Uniform access and distribution service along the freeway corridor thus induces a more uniform distribution of traffic generators.



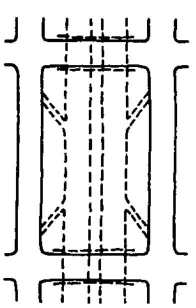
Nonfreeway through traffic uses



arterial routes. Access traffic is distributed to the frontage roads as well as to all of the cross streets. Externally oriented traffic from the freeway is generally concentrated along the frontage roads and does not penetrate into the interior because its destination lies along the freeway perimeter.

The frontage road interchange pattern reduces traffic concentrations on the cross arterial because a number of perpendicular arterial and collector facilities can be developed off the frontage roads to distribute freeway traffic. One-way frontage roads offer a higher level of capacity and service and are subject to fewer traffic conflicts and controls than two-way frontage roads.

Frontage Road Operation.—Frontage road design can provide flexibility in stage development of a freeway in undeveloped areas. In fringe areas it is often economical to build only the relatively inexpensive frontage roads initially, reserving the right-of-way between the two frontage roads for future construction of the freeway facility.



The freeway roadways, grade separations, and ramps are added as the need develops. All right-of-way is acquired at the time of initial development, and frontage to all adjacent property is provided initially, with no revision required when the freeway is constructed. During the freeway construction stage the frontage roads insulate the freeway construction area from the community on both sides.

In the operation of a frontage road system, the frontage road provides a parallel road that can serve as an overflow facility during critical or emergency periods. New freeway surveillance systems that determine when a freeway is reaching a point of critical overload permit access ramps to be closed and traffic diverted to the frontage road system to relieve critical overloads. Frontage roads also allow flexible interchange operation by permitting a spreading of the load; if one ramp is overloaded, traffic can continue to the next one and use the continuous frontage road as a connecting link. The continuous frontage road is an extension of the surface street system, reducing the barrier effect of a freeway without frontage roads.

INTERCHANGE DEVELOPMENT

Land-Use Types

The freeway interchange naturally attracts highway-oriented land uses and large-scale developments. These include shopping centers and major regional stores, manufacturing plants and industrial centers, hotels and motels, office buildings, distribution warehouses and truck terminals, bowling alleys and drive-in theaters, service stations and eating places, hospitals and churches, residential subdivisions and apartments, and trailer parks.

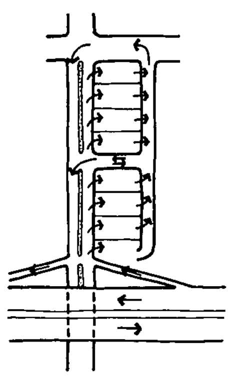
The freeway provides rapid access to a much greater area than do arterial surface streets. It collects employees from a much wider area within a reasonable commuting time; it collects customers, clients, pupils, and spectators from greater distances; it collects and distributes supplies and products over a greatly extended range. It is also an advertising channel that is visible to hundreds of thousands of persons daily. Highway-oriented land uses generally expand in scale when located along a freeway interchange.

Commercial development benefits most from a location at the freeway interchange. Some developments depend almost exclusively on freeway traffic for their patronage. The large shopping center that serves a wide region seeks an interchange location because the freeway system provides the principal access route for its patrons and employees; only a minor proportion of its trade is drawn from the community within which it is located. Industry also benefits from regional accessibility because it draws a major portion of its employees from considerable distances and trucking of goods and materials is expedited. Multi-family residential development benefits from freeway interchange locations because of increased visibility of buildings and the opportunity for advertising rental vacancies.

Rural Interchanges

Development that occurs adjacent to rural freeway interchanges is largely highway-service oriented—service stations, restaurants, motels, etc. The factors that influence development at such interchanges include visibility, accessibility, traffic volumes, distance to major urban centers, size of city served, topography, and other factors of varying degrees of influence. The ranges of traffic generation for rural interchanges are significant for such areas. However, compared to the traffic volumes generated by urban uses around freeway interchanges, these volumes are quite low.

The usual strip development of a series of private driveways, usually starting too close to the ramp terminal, can be avoided through appropriate controls and design solutions. Legal and administrative tools and design techniques can encourage cluster developments that have only one or two well-located access points. These can be controlled and interconnected, or served by a supplemental street, which can provide excellent access and avoid the usual problems of access interference.



Urban Interchanges

The most serious problems around interchanges involve large traffic generators that locate in urbanized regions. Problems of delay and interference tend to be severe in the interchange area because traffic on the cross street is building up toward the interchange and has its most dense flow patterns in the proximity of the ramps; a substantial part of that traffic is directed to the freeway or coming from it. When through traffic and local traffic are superimposed on access traffic, the advantage of accessibility to adjacent land is lost through mounting interference and congestion. The objective of planning in connection with freeway interchanges is to design interchange facilities that will serve adequately the traffic needs of the freeway, and to guide the uses of land in the vicinity of interchanges so that these highway facilities may become forces that stabilize rather than jeopardize private capital invested in this area (*243*).

Land-Use Balance

The lands that surround interchanges are separated into four separate quadrants by the freeway and the cross arterial. The objective in planning land uses in the four quadrants should be to retain this separation. Interrelated land uses, among which there is intended to be considerable interaction, should preferably be located in one quadrant of an interchange or intersection; internal movement should be made on foot. The relationships between quadrants should be minimal.

The interchange can benefit from a wide distribution of the traffic peak in both time and directional orientation. More than one quadrant can be developed to residential use, for residential traffic is not interactive and peaks are not of great intensity. Also, industries of different types may locate in adjoining quadrants if their traffic peaks do not occur at the same time and if they have no relationship to each other. Commercial developments, however, should preferably not occupy adjoining quadrants if they are interactive and have similar peak periods.

Land-Use Influences

The location and design of freeway ramp facilities can have an influence on the manner in which the entire community develops. The influences on the pattern of land-use development are felt both in the immediate vicinity of the freeway and throughout the community, for they affect the locational decisions of large traffic generators.

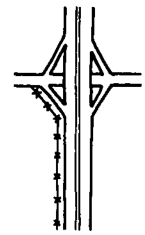
Freeway interchange design can be a powerful tool because of the influence that it exerts on the community. If the freeway is viewed solely as a transportation service facility and designed accordingly, it will still have a tremendous influence on the community, but the effects will be accidental and unplanned rather than purposeful. The alternative is to use freeway design as an implementation tool for achieving the community's planning objectives. Although it has been generally recognized that the freeway dramatically affects the immediate area through which it passes, it is not as apparent that these effects extend beyond the immediate vicinity of the freeway and embrace other aspects of community development.

INTERCHANGE PROBLEMS

Interchange Area Conflicts

The freeway was inaugurated to eliminate permanently the inherent conflict between the highway and abutting land. However, the traditional conflict between land development practices and the highway system, which was previously in greatest evidence at the intersection of arterial highways, has now been relocated to the freeway interchange area.

The primary safeguard built into the freeway is access control. The freeway facility is permanently divorced from the land that abuts it so that the conflicts of access are eliminated along the right-of-way. Access control is continued along the ramps that lead to the cross street. At the junction of the ramp with the cross street, it is customary to terminate the design characteristics of the freeway and resume the normal characteristics of the surface street. The degree of protection provided along the cross street to safeguard the traffic capacity of the interchange area is dependent on existing practices in the local jurisdiction that maintains the cross street, so that protection of the interchange varies considerably from one area to another.



Interchange Operation Interference

The needs of the freeway and of adjoining land uses conflict in the interchange area when the distribution of freeway traffic must compete with the access needs of land development around the interchange. The degree of interference varies with the geometric design of the interchange ramps, the surface street pattern in the vicinity, the access control restrictions imposed on the cross street, the location, spacing, design, and operation of access driveways, the internal circulation design within the site, the type and intensity of land-use development, the location and mix of different land uses in the vicinity of the interchange, and other relationships between the development and the abutting circulation system.

Any development that locates in the vicinity of a freeway interchange will generate traffic that requires access to the interchange; development that chooses to locate in this area wishes to attract patronage, and the potential patron desires to enter the site conveniently. The location of a development within an interchange area therefore carries with it certain expectations about access to and from the freeway and the cross street. The access movements to and from driveways conflict with interchange traffic movements and through traffic movements along the cross street. The conflicts between access movements and interchange movements are the basic source of the problem.

Development Prohibition

One obvious solution to the interchange problem is not to permit intensive development to take place in the vicinity of the interchange. Open space, parks, recreational facilities, and other low-intensity uses are occasionally located in such areas. This minimizes the amount of traffic generated in the vicinity of the interchange; access to such areas is sometimes located some distance from the interchange ramps to further minimize potential interference.

Major development that would ordinarily prefer to locate in the interchange area might be relocated to a site a short distance from the interchange without detrimental effects on the community or on potential patronage. Large-scale developments would still be visible and access needs could be satisfied with minimum interchange conflict. This is one approach to a solution; land-use controls that bar intense developments from interchange areas will usually resolve the immediate problem around the interchange.

In most cases, however, development pressures will demand a location in the immediate vicinity of the interchange because such location provides maximum visibility and exposure. The entrepreneur may not accept a more distant location and may choose to locate in some other community if a site in the immediate interchange area cannot be provided.

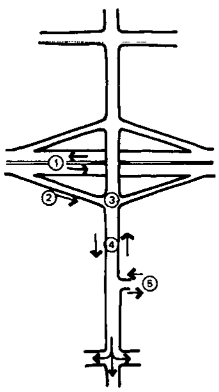
Access Location

The mere location of a development within the interchange area does not necessarily create a problem for the freeway; the problem is initiated when the development seeks access to the interchange area. For instance, if all access driveways were located a quarter-mile from the interchange ramp, the fact that the development was located within the immediate interchange area would be immaterial. Choosing the proper access locations is therefore the primary approach in resolving the typical interchange problem.

THE INTERCHANGE AREA

Interchange Components

The freeway interchange comprises a series of components in a hierarchical organization. The major element in the hierarchy is the freeway roadway itself, where through traffic movement is given preferential treatment. Second in importance is the freeway ramp, which provides access to the freeway roadways. The ramp must be kept clear of backup so that congestion does not extend into the freeway lanes. The connecting cross street is the third level in the hierarchy; the needs of traffic along the cross street must give way to the needs of interchange movements. Because most of the traffic on the cross street may be entering or leaving the freeway, through progression along the cross street is of less significance than is the progression that facilitates turning movement to and from the freeway. Last in importance are access needs of adjoining properties. This is the hierarchy of preferential treatment within the interchange area; traffic controls should facilitate movement in this order.



The first test of the adequacy of an interchange is whether its capacity is in balance with the traffic generated by the tributary area served. If the tributary area generates more freeway traffic than the interchange system can handle, there is a need for additional interchanges or for the redesign of the interchange system to handle the loads imposed.

The next task is to analyze the interchange system in greater detail to determine whether each element of the system has equal capacity. As is true of any system made up of diverse elements, a weak link in any of the components will cause system breakdown. The interchange ramp design may be unable to accommodate the traffic load that the cross highway delivers; the cross highway may be unable to absorb traffic from the interchange ramp as rapidly as the freeway delivers it to the ramp; traffic controls at the intersection of the ramp with the cross street may be inadequate to handle the load; the next major intersection beyond the interchange may have inadequate capacity and cause interchange traffic to back up. There may be inadequate distances for merging and weaving along the cross street, inadequate marginal regulation along the perimeter of the cross street, or other roadway design deficiencies that cause the system to break down. There may also be deficiencies of access or internal site capacity that cause backups into the interchange area.

Interchange Area Definition

The limits of the freeway interchange area are not subject to exact definition. The interchange area is more correctly a functional area than a specific physical area; it can be defined as that area directly affected by the existence of an interchange, particularly the localized area that has a direct influence on the operation of the freeway ramps.

One way to define the interchange area is to refer to the traffic characteristics within the area. Along the normal arterial outside an interchange, a progressive traffic signal system will set up a platoon type of traffic operation. This regular platoon operation does not exist within a freeway interchange area because of the preponderance of turning movements.

Traffic flow is rather turbulent within the interchange area; this is especially true under free-flow conditions where ramp traffic enters the cross arterial without being stopped by a traffic signal. In an urban situation this turbulence may continue until the first signalized intersection beyond the interchange ramps. At that point, traffic from the interchange distributes in three different directions and begins to assume normal arterial operation. The area between the interchange ramps and the first signalized intersection in each direction is subject to turbulence caused by merging, weaving, and crossing; special precautions must be used within this area.

The freeway interchange area can be broadly defined as the specific area around the interchange in which there is an abnormal degree of traffic turbulence. Because the full attention of the motorist is concentrated on making the proper decisions regarding his orientation, direction, turning desire, and appropriate lane, his attention should not be diverted excessively from these primary driving tasks. Additional conflicts or diversions imposed within this area complicate the driving task and increase turbulence. Access turning movements that require sudden weaving motions or blocking of lanes complicate traffic operation within the interchange area.

The extent of the interchange area can be defined as the distance from the interchange ramps that is required for traffic to resume normal operating conditions along the cross highway. At the limits of the area, all traffic has completed the necessary merging and weaving maneuvers and turbulence has ceased. This is a variable distance that depends on the interchange design, width of highway, volume and orientation of traffic, and traffic destinations.

The interchange area may be relatively short in the case of low-volume, narrow cross streets where traffic turbulence extends only a short distance beyond the ramps. In densely developed urban areas having multilane cross highways and heavily traveled interchange ramps, turbulence may be much greater under free-flow merging operation and the interchange area may extend for longer distances. Ramps carrying heavy volumes are frequently signalized so that all traffic on the cross street is halted; ramp traffic can enter the cross street and weave over to the left lane without conflict, resulting in little turbulence.

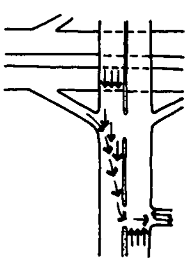
The interchange area is commonly referred to as an area within a certain "radius" of the interchange ramps. This concept can lead to a misinterpretation of the problem. The area immediately involved is along the cross highway only and is limited to the length of cross highway that is subject to turbulence. What takes place on the land along the perimeter is of consequence only with respect to land access. If access to land development abutting the interchange area is provided by some means that does not affect the operation of the interchange area, the influence of the development is not material. Protection of the interchange can therefore be redefined as protection of the cross highway within the distance designated as the interchange area.

Access Problem

The access problem can be defined as the complications created by superimposing an additional burden within the interchange area, more than that normally experienced by the traffic movements generated by the interchange ramps themselves. Access requirements within the interchange area contribute to the interchange problem if they introduce additional turning movements and points of conflict within the area. The intensity of the problem is governed by the proximity of access driveways to the interchange ramps, the number of such driveways, the intensity of development, and the peaking characteristics and directional orientation of traffic generated by the development.

The effects of access on the interchange area vary considerably with the size of development and type of access. If the traffic generated by a development is small, the effects on the interchange area may be of minor consequence. The degree of control exercised should vary with the size of the problem.

There is also a considerable difference in conflict created by left-turn movements as compared with right-turn movements. Although right turns may not have a serious influence on interchange operation, left turns can cause service failure. Left-turn access close to a ramp intersection is especially detrimental because it requires abnormally sharp weaving maneuvers and does not allow sufficient storage for left turns that can block through lanes.

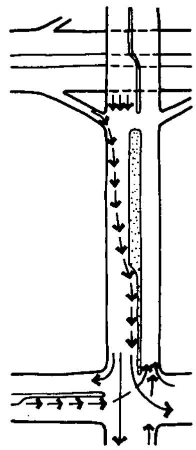


Therefore, a number of variables affect the amount of interference that access can inflict. The controls exercised within the interchange area should be in keeping with these variables.

The Critical Intersection

At arterial interchanges, the first major intersection beyond the interchange ramps is usually the most critical intersection in the system because interchange traffic has its first opportunity to distribute to the surface street system at that point. These intersections exhibit a high proportion of turning movements, usually requiring multiphase signal control and long left-turn storage lanes. Similarly, there is a large volume of turning movement into the area by traffic approaching the interchange, so that a separate left-turn phase may be required on other intersection approaches as well. The resulting multiphase signal control materially reduces the capacity and efficiency of the intersection. Beyond the intersection, the seriousness of the problem diminishes rapidly. A considerable amount of exiting interchange traffic turns off the cross street at the intersection and only a portion continues straight ahead.

The distance between the ramp and the intersection is critical, because several functions must be performed in this distance. It is a weaving section for vehicles turning right from the ramp and weaving across the road into the left lane to make a left turn at the intersection. The weaving length needed depends on whether ramp traffic merges with or stops for cross-street traffic, the volumes of cross-street traffic, and the number of lanes with which the weaving movement is in conflict. Beyond the weaving length, there must be an additional storage length for the number of vehicles turning left at the intersection. These requirements determine the minimum acceptable distance between the ramp and the intersection. Special controls are also useful in this area to minimize access friction and marginal friction.

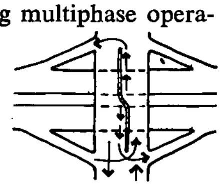


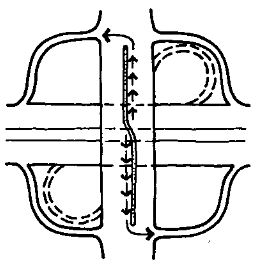
INTERCHANGE PATTERNS

The design patterns of freeway interchanges have a considerable influence on their susceptibility to service breakdowns. Some geometric patterns serve interchange traffic and abutting development better than others. The principles can be illustrated by analyzing the operation of four primary types of arterial interchange ramp design and of various forms of frontage road interchange design.

Diamond Ramp Design

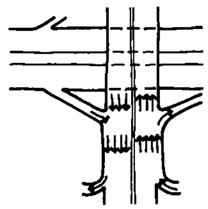
In the simple diamond interchange, on and off ramps are opposite each other, generally requiring multiphase operation when signalized. A conventional tight diamond design has limited left-turn capacity because of restricted storage and conflicts with other movements. The capacities avail-





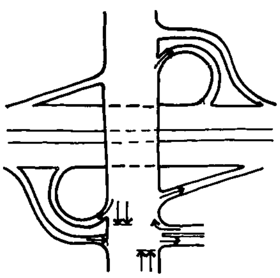
able are sometimes inadequate for heavy traffic loads generated by large developments. The capacity of the diamond interchange can be improved by spreading out the ramps, providing a greater storage distance between ramp intersections, as in the spread diamond design where land is reserved for the future addition of cloverleaf ramps in some quadrants.

In a diamond design, all interchange traffic is required to combine with cross-street traffic and is distributed by the cross street to its destination. It is necessary to provide a substantial distance between the ramp intersections and the first left-turn opportunity beyond. Right turns can be allowed much closer to the exit ramp. It is sometimes advantageous to permit a free right-turn movement from the exit ramp into the cross street and then into a development. In complementary fashion on the opposite side of the street, a free right turn from a development site into the cross street and then into the entrance ramp can increase capacity.



Partial Cloverleaf Design

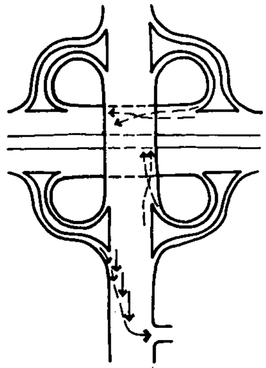
Partial cloverleaf ramp designs provide high-capacity cloverleaf ramps in those quadrants where they are needed to handle heavy interchange loads. Partial cloverleaf designs have the advantage of permitting efficient two-phase signal operation, spreading the ramp intersections to elimi-left turns from the cross street by accommodating those moves in cloverleaf ramps. With this design there is also an opportunity to locate access points directly opposite exit ramps. Major access movements can cross the highway directly and efficiently without the usual merging, weaving, and crossing. By coordinating the access requirements of interchange development with the interchange ramp system, service failures that sometimes occur with lower-capacity designs can be avoided.



Full Cloverleaf Design

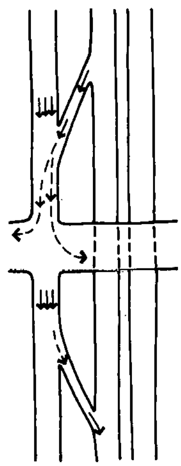
The use of cloverleafs in all four quadrants of an interchange might appear to provide the highest interchange capacity and be least subject to service failure. However, the weaving conflicts inherent in full cloverleaf design do not necessarily result in the best operation; partial cloverleaf design is frequently more satisfactory.

Full cloverleaf design also has one of the disadvantages inherent in diamond ramp design—all interchange traffic is required to enter and combine with cross-street traffic regardless of destination. In free-flow operation, those vehicles leaving the ramp that wish to negotiate a left turn find this maneuver especially difficult when traffic within the interchange area is continuous. In diamond interchange operation, traffic on the cross street is interrupted and there are gaps that permit the weaving action to take place; in free-flow cloverleaf design such gaps do not appear. To accommodate this additional problem it is necessary for left-turn access locations to occur at a greater distance from the ramps. This requirement is an additional restriction on adjoining development.



Frontage Road Ramp Design

With frontage road interchange design, slip ramps enter and leave the freeway at various points. When the frontage roads are one-way roadways, the freeway ramps merge with the frontage road. Interchange ramps generally lead into the frontage road in advance of a major cross street and enter the freeway just beyond the cross street. The exit ramp enters the frontage road on the left side under free-flow conditions and traffic must weave over to the right side to turn right at the cross street ahead. The weaving actions along the section of frontage road between the ramp junction and the cross street require the full attention of the motorist, so any additional conflicts or frictions along the perimeter of the frontage road interfere with safe operation. It is necessary to protect the frontage road in this critical section from any unnecessary marginal friction or access interference. Any stopping, loading, parking, or turning in this area seriously affects the operation of the interchange.



Along the opposite side of the frontage road leading to the on-ramp, the problem is not as serious because traffic is slower and the driver action is a diverging maneuver that is simpler than a merging and weaving maneuver. The controls on access and marginal friction on the leaving side of the interchange need not be as severe as on the entering side.

The frontage road interchange is basically a diamond interchange that leads into frontage roads instead of into a cross arterial directly. It has the deficiencies of the diamond interchange with regard to capacity limitations, with the addition of weaving conflicts along the frontage road for right-turn movements. It also has limited left-turn storage on the cross street when the frontage roads are close together. Some of these deficiencies can be alleviated with special designs. Frontage road interchange also offers some operational advantages; this design is especially applicable in locations where the deficiencies are not critical.

Arterial Interchange Comparisons

Comparing the usual types of arterial interchange design with respect to interchange capacity, freedom from weaving conflicts, and maximum flexibility of access location, the most satisfactory operation is obtainable with the partial cloverleaf design. It offers the greatest opportunity to operate efficiently with least likelihood of service failure.

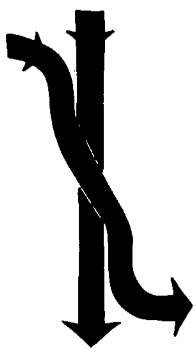
Each type of interchange design imposes different operating conditions; access design for abutting properties must be directly related to interchange design with regard to access location and type. The usual rules of thumb regarding access controls around freeway interchanges do not apply uniformly to all types of interchange designs.

INTERCHANGE ACCESS DESIGN CONSIDERATIONS

The efficiency with which developments can be served in each of the four quadrants of an interchange varies greatly with the geometric design of the interchange and with the primary directional orientation of approach traffic. Some quadrants can be served readily by certain types of interchange designs, whereas others can be served with difficulty and low efficiency. For the system to operate harmoniously, it is necessary to consider the principal directional orientation of traffic for each type of land use, the quadrant in which each land use can most effectively be located to be served efficiently, the type of interchange pattern that will best permit the service of each land use in each quadrant, and the best pattern of access design for each of these land uses.

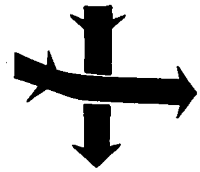
The complex relationships between interchange operation and access design can be illustrated by a typical example at a simple diamond ramp interchange. A shopping center development wishes to locate in the far-side quadrant across from the exit ramp. Access controls would commonly be extended along the cross street to prevent the location of driveways near the ramps, and some separation would be maintained between the ramps and the first permissible driveway entrance.

The operational conditions created by this typical design are very poor from the standpoint of interchange operation if the development is a major traffic generator. Vehicles exiting from the freeway that are destined for the development are required to combine with and weave across several lanes of cross-street traffic, then stop in the left lane and wait for an appropriate interval to turn into the development.



If there is considerable traffic already on the cross street and if the number of vehicles desiring access to the development is substantial, the conflicts are serious. Because left-turn capacity is limited, only a few vehicles can negotiate this turn; the remainder back up in the left lane and across the other lanes. This congestion along the cross street can extend back to the interchange ramps and cause a breakdown of the entire interchange operation.

The basic problem is that a large proportion of freeway traffic is exiting at the ramp, not to travel along the cross street, but to cross the street directly into the development. The extension of access controls along the cross street requires this major segment of interchange traffic to merge with and immediately diverge from cross-street traffic. This routing does not serve the best interests of the interchange system, the development, or the driver. For efficient operation, a major traffic stream wishing to cross another major traffic stream should be permitted to do so directly. The combining of two unrelated traffic streams into a single stream for a short distance frequently leads to service failure.

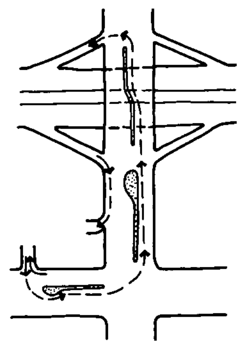


This illustration demonstrates that the simple extension of conventional access controls to cross streets in interchange areas is not a complete solution to the interchange problem. It is not applicable in all cases and can sometimes be inimical to the operation of both the interchange and the cross street.

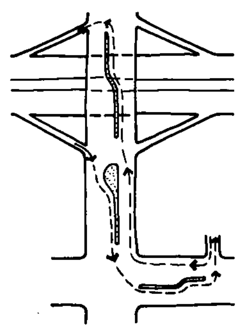
An interchange should be designed specifically to accommodate the particular sources and patterns of traffic served by that interchange. In the case of a very large traffic generator located at an interchange, that generator may be the primary source of traffic using the interchange. The objective is then to facilitate ingress and egress to that generator, which may involve a direct type of access design. Indirect access, as normally provided, may cause a breakdown in interchange operation instead of facilitating its operation.

Diamond Ramp

The quadrant location of a large traffic generator has a considerable bearing on the efficiency with which the development can be served. In the simplest case of a conventional diamond ramp system with a nearby arterial paralleling the freeway, the efficiency with which the quadrants can be served varies greatly. A development located in the near-side quadrant, adjacent to the off-ramp, is served much more readily than a comparable development in the far-side quadrant. Access traffic destined for the near-side quadrant can enter the site with convenient right turns that will accommodate almost any volume of traffic that can leave the freeway.



In contrast, traffic destined for the far-side quadrant must weave across to the left lane, make a left turn into the arterial, then turn left again into the site. The limited capacity of these maneuvers may cause access traffic to extend back into the



ramp and the freeway. A large development in the far-side quadrant can thus create congestion problems at a diamond interchange even though left-turn access controls are extended along the cross street to the first intersection.

Traffic returning to the interchange from the development has a different effect on the interchange system. From the near-side quadrant of the interchange, leaving vehicles turn left into the parallel arterial, turn left again into the cross street, and left again into the on-ramp. This series of left turns limits the leaving capacity and can cause congestion at one or more of the left-turn intersections. If congestion does occur, it will take place on the development site or on one of the surface streets, not necessarily affecting interchange operation.

Traffic leaving from the far-side quadrant negotiates a right turn out of the site, a right turn into the cross street and a left turn into the freeway ramp. The control is the left turn into the freeway ramp and any congestion will be experienced along the cross street. For both the near-side and far-side development sites, the left-turn movement into the freeway ramp is the controlling link. This is one of the deficiencies of conventional diamond interchange design.

Partial Cloverleaf

In partial cloverleaf design patterns, cloverleaf ramps are normally located in diagonally opposite quadrants, although they may be in adjacent quadrants to accommodate special conditions. The preferred pattern is one in which the cloverleaf ramps are used by vehicles entering the freeway from the cross street. Left-turn movements from the cross street into the freeway ramp are eliminated and all traffic entering the freeway flows freely at high capacities. The only signal control is for freeway exiting traffic; very high exit capacities are obtainable by increasing the number of approach lanes entering the cross street from the off-ramp.

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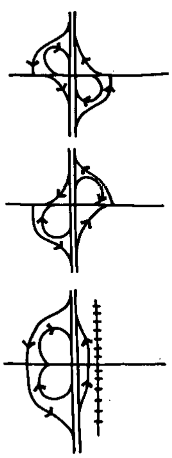
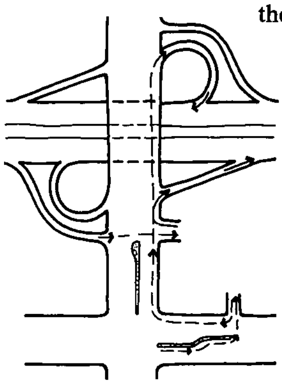
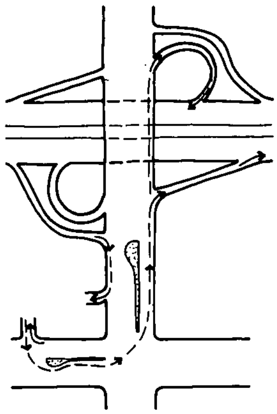
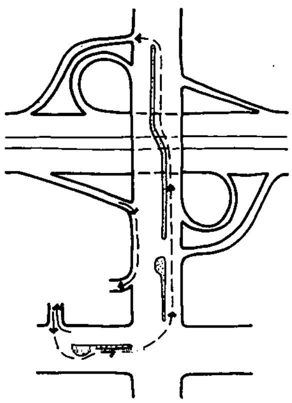


A development located in the far-side quadrant is served very readily by this type of partial cloverleaf design. If an access driveway is provided opposite the off-ramp, traffic from the freeway destined for the development can cross into the development directly. This direct entrance eliminates the problems normally associated with merging, weaving, stopping, and storage that accompany other types of interchange access design. This design will handle very high volumes if the internal site design provides sufficient acceptance capacity. Exiting vehicles turn right leaving the site and enter free-flowing on-ramps in either direction, providing very high exit flow capacities.

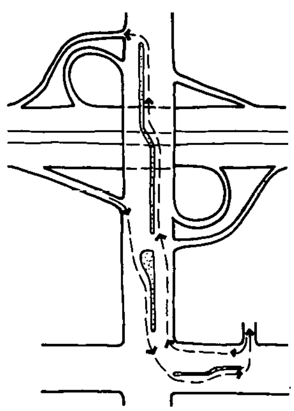


A development located in the near-side quadrant is served in the same manner as with a diamond ramp design. Vehicles leaving the freeway ramp enter the site with convenient right turns that will accommodate very high volumes of traffic. Vehicles leaving the site are required to negotiate left-turn movements into the parallel arterial and into the cross street; these movements tend to limit leaving capacities. However, both entrances to the freeway are free-flow designs without the left-turn limitation that restricts the capacity of diamond ramps.





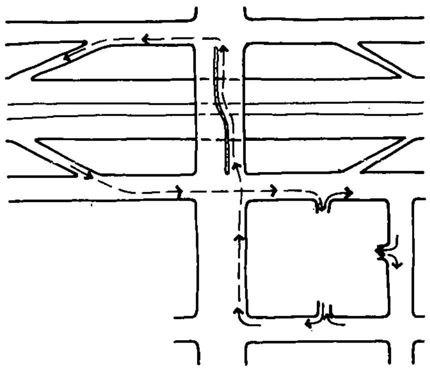
Another type of partial cloverleaf design provides the cloverleaf ramps for vehicles exiting from the freeway into the cross street. This design operates essentially like a conventional diamond interchange with regard to the access service that it provides to developments in the near-side or far-side quadrants. It does not eliminate any of the weaving conflicts or left-turn storage conflicts from the cross street and is inferior to the other type of partial cloverleaf design.



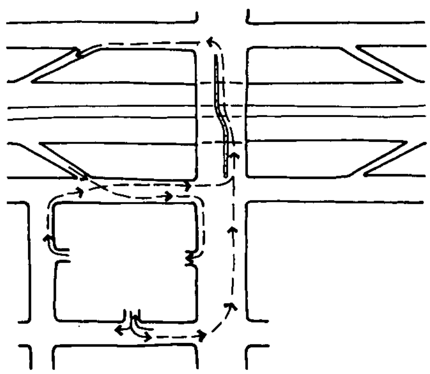
Frontage Road

When one-way frontage roads are provided on both sides of a freeway, the exit ramp enters the frontage road in advance of the cross street and the entrance ramp enters the freeway beyond the cross street. With this pattern, the opportunities for serving adjoining properties are materially enhanced. Development in the far-side quadrant can be served by a series of right-turn movements. Vehicles leaving the freeway continue straight across on the frontage road and turn right to enter the development. Vehicles leaving the development turn right around the block to return to the interchange area, then turn left into the return frontage road and entrance ramp.

To serve development in the near-side quadrant, vehicles leaving the freeway turn right to enter the development directly. Leaving traffic can exit left into the paralleling arterial, left again into the cross arterial, and left into the

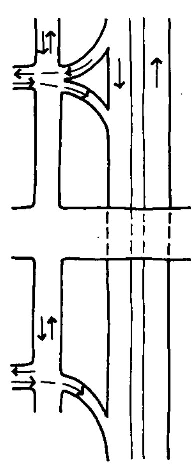


return frontage road and entrance ramp. An alternative exit pattern is a right turn into the frontage road before the off-ramp, a weave across off-ramp traffic, a left turn into the cross street, and a left again into the return frontage road and entrance ramp.



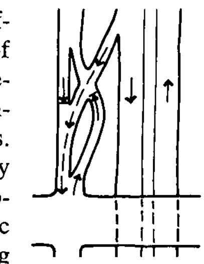
Both quadrants can be served readily with continuous frontage road design. Far-side development is served almost entirely by right-turn movements—an advantage compared with the near-side service pattern. The only limitation in this system is left-turn capacity for vehicles entering the far-side frontage road for entrance to the freeway. If this capacity is deficient, additional space is needed for a cloverleaf ramp that can provide more capacity for this movement. Access opportunities are distributed widely in frontage road design, and the stringent limitation imposed by other interchange patterns is avoided.

Buttonhook



When off- and on-ramps turn perpendicularly to create a right-angle intersection with a two-way frontage road, the resulting configuration is a buttonhook design. This design subordinates ramp traffic to frontage road traffic, requiring it to stop. Because an intersection is created, it is frequently efficient to provide a fourth leg to this intersection opposite the ramp and leading into a development site. This intersection should be far enough from the next major intersection for intersectional operations to be independently coordinated.

Buttonhook design can serve developments well in both the near- and far-side quadrants, offering relatively direct ingress and egress from the freeway. Variations on the buttonhook design include separation of the exit ramp and entrance ramp on either side of the cross street, or a combination of the entrance and exit ramp at the same intersection either before or after the cross street. Another variation of buttonhook design is possible with one-way frontage roads where the buttonhook intersection serves property access. A combination of features is possible by braiding off-ramp movement into a two-way frontage road so that ramp traffic continues without stopping, subordinating opposing frontage road movements.



Direct Access

Highway administrators have been reluctant to permit direct access from interchange ramps into large traffic generators, especially where no control is exercised over the site circulation design to prevent backup from occurring. This is also a major reason for the reluctance to consider direct-access ramps into large terminal facilities, so that vehicles can enter a parking garage directly from a freeway ramp rather than being required to mix with surface highway traffic prior to entering the garage.

Because the governmental agency usually does not exercise control over parking garage design or internal site design, the problem is side-stepped by providing a buffer between the terminus of the freeway ramps and the access drive to a garage or private development site. The greater the separation between them, the greater the safety margin. This separation is a protective device which, unfortunately, introduces many other problems of unnecessary merging, weaving, and crossing by traffic streams that should preferably not be mixed together.

It is necessary to attack the basic problem of inadequate controls over internal site design. Rigid rules of access control evade the problem and introduce other deficiencies. The access and internal circulation design for large developments that locate in the immediate vicinity of a freeway interchange should be subject to review to achieve compatibility between the interchange and the development around it.

INTERCHANGE PROTECTION

Analysis of the interchange area has revealed that its problems need to be redefined in terms of the actual influences that affect the interchange. There are a number of variables and a number of approaches to solution. Simple administrative procedures and rules of thumb can be overly or underly restrictive; they may even impose restrictions that increase the difficulties of interchange operation.

One of the problems with most interchanges is the divided responsibility for different portions of the interchange area. The state highway department assumes responsibility for the freeway and its ramps, usually terminating its interest at the junction of the ramp with the cross highway. The local jurisdiction assumes responsibility for the cross highway and for land development around the interchange. The local responsibility may be further split between different departments that are interested either in the roadway or in the land uses that abut the roadway. This divided responsibility hampers coordination of all the different elements into a single coherent interchange system.

Access Control Extension

The principal solution to interchange access problems has been the extension of access controls along the cross street beyond the ramp terminals, so as to eliminate the usual frictions of turning movements in the immediate vicinity of interchange ramps. This solution is suitable at rural interchanges and in many other situations where it can prevent the problem of access interference without introducing other more serious problems.

There is no general agreement among the states as to how far access control should extend to achieve effective results. The distances suggested vary from 100 ft to 1,500 ft (*157*). Some states provide for the extension of access control to distances up to 1,000 ft (Wisconsin, New Hampshire, and Michigan). A few permit the control to be extended for distances from 300 to 500 ft (New Jersey, Indiana, and Iowa). About ten states extend the access control feature for distances of 100 to 200 ft. Some states believe that there is no need to extend control of access beyond the right-of-way. Others approve extensions beyond the right-of-way and ramp terminals when circumstances and conditions make it necessary.

The feasibility of extending access control frequently depends on whether the cross road is a new or an existing facility. At new locations, where no access rights previously existed, no compensation is required to retain access control. However, on an existing road any change in preexisting access may be expensive.

The extension of access controls along the arterial can resolve the interchange problem in those locations where it does not aggrevate the situation by compounding merging, weaving, and left-turn conflicts or inundate the cross street with excessive traffic that could be more readily accommodated in some other manner. The distance from the interchange ramps within which access should be prohibited can be established from the definition of the interchange area. Access control is desirable within the area of traffic turbulence, which varies with interchange design type, width of highway, and volume and orientation of traffic.

Development Restriction

Some other implementation mechanisms that can be used to protect the freeway interchange are those that restrict development, such as the acquisition of property with the purpose of restricting development within the interchange area; the acquisition of development rights or easements to control development that does take place; or a temporary acquisition and resale pursuant to a development plan. In the acquisition of private adjacent areas by the public authority, contractual provisions can impose restrictions on private developers, individuals, or firms leasing the land against uses that would be incompatible with protection of the highway. Where interchange development rights or easements are obtained, the public body exercises the right only to restrict the development of the property. The right to develop the land becomes the property of the public body and the right may be sold or leased back to the landowner or to a third party according to an approved development plan.

Interchange Development Sectors

Some jurisdictions establish land-use policies and controls, such as zoning, that provide the necessary tools to maintain reasonable control over land development in interchange areas. In a growing suburban area, where there are such large amounts of vacant land that the development pattern is not yet clearly established, more general policies and guidelines may be used to provide a wide freedom of choice within certain broad limitations. Such broad guidelines are sometimes used in lieu of conventional controls, which are more specific in allocating particular land uses (Chapter Twelve).

The concept of interchange development sectors (*97*) permits the generalized area around the freeway interchange to be mapped and incorporated into the local zoning ordinance. These sectors, which may constitute areas within a radius of a quarter or half mile of the interchange, are designated as subject to significant growth potential. To regulate the development of land, criteria are established for access, density, and other development characteristics. A required part of the rezoning process can be review and approval of the site plan, which will show the proposed internal and external access and circulation system.

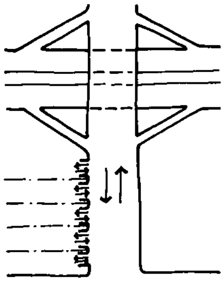
A closely related concept is the interchange development zone that has been used in some states to retain control over land in the vicinity of an interchange. The purpose is to protect the freeway from excessive traffic generation in the vicinity of the interchange, with particular emphasis on controlling the location of access and the volume of entering traffic.

Legislation to implement this concept at the state level has been attempted but has not been accepted to date (Wisconsin). Some interchange zones have been established with authority placed under the county, but the results to date have been inconclusive (California). Concepts for interchange area access design could be applied within the intent of the interchange zone concept.

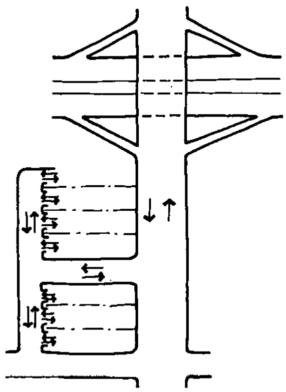
Interchange Access Design

An alternative to access control is access design—the establishment of criteria for the location and design of access. Access control tends to be a negative type of regulation; access design implies a positive attempt to resolve access problems to the benefit of the user and the highway. Access control, furthermore, requires the acquisition of access rights; in many locations the purchase of access rights can be prohibitively costly, especially when existing access must be eliminated.

Access design should provide for legitimate access needs, preferably through voluntary cooperative means. Access design along the cross street that serves a freeway interchange follows design criteria similar to those suggested along other arterials. A major difference in an interchange area, as compared with conditions along a typical arterial, is the unusual traffic movement pattern within the interchange area. The typical platoon-type operation does not prevail and the locational criteria for access driveways should be directly related to the major traffic pattern within the interchange areas.



A customary cause of service failure in an interchange area is the attempt to provide individual access driveways to a series of developments along the cross street. A solution is to combine all of the individual access requirements along a common collector facility, and to bring the collector into the cross street at appropriate locations (Chapter Nine). This is most readily achieved when the parcel is in single ownership or control. When the frontage is subdivided into many small parcels, each will desire separate access. It is therefore desirable to retain the land in relatively large holdings initially to avoid numerous access points and concentrate all access at a few select locations. Land-use controls should seek to retain this flexibility by preventing the subdivision of land near interchanges into many small parcels until adequate provision is made for combined access.

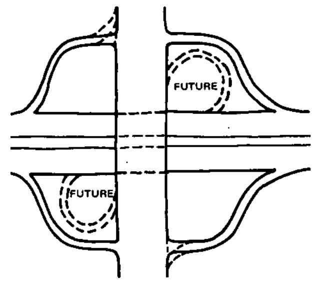


The design components that determine how effectively the freeway interchange will operate in conjunction with development access include: the relative location of access driveways with respect to the freeway ramp; the design and operation of the access driveways; the traffic controls exercised over those driveways; the development's internal design that governs the efficiency of ingress and egress; and the facility's operational practices that govern the intensity of peak loading. The design criteria for these elements are similar to those enumerated for other arterial highways, with special consideration of the unusual traffic characteristics that prevail in the interchange area.

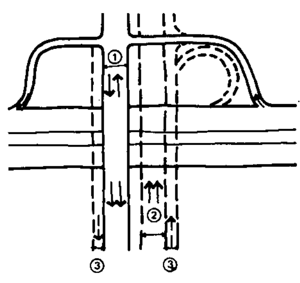
Interchange Design Flexibility

The best protection that can be provided for the interchange is a flexible design that can adapt to future needs. In most cases a freeway route is adopted in advance of land-use planning, particularly in outlying areas that are relatively undeveloped. Freeway designs are then prepared that may precede development by several years. It is difficult to anticipate the types of development that will take place around interchanges, and coordination is obviously not feasible. At this early stage it is difficult to determine whether the interchange should be of the simplest, least expensive design, or of more sophisticated design, inasmuch as the traffic needs cannot be accurately determined.

Some states have adopted a policy of flexible design that allows for future improvement of the interchange when the need develops. To provide for this high degree of design flexibility sufficient land must be acquired around the interchange so that any of the normal types of interchange design can be incorporated within the right-of-way. The interchange requiring the greatest amount of land is the full cloverleaf design, allowing free-flow interchange that eliminates all traffic signals and crossing conflicts. The simplest and least expensive type of freeway interchange is the compact diamond design allowing left turns on and off the cross street at a common intersection. The most flexible design is a spread diamond interchange, in which the diamond ramps are sufficiently far apart so that some cloverleafs can be inserted if and when the need develops. The initial diamond ramps permit left-turn movements; if cloverleaf ramps are added later, some diamond ramps are converted to right-turn-only operation. As land development takes place and traffic needs are defined, cloverleaf ramps are inserted in those quadrants that require them; they do not have to be anticipated in advance.



Another feature of flexible design involves the cross street into which the interchange ramps feed. A crossing is initially planned for the maximum probable width. Initially, a two-lane bridge may be constructed over the freeway. As cross traffic increases, a second, parallel bridge is constructed, providing two lanes in each direction. If the demand continues to grow, an additional third lane in each direction can be provided without major reconstruction of the interchange. Sufficient right-of-way is acquired initially to make this phased construction possible.



Another important consideration in design flexibility is the freedom with which modifications in interchange capacity can be made. If a cross street underpasses the freeway it is difficult to justify a six-lane underpass that might ultimately be needed when only two lanes are needed in the foreseeable future. To widen an underpass is a major and costly undertaking. With an overcrossing of the freeway it is far simpler to add additional lanes.

CHAPTER TWELVE

LAND-USE CONTROLS

LAND-USE REGULATION

The two principal devices to protect highway utility are: design controls that can be implemented by the highway agency within the public right-of-way, and land-use controls that regulate the private use of land around the highway right-of-way. The previous sections deal with intrinsic controls that can be incorporated into the highway design so that the highway can achieve maximum built-in protection. Methods are also developed to relate land development practices and site design to highway design controls and criteria. The implementation of these practices and relationships through land-use control techniques constitutes the second major area of control.

The tool used in the control of land use can encourage desirable development practices, regulate the type and intensity of land use, regulate site access and design, and control other facets of land use that have an influence on the highway. The institution of appropriate land-use controls is effective only if some degree of stability is achieved to assure that such controls are not subject to constant manipulation and change. The stability of land-use controls is therefore of considerable consequence with relation to highway utility. An analysis of available land-use controls, land-use stability, and current development practices as they relate to highway utility will offer additional guidelines for land-use regulation.

Current Land-Use Controls

The primary instruments for land-use control have been zoning ordinances and land subdivision regulations. These legal devices are police power enactments of the local government having jurisdiction over the area. They have been tested in the courts and found to be enforceable without compensation to the affected land owner. The state does not take the property from the owner but merely regulates its use on behalf of the public welfare; the owner retains the property. Police powers allow for consideration of special local needs; and the cost is only that of administration. A basic disadvantage is their potential instability; in many communities their application is subject to considerable variance as both political and economic pressures develop.

Zoning Control

The original intent of zoning legislation was to regulate potential nuisances and hazards. Activities that were offensive or dangerous to community residents were restricted on an individual basis and in certain locations. This was later broadened to cover not only the nature of a specific use but also the relationship between uses, by prohibiting certain types of activities within a particular distance of other land uses. Zoning legislation was intended to lessen street congestion, to ensure safety from fire and other dangers, to promote health and general welfare, to provide adequate light and air, to prevent overcrowding of land, to avoid undue concentration of population, to facilitate adequate provision of transportation, water, sewerage, schools, and parks, and to meet other public requirements.

Confirmation of the legality of zoning occurred in 1926 when a landmark case came before the U.S. Supreme Court (*297*). The Court's decision established zoning as a tool for land-use control by ruling that zoning was an exercise of the police power. This opinion stated: "The primary objective of modern zoning under the police power is to lessen or prevent those private uses of land which, if allowed, would depreciate the value of all surrounding land through practical restriction of its usefulness." This decision established the premise that the concept of a police power has a positive aspect enabling the community to act before private land use injures its public interest. Zoning is a legislative act and its validity depends on its reasonableness; it is valid only if asserted for the public welfare. This was a change from the foregoing rules, which were based on public menace. This court decision caused zoning ordinances to become the major land-use control device. Zoning has been vastly expanded since that time to cover incompatibility, nuisances, public health, safety, welfare, and other influences.

Zoning is actually an uncommon device in many areas of the U.S. The Bureau of Public Roads reported in 1964 (*321*) that only 17 percent of all the counties in the United States had adopted zoning ordinances. A sizable number of those that had zoning ordinances did not have planning staffs to carry out the objectives of the ordinances. Although many areas of the country have no land-use controls, most metropolitan areas, in which problems of growth are significant, are regulated by land-use controls. The traditional subject matter of zoning ordinances are land use, height and bulk, and density standards, but the trend is toward inclusion of a wider variety of such items as locational features, parking arrangements, detailed land-use standards, and provisions for special problem areas.

Subdivision Control

The subdivision and development of land intensifies the use of that land, generates more traffic, and creates new problems for the community. Regulation of the subdivision process ensures a satisfactory relationship between the subdivision layout and the abutting highways. Regulation assures a rational pattern of streets in new areas through controls on street alignments and width, roadway design and construction, lot size and configuration, water supply, sewerage, drainage, and grading. This device also controls the points of access to the highway.

Eminent Domain

Eminent domain is the taking of land for a public purpose involving actual acquisition by the governmental agency, the owner being appropriately compensated for the land. This is a very expensive type of land-use control and extensive use of this method would be economically infeasible. However, eminent domain procedures are applicable in the acquisition of highway right-of-way where direct purchase, excess condemnation, lease-back, acquisition of development or conservation easements, and acquisition of access rights are necessary for the acquisition or protection of rights-of-way.

Public Ownership

Public ownership of land permits the public agency to exercise full control over its use. Master planning in Europe was made possible largely by public land ownership, which permitted the community to plan its physical, economic, and social development well in advance of need. Given public ownership of undeveloped land, the timing, kind, and pattern of development can be strictly controlled. Increases in value that result from public improvements in facilities that serve the land are recouped by the agency that installed the improvements. When development is appropriate, the government may sell the land subject to covenants that control its use, lease the land for specific development, or develop the land itself.

Private Restrictive Covenants

Another method of land-use control is by private restrictive covenants placed in deeds at the time of development. Houston, Texas, is the most prominent example of such controls exercised privately in a large city where zoning is not used as in other cities. Development is subject to private restrictions similar to the regulations customarily found in zoning ordinances.

The City's major thoroughfare plan sets patterns for urban growth. Development naturally follows the roadway system, and economics dictate the separation of different land uses. Commercial and industrial development tend to cling to the main arteries, whereas residential development tends to be developed in the interior between arteries. Economic factors normally determine where different types of growth take place.

Requirements set minimum lot size, road widths, and other circulation elements. Protective covenants specify use, size, type and number of buildings, and setback. Control over building permits offers one implementation device to enforce the deed restrictions.

Although Houston has many of the protective devices that characterize zoning, there remain some defects that zoning has prevented in other cities—undersized lots, alley dwellings, residential over-building, some indiscriminate mixtures of different land uses, and a proliferation of signs and billboards (*30*).

Other Controls

Other police powers available to the community for controlling land use include the mapped-streets ordinance, licenses and permits, setback and building lines regulations. The mapped-streets ordinance prevents development in the officially designated paths of present and future streets, usually by holding off such development temporarily, pending acquisition of the land needed for the street by the public agency. When a legislative body has filed a map of future public streets, landowners may not obtain permits to build on areas within the platted rights-of-way, usually for a certain period of time. Uses of this device include the fixing of building lines, the platting of streets, the protection of future street rights-of-way from building encroachments, and the fixing of precise locations for utility lines. Licenses and permits allow the agency to regulate the location and design of driveways. Regulations requiring setback of building lines reserve land for future roadway widening.

Other possible controls include contractual agreements, which may or may not involve direct money transfers. These are sometimes entered into by highway departments to minimize adverse development of land. Another technique is the Doctrine of Nuisance Law, which relies on legal interpretation to prevent or eliminate land uses that damage the highway. Use of these devices is rare.

In addition to these regulations, land use is also affected and regulated by other instruments and ordinances of local government, including the comprehensive plan, the capital improvements program, urban renewal programs, building and housing codes, licensing ordinances, health regulations, air pollution ordinances, tax and assessment policies, and local decisions on highways, schools, sewers, and other facilities. In recent years, variations on these basic instruments of regulation have been devised. One of these is the planned unit development, a hybrid of zoning, subdivision regulation, and design control.

ZONING TRENDS

Evolution of Zoning Control

The history of land use and of zoning illustrates that the patterns of land use and of controls have changed considerably since the 1920's. Originally, urban development was fine-textured and had intermingled uses; this was the result of natural development without control. Laws were then passed to exclude nuisances, each nuisance being covered by a different law. This culminated in the comprehensive zoning ordinance in the late twenties.

As the urbanization process continued, a coarser grain of development became apparent. This was the period of accumulative, or pyramidal, zoning, which is structured so that one use is found primarily in one particular zone. Less restrictive zones allow more restrictive land uses to enter (a multifamily zone may include single-family development; industrial zones may include all uses).

Subsequent court cases held that more restrictive uses were incompatible with less restrictive zones (single-family dwellings in industrial zones). The result was exclusive-use zoning, where only one class of use was allowed in each zone, with no mixing of uses. An ever coarser grain of city texture resulted, representing the high point of land-use separation. In cities large areas, often oversized and unrealistic, were set aside for specific uses. Existing land uses located in the wrong zone were given special variances and, to expedite their relocation, improvements were discouraged.

Heavy industry and other objectionable uses, which could pollute the atmosphere, emit excessive noise and vibration, or otherwise degrade the environment, were segregated in special areas where their objectionable features would have a minimum effect on the remainder of the community. Commercial developments were categorized by types and sizes and confined to specialized areas corresponding to their service and environmental characteristics. Separation was extended to different densities of residential development to create homogeneous areas within which all residences were of similar size.

Zoning generally has a creditable record in accomplishing limited objectives. However, there are some problem areas. Because of looseness in the interpretation of reasonable flexibility, inappropriate uses are sometimes introduced by means of the legal devices of variance, exception, and amendment. There is often speculative overzoning for particular uses for which there is no market.

Local Interests

The power to zone resides with the local authority and the interest such an authority represents is the local interest. Local interests may be considerably different from regional interests or statewide interests. The interests of the taxpayers of that community may be at variance with the interests of motorists at large or with the citizens of the region affected by land-use changes.

Considering the competition between communities to attract specific types of land uses, the benefits that a city perceives as resulting from a particular land use may vastly outweigh the disadvantages that might accrue to the region. It may be to the municipality's immediate financial benefit to permit intensive land uses in areas adjacent to a highway; but the burden of sharing the costs of traffic congestion is borne by all persons using the highway, including the people of other municipalities that do not share in the benefits. The over-all cost to the region resulting from particular land-use decisions can be evaluated, but only the local community has the power to zone or enforce zoning; the over-all interest is not represented in the decision-making process. A more enlightened community will attempt to take these other viewpoints into consideration, but local interests are frequently very compelling.

The problems of conflict between local and regional interests in land-use regulation are comparable to the problens encountered in other areas of conflicting interests. Some authorities suggest the transfer of certain of the larger land-use controls to a regional authority, leaving some of the more detailed determinations with the local community. This would permit the rational planning of those elements that are of regional concern. These matters must ultimately be decided by a resolution of the larger controversy—the respective roles of metropolitan government versus local government. Perhaps a combination of the two might ultimately be achieved.

Some states attempt to provide guidance to local jurisdictions in matters that affect state highways. Others have sought to obtain the zoning power around freeway interchanges and state highways to exercise firmer controls in protecting the utility of the highway (Wisconsin). However, the question of state control of land use is a highly controversial one; most states attempt to avoid such controls at the state level and favor the strengthening of local land-use controls instead.

Changing Needs

Current zoning ordinances are appropriate for regulating construction in built-up communities, so as to prevent injury to one lot through misuse of an adjoining lot. However, much of the urban growth today takes place in larger units; the regulating of urban development on a lot-by-lot basis may not be the most appropriate device for present purposes.

Since the inception of zoning, emphasis in application has taken on a new and subtle difference. Initially, land-use controls were viewed as preventive measures to combat potential nuisance. As a police power, they were intended to prevent damage to public health, welfare, and safety, and were basically a negative device involving prohibitory characteristics.

More recently, applications of zoning have attempted to take a positive approach. The zoning plan, which is intended to implement the general plan, represents a positive device to achieve specified community objectives. Zoning has begun to assume programming characteristics that seek to lead toward a particular objective in a positive manner. Zoning has therefore extended its role over the years to include both negative and positive applications.

In the future it may be expected that greater use will be made of the positive role that it can play in implementing desirable objectives, for the former nuisance factors have gradually diminished; the emphasis will tend more in the direction of achieving positive values and providing greater quality control over the environment.

THE GENERAL PLAN

Plan Objectives

In recent years many communities have developed a general plan for growth and change, which is intended to guide changes in the zoning plan. The general plan is a schematic illustration showing where different types of land use should ultimately be located. Ideally, the plan locates land uses based partially on a program developed in an economic analysis, which establishes the quantities and intensities of each type of use that appears to be marketable within a given period of time.

The general land-use plan specifies the approximate locations of various land uses but does not necessarily locate them exactly. The intent is to leave some degree of flexibility in their location so that no landowner has a monopoly that would lead to excessive land costs. The general plan is thus not intended as a precise document, but as a guide to the community illustrating how the land uses can be distributed to serve the best interests of the community. Neither is it intended as a final document; it must be reassessed and adjusted continually as economic patterns change and as community goals change.

The Zoning Ordinance

The zoning ordinance is the principal legal device to implement the general plan and carry out its objectives. Where the general plan is only a generalized illustration, the zoning plan specifies the use of each parcel of property.

Zoning covers a shorter time span than does the general plan; it is intended to be modified over time to approach the land-use objectives expressed in the general plan. As proposals are made for rezoning, the general plan provides the community with long-range goals against which the request for zoning change can be evaluated. If the change is in accordance with the general plan, the rezoning presumably adheres to the community's long-range objectives and should be approved. If the rezoning proposal conflicts with the intent of the general plan, the request should theoretically be refused.

The zoning plan and the general plan are different in their time horizons, in their legal status, in the degree of specifics, and in the manner of intended use. Unless the general plan represents the community's realistic objectives and is consulted during the course of zone change applications, it does not serve its intended purpose and becomes useless. If the zoning plan has no model for the future against which it can be compared, it becomes largely a mirror of the status quo and is subject to political manipulation.

The most serious deviation of land-use regulation from its original intent is in its relation to the general plan. The standard zoning enabling act states that land-use regulations shall be made in accordance with the general plan. The failure to follow the general plan in zoning is a serious failing of the political process. Municipalities continue to amend land-use controls on an *ad hoc* basis without clear, long-range, community development concepts in mind.

Conformance of land-use controls to the general plan varies in different states. Some states require all zoning changes to conform to the general plan (Virginia). Other states are very loose in their requirements, making it desirable but not mandatory. A strengthening of state legislation to require zoning changes to conform to the general plan can be effective in reinstituting meaningful land-use controls, governed by over-all planning concepts.

Unfortunately, many officials and members of the public view the zoning ordinance as a device for protecting individual property rights rather than for carrying out a public policy or plan. One possible solution is to require prior adoption of a general plan, with the zoning ordinance related to the general concepts in the plan. Each zoning change can then be tested as to conformance with the plan prior to approval. This will be feasible only when the general plan is realistic and current. Zoning and the general plan will become more compatible in the future as community objectives are better defined and reflected in the plan.

NEW LAND-USE CONTROLS

Planned Unit Development

New concepts in land-use controls are now being introduced that are reversing the trend toward exclusiveness that formerly prevailed in zoning practices. The planned unit development zone (PUD) is one of the latest concepts that is finding acceptance in some cities. It allows a limited mixture of uses to make an area more livable. A planned unit development allows the developer some flexibility to intermix certain types of development that were formerly kept separate. It also permits various methods of instituting population density controls that are less rigid than were earlier controls.

This is the type of regulatory device that will control some of the land use in newly developed areas in the future. It places great emphasis on design to a large scale, and raises the concept of zoning to one of comprehensive land development controls.

Performance Standard Zoning

Another new concept that has begun to assert an influence on zoning practices is performance standard zoning, which is applied primarily to industrial zoning. The practice in the past was to separate different categories of industrial use according to the degree of nuisance—light industrial, medium industrial, heavy industrial. This type of categorization was valid when the relative nuisance of a particular industry could be categorized. This changed when some industries succeeded in decreasing their nuisance factor by changes in manufacturing processes and operations. Technology has succeeded in upgrading some industrial operations so that these plants no longer represent a nuisance to their environments.

The new basis for evaluation is a performance standard that defines levels of operation not constituting a significant nuisance. If a particular operation meets these rigid performance standards it need no longer be confined to restricted industrial zones but can be distributed in other areas where compatibility can be demonstrated.

With these concepts zoning is returning somewhat to a modified pattern of intermingled uses. There is one major difference, however—the control of environmental quality through technology and design expertise. When zoning was first instituted, technology was unable to provide the control of nuisances; it was more expedient to separate antagonistic elements. The transportation revolution caused by the automobile, also in the making at that time, accommodated the separation of land uses. Today the technology is available to permit some previously incompatible land uses to locate in proximity to each other, with neither suffering from the effects of the other.

The objective of zoning is to permit the quality and character of an environment to be maintained without sacrifice. This was also the objective in the first zoning ordinance, which provided protection for the single-family residential area; but to preserve the quality of environment there was a sacrifice in utility, convenience, and community character. With the technological and design tools now available, better environments are achievable without arbitrary separation. The trend to planned unit development and performance standard zoning appears to be a logical progression to a freer pattern of controls that will better serve the community of the future.

Precise Plot Plan

Zoning is effective in regulating the type and intensity of land-use development. However, many of the design aspects of development that have the greatest influence on the highway are not controlled in the zoning process. The location of access, design of access, frequency of access, internal site circulation, and other site design relationships that affect the highway are not normally governed by the zoning ordinance.

The precise plot plan is an implementation tool that makes it possible to control the relationships between land-use development and the abutting highway to a much greater degree. The precise plot plan is currently used in some communities, authorized by state legislation; in many states new legislation would be required to permit the application of this device. Basically, the requirement is that a precise plot plan be submitted to the local agency for approval as a condition of zoning. The intent is to give the agency an opportunity to review all of the access and circulation provisions on the site to determine whether these are consistent with the needs of abutting highways.

The plan review requirement is a potent device that should be exercised with care to avoid excessive or unnecessary controls that could inhibit development unnecessarily. To be acceptable, this type of control should be coupled with principles and criteria that clearly establish the objectives of the plan review and the elements and measures of adequacy to be reviewed.

The principal application for the precise plot plan review is in conjunction with more intensive development types whose influence on the highway is significant. It applies particularly to development along arterials where the greatest conflicts take place.

Development Sector

Prezoning in advance of development has sometimes failed when it has relied on overly rigid mapping that did not allow flexibility for change. If the zoning designation is premature, pressures for rezoning arise as development nears. Because the zoning is usually not tied to commitments for development, higher-intensity zoning is frequently speculative to boost land values. Higher land values then make that land more difficult to sell and may keep the land from being developed. This leads to new pressures for rezoning of other, less expensive land for development.

A new flexible concept of land-use control has been suggested for fringe areas that will become developed in the future (*97*). The development sector approach proposes a planning and policy framework that accommodates and guides the process of change. Development sectors are undeveloped areas designated for land uses of similar density where rezoning is allowed if explicit site plan and performance standards are met. A wide range of site and location choices is available. The sector does not fix the actual location of land uses. A maximum private choice is allowed as long as it is not detrimental to the community or to surrounding private development.

Application of the development sector concept includes a plan that identifies development sectors for high- and low-density uses for those areas where development cannot be detailed in advance. The dominant criterion for high-density use is access to high-speed transportation, such as freeways. The controls exercised over land use are similar to those used for planned unit developments and cluster developments. There are written locational criteria and performance standards with requirements for site plan review as part of the rezoning process.

Planning Controls

A recent trend in planning that is responsive to roadside control of development is the granting of authority for administrative control of development along existing and proposed roads and streets. Any building permit issued for a structure along a major arterial is referred to the agency responsible for the arterial for report and approval. This approval may be given subject to stated conditions with reference to driveways or other means of access. Analysis takes into consideration the character of development proposed, the traffic it will generate, the effect of such traffic on the street system, the design and frequency of access, and the extent to which such development may impair the safety and traffic-carrying capability of the arterial. Such control measures can be used to require adequate access for adjacent development and to encourage access provisions from other streets rather than directly from the arterial.

Contract Zoning

Some rezoning is done for speculative reasons, with no intent to develop but rather to increase the land value for resale. Speculative zoning leads to unrealistic quantities of land that have been artificially elevated in price, but remain undeveloped indefinitely.

Current attempts to institute realism in land-use controls are using a new technique of contract or temporary zoning. A change in zone is authorized for a specific period of time if it is accordance with the general plan. If construction is not commenced and prosecuted diligently during that period of time, the new zoning is invalidated and the property reverts to its previous classification.

The practice of contract zoning promotes the welfare of an area by permitting development to take place in accordance with market needs. It provides maximum opportunities for entrepreneurial flexibility by retaining some fluidity in land-use controls to accommodate realistic situations as they occur.

LAND-USE STABILITY

Changing Philosophies of Zoning Control

Zoning principles and practices have undergone many changes in the past 40 years. The philosophies of zoning control have evolved—from minimal control to selective control, to accumulative zoning, to exclusive zoning, to the latest concepts of planned unit development and performance standard zoning. The grouping of land uses has evolved from the extreme of completely intermingled uses to the other extreme of exclusive use zones. There are now signs of a reversal to some intermingled uses. The pattern and texture of land uses has evolved from a fine texture to an extremely coarse texture and is now returning to a finer texture. The reversal in the trend has started only recently, so that most current development patterns still exhibit the results of the exclusive zone concept; it will take many years before the latest practices are reflected in physical changes in the community.

The history of zoning practices illustrates the processes of change that are constantly taking place. Each change in philosophy is reflected in a change in practices, which ultimately becomes apparent in physical changes in the community. Change, rather than stability, appears to have been the trend in the past. It would be presumptuous to assume that the most recent zoning philosophies and concepts will be retained permanently in the future. More likely, new concepts will, in their turn, replace previous methods.

Land-Use Evolution

The process of evolution is experienced in land-use controls as in all other aspects of urban advancement. Stability of land-use controls implies that land uses can be fixed according to some optimum or ultimate master plan concept that is permanent and final. Previous experience has indicated that no plan can be considered as final; reevaluation is constantly under way to fit the land into the evolutionary development of the urban area of which it is a part.

The environment of urbanized communities is in a state of continual change. To cope with this change and to keep the environment from decaying, communities are continually developing and redeveloping, planning and replanning. Therefore, land-use stability is essentially an unattainable goal in a growing and developing society.

Zoning Limitations

The limitations of zoning in a growing community are expressed by many authorities who emphasize that land use is dynamic, constantly changing, and subject to continual review. Zoning is not long-run but is an attempt to stabilize economic influences for successive short runs. Controls on land must apply to a realistic situation and must keep pace with change.

Studies have indicated that in some areas 80 to 90 percent of the requests are granted for rezoning, exceptions, special use permits, etc. (*312*). Most of these requests involve a change from a more restrictive to a less restrictive category. However, the large proportion of requests granted may not be as significant as it appears; many of the changes affect only a minor portion of zoned land.

Stable Land-Use Controls

There are some instances in which stable land-use controls have been attained. The prime examples are in Europe, where some countries exercise effective control over land development. In many such cases this is attributable to public ownership of the land, which permits master plans to be developed and implemented. Governments in these countries exercise considerably more power than does the U.S. Government and firm control is retained over land-use development. Many new towns are constructed by governmental agencies.

In the United States, that degree of control would be difficult to exercise. Economic and political pressures, as well as changing community objectives, alter various plans; in fact, much planning is based on a degree of flexibility that can accommodate dynamic change.

True stability of controls is obtainable in areas where no appreciable growth is taking place. Land-use controls in these areas generally reflect the status quo stability. In most of the larger metropolitan areas, change is taking place; these are the places where problems of instability are experienced.

Unrealistic Land-Use Goals

Land-use controls are ineffective as a means of implementing community objectives if the goals are not attainable. For example, many communities reserve substantial parcels of land for industry when there is no foreseeable market for such land. The land may lie fallow for decades while pressures mount for rezoning to uses that can be readily marketed. Land-use controls that reflect community aspirations rather than realistic economic potential illustrate this lack of realism in some zoning practices.

Land-use controls that adhere rigidly to older criteria, rather than reflecting a viable and dynamic economy, may break down. The development of new highway facilities such as freeways opens up new commercial opportunities on larger, less expensive, and more accessible tracts of land. These new areas can be developed according to modern design standards in a superior environment. Although the community may theoretically have sufficient land already zoned for commercial use to accommodate anticipated future demands, the locations may be obsolete for modern, large-scale commercial development. Multiplicity of ownership and difficulties of land assembly also inhibit new development in older areas. Current land-use controls may be stable and represent community objectives as they were perceived when the plan was developed, but they may no longer reflect economic reality.

Community Competition

Prior to decentralization a city was a well-defined entity with a single central business district and an established trade area. Any commercial development that wished to serve that trade area had to locate in the central business district. With the growth of suburbia and decentralization of large-scale commercial development, a new freedom of location has resulted. The entrepreneur now has a wide choice of locations available within a large geographic area. He generally seeks a prominent location adjoining a major highway facility, on relatively low-cost land that has good accessibility to the market area that he wishes to serve. Locational alternatives that meet these criteria may lie in several different suburban communities. To obtain the sales tax and employment advantages, each community is in competition for the development; the larger the development, the more desirable it is to the community.

The same phenomenon is observable in the case of industrial development. Industry provides a solid tax base from which the community derives substantial support. Most communities offer major incentives to attract industry; these may be tax incentives or other concessions. In major decisions where large developments are at stake (where the influence on the highway system is especially critical), over-all community needs are the principal determinant.

Economic Controls

A major control over the use of land is economic. There is a balance maintained among different types of land use by economic determinants that establish how much of each type of use can be supported in a given market. A land-use plan or zoning ordinance should be in general accord with economic needs.

The total quantity of each type of land use that appears to be justified in a given section of the community can be predicted by economic analysis based on the market evaluation at a particular time. However, the demands for certain uses may change over time; the land-use plan and the controls that seek to implement that plan must be adjusted periodically to comply with current economic reality.

Economic obsolescence is a major determinant of changing land-use needs; it is just as significant as physical obsolescence. The succession of land-use cycle changes that takes place in rapidly growing communities is a phase of economic obsolescence. Intensification of use of land is part of the evolution of a growing urban area. Land-use controls can foster some degree of stability by damping rapid changes in land use, but they cannot radically change economic reality in a normal competitive situation. When there is an oversupply of a particular land use, some development will fail, and the use will tend to change to fit the demands of the community. When there is an undersupply of a particular land use, economic pressures may cause a change in the controls to meet the demand.

This continual balancing of supply and demand is not only quantitative but also qualitative. There may be enough total land allocated to a particular land use, but the market demand may call for a higher quality of development than is obtainable from the land currently allocated. This demand may require that another location be developed for that use regardless of the availability of land for such development in the less desirable location.

Cost of land is another factor that can upset land-use controls. Land zoned for a particular use may realize an artificial rise in value as a result of its allocation for a type of development that yields a higher return. Speculative increases in the value of such land may make it impossible for development to take place, and the land may remain fallow. Pressures may then overcome existing controls because those controls seek to safeguard an unworkable status quo.

Even in consideration of these unstabilizing influences, land-use controls can be relatively stable over a limited period of time if based on economic reality. The amount of each type of land use and the intensity of each use can be predicted within certain limits, based on population and economic trends. These predictions are fairly reliable with respect to the quantity of each type of development within a given area. However, the specific locations for each type of development may be subject to variation. The allocation of land uses by location is the function of the land-use plan.

Future Stability

During the past decade large-scale transportation studies, which were necessarily based on land-use studies, initiated a new era both in land use and in transportation planning. The availability of large sums for planning purposes, and the high level of interest in planning programs, is expected to continue. Future land-use plans will be far more reliable and realistic than those of the past and will have a sounder basis in economic reality.

With a sound land-use plan as a base, it should be possible for the community to maintain land-use controls that are as realistic as the general plan they seek to implement. If the controls are based on sound economic and planning criteria, they will anticipate the market rather than follow it. There should then be less need for control changes.

This trend does not necessarily signify that the future will be more stable than the past. It signifies that the need for change will be evaluated at periodic intervals; the land-use plan and controls to implement that plan will be updated regularly to keep pace with changing requirements. The controls will continue to change, but in an incremental and predictable manner based on factual evidence.

Although the tools and the funds will be available to improve the entire process of land-use regulation, not all communities will take advantage of them to develop realistic land-use plans and controls. Whether the community chooses to do so is a local decision. The effectiveness with which each community carries out its responsibilities is dependent on local initiative and the will to use the facilities available.

LAND-USE CONTROL IMPLEMENTATION

Community Obligations

Land-use control decisions by the community carry with them certain concomitant obligations that the community must be prepared to assume. The traffic control changes and highway improvements needed to accommodate a particular land-use change should theoretically be provided for concurrently with the change in land use, or an imbalance will be created.

When additional capacity is needed to accommodate the new land use, it is frequently possible to upgrade and improve traffic capacity by more effective traffic control measures and restrictions. Such restrictive devices may have more than local consequences, affecting other property owners and other segments of the community. These traffic control changes must accompany land-use control decisions; their effects should be evaluated during the decision-making process. When the decision is made the community should be prepared to institute these changes.

If more effective traffic control measures cannot accommodate the additional traffic generation, then additional highway improvements become necessary. Widening of existing facilities, construction of a new highway facility, or even construction of a new freeway route may be necessary concomitants of the land-use decision. There is some obligation to reinstate a balance between new land-use needs and transportation facilities.

Administrative Needs

The pattern of concentration of new development in the fringe areas incurs certain dangers as well as opportunities. Unfortunately many of these fringe areas do not have professional technical staffs or experienced administrators who are familiar with the problems and techniques of urban development. With limited staffs they can satisfy only minimum requirements dictated by considerations of safety and essential services. Even if there are appropriate principles and guidelines to guide this new growth and to prevent some of the anticipated problems from occurring, the governmental structure to carry out an effective program may be unavailable. Administration and implementation may become the most serious problem in attempting to carry through any effective program in such areas.

Under conditions of weak governmental control, the danger is that suburban communities will evolve piecemeal on the basis of isolated decisions regarding individual land parcels by different developers. The principal exception will be that of larger planned communities, for which the developer can retain a professional planning staff or consultants to implement the development program.

Presently available land-use controls, together with new controls that are gaining prominence, provide the tools necessary to adequately regulate development in newly developing fringe areas. However, there must also be well-defined goals, the conviction needed to implement those objectives, and the political will and courage to carry them through. These must be supported by an adequate technical and administrative staff that can implement the program effectively.

LAND-USE DEVELOPMENT TRENDS

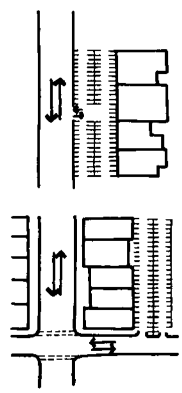
Current trends in land-use development have a significant influence on the protection of highway utility. The problems of premature highway obsolescence experienced in recent decades have frequently been related to the practices of land-use development. Many of the prevailing attitudes about relationships between the highway and adjoining land uses are a direct result of previous experiences. However, many radical changes are taking place in development practices and in highway design. Attitudes stemming from historical experience may have only limited validity in the future.

Commercial Trends

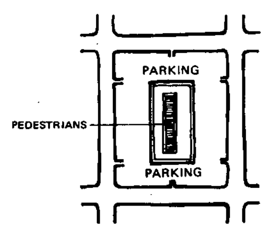
Strip development is one of the facts that has been associated with functional highway obsolescence. The subdivision of highway frontage into numerous small parcels led to frequent driveway access points, causing a proliferation of conflicts along the highway. Increasing traffic volumes and conflicts resulted in the application of highway design controls that reduced conflicts by limiting left-turn opportunities and restricting free access. Strip development is now subject to a higher level of control that has lessened the detrimental influences on the highway.

This has been accompanied by a change in merchandising and retailing practices that has reduced the need for strip commercial development. The development of chain store operation and the spread of the shopping center to the suburbs have inaugurated large retailing operations that are vastly different from the numerous small-scale strip developments of the past. There has been a concentration of retail activity within a smaller total area of productive floor space, although this has been counterbalanced by the provision of extensive auxiliary facilities such as parking. The business that was formerly conducted in numerous small establishments spread along an arterial highway now tends to concentrate increasingly in fewer large establishments at key locations.

Another new practice is the tendency to group facilities of a complementary nature within a single large complex. At first, new development extended the practice of strip commercial development along the highway in a modern context. A series of individual building sites was provided along both sides of a major highway where compatible commercial facilities obtain individual sites contiguous to each other. Parking facilities were usually provided either in front or in the rear of the building (on an individual basis or as a grouped parking facility). The wide arterial highway separated stores on one side of the street from those on the other. The basic concept was inefficient and there were inherent conflicts between the pedestrian and moving traffic.



Eventually, the whole concept of merchandising in the automobile era was reexamined. The revolutionary new shopping center concept vastly improved upon previous strip development designs. Prior principles of access, circulation, parking, and pedestrian movement were literally turned inside out in shopping center designs. The shopping center was viewed as an integral complex to be surrounded by, rather than straddle, the highways. Street parking was eliminated and all parking was placed off street, immediately accessible from the circumferential highways and adjacent to the commercial complex. Pedestrians were not required to walk on the sidewalk abutting highways but were given their own circulation facilities in the form of a pedestrian mall completely divorced from the highway. The shopping center provided greater accessibility, improved parking, superior pedestrian circulation,



and greater safety and convenience. At the same time, it removed unnecessary conflicts and congestion from arterial facilities.

The trend to collective development of compatible uses has not stopped with the shopping center. Other types of development are elaborating on the principle of group location. The grouping of professional offices, financial institutions, hotels and motels, automotive sales and services, home furnishings, clothing, eating establishments, and almost every other facet of retailing activity is a recent innovation. Large single-purpose complexes are also expanding to accommodate compatible groupings of other uses, constituting multipurpose centers. The regional shopping center has now developed into the urban core, providing not only retail facilities but also other types of community facilities, including professional, office, entertainment, cultural, financial, and hotel uses.

Although there is a strong trend toward the grouping of activities within large developments, the amount of land involved is still relatively modest. A large proportion of current development still involves individual sites along highway frontage.

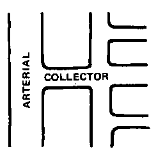
The access design principles and guidelines that have proposed in previous chapters can be applied to shopping center developments or to individual development sites. The greater possibilities for improved traffic control available with shopping centers and with integrated cluster development imply that land-use controls should encourage this type of coordinated development rather than uncoordinated strip development. However, even access to strip development can be controlled if provision is first made for combining access in relatively few locations. Such provision must normally be made prior to the subdivision of the highway frontage. Land-use controls to effect such practices are available so that strip development need not result in a deterioration of traffic movement.

With such controls in effect, the previous problem of many independent access points, each representing an irritant in the traffic stream, will be replaced by the problem of fewer but larger traffic concentrations at select locations. There are better opportunities to control such concentrations, which will result in an improvement in traffic operation if appropriate measures are taken. However, these larger traffic concentrations can present greater dangers unless adequate control measures are taken.

Residential Trends

Early residential development consisted mainly of small-scale subdivisions, generally in a gridiron pattern with narrow, shallow lots. The street pattern was uniform and undifferentiated. Each street served all purposes—streets that happened to have greater continuity would develop substantial traffic loads; other served predominantly as access streets.

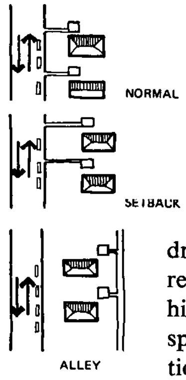
Recent development of the concept of the limited-access subdivision has resulted in a new inward orientation of the neighborhood. One effect that this has had on the highway system is to limit intersections along the arterial.



This provides the opportunity to establish desirable intersection locations and to adhere to a specific pattern of intersectional spacing.

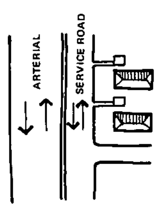
The increase of traffic along arterial streets has reduced the desirability of single-family residences along the arterial; at the same time the concomitant activities associated with residential living have interfered with arterial traffic. Marginal friction (created by driveway access, parking operations, parked automobiles, deliveries, service, and other activities related to residential living) causes conflicts with arterial movement and inevitably results in a deterioration of traffic service. The conflicts between arterial traffic and residential use are therefore mutual.

One method used to improve this relationship uses the principle of buffering, which provides a wider separation between the arterial and abutting residential property through greater setbacks and deeper front yards. This reduces some of the detrimental consequences of heavy traffic on the residence and provides some aesthetic advantages, but it does not materially improve livability or safety, nor does it safeguard highway utility.



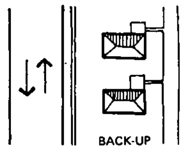
Another technique is the use of rear alleys that eliminate continuous access driveways along the arterial. However, the resident may still park his car in front of his house and use the rear garages only sporadically, retaining most of the objectionable marginal frictions.

The service road combines the features of buffering and access control by providing an auxiliary roadway between the residence and the arterial. Individual driveways have access directly to the service road, which collects all vehicles from individual properties and delivers them to the arterial at a single point of access. The service road also acts as a traffic collector for interior local streets by intercepting them before they enter the arterial. Service road design provides a positive separation of through traffic from local traffic and is effective in reducing the traffic conflicts normally associated with driveway access and parking along the arterial.

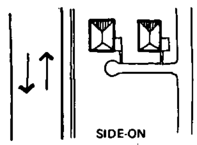


These earlier design techniques have been only partially successful because they deal with symptoms rather than with the basic cause—incompatibility between the residence and the arterial. The primary orientation of the residence is inward toward the internal neighborhood of which it is a part, rather than outward toward the arterial. Neighborhood design seeks to integrate activity inwardly, with the arterial representing the boundary of the neighborhood and defining its outer limits. In fact, the neighborhood unit could function well if it were literally surrounded by walls around its outer perimeter and if access gates were provided at infrequent entrance points.

This basic incompatibility between residence and arterial is best resolved by a newer design technique known as reverse frontage design, which incorporates all of the best features of other access control methods and few of their disadvantages. The residence is turned around to front on an interior street; the back or side of the residence abuts the arterial without direct access to it.



Reverse frontage design is the logical solution for the conflicting requirements. The residence is divorced from the arterial, preferably with access rights dedicated to the community. The inward orientation may be emphasized by construction of a physical barrier such as a wall, fence, or shrubs along the arterial. Without physical separation, many of the problems of parking, loading, service, visual intrusion, pedestrian crossings, and safety hazards along the arterial will remain, and the full advantages of reverse frontage design are not achieved.



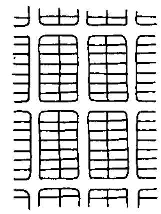
The practice of reverse frontage design along arterials is basically an extension of current practices along freeways and expressways. The high-speed arterial is not vastly different from the freeway with regard to the needs of moving traffic; marginal friction and midblock crossing and conflicts are hazardous and should be prevented by physical design if this is possible.

Land-use controls that encourage reverse frontage design for residential development eliminate the basic incompatibility between the residence and the arterial. When complete physical separation is achieved, all of the auxiliary functions that accompany land development are relocated to the interior. The arterial is kept relatively free of most of the frictional elements that commonly reduce the utility of the highway. Other techniques are less effective, although they do reduce some of the frictions.

UNIFIED DEVELOPMENT

Environmental Conflicts

A significant change in new land-use development practices has been the drastic change in scale from small individual parcel development to large-scale area development. In the older community made up of a series of small land-use islands or blocks circumscribed by streets of equal caliber, each block is independent of all other blocks and the only corridor of circulation is the public street. The single, all-purpose street accommodates all forms of circulation and there is a conflict between accessibility and environment; the provisions for accessibility interfere with an appropriate environment for the land uses through which the transportation corridors pass.

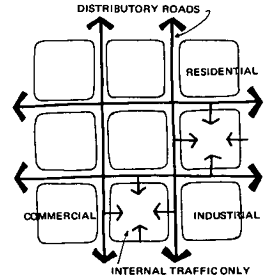


In new large-scale developments, these requirements need not be contradictory, for the arrangement of land uses and access ways can be planned to accommodate both in a more logical fashion. There can be areas where people live, work, shop, and move around in reasonable freedom from traffic. There can also be a complementary network of urban transportation corridors serving these areas.

This concept produces a series of community units or clusters within which considerations of environment are predominant. Only traffic destined to or originating from activities within the unit is found there; individual units are tied together by an interlacing network of distributory roads. The routes circumscribing the environmental areas are corridors of movement that connect adjoining areas and provide access to the larger regional networks.

Types of Environmental Areas

There are several types and levels of environmental areas, each of which has a certain maximum acceptable level of traffic. Such areas can be predominantly residential, commercial, or industrial. The most critical is the residential area, which is usually of neighborhood size and whose circulation is designed to permit penetration only by vehicles having destinations within. This is accomplished by using discontinuous local access and collector streets. The arterial is the external distributory highway that passes between neighborhoods.



ENVIRONMENTAL AREAS

A commercial area may also be visualized as a single functional entity where there is considerable interaction between different stores and shops. The shopping center is a self-contained commercial environmental area undivided by traffic facilities; it is bounded by arterial highways and penetrated by access routes that bring patrons into the center but discourage traffic from passing through the center. It cannot be operated efficiently when it is bisected by a highway, with portions of the complex separated by a major traffic flow.

The industrial park is another type of environmental area served by collector streets that provide access to individual plants. Through traffic is accommodated by arterial highways on the perimeter. Other types of environmental areas include hospital and medical complexes, civic centers, parks and playgrounds, educational institutions, recreational and cultural facilities, and other large enclaves of development. Environmental areas can combine a number of compatible functions within the same area. The most concentrated type of environmental area is the central core of the city. All environmental areas are designed with the same circulation objectives. They have a system of internal circulation facilities that specifically provide access to the interior and discourage through traffic. They also have a system of external distributory highways that accommodate through traffic around the periphery of the area.

The level of circulation facility appropriate within a particular environmental enclave is dependent on the type and size of area. It may be a pathway, a short access street, or a collector street. The arterial can act as a separator between different types of environmental and functional units.

Unified Development Advantages

The trend toward large-scale unified development constitutes an opportunity with respect to the highway system. Many new developments that locate along an arterial are becoming inwardly oriented. The residential neighborhood is most obviously oriented toward the interior when reverse frontage design is used. A large superblock residential neighborhood is created that is bordered by arterials. In a similar manner the shopping center is inwardly oriented, frequently bordered, but not penetrated, by arterials. The same general conditions prevail with respect to school campuses, civic center developments, commercial-recreational developments, and many other types of large-scale developments.

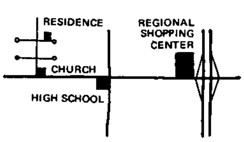
This tendency toward unified development can materially enhance highway efficiency. The large-scale design of the complex provides ample opportunities for internal circulation and the collection of internal traffic, so that access can be limited to specific points that are well located in relation to the highway's requirements for access control. Land-use controls exercised along the highway should encourage this type of development. Uses having strong interrelationships should be located contiguously, undivided by arterial traffic.

LAND-USE LOCATIONAL CRITERIA

Density Hierarchy

Hierarchical relationships tend to develop between the density of land use and proximity to different levels of highway facilities. The circulation system, consisting of a hierarchy of functional subsystems (freeway, arterial, collector, access street), corresponds to a hierarchy of land-use densities ranging from large developments with high traffic generation potential to small developments with very low traffic generation potential.

Very small traffic generators, such as single-family residences, should logically be located along a local access street, which corresponds in scale to this land use. Larger units of development, which generate greater traffic volumes, should not be located along the residential access street, which provides a restricted environment with minimal traffic. An opposite premise can also be stated: the single-family residence should preferably not abut higher street classifications, such as collectors or arterials, because the character of traffic and the environment that results are not compatible with the scale of the individual residence.



A multifamily residential unit, or a community facility such as a school or church, represents a larger traffic generator that should logically adjoin a circulation facility intended to carry traffic of greater magnitude, such as a neighborhood collector street. There are also industrial and commercial collector streets that are suitable for service to medium-sized industrial and commercial developments. The location of very large traffic generators along collector streets is not appropriate because they are out of scale with the service capacity of a collector. Large traffic generators such as high-rise apartments, community shopping centers, large industrial plants, high schools, and public buildings are at a scale that corresponds with the capacity provided by an arterial highway. There are usually not enough of these large generators to fill all of the frontage available along arterials, and lower-density uses also locate along the arterial highway.

Very large traffic generators draw most of their patronage from long distances, and these types of facilities are most appropriately located near regional transportation facilities such as freeways. The scale of traffic generated and the majority of destinations served are compatible with the regional-scale freeway facility, and the normal locational preference is near freeway interchanges. Very large facilities—regional shopping centers, large industrial plants, and large commercial-recreational facilities—correspond with the scale of the freeway.

Highway-Use Optimization

The foregoing traffic locational criteria illustrate the types of relationships that should be maintained between different types and densities of land use and highway facilities. There should be a definite correlation between type of development, size of development, area served, intensity of traffic generated, and type of abutting circulation facility. Fortunately, many of these locational criteria correspond to normal market preferences and current community planning objectives. The locational criteria can satisfy a number of objectives without violating common practices.

There are also opportunities to minimize total travel demands by using hierarchical location relationships. The gradation of trip distances in accordance with development densities minimizes total transportation requirements. The densest developments are brought into closest proximity with major traffic arteries; low-density developments are located farther away.

Under ideal conditions a specific type of highway would carry only that traffic for which it was best suited. The residential access street would carry only residential access traffic; the residential collector street would carry only traffic destined for the neighborhood it served; the arterial highway would serve primarily community-oriented traffic; the freeway would serve long-distance regional traffic.

To respond to these optimization criteria, the location of land uses should be related to the type of facility that handles that type of traffic most efficiently. The large regional traffic generator should be located near the regional freeway; the community facility should be located on the arterial away from the freeway.

If large regional traffic generators are located on an arterial some distance from the freeway, traffic must travel along surface arterials to reach the generator. The surface arterial is then required to carry a substantial additional traffic burden, which it should not be required to carry because this traffic is external to the needs of the community.

A similar objection can be raised to the location of local community generators near a freeway interchange. The section of arterial near the freeway interchange area is the most heavily used. It is preferable that this critical portion of the arterial not be required to carry any traffic other than that which must necessarily pass through the interchange area—predominantly regional traffic and through traffic on longer trips. When community traffic generators locate near a freeway interchange, local traffic must travel toward the freeway interchange area to reach the development even though these drivers have no desire to mix with regional traffic around the interchange. This further compounds the traffic problem around the interchange.

These are valid reasons for establishing controls around interchange areas to encourage regional generators and discourage community or local generators. The objective of these land-use controls would be to avoid unnecessary cross flows of traffic, which are cumulative along the arterial as traffic approaches the freeway interchange. Land uses should be located close to their primary service and patronage areas or close to the traffic facilities that give them primary access, to eliminate unnecessary traffic on the arterial system, particularly at its most critical points.

Land-Use Balancing

Because each type of land use has specific traffic generation characteristics, the density of development of a particular use determines the quantitative total for each particular type of traffic. If twice as much of a particular use is developed in a specific location, the amount of traffic that will affect the highway will be twice as great. Inasmuch as the various types of land use have different traffic generation characteristics (peaks and directional orientations), it may be possible to combine different types of land use in a particular area so that the cumulative effect on the highway system may be only slightly greater than the effect of each one individually. When land uses are properly grouped, their traffic characteristics may dovetail in such a way that the burden on the highway is equalized.

For example, traffic leaving an industrial facility may be traveling toward a freeway while traffic returning to a residential area is traveling away from the freeway. The sharing of the same arterial by both types of traffic provides for balanced use rather than cumulative loading. A shopping center may have its heaviest peak in the evening hours when other traffic along the highway is light. A commercial-recreational facility may have its traffic peaks on weekends when industrial and commercial traffic is quite low.

The objective of traffic planning is to combine and group various land-use categories so that their traffic characteristics complement each other in sharing a particular highway facility. This results in a pattern of uniform traffic loading that eliminates intensive peak loadings, which inundate the facility for very short periods of time.

The distribution of land uses should correspond primarily with community objectives and the general plan. Land-use balancing is only one of many considerations in the planned distribution of land uses and can be applied only when it is not in conflict with other more significant considerations.

Locational Prediction

When land-use controls encourage consistent locational criteria, prediction techniques can become more accurate. Because traffic generators are liable to locate almost anywhere, all arterial facilities must be capable of carrying maximum loads; this results in inefficiencies because some facilities are overloaded and others are underused.

When the locational criteria of large traffic generators are better defined, it becomes feasible to better predict capacity requirements, so that highway facilities can be designed in keeping with probable demand. Land uses that serve elements outside the area and have close external relationships are located on the periphery of the area. Land uses that serve the internal needs of a specific area are centrally located within the area. Heavy-traffic generators with regional associations are close to the freeway and light-traffic generators with local orientations are farther from the freeway. Heavier traffic loads then occur primarily in the vicinity of the freeway and diminish in a direction away from the freeway. Most surface street facilities will not be subject to unforeseen overloads and can be designed with some assurance that they will continue to be adequate in the future.

Fortunately, market desires, entrepreneurial preferences, and locational probabilities are not in conflict with community objectives and transportation efficiency, so that the likelihood of improved predictability is high. The planning of transportation facilities can therefore proceed with a reasonable level of confidence if effective land-use controls encourage consistent locational practices that are not in conflict with highway utility criteria.

CHAPTER THIRTEEN

CONCLUSIONS AND SUGGESTED RESEARCH

The study has concluded that the protection of highway utility ultimately depends on the control of the land use-transportation cycle to maintain a balance between the various elements of the urban environmental system. Such control involves all the components of the cycle, including the land-use activities on the site, the traffic generated by these land uses, the highway facilities provided to accommodate the traffic, the access provided to the land from the highway, and the internal design of the site. Application of the principles and guidelines developed in this study can help to maintain the necessary balance and implement relationships between transportation and land use that will contribute to the effective use of the highway system.

Land-use development affects the highway through the type of development, development intensity, development location, access location, access design, and site design. Reciprocally, highway design influences land development through access control, geometric design, traffic controls, and other operational and design characteristics.

The controls exercised on land use and on highway design are intended to achieve balance between the respective needs of traffic movement on the highway and access to development. This does not necessarily imply that there are serious inherent conflicts that can be resolved only through stringent restrictions; controls do not necessarily imply severe inhibition of either movement or access. Rather, it has been shown that the meshing of land-use needs and highway needs into coordinated design solutions can result in both improved access and improved traffic movement. This finding has far-reaching implications that can greatly influence both highway design and land-use design in the future.

The two principal approaches used in this study for the protection of highway utility are: (1) to provide intrinsic protection through the application of highway design controls that maintain the capacity and efficiency of the highway by protecting it from detrimental influences outside the highway right-of-way, and (2) the establishment of relatively stable and realistic land-use controls that seek to implement a sound general plan and encourage development practices achieving proper coordination with highway operational needs. As the study developed, these goals were translated into guidelines that can be grouped into eight major areas:

1. Traffic Generation

The proposed traffic generation vocabulary and land-use classification system permit the evaluation of the transportation effects of alternative land-use development proposals. This new tool permits an evaluation of the possible interchangeability of land uses with respect to traffic generation implications. Guidelines provided for determining peak-hour generation permit a direct correlation with peak-hour highway capacity. Variable peaking characteristics allow a balancing of land uses so that greater intensities of development can occur without overloading the highway.

2. Functional Classification

The use of the functional classification process to improve the efficiency of existing streets achieves greater effectiveness through increased specialization, eliminating the problems of obsolescence associated with the all-purpose street. The proposed system of design classification for new facilities can achieve a clear functional definition for each street category, with well-defined demarcations. Each category can be related to specific design criteria, features, and operational ranges in a hierarchical pattern. The raising of design standards can ultimately lead to an optimum system of highway design. The extension of functional classification principles to the design of access and internal site design by use of a hierarchical sequence of functional elements can reduce the detrimental influences of access on the abutting highway.

3. Access Design

The direct effects of land-use development on the highway are observed at the location of access and are influenced by the design of the driveway and of internal site circulation. Guidelines are presented to mesh land-use access and highway needs so that the location of access driveways is interrelated with traffic progression criteria and traffic controls. In this way, movement and access need not be in conflict. Proposed guidelines for internal site circulation and driveway approach design can provide efficient service of site access needs.

4. Arterial Design

Changes in arterial traffic patterns resulting from completion of the freeway network may result in variations of traffic intensity along different routes and sections of arterials. This suggests a possible reevaluation of arterial route spacing and design standards based on the proximity of the arterials to freeways and interchanges, so as to retain balanced volume-capacity relationships.

Guidelines are presented for the application of intrinsic design controls that provide built-in protection for the highway, reducing to a minimum the effect of detrimental external influences. Techniques for the use of traffic controls as a major highway planning element are proposed to regulate traffic flow and obtain greater efficiency.

5. Intersection Design

Changing traffic patterns resulting from new land subdivision design practices will tend to intensify intersection problems in the future. The elimination of alternative routings resulting from new hierarchical street patterns, plus increases in intersectional turning movements, will further restrict intersectional capacity. More sophisticated intersection design techniques are recommended for use at critical intersections to provide greater efficiency of intersectional use and overcome these limitations. New practices employed in freeway design provide a source of new intersectional design treatments that can be adapted to major arterial intersections.

6. Transportation Corridor Capacity

The permanent transportation corridor concept can provide flexibility to accommodate innovative new highway designs in the future, so that the capacity of the corridor can be increased as required. This technique is particularly adaptable in new areas where sufficient right-of-way can be reserved to provide for unpredictable future demands. The transportation corridor concept can be expanded to a multimodal corridor to incorporate both rapid modes of public transportation and slower modes of individual transport in addition to the highway mode. The multiple-use public corridor could incorporate current and future transportation modes and provide for any required combination of corridor transportation capacities.

7. Freeway Interchange Design

The extension of access controls to the cross street is an applicable solution to the interchange problem when used in a selective manner in areas where it does not introduce supplemental problems of excessive weaving and crossing conflict. Specific guidelines are provided for application of various interchange designs and access designs within the interchange area. Particular design types have certain advantages in achieving access to land development with minimal detrimental influence on interchange operation. New land-use control techniques, such as the interchange sector and the interchange zone concept, can provide for better control of development in interchange areas.

8. Land-Use Controls

Changes in land development practices, particularly the development of larger units in place of small individual parcel development, permit improved relationships with the abutting highway. Larger-sized parcels and longer frontages permit a concentration of access at favorable points and allow a flexibility of internal circulation design. However, these larger developments also entail new dangers for the highway unless adequate controls are exercised on access location and site design to properly coordinate access with traffic movement criteria. Guidelines are presented for land-use controls that will coordinate access needs with highway needs and provide proper relationships of site design with the highway. Land subdivision regulations are proposed to provide for the collection of access traffic by means of a supplemental collector road to avoid numerous points of access conflict. Given such provision, strip development can be prevented from having a detrimental influence on highway utility.

The stability of land-use controls is necessary to maintain balance between land use and highway design and to retain control over the land use-transportation cycle. Guidelines for improving land-use control stability are proposed through the adherence of land-use controls to a general plan of development based on the realistic goals of the community.

In reviewing the areas of interrelationship between land use and the highway, it has been concluded that the influences of the highway on land-use development must be given equal consideration with the influences of development on the highway. The effects of the freeway on the community, as well as the effects of land-use development on the freeway interchange, must be equally evaluated. Joint consideration of highway needs and land-use needs can be achieved through the use of multidisciplinary teams that are responsible for the planning of both the highway and the abutting land uses. The ultimate objective is to implement desirable community planning principles. Joint planning can be a protective tool to provide protection of highway utility and to achieve proper environmental relationships with abutting uses.

The conclusions of the study are relatively optimistic with regard to the opportunities for achieving protection of highway utility in the future. In most large metropolitan areas, where the problems are most serious, the basic tools and implementation techniques are already generally available. The greatest deficiency appears to be in the effective application of these techniques to resolve current problems.

One of the deterrents to effective action in the past has been the lack of principles and guidelines on which sound decision-making could be based. The increased availability of factual evidence and easily applied guidelines should materially improve the implementation of desirable practices in the future.

This study has identified many of the factors that offer the best opportunities for achieving the desired objectives. Some subject areas were developed in considerable detail, and definitive principles and guidelines were evolved that can be directly applied by land-use and highway administrators. In other areas general guidelines were developed that suggest an approach to be taken. In still other areas, further research is suggested where it appears that valuable results could be achieved and definitive guidelines developed. The following listing includes some subjects introduced in the current study that are deserving of further effort.

SUGGESTED RESEARCH

1. A mathematical model that expresses quantitative relationships between transportation and land use, including the major dependent variables.

2. Techniques for objective measurement of highway deficiency, including the components of congestion, hazard, and inconvenience.

3. A theory of highway optimization that defines the criteria for measurement and develops the functional com-

ponents of an optimum system, an optimum mix of elements, and the geometric pattern of the system.

4. Detailed development of an optimum arterial design concept with an evaluation of new design features.

5. A single system of highway functional classification based on design criteria, with development of specific design features that define purpose, function, and administrative responsibility.

6. A comprehensive functional classification system that includes both primary and corollary highway functions, with prototypical applications to various community types.

7. A comprehensive traffic generation vocabulary and land-use classification system that provides reliable traffic generation data by daily and peak-period generation rates by use of a common base of comparison.

8. A basic traffic generation model that can test alternative development possibilities and different mixes of land use and density to evaluate the effects of land-use proposals on the highway system.

9. Analysis of changed arterial traffic patterns following freeway development, and possible modifications of route spacing and of design standards to accommodate variable traffic loadings.

10. Policies for coordination of access location, median openings, signal location, and other design controls in relation to development.

11. Detailed analysis of various techniques to increase intersectional efficiency, including development of alternative proposals based on capacity quantification.

12. A system of prototypical design solutions for the improvement of commonly existing conditions to provide a model for highway improvement programs.

APPENDIX

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