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Parking as an Alterant to the Traffic Pattern

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FOREWORD

In recent times, there has been an increasing concern voiced over the lack of protection of environmental and ecological attributes of this country. This concern has progressed to the point where proposals are increasingly being made to curtail uncontrolled use of the motor vehicle, particularly in the core areas of larger cities. One response to the recognition of this problem would be the total abandonment of the use of motor vehicles in urban areas. It seems difficult to find acceptable midground solutions at first in attacking problems such as this because technicians often do not present acceptable alternatives as solutions.

To explore one element in the effort to achieve some balance between uncontrolled use of the motor vehicle and maximum protection of our environment, the five papers presented here consider parking controls as a way to alter the traffic pattern. Because most vehicle trips are related to work or shopping, it is hypothesized that desired modifications in traffic patterns can be obtained through the manipulation of parking accommodations. The papers included in this RECORD serve as a foundation for guiding public policy toward a solution of the urban traffic problem.

In his paper, Jackson attempts to place parking in the larger urban transportation planning process. Based on established mathematical models and transportation planning definitions, the effects of change in parking policy on trip-making characteristics within the urban area are identified. The planned application of parking policy as a tool to implement a growth concept for the Denver region is presented.

Silence develops a technical information system procedure to guide planners and urban decision-makers in understanding what is best for the core area of their city. The procedure maximizes the use of currently available data, minimizes the collection of new data, and provides a procedure for testing a proposal without the need for a full-scale demonstration.

May reports on the control of the supply and use of parking space as a tool to regulate travel in Greater London. The paper discusses the objectives and principles of the plan and assesses the effects of future implications. Pricing mechanism is the primary control employed, and a 15 percent reduction in travel is anticipated during peak hours.

Lindqvist reports on an experiment in Gothenburg, Sweden, which divided the core area of the city into five sectors and prohibited the movement of privately owned vehicles and certain other traffic from passing from one zone to another. This proscription and the attendant provision of parking on the periphery of the core have resulted in interesting and beneficial alterations of the traffic pattern.

Ellis, Bennett, and Rassam analyze the operation of five fringe parking programs, some of which have been in operation since before World War II. The analyses are then utilized to synthesize future operations and define the implications of their operation.

—Harry B. Skinner

PARKING POLICY AS AN INTEGRAL PART OF URBAN DEVELOPMENT OBJECTIVES

Ralph E. Jackson, Federal Regional Transportation District, Denver

The mathematical models of economics and transportation planning are utilized to establish that parking policy is an integral part of urban development objectives. Based on established mathematical models and transportation planning definitions, the effects of change in parking policy on trip-making characteristics within an urban area are identified. The planned application of parking policy as a tool to implement a growth concept for the Denver region is presented.

•PARKING is an everyday term and activity well-known and understood by virtually everyone in our society. In fact, it has become so common that most people forget that it is an integral and distinctive step in the process of making a trip within the community. As housewives go to the grocery store to do their shopping, they normally do not think of the element in their trip that involves parking their automobiles. Unless the cost is unusually high or parking spaces are difficult to find, a trip-maker rarely gives any thought to the element of his trip related to parking his car. The purpose of this paper is to place the activity of parking in perspective as it relates to the overall trip-making process within the community. By identifying fairly rigorous relations that affect trip-making characteristics, we can establish the effect of parking policy as an integral part of urban development objectives.

It is not the intent of this paper to identify potential or desirable solutions to the parking problem in urban areas. Ideas and concepts that have been developed or applied are discussed in other papers. There is considerable documentation on the success or failure of these approaches and techniques. The intent of this paper is to establish, as rigorously as possible, how parking policy can affect urban development objectives. It is hoped that the material presented in this paper will provide a general framework and background for the more detailed discussions in other papers.

WHAT IS PARKING?

The dictionary definition of parking is to "set and leave temporarily." Perhaps oversimplified, parking is a temporary storage of automobiles not being used. The word "temporary" should be emphasized. Parking in this paper does not pertain to storage of vehicles in a garage or at some other location for an extended period of time. The concept of "temporary" is further defined when we place parking in the perspective of being a distinct element in the process of trip-making.

When we go back to the basic definitions of transportation planning, we remember that people make person-trips to move from one activity to another. For example, when a trip is made from home to office, the reason for the trip is to change from living at the home to working at the office. Most person-trips are made so that the trip-maker can change from one activity to another and not just for the sake of making a trip. Thus, the primary reason for making a person-trip is to change activities.

Consumer Perspective

From the consumer perspective, parking may have an out-of-pocket cost in terms of fees or it may require an investment in time to find a space and get the vehicle parked. If the dollar cost and time requirements are held to a minimum, then parking is a relatively minimal element in the trip-making process. If, on the other hand, parking is expensive or time-consuming, it can be a very important element in the trip-making process.

Parking as an element in the trip-making process is shown in Figure 1. For the vast majority of trips in urban areas today, a person leaves an activity in his car, drives to the location of the next desired activity, parks his car, and undertakes the activity (Fig. 1a). If parking costs are high or it is difficult to find parking spaces, the consumer may choose to drive his car for only a portion of the trip, park his car, and ride public transportation to reach his desired activity location (Fig. 1b). In other cases, the consumer may choose to make the entire trip by transit (Fig. 1c). It is recognized that parking alone is not the only determinant in the trip-making decision process. The following discussion will, however, demonstrate how parking and parking policy can have a very strong and definite effect on the consumer's trip-making decision process.

Supplier Perspective

The supplier perspective on parking is related to the number and cost of parking spaces provided for the consumer. For example, in order to attract customers, the shopping center merchant must provide adequate parking at a reasonable cost. He must carefully balance the cost of providing the spaces against the potential revenue derived or lost by providing or not providing the space. Consumers will avoid shopping at a location where parking is difficult to find or expensive. The supplier soon learns that parking can have a direct relation to the level of activity (business) at his establishment.

One of the major problems in many of our urban areas today is related to the increasing cost of providing adequate parking. The supplier has a limit on what he can afford to spend on providing parking for his customers. If increasing land costs and congestion raise the supplier's cost of maintaining the spaces, then either the price to the consumer increases or the spaces are not provided. Either situation directly affects the level of activity at the location involved.

Economic Perspective

We can now state explicitly what has been implied in the previous discussion. Parking is an economic commodity and is subject to the basic laws of economics (Fig. 2). The number and cost of parking spaces provided are determined by the point of equilibrium where the cost of providing space from the supplier's perspective is equal to the price the consumer is willing to pay. This relation is considerably more complex than that described here. It is useful, however, to identify and understand this basic economic relation.

There is a wide range of factors that can alter the supply-demand relation related to parking. If a parking policy is implemented, for example, that reduces the number of available spaces from the equilibrium quantity, then a new quantity and price are defined as shown in Figure 2. If a policy decision is made to provide fewer parking spaces, then a new equilibrium point will be established resulting in a higher price to the consumer for parking. We will see in this paper how this change in price potentially affects the decision process of the trip-maker. The important thing to recognize and establish is that parking is an economic commodity that is subject to the basic laws of supply and demand.

HOW DOES PARKING AFFECT TRIP-MAKING?

Thus far we have established that parking is an element in the trip-making process and, as such, follows the basic economic laws of supply and demand. Fairly sophisticated computer and mathematical models have been developed to predict human behavior in the trip-making process. These models have been developed and refined over a period of time and are now established as reasonably accurate predictors of the trip-maker's response to differing conditions. The decision of where a person goes to find a desired activity is represented by a mathematical relation called the distribution

Figure 1. Person-trip alternatives.

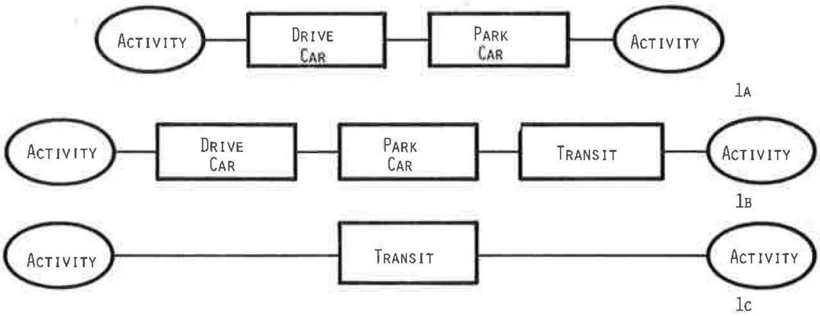


Figure 2. Parking supply and demand.

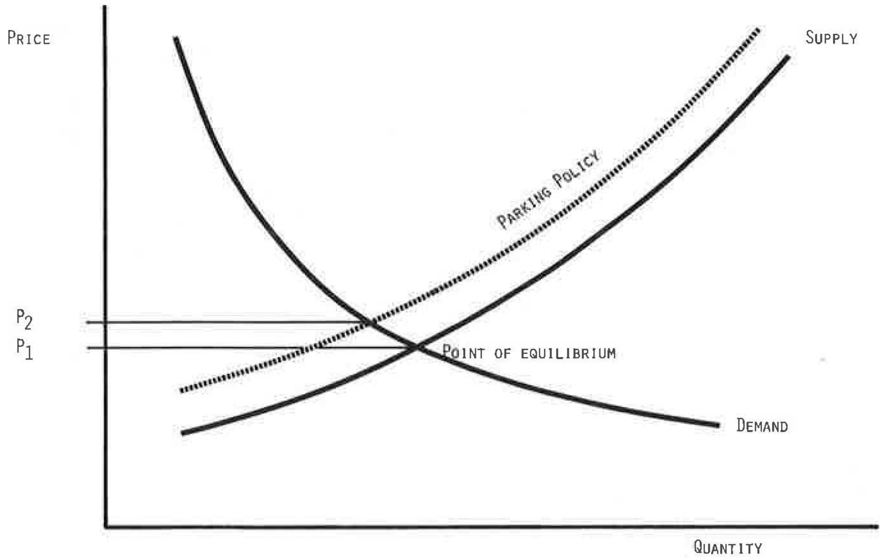
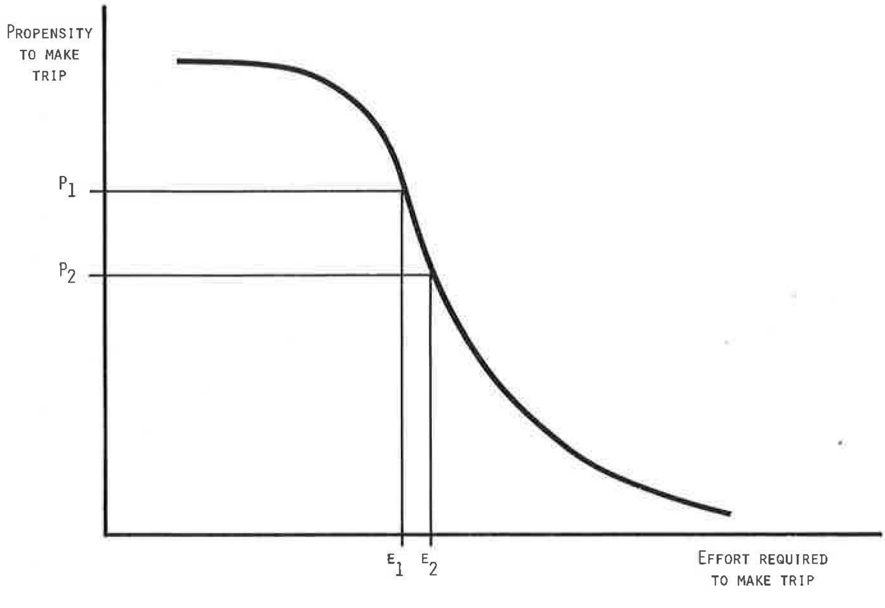


Figure 3. Person-trip distribution model.



model. The decision of how a person will make his trip (by what mode) is represented by a mathematical relation known as the mode-of-choice model. The following sections will discuss each of these mathematical models and how the effect of parking can be traced by their application.

Where Will the Trip Go?

As discussed earlier, trips are made in order to reach a location where a desired activity can take place. In deciding where to go for the desired activity, the trip-maker must first identify the alternative destinations throughout the community where the activity is located. For many trips, there is only one possible destination. An employee with a regular office position can only travel to a single location to carry out his work. He does not make a decision each morning as to where he will go to work that day. Many trips, on the other hand, can be made to a number of different locations where virtually identical activities can be found. Perhaps the best example is the housewife going to the grocery store. In most cases, numerous alternatives exist for her to do her grocery shopping. Parking can affect a person's trip-making decision only if alternative locations are available for the same activity.

When alternative locations for the same activity exist, the trip-maker usually selects the location that requires the least effort on his part to make the trip. If a housewife can travel two blocks and find the grocery shopping facilities she needs, she will not travel 5 miles across town for the same facilities. It is important, of course, to emphasize that true alternatives must have the same activities. If a particular location does not have the desired activities, then it will certainly not be selected as the destination of the trip.

The mathematical relation known as the distribution model relates the level of effort required to make a trip to the propensity of the trip-maker to travel to that destination. It is not important for purposes of this paper that the exact mathematical form of the model be presented or understood. The relation defined by the distribution model is shown in Figure 3. Perhaps oversimplified, the distribution model indicates that, as more effort is required to make the trip, the propensity to make the trip is reduced. An example best explains this relation. If a consumer has to travel on local streets for perhaps 5 miles to reach a regional shopping center, he would have a relatively low propensity to make such a trip. If the amount of effort required to make the trip is reduced by putting in a new freeway system or providing rapid transit service, then the consumer's propensity to make such a trip is increased. The distribution model relation for trip-making has been applied for a number of years and established to be a fairly reliable predictor of where people will go to find the activities desired.

The distribution model can be utilized to identify the effect of parking on a person's trip-making decisions. Figure 3 shows this potential effect. The level of effort required to reach a particular destination is represented by E_1. Related to this level of effort is a propensity P_1 that the consumer will make the trip to that particular destination. Let us assume that a parking policy to provide fewer parking spaces has been implemented as we discussed earlier in reference to the supply and demand relation. Through economic analysis, we have already established that the price of parking spaces to the consumer would increase. This increase in parking cost represents an increase in the level of effort required on the part of the consumer to obtain the desired activity at the same location. The new increased effort is represented by E_2. As shown in Figure 3, a new and lower propensity P_2 is now related to the same location. Because of the lower propensity due to increased effort required, the consumer may decide that an alternative destination is more desirable.

Using a standard transportation planning model, we have now been able to identify at least one potential impact of parking on a person's trip-making decision process. It should be emphasized that parking is not the only element that can increase or decrease the level of trip-making effort that in turn affects the trip-maker's choice of destination. Many other factors, such as travel time, quality of activity, habit, and personal preference, can also affect the decision process. If the effort required to park is minimal with respect to other elements of the trip, it will probably have little impact on the trip-making decision process. If, on the other hand, parking requires major effort in terms of either time or out-of-pocket cost, then it can have a substantial effect on where a person goes to find the activities desired.

How Will the Trip Be Made?

The second basic decision a trip-maker must make to complete a trip is deciding which mode he will use to make the trip. Will he travel on foot, on a bicycle, by automobile, or by public transportation? This decision, again, is related to the relative level of effort required to travel by each available mode. The mathematical model that has been developed to represent this element of the trip-making decision process is called the mode-of-choice model. Numerous mathematical forms have been developed in recent years. One such relation is shown in Figure 4. The mode-of-choice model indicates that the difference in effort between making the trip by transit and making the trip by automobile defines a certain probability of the trip being made by transit.

Perhaps the best way to explore this relation is to once again turn to our previous example. For a particular trip, the difference in effort required to go by transit as compared to automobile is D_1, which results in a probability P_1 of making the trip by transit. Returning to the example used earlier, we can now trace the impact of reducing parking supply. The economic analysis indicated that a reduction in parking supply results in an increase in parking cost based on the supply and demand relation. Because parking is a part of the trip-making process when the trip is made by automobile, then the total effort required to make the trip by automobile increases and the difference in effort (transit minus automobile) decreases to level D_2 as shown in Figure 4. Based on the mode-of-choice relation, a new and higher probability P_2 is now defined for making the trip by transit. In other words, the increased effort required for parking resulted in an increased probability that the trip would be made by transit rather than by automobile.

We have now established how parking can affect both where the trip-maker will go to find his desired activity and how he will travel. The examples presented were admittedly oversimplified, and certainly the decision-making process is considerably more complex. The transportation planner is limited, however, by the tools available to him. Based on the relations established previously, we have a reasonable capability of tracint out the potential impact of changes in parking policy on trip-making characteristics.

It is important now to go back to the discussion that related trip-making to activities. People make trips to engage in the activities that they find at their destinations. As we affect their trip-making characteristics, we affect the level of activity. As we alter parking policies, we can affect the amount of activity that will take place and how people will travel to reach an activity. In an extreme case, for example, we could eliminate all parking from a regional shopping center and provide no alternative means of traveling to that facility. The effect would be an immediate total decay of activity at the center. This is, of course, an exaggerated example, but it serves to prove a point. Parking and parking policy can directly affect the level of activity for a particular land use. We must, therefore, recognize and utilize parking as one of many available tools that can be applied to accomplish our urban development objectives. As indicated in this paper, rigorous modeling techniques are available to assist us in predicting the potential of alternative parking policies.

EFFECT OF PARKING POLICY

With the relations established in this paper, we are now able to identify the potential effect of parking policy on the achievement of urban development objectives. The relations and potential effect are shown in Figure 5. Parking policy is composed of two basic elements: number of spaces provided (quantity) and cost to the consumer (price) for utilizing each space. Parking policy can be implemented to affect either one or both of these elements, resulting in a new point of equilibrium based on the economic relation of supply and demand. Utilizing the distribution and mode-of-choice models, we can then trace out the effect of this parking policy in four major impact areas: social, behavioral, economic, and environmental-land use. A given parking policy

Figure 4. Mode-of-choice model.

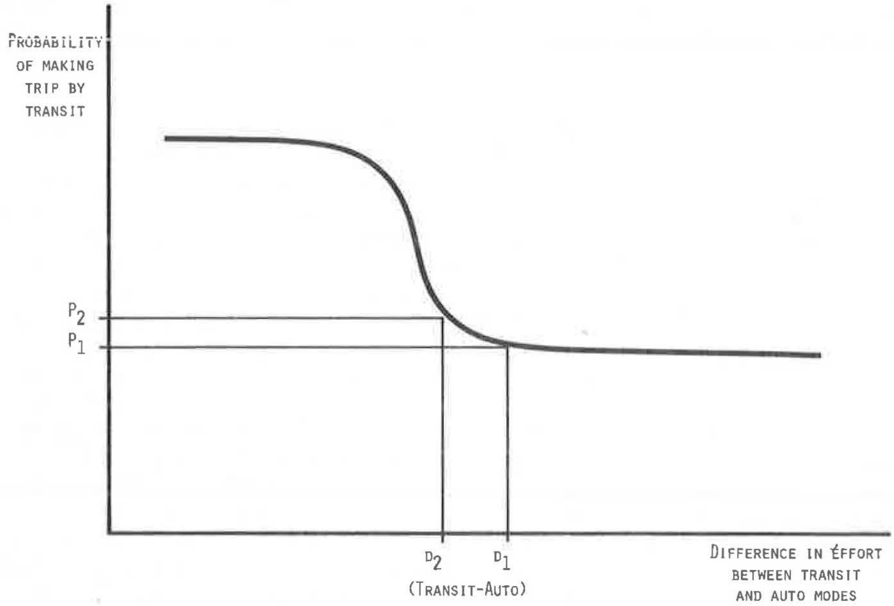
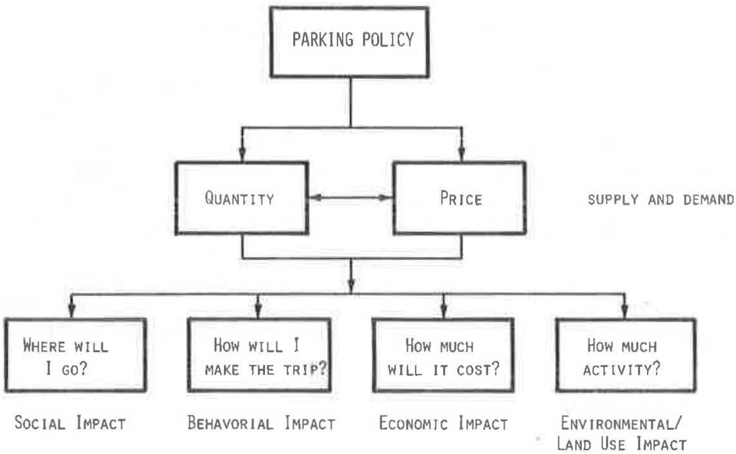


Figure 5. Effects of parking policy.



will influence the trip-maker's ultimate answer to each of the following questions that relate to the specific areas of impact:

1. Social—where will I go?
2. Behavioral—how will I make the trip?
3. Economic—how much will the trip cost?
4. Environmental-land use—how much activity will take place?

PLANNED APPLICATION IN DENVER

Planners in the Denver region have recently undertaken a very extensive land use and transportation planning study to produce land development and transportation plans for the year 2000. To accomplish this task, a joint regional planning program was organized and carried out by the Regional Transportation District, the Colorado Department of Highways, and the Denver Regional Council of Governments. The potential effects of parking policy on urban development have been explicitly recognized and applied in the process of alternative plan testing and final plan selection.

The Denver region is one of the fastest growing areas in the country. Because of its unique environmental setting, the inhabitants of this region are very concerned that growth be accommodated in a properly guided and acceptable form. For this reason, an extensive environmental resources inventory was undertaken early in the planning process. Based on a set of criteria developed from this and other inventories within the region, a growth concept for the region was established. The resulting growth concept represents a bold and vigorous approach to future development within the region based on very specific guidelines and objectives.

Considerable effort was spent in identifying steps that can be taken to make the plan become a reality. Parking policy will be one of the tools applied to implement the plan. This relates most specifically to the development of carefully selected community service centers where high-density activity can and should occur. The concept is to provide many activities within a short distance of the consumer. Stated differently, the objective is to reduce the level of effort required for a consumer to find his desired activities. Provision of parking will be a key element in making these community service centers a reality. By substantially limiting or reducing the amount of parking, a greater percentage of available land can be utilized for construction of buildings that provide activities desired by the consumer. Parking lots will be replaced with additional residential, commercial, and employment activities. The level of activity will therefore increase.

As indicated earlier in this paper, the removal of parking spaces will result in trips going elsewhere unless a reasonable mode of travel alternative is provided. A key element in implementing the plan will be a personal rapid transit system that will provide fast and efficient access to and within each center. A parking policy of providing limited parking capacity within these centers will encourage transit use and make more land available for development. The added development will, in turn, result in a higher and a greater variety of alternatives within easy access to the consumer.

Computer simulation of this approach indicates potential for affecting and accomplishing the urban development objectives identified in the regional growth concept. The real impact of this approach will, of course, not be completely defined and understood until implementation of the plan begins and consumer reaction can actually be observed.

CONCLUSION

From the discussion presented in this paper, we conclude that parking policy is an integral part of urban development objectives. Parking is one element in the automobile trip-making process. Trip-making, on the other hand, has a direct impact on the type and level of activity at a particular location of land use. The relations identified and presented in this paper establish that, as we alter parking policy in terms of quantity or price, we affect the consumer's travel patterns. Parking policy is therefore a strong and controllable tool available to land use and transportation planners in accomplishing urban development objectives.

As we proceed to explore and experiment with alternative approaches to parking and parking policy, we must keep in mind the relations presented in this paper and how we are potentially affecting the trip-making process. Parking can be used as an effective tool in accomplishing our urban development objectives if we fully understand these relations and properly use the tools. Just as a master craftsman must know and understand the characteristics and proper use of each tool, so we as land use and transportation planners must know and understand our tools and how they can work for our benefit if properly used.

PROCEDURES FOR MEASURING THE ACTIVITY LEVEL AND THE PARKING DEMAND OF THE CBD

Steiner M. Silence, Federal Highway Administration

This paper focuses on analytical procedures for evaluating proposed transportation alternatives for the CBD. Problems on delimitation of the CBD are discussed. Procedures for measuring the activity level and the parking demand with origin-destination studies, cordon count studies, and parking or special studies are included. The importance of trends in travel mode over time is emphasized. Also, several transportation alternatives are suggested. These alternatives include bus improvements, parking innovations, and revised time patterns.

•CHANGING times and national priorities have brought a resurgence of interest in the CBD. New proposals are made daily for some kind of "solution" to downtown traffic, parking, and transit problems. The reference to "new" is misleading because most of these approaches were suggested more than 50 years ago. They are new, however, in the sense that they have not been greatly applied and that new or changing emphasis could allow successful implementation. Changing times also bring uncertainty, and there are few solid benchmarks on which to base sound administrative decisions. The one thing that seems obvious is that the current surge of activity in the CBD is bound to stimulate a need for new information and knowledge.

The focus of this revived interest is the central hub or locus of traffic congestion and yields the highest concentrations of daytime population, air pollution, and noise. In cities of between 1 million and 5 million population, only about 10 percent of all metropolitan trips are directed to the CBD and more than 80 percent of these are work trips. It is the high concentration of these trips that creates the CBD's characteristic problems. On the other hand, it is the unique services historically performed in the fields of trade, finance, government, transportation, and communications that generate the particular interest accorded this area. Almost everyone is desirous of solving the long-standing problems, but few are willing to go on record as wishing to lessen the importance of the downtown area.

The primary focus of transportation planning in the past has been to vary (usually increase) the supply of transportation service to meet ostensible demands. Many of the more recent measures propose limiting the demand for service. This calls for the regulation of activities or the promotion of "more desirable" behavior by controlling prices or the supply of facilities. Such thinking demands considerable philosophical and institutional change, and our planning must consider such solutions in order to be responsive to modern needs. On the other hand, an objective view requires that proposed solutions meet the tests of clarity, simplicity, feasibility, salability, and political feasibility.

It seems clear that an effective means of solving CBD transportation problems lies in the development of a unified policy for all transportation services. Implementation of such a plan, however, is far from simple and involves diverse interest and diverse views as to what the "best" policies and the "best" result should be. Again from this viewpoint, the planning procedure that we want must meet a variety of problems and allow evaluation of a variety of solutions to be effective.

The purpose of this paper is to suggest a pattern of information gathering and analysis that would assist in evaluating proposed combinations or mixes of transportation alternatives in light of community goals. The local traffic engineer and the urban

A more detailed discussion of these procedures follows.

Delimiting the CBD

Almost anyone can construct a mental image of downtown. The picture may vary based on past experiences or on the city he knows best, but the term CBD or downtown is generally considered to be understood for purposes of conversation. All this notwithstanding, the literature is sparse on methods of selecting or delineating the CBD.

So why make a thing about it? If we have come this far without being precise in our definitions, we may well not need such precision. This is true in at least one sense. When a local agency deals with a local problem, such as zoning, planning, or traffic management, there is little apparent reason for precision in CBD definition. The real reasons for an objective determination involve the development of trends in activity over time or the making of comparisons between cities. In other words, the reason is for statistical purposes, but these purposes gain importance as the results become more critical.

I will clearly state that more research is needed. Most past work ignores the boundary problem. A considerable number of studies comparing the CBD's of several cities have been conducted without reference to any standardized definition of the CBD. This approach assumes that CBD definition is intuitive. It is most commonly used when one wishes to get most out of existing data [of either a cordon count or an origin-destination (O-D) type]. Persons employing this approach occasionally feel that they may, as their tutors once admonished, have combined apples and oranges. This introduces an element of uncertainty that might be better removed.

Some accept boundary delineation as an important and continuing problem and then proceed to draw conclusions after expressing the hope that ultimately a satisfactory universal definition of the CBD will be developed. Unless an approach is put forward and practically universally used, such groundless hopes will continue to be voiced; we will continue to collect insufficient data on unsatisfactory cordons, and it is reasonable to expect that the delineation problem as stated here will never be effectively solved.

Another means of avoiding CBD delineation is for the writer to conclude that delineation is a local matter and not within the purview of other jurisdictions. There is considerable merit in this because boundaries should be worked out locally; however, common definition would provide a data base useful to other jurisdictions as well. This allows an assessment of problems of importance not only to the community but also to the state and nation.

It is not within the scope of this paper to solve the whole question of standardizing delimitation. For now, it remains a problem of agencies at all levels to establish acceptable criteria and apply them to our major cities. We can only hope to come to better agreements on this matter as time goes on.

Person Travel to the CBD

The primary point at issue in better serving the CBD is how much activity exists, what are the trends in its magnitude, and what is it likely to be in the future. With some scale as to the magnitude of this demand, we can then face the secondary question of how to serve it (or more appropriately how well to serve it). For the moment, we will neglect the point that the level of transportation service provided will undoubtedly influence the magnitude of the demand or activity.

The activity level can be measured in a number of ways depending on one's personal interest and selected goals. For example, an environmentalist might measure carbon monoxide and unburned hydrocarbons and rate them against a predetermined acceptable level, a transit man might measure ridership or clear profit or loss, a businessman might measure retail sales or company profits, and a traffic engineer might measure vehicular speed or volume. There are interrelations among these measures, but they are seldom clearly defined. Daytime population, as indicated by person travel to the CBD, is taken here as the best single measure of transportation effectiveness. No measure is ideal for all purposes, but person travel seems to be the most effective way to relate transportation service to several possible urban goals.

There are a number of approaches that might be taken to obtain a measure of the activity discussed here. Most of them have definite disadvantages, and none is without fault. All of them relate to the problem at hand, however, and any one or a combination of procedures designed to make best use of the advantages of several procedures may be called for.

ORIGIN-DESTINATION STUDIES

The chief advantage of O-D information is that the interviewer obtains actual trip origins and destinations within any established study area. Separate checks can be made of trips "passing through" the study area with greater or lesser accuracy. O-D cordon data used in this manner or combined with cordon count data offer a measure of the possible advantages to be obtained by providing a bypass of the selected area. O-D data are also carefully controlled by the time of day, and the temporal distribution of person trips can be readily obtained by purpose, mode, or other stratifications obtained as a part of the basic data (Figs. 1 through 5).

On the other hand, O-D data are difficult and expensive to obtain (particularly home-interview data), and new data are not collected frequently. Check samples might be obtained from time to time, but these can seldom be considered conclusive.

The base data from a home-interview O-D study might be used to good advantage to factor cordon count data under certain conditions. Factors obtained in this way might be applied to a number of cordon analyses until a new O-D data collection is made.

Another problem with using O-D data is that the typical urban transportation planning study takes count checks over screenlines and factors these trips to compare more favorably with count data. The need to correct these data shows that there are some problems of direct comparison between O-D and count data.

Another point that should be raised is that O-D data do not need to be collected at the home but might be collected at a downtown destination or even at a parking space. A number of suggestions have been offered as to various methods by which O-D data can be obtained (1).

CORDON COUNT STUDIES

A cordon count involves the taking of (at least) count information on most entry and exit points to a defined area. The line defining the area is known as the cordon. By totaling the entrances and exits at each counting point, the total accumulation of vehicles or persons within the area can be determined. Occupancy of individual automobiles can be checked at cordon stations, or a separate occupancy study can be made and related to vehicle counts to obtain better measures of person travel. Transit ridership figures across the cordon for the study period should also be obtained.

Cordon counts are frequently taken to check screenline crossing as part of a comprehensive transportation planning study, as a part of a CBD study, or as a part of a comprehensive parking study.

Both manual and machine counts are typically made. The manual counts can be used to classify vehicles by type and perhaps occupancy, and the machine counts obtain entering and leaving volumes and can be factored by use of the manually obtained data.

CBD cordon line counts are made to record daily and long-term trends in movements to and from the CBD. Volume counts are recorded by type of vehicle, direction of travel, and usually 15-min intervals. Passengers in automobiles, trucks, and buses are also recorded. This information may be collected annually or at least every few years to provide the historical relation of transit riding and automobile riding.

CBD cordon counts are normally taken for one weekday each year. The day selected is usually in a month whose average daily traffic is close to the annual average. Counts are usually made for 12-hour periods. The study is normally made in the same month each year.

Cordon counts are frequently made annually in our largest cities by the traffic engineering department. They provide a valuable source of information on which to base transportation decisions. The primary difficulty is that the studies are seldom summarized or checked against available O-D information that might add greatly to their usefulness. This deficiency detracts from the usefulness of the data.

Figure 1. Inbound travel by purpose.

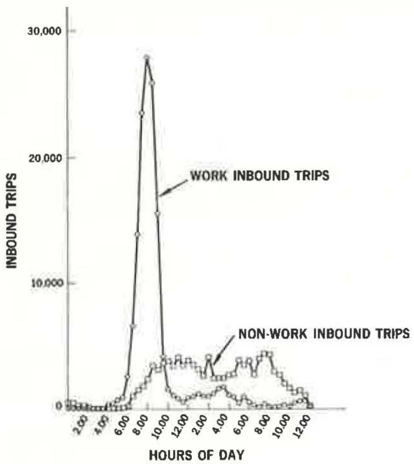


Figure 2. Inbound travel by mode.

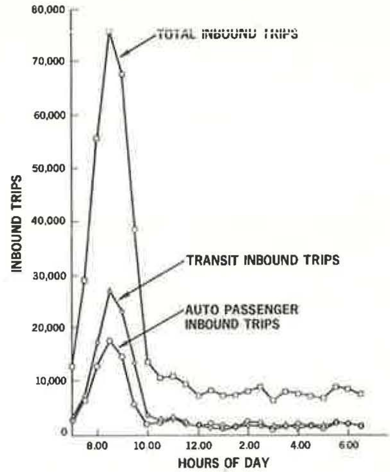


Figure 3. Outbound travel by mode.

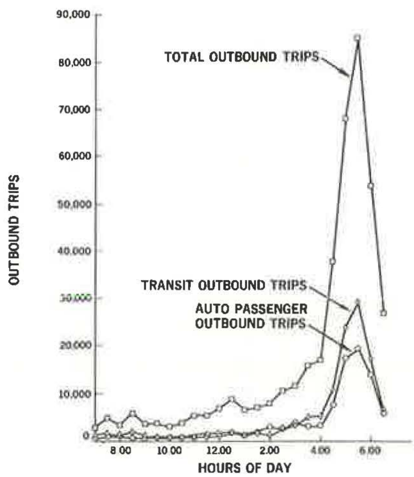
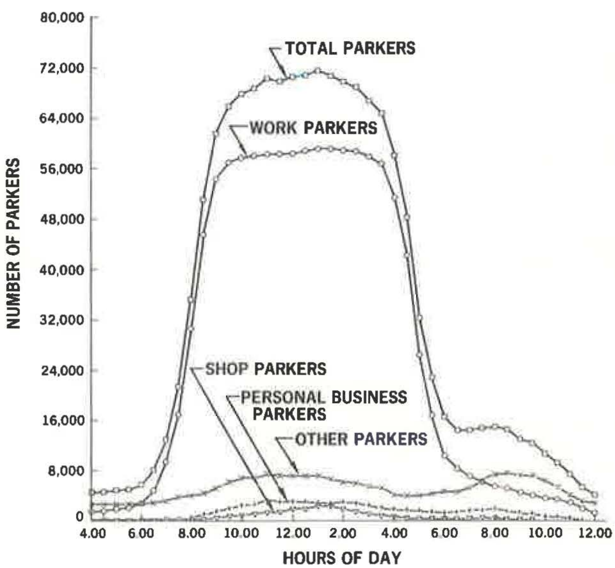


Figure 4. Parking accumulation by purpose.



transportation study staff have a unique knowledge of the travel patterns of the community. These and other groups working together can provide substantial data resources on which to base transportation decisions. The following criteria would seem to be most important for guiding the development of such procedures:

1. The methods should address and be responsive to the questions raised by the community and by the governments. They should be flexible such that additional questions raised in the future may be considered.
2. It should be possible to initiate the analysis with existing data sources, but allowance should be made for improvement of these sources as needs become clearer.
3. The methods should allow means of evaluating the probable effects of proposed alternatives without the need for demonstration or full-scale test.
4. The methods should be capable of application as frequently as necessary at low cost so that the effects of procedures already implemented can be evaluated and their effectiveness measured. Simplicity is desirable and there is no need to make a method complicated in order for it to be effective.
5. Finally, the results of this analysis should be consistent with and measurable against other community planning efforts including long-range transportation planning.

With these goals in mind, we can now proceed to develop a skeleton of procedures and then return to discuss them in greater detail.

ANALYTICAL PROCEDURES

Before work can proceed, a conclusion must be reached about the boundary or limits of the CBD (sometimes called the cordon). Means of accomplishing such a delineation have been proposed but have not been standardized to any great degree. Although a later section discusses this matter in greater detail, a full coverage of delineation methods is beyond the scope of this paper.

The primary commodity that we wish to measure and better understand is person trips entering and leaving the CBD on typical (or above average) days, normally weekdays. Because problems are usually related to the hourly "peaking" of these movements, we should also obtain the temporal distribution of trips across the cordon as well as accumulations of activity within the cordon (in either persons or vehicles). Total person trips entering or leaving should also be stratified by mode of travel, trip purpose, and perhaps other available categories by hour of the day. Occupancy checks of private automobiles in order to determine person movements might be made for all vehicles and can also be obtained by sampling.

One purpose of such studies will ultimately be to develop a temporal distribution of travel by mode over the years. The object here is not to rely on trend projections but to use past trends as a check on other independent estimates such as a transportation study. Do present estimates of downtown travel compare favorably with the trends? If not, can the projections be supported by anticipated inputs of transportation, investment, and so forth? Past studies rate floor space as a fair indicator of most types of downtown activity. Some caution is necessary because in some communities floor space appears to be increasing very rapidly without a commensurate increase in downtown activity.

Means of improving CBD travel should be listed, and likely alternatives should be analyzed in depth. It is not only the choice of improvements that is important here, but also the probable effort of such improvements if initiated on the temporal distribution of person trips.

An analysis should also be made of the individual and collective effects of proposed improvements or sets of improvements on cordon crossings. Several benchmarks, discussed later, for improvement may be used for evaluation. The main point is that specific objectives should be decided on to evaluate the results.

Finally, the results of the analysis shown as alternatives or systems of improvements must be synthesized and brought together in the form of a plan for action. Probable results should be described in as much detail as possible so that implementation can proceed when final approval and funding are obtained.

PARKING OR SPECIAL STUDIES

Procedures for parking studies in the past have frequently allowed the development of some of this information. These studies have frequently included a count cordon as a part of their study design. Although the work has sometimes not related vehicle travel to person travel, it might be possible by the application of occupancy relation and transit data to obtain an estimate of person travel at a given point in time by this means. Purpose data and parking information would also be available if this route were taken.

The disadvantage of this is that a minor error in automobile occupancy or incorrect assumptions used in handling transit data might lead to substantial inaccuracy in the final results. In other words, the use of old data from several sources is not desirable.

Another similar means of developing person-trip information is to relate it to the actual activities that take place in the CBD. Some cities may already have a good base of information on employment, retail sales, and land use from efforts that have gone on over the years. Some work of this type has been assembled as a part of local transportation studies.

The obvious disadvantage of this type of information is the rather abstract means that might have to be taken to translate the information into the person-trip base provided by the other types of studies mentioned. Although modal relations might well be available from transit ridership or revenue data, travel by time of day is unlikely to be available without a special effort to obtain such data. Calibration would be difficult, and again some of the assumptions that would be required to use such data might well affect the conclusions.

Trends in Travel Mode Over Time

One purpose of the type of analysis proposed here is the development of trends over time. Although the most important of these from a transportation point of view is choice of travel mode, substantial value would also be obtained if such annual trends were obtained stratified by purpose and perhaps by parking cost, type of parking used, duration of stay in the study area, income of entering persons, and so forth. This is idealized, and the description provided here relates only to trends in entering travel by mode.

The most effective of the data sources listed in the previous discussion relative to modal choice over time is the cordon study. It offers frequent data points and is relatively inexpensive to reproduce at any time. It does not offer much on trip purpose. This is not as important as modal choice, and modal selection is particularly well covered.

There are a number of misconceptions among the general public as to the shape of trends of travel mode selection over the years. Figure 6 offers a look at the percentage of person trips by mode for Chicago from 1926 to 1961. The absolute trend in person travel directed to the CBD has not changed appreciably over the years as shown by Figure 7. The percentages are closely representative of the real number of persons using the available modal choice. It can be seen from Figure 6 that both automobile passengers and rail transit passengers to the central area have increased over the years, and the decline in bus travel reduces the total portion of travel by transit to the CBD.

The representation of Chicago downtown travel shown here is obviously not typical of all cities. Some cities of more than 500,000 population do not have rail facilities. It would be interesting to see the shape of this curve for other cities, however, for comparison purposes and as a check against projections of future travel.

Projections of CBD Activity

The previous section relates to the development of trends in modal travel to the CBD over time. It might be inferred from the discussion that we would then extend these trends to reach a future projection of mode of person travel. This is not the intent because we believe that there are better ways of making future projections including the whole range of modal split procedures that have been developed over the years.

Figure 5. Parking accumulation by type.

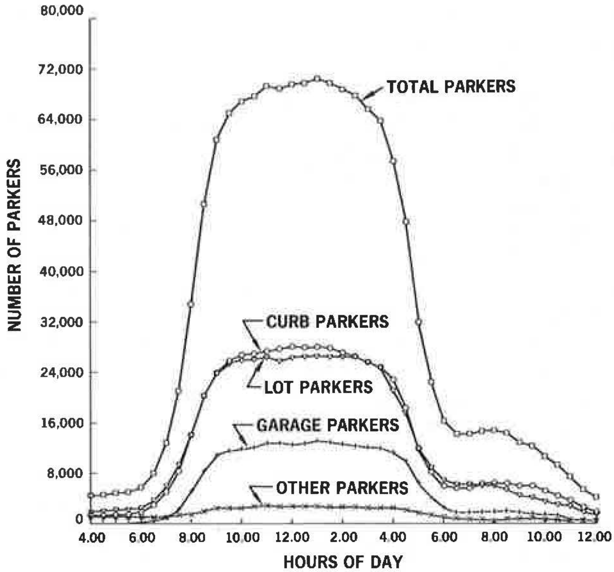


Figure 6. Modal distribution of persons leaving Chicago Loop (p.m. peak hour).

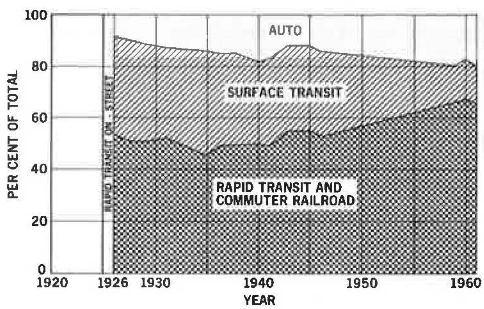
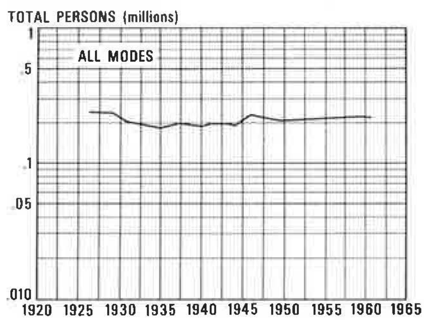


Figure 7. Trends in peak-hour Chicago Loop cordon movements (one direction).



Furthermore, it is our contention that trends can be reversed or at least altered by the application of other measures, some of which are discussed here.

The point of this is that projection of present trends in CBD-directed travel leads to a conclusion of what future travel will be like. Projection made in relation to transportation planning studies may offer an entirely different conclusion. If a revision in either activity level or modal selection is anticipated, it will probably come about because of changed conditions in the CBD. If conditions do not change, an entirely different result may be expected.

The annual cordon count supplemented by the occasional collection of O-D data oriented to the CBD would allow the periodic checking of such trends and revision of such projections from time to time based on anticipated or imminent changes.

Most urban transportation planning studies for large cities now project considerable increases in CBD activity in the future. This is frequently in direct conflict with present trends. It seems likely that the relations involved in making such projections should be checked against probable future development in terms of types of activity, levels of activity, and intensity of activity in order to more effectively provide for future needs.

MEASURES THAT MIGHT BE APPLIED

The following discussion relates to measures proposed to solve urban transportation problems. Most of them have their greatest application in the CBD or its surroundings. Some items specifically not mentioned are technological advances that may receive broader application at a future time. The material is grouped into functional areas to allow the combination of related ideas. Discussions are not exhaustive and are only intended to provide a buffet from which one can choose and then embark on his own more exhaustive study.

Bus Improvements

One means of improving urban transportation that has received more attention in recent years is the bus roadway or bus roadway system. This is due in part to the successful operation of bus lanes on the Shirley Highway in the Washington, D.C., metropolitan area and on I-495 through the Lincoln Tunnel in New York City.

Providing a roadway for buses removes them from normal traffic congestion and improves travel time for bus riders. This improvement in travel time may allow time savings over private passenger vehicles and still provide other transit advantages. The concept is more flexible than rail service in that the bus picks up and delivers passengers near home.

Bus roadways may be provided exclusively for buses or may also serve other vehicles. The numbers and types of other vehicles allowed would be restricted. Vehicles that might be allowed could include car pools, trucks, emergency vehicles, police, or a combination of types of vehicles.

Bus roadways may be constructed as new facilities or use existing lanes. Removal of parking on an arterial street might provide the street width necessary to include a busway. Abandoned railroad rights-of-way have also been proposed for construction of busway systems.

Private or publicly owned minibuses carrying from 9 to 16 passengers could be operated by commuters as a sort of large car pool to reduce operating costs. Small units such as this might be leased for charter line-haul commuter service. A private individual, governmental unit, or private company might set up car pools and lease the vehicles primarily for work travel. These operations provide for relatively low operating costs because commuters normally drive. A company or the government could take advantage of fleet purchase prices and insurance rates if they provided such service.

Small buses (those accommodating 16 to 30 passengers) could also be operated on fixed schedules on circulatory routes in the CBD. This concept might also be applicable to medical or airport complexes or for neighborhood pickup and distribution feeding line-haul transit stations.

Other novel transit operating concepts might include the following:

1. Demand-actuated systems on low-cost or free taxicab or jitney service for the aged, the disabled or sick, or the very young on either a routing or phone-call basis; and
2. Several buses linked together into a train for improved line-haul service.

Parking Innovations

Fringe parking is a term that has come to mean parking on the outskirts of the CBD or farther out in the metropolitan area with public transportation service to the city center. Such parking encourages the commuter to leave his car at the lot and to ride public transportation.

Fringe parking may be provided at or near strategic interchanges on the freeway system. There are sound reasons for not providing parking in the interchange, but space can frequently be found adjacent to interchanges or frontage roads. Such parking may merely provide a formation point for car pools.

Free or inexpensive parking near downtown can reduce congestion. Bus or people-mover service can be provided to shuttle persons to their final destination.

The elimination or restriction of on-street parking can greatly reduce traffic congestion. Combined with an adequate off-street replacement program, the elimination of street parking adds travel lanes to increase capacity and at the same time eliminates the accident potential created by high-turnover curb parking.

The planned application and control of parking rates offer a means of controlling the use of parking facilities to promote other transportation objectives:

1. Rates in the core area might be revised in favor of better service to shoppers. This can be accomplished by establishing a low first-hour parking rate with increasingly higher hourly rates leading to a very high all-day parking charge. This is the reverse of most present parking rate structures.
2. On-street parking rates can be raised to more accurately reflect the value of such spaces. High rates for on-street parking should reduce all-day use, promote higher turnover, and shift meter feeders to off-street parking.
3. Merchants and businessmen can cooperate to better serve downtown shoppers. Parking validation systems may ensure spaces earmarked for shopper use and allow participating merchants to pay their proportionate share of costs. Incentives of this type might be supported by the city to keep shopping interests in the CBD.

Zoning requirements for the type and location of parking facilities need not be applied piecemeal but should be related to transportation goals based on analysis of downtown transportation needs.

Most zoning codes specify minimum parking space requirements according to type and intensity of land use on a per square foot, per seat, per bed, or similar basis. These requirements might be revised to restrict the number of parking spaces provided. This practice would eventually reduce the supply of parking spaces and discourage personal vehicle trips to the CBD. Conversely, such a policy may affect downtown business and the tax base of the community so that caution is required in its application.

Parking fees provide a direct means of imposing a congestion toll on vehicle users. Free parking attracts because its cost is hidden. The elimination of free parking and initiation of a progressive parking rate structure provide another means of reducing urban area traffic congestion. Other pricing methods are as follows:

1. Where tolls are paid on entry to congested areas, the tolls might be raised to promote transit use or car pools.
2. A tax might be levied on all vehicles entering parking facilities between, for example, 7:00 and 10:00 a.m. This might cause the commuter to consider alternative travel.
3. Free transit service has been proposed as an incentive to increase ridership. Although present revenues would become a new burden on the community, the costs and inconveniences of fare collection, token sales, and exact change systems would be eliminated, thus reducing costs.

4. A tax on parking might provide revenue to support improved transit service.

Improved integration and interchange among modes is a real need in some cities. One way that this can be accomplished is by the provision of a center where modal transfer is simplified. A center might include rail facilities, bus terminals, taxicab loading areas, limousine loading, curb frontage or turnouts for kiss-and-ride passengers, off-street parking, car rental areas, or some combination of these services. The terminal would require good connections to local and regional access roads and might have direct freeway access.

Complementary uses such as shopping, pedestrian services, service stations, and ticket agencies might be included to offset the cost.

Car pool matching systems might bring together travelers into fewer vehicles for trips to congested areas. A questionnaire submitted by each individual car pooler would provide information on travel times, locations of home and work, and willingness to ride, drive, or share driving. Home origins might be matched based on a grid map of the area or on other information such as zip codes, telephone exchanges, or transportation study zones. Other incentives to car pools might be provided in the form of lower parking costs for car pools and reduction or elimination of tolls based on automobile occupancy.

Revised Time Patterns

Urban traffic volumes exhibit marked peaking characteristics primarily because of the controlling influence of work trips. A relatively simple and inexpensive method of reducing peak-hour traffic is to introduce staggered work hours at major traffic generators. Reductions in the travel peaks should result in immediate improvement in travel service even if no additional transportation capacity is provided.

Employees are generally agreeable to changes of up to 30 min before or after their normal duty hours. The results of staggered work hours should be less congestion and better utilization of transportation facilities.

A logical extension of the staggered work hours concept is the 4-day week. This simply consists of rescheduling the workweek from five 8-hour days to four 10-hour days. There are several ways in which this could be scheduled including revisions in total number of days per week a firm stays open and the ways in which a given employee's 4 workdays are scheduled.

The net result of this improvement would be a decrease of travel to the CBD in the range of 17 to 33 percent. Other results would include a reduction in parking demand and a possible reduction in transit ridership.

The concept of Gleitende Arbeitzeit has been introduced in Germany, and the name can be translated as "gliding work time." Under this arrangement, each employee is allowed to report for work any time between, for example, 6:00 a.m. and 10:00 a.m., work for 8 hours, and then depart. The concept could not be adopted for all types of employees, but would allow a good many to revise their travel schedule, thus reducing congestion.

All of these proposed improvements can be analyzed to greater or lesser degree in terms of the procedures discussed here. The biggest single problem in applying them is the present lack of means of judging their relative or absolute effectiveness. This is not possible currently because of a lack of information, but relations can be developed in the context developed here. The more likely event at this time is the introduction of these measures because of their ostensible "goodness" without at the same time judging, measuring, or evaluating their effectiveness.

REFERENCE

1. Manual of Traffic Engineering Studies. Institute of Traffic Engineers, 1964, pp. 47-64.

TRAFFIC MANAGEMENT AND RESTRAINT BY PARKING CONTROL IN GREATER LONDON

A. D. May, Department of Planning and Transportation, Greater London Council

This paper sets out the objectives and methods of parking control as used for traffic restraint in Greater London and advocates control predominantly by pricing. Using results of surveys summarized in the report it suggests that a 15 percent reduction can be achieved in car commuting to Central London.

•THE Greater London Council (GLC) is the strategic planning and traffic authority for Greater London and has set out in the Greater London Development Plan broad strategies and policies for London's future. The plan provides a framework for the 33 local planning authorities whose responsibilities include parking provision and control.

In discussing transportation planning, the plan accepts that full demand for road use cannot be met by building new primary roads and that some means of regulating this demand (other than the inefficient deterrent of congestion) is required (1). To this end, the plan supports traffic restraint measures that have the following characteristics:

1. Flexibility—so that demand can be adjusted to match traffic and environmental needs in a changing transport network without imposing too severe a restriction on any element of the community;
2. Selectivity—so that greater control can be imposed on the journey to work and other trips for which public transportation is available;
3. Equity—so that the measures can be accepted by the community at large; and
4. Simplicity—so that the measures are easy to administer and enforce.

The potential restraint measures fall into three categories:

1. Parking controls, placed on either the availability or use of parking space;
2. Charging for use, by establishing, for example, supplementary licensing or road pricing (2); and
3. Physical controls, by using, for example, bus lanes, pedestrian areas, and road closures.

The plan recognizes that, of these measures, parking control is most readily available and advocates its use as the main restraint tool. However, it foresees the need for other types of restraint in the future.

BASIS OF PARKING POLICY

The GLC's parking policy has been developed over a number of years. Its framework is set out in the plan, but some of its details are still being determined as experience is gained in the use of parking control as a restraint tool.

Objectives

The main objectives are those of flexibility, selectivity, equity, and simplicity. In addition to these objectives, which are common to all restraint methods, there are three main considerations arising from the need to provide parking space as a service:

1. Finance—Any subsidy to the motorist in apportioning costs of parking supply and operation will need to be justified and should not conflict with the need for restraint.

2. New provision—New parking places should be provided if the demand justifies them after restraint has been imposed and if the financial objectives can be met.

3. Operational efficiency—Those who use parking spaces should be able to do so with the minimum of inconvenience. In practice this means that, except in unusual circumstances, some spare spaces must always be available and that all forms of publicly operated parking should be operated so as to be internally compatible.

Areas of Control

Because parking control provides a restraint on the trip end, it will be most effective if imposed in areas with high concentrations of trip ends. Because these are also the areas best served by public transport, restrictions on car use will cause the user less inconvenience. The areas in which it is proposed to exercise control are the Inner London parking area, a 40-square-mile area that includes the central area and a surrounding belt of shopping, office, and higher density residential districts, and the 24 town centers outside this area that have been designated in the plan as the main centers of attraction in Outer London. These areas are shown in Figure 1.

Control on Supply

Limits on the number of parking spaces would clearly help to reduce trip ends in an area; however, they provide a very inflexible means of control and do not of themselves ensure that the available space is used in the required way. Without control of use, the limited number of spaces would operate on a first-come, first-served basis, thus accommodating predominantly commuter parkers, and would also be heavily oversubscribed, leading to inefficient use because drivers would have to search for parking spaces.

Current policy therefore places more stress on control of use and only imposes stringent controls on supply when use cannot be controlled.

For efficient operation, the policy recommends that some spare capacity should be available even at peak-demand periods. Peak occupancies of 85 percent for on-street parking and 90 to 95 percent in public parking lots are recommended.

Within the overall supply, some change from on-street to off-street provision could take place. However, the extent will be limited by the cost of conversions [in Central London average costs per parking space per year, including debt charges, are $720 for multistory parking lots and $140 for meters (3)] and by the need to maintain some short-term parking space within easy reach of all points of attraction in the area.

Control on Use

Four main methods of control are available, either individually or in combination. They are as follows:

1. Time limits on the availability of parking space—Such limits could be imposed, for instance, to limit supply during the peak periods. Although they provide a somewhat more flexible means of control than limits directly on the supply of parking space and are relatively easy to enforce, the limits are not equitable because they do not permit essential parking during the control periods and they put undue pressure on the spaces that are not similarly controlled. In Central London, at least, they would have to be very restrictive because more than 30 percent of on-street spaces are still unoccupied by the end of the morning peak.

2. Time limits on parking duration—These limits are imposed mainly on meter parking. They provide space for short-term parkers, who are predominantly on shopping, business, and leisure trips, and deter the car commuter. However, they also deter the essential long-term parker and particularly the resident, who should be encouraged to leave his car at home. Of particular concern is the difficulty of enforcing such limits adequately.

3. Allocation by permit to certain classes of user—Such allocation is usually used to safeguard certain users, such as residents, rather than to restrain those users who are not favored. It is clearly selective but may not be a sufficiently flexible means of

control because, for administrative reasons, fairly broad classes of users have to be defined. Although easy to enforce, this type of allocation does not necessarily ensure availability of space to the permit holder.

4. Pricing—Pricing provides a highly flexible means of control that can be used to discourage certain types of users and encourage others. By charging at different levels in different types of parking space, a satisfactory distribution of parking can be obtained, demand can be kept below the supply level, and some return on investment can be obtained. The main drawback is that pricing favors the wealthier members of the community and particularly those who have their parking charges paid for them. A survey in 1966 indicated that 28 percent of Central London car commuters had their parking expenses refunded (4). Even so, willingness to pay provides some measure of need to park, and increases in parking charges can be expected to have some effect on the majority of users.

DETAILED POLICY AND ITS IMPLEMENTATION

Types of Parking Spaces Available

The detailed parking policy is best considered in terms of the different types of spaces available. These are as follows:

1. Free, uncontrolled on-street spaces that are being eliminated as controls are introduced.
2. Free, controlled on-street spaces that are provided where demand is low. Controls dictate the places in which cars may park, in the interests of safety, but not the way in which spaces are used.
3. Paid for, controlled on-street spaces that are usually regulated by meter although some ticket machines are used. The control period is usually 8:30 a.m. to 6:30 p.m., Monday through Saturday.
4. Residents' on-street space permits that are obtained from the local authority. The resident pays either daily or for longer periods to use such space in the zone in which he lives. The control period is identical to that for meters.
5. Publicly available off-street parking lots that are operated by the local authority.
6. Publicly available off-street parking lots that are operated privately. In these, the private operator determines the terms of operation.
7. Private off-street parking lots that are attached to nonresidential developments. Use of these is restricted to trips connected with the development; they are predominantly attached to office development. Legally, they cannot be used as public parking lots.
8. Private off-street parking lots that are attached to residential developments. These operate in the same way as in the preceding item.

Table 1 gives the current distribution of parking spaces by type in the central area, the remainder of the Inner London parking area, and three strategic centers: a large shopping and office center (Croydon), a smaller shopping center (Woolwich), and a medium-sized shopping center in which parking has not yet been controlled (Wood Green). It can be seen that, in Central London and Croydon, private nonresidential parking forms the largest single element of the total supply and public parking spaces form the second largest group. In the remainder of the Inner London parking area (about 20 percent of which has on-street controls) and in Wood Green, uncontrolled on-street spaces predominate. Woolwich is typical of many of the shopping centers with on-street controls in having the largest proportion of spaces in public parking lots.

Patterns of Use of Different Types of Parking

Use of different types of parking spaces was recorded in a study of nonresidential parking spaces conducted in Central London in 1966 (4), which is summarized in Table 2. Free on-street space had the highest peak occupancy, average levels of peak-period arrivals, turnover, and duration, and an even distribution of trip purposes. Experience since the survey suggests that, as the number of free spaces has fallen, occupancy has

Figure 1. Centers of activity in Greater London.

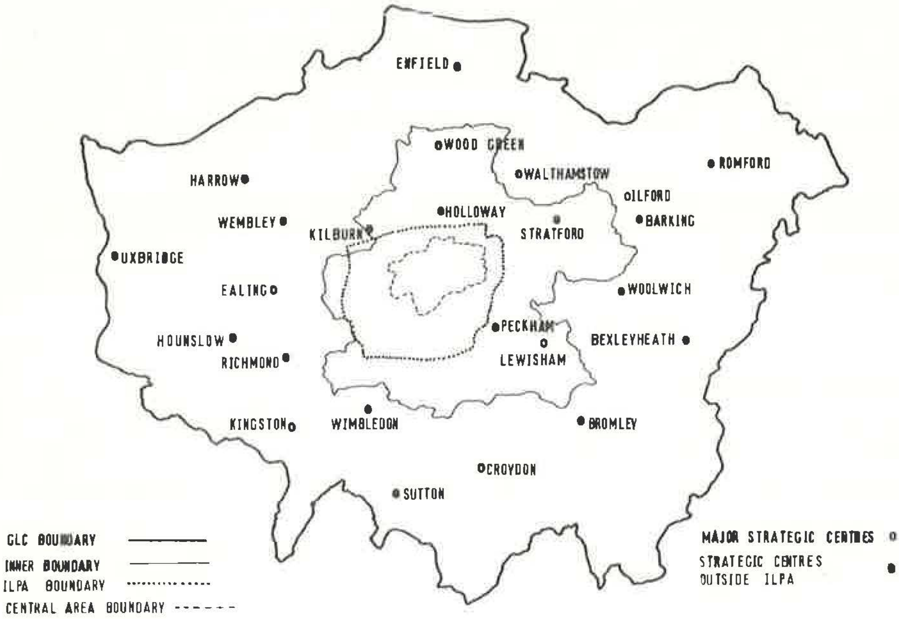


Table 1. Distribution of parking spaces in London areas, 1972.

	Central Area (10.4)[a]		Remainder of ILPA[b] (40)		Croydon (2.0)		Woolwich (0.15)		Wood Green (0.4)	
Characteristic	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
On-street parking										
Free and uncontrolled	5,000	4	252,000	61	Nil	—	Nil	—	2,500	73
Free and controlled	Nil	—	Nil	—	2,200	10	500	18	Nil	—
Metered	21,000	17	9,000	2	1,400	7	300	11	Nil	—
Residents only	8,000	6	22,000	5	Nil	—	Nil	—	Nil	—
Total	34,000	27	283,000	68	3,600	17	800	29	2,500	73
Off-street parking										
Public, officially operated	5,000	4	4,000[c]	1	5,400	26	700	25	200	6
Public, privately operated	27,000	21	9,000[c]	2	200	1	300	11	Nil	—
Total public	32,000	25	13,000	3	5,600	27	1,000	36	200	6
Private nonresidential	45,000	36	53,000	13	5,700	27	600	21	300	9
Private residential	15,000	12	65,000	16	400	2	400	14	400	12
Total off-street	92,000	73	131,000	32	17,300	83	2,000	71	900	27
Grand total	126,000	100	414,000	100	20,900	100	2,800	100	3,400	100

[a]Area in square miles.
[b]For enumeration purposes a somewhat larger area has been used.
[c]Estimated proportions based on proportion of Inner London public parking lot spaces operated by the local authority.

Table 2. Use of different types of parking spaces.

Type of Space	Free On-Street (uncontrolled)	Metered On-Street	Public Off-Street	Private Nonresidential
Peak occupancy (percent)	87.4	84.3	67.5	72.6
Percentage of all arrivals during morning peak (7:00 to 10:00 a.m.)[a]	29.5	14.8	56.9	48.0
Turnover[a]	2.24	5.62	0.94	1.15
Average duration[a] (hours)	4.5	1.6	7.5	6.1
Percentage of all arrivals[a]				
Work trips	39	20	44	65
Employers' business trips	24	37	28	16
Shopping and personal business	17	29	19	10
Other purposes	20	14	9	9

[a]Parking was surveyed from 6:00 a.m. to 8:00 p.m.

reached virtually 100 percent with most spaces being used all day by commuters. The results for the other types of space are, however, more typical of present conditions. Meters have high turnover, low duration, a small proportion of all arrivals during the morning peak, and a low proportion of all arrivals making work trips. Public off-street spaces have low turnover, high parking duration, a high proportion of morning peak arrivals, and a high proportion of work trips. Private nonresidential spaces operate similarly but have an even higher proportion of work trips.

On-Street Parking

All on-street parking is to be controlled within the Inner London parking area and in the strategic centers outside this area. New areas are controlled as demand for uncontrolled on-street space spreads. The original on-street control policy drafted in 1966 laid down the following priorities for allocation of street space:

1. In the interests of safety and traffic movement, street corners and other critical points should be kept clear of standing vehicles by restrictions on both waiting and loading;
2. Suitable curbside lengths, including the full length of main roads where practicable and loading gaps in side roads, should, by use of waiting restrictions, be kept clear of parked vehicles;
3. A reasonable number of spaces for short-term parking should be provided in groups near centers of attraction and in smaller numbers elsewhere, with parking meters enforcing time limits (up to 2 or 5 hours) and collecting charges; and
4. All-day parking should be permitted in the remaining curbside space, under arrangements giving preference to residents.

In practice, amendments to these priorities have been made, or are being considered, as follows:

1. In the interests of traffic restraint, parking is not necessarily permitted at all the lengths of curb not excluded previously;
2. Some parking spaces are being removed as off-street parking lots are open in the immediate vicinity;
3. Long-term parking is generally being charged for; and
4. Proposals are being considered for permits for local employees or merchants in areas where spare space is available after residents' needs have been met in order to give them priority over park-and-ride commuters.

In Central London, meter charges vary from 6 to 24 cents per hour, but a fare of 48 cents per hour is proposed to combat excess demand. In the strategic centers, charges vary from 12 cents for 5 hours to 12 cents for ½ hour. Residents' permit charges vary from 24 to 36 cents per day and from $1.20 to $6.60 per month. The rate levied depends more on the local authority's attitude toward subsidizing its residents than on the need to equate demand to supply.

Public Parking Lots

The local authorities at present can only dictate the conditions of operation in parking lots that they operate. These form about one-quarter of all public parking spaces in Inner London and three-quarters of the spaces in Outer London. However, the GLC has recently been given powers to require that all privately operated public parking lots in areas that it designates are operated according to conditions set out in licenses issued by the local authority. Subject to any modifications the GLC may make, local authority parking lots should be operated on the same basis. The GLC is able to place overall conditions on the control of an area, and both the GLC and the local authority are able to dictate the conditions on the license, which could affect traffic patterns in the following ways:

1. Maximum number of spaces in an area for all parking, short- or long-term parking, or casual or regular parking may be specified;

2. Capacity of each parking lot must be specified;
3. Scale of charges, including the minimum and maximum charges, can be specified for each parking lot;
4. Proportion of spaces to be made available in each parking lot for casual or regular parking can be specified; and
5. Times of opening and closing of each parking lot can be specified.

The ways in which these powers are to be used are still being discussed, but the following have been suggested:

1. All areas with on-street control should, in time, also be subject to off-street control through licensing.
2. Control would predominantly be by pricing.
3. Charges during the working day (7:00 a.m. to 7:00 p.m.) would be levied at a fixed rate per hour, with a minimum level equivalent to about 75 percent of the 1-hour meter charge in the area. It is anticipated that this would provide high enough charges to discourage many long-term parkers and would also discourage illegal long-term parking at meters. If necessary, surcharges could be made for durations of more than, say, 6 hours.
4. Residents would be able to purchase season tickets at a rate lower than the normal fixed hourly rate.
5. Except in special cases, prepaid parking could not be obtained other than by residents because such season tickets tend to encourage greater use of the vehicle.
6. Charges would in theory be levied so as to equate demand to about 90 to 95 percent of supply to ensure that space was available to those requiring it.

In practice, when licensing is introduced, 90 to 95 percent occupancy will not be achieved in all areas, either because short-term parking demand is not high enough or because the additional traffic would itself cause congestion. In these cases, some removal of meter bays may be justified in streets adjacent to the parking lots to encourage great use of off-street parking. It is hoped that decisions on future parking lot developments will be dictated largely by financial considerations and hence by the demand for short-term parking and for residents' places (at the charging levels imposed by licenses in the area) that cannot be accommodated in existing parking lots even after long-term parkers have been restrained.

Private Nonresidential Parking Lots

No controls can be placed on the use of these, and it is therefore important to control the future supply of such space. To this end, new standards have been laid down in the plan for parking provision in offices and shops, and criteria have been established for assessing parking requirements in other types of development. The new standards are compared with the earlier standards given in Table 3. The old standards were for minimum provision, with the idea that developments should account for all parking demand that they generate. The new standards are maximum standards, designed to provide for the operational needs of the building, including space for vehicles garaged on site, staff vehicles used for essential purposes during the day, and some visitors' vehicles. There is also provision for those employees for whom public transport is not available. These standards were based on a detailed study of business traffic generation (5), in which it was found that 80 percent of parking spaces in some office parking lots were used solely for commuting.

The local authorities have been asked to introduce standards within the ranges based on the availability of public transport in individual areas; to date, new standards of between 1 space per 10,000 ft^2 and 1 space per 12,000 ft^2 have been introduced in 85 percent of the 10-square-mile central area.

The possibility of encouraging owners of existing private parking lots to convert their spaces either to public lots or to other uses is being investigated. It is not expected that requests for voluntary action will be very successful although, as parking charges and land values rise, some owners may find alternative uses attractive. In the long term, powers may be needed to control the use of such spaces, and consideration is being given to imposition of a tax for ownership of private parking spaces and to the possibility of compulsory purchase of such spaces.

Private Residential Parking Space

Because it is considered important to encourage the resident to keep his car at home during the day, the plan includes a requirement that at least one parking space be provided for each new dwelling. In areas of low car ownership, however, a minimum of half the required spaces can be made available initially, provided that space is set aside for full provision at a later date.

EFFECTS OF POLICY TO DATE

Parking Supply

Table 4 compares parking supply in the central area in 1962, soon after on-street parking controls were introduced and before the GLC's parking policy had been developed, with conditions that prevail today. It can be seen that the reduction of 26,000 spaces produced by on-street controls has been almost balanced by increases of 8,000, 10,000, and 7,000 in public, private nonresidential, and private residential space respectively. The proportion of spaces in the central area that were publicly controlled has risen from 14 to 29 percent. The increase of 10,000 in the number of private nonresidential spaces indicates the effect of the old standards for parking provision in a period of considerable postwar redevelopment. The pattern elsewhere in London has been similar. Some 40,000 spaces have been lost through on-street controls elsewhere in the Inner London parking area, and 10 strategic centers have on-street parking control now, compared with 1 in 1962. Figure 2 shows the present extent of on-street control. In all these areas, sizable increases in off-street parking have occurred.

Parking Use

Figure 3 shows trends in evening peak-period traffic on a representative road network in Central London over the past 20 years. The rate of growth has fallen from about 7 percent per annum to zero since 1964, whereas level of employment in the area has remained virtually constant. This reduction can be attributed largely to parking control. The figure also includes trends in numbers of car occupants entering Central London during the a.m. peak; although the pattern here is somewhat less clear, there has been a reduction in the growth rate since 1964. That there has not been a fall in peak-period flows is largely the result of increases in supply of off-street space and occupancy of all types of parking space. Table 5 gives estimates of occupancy of parking spaces at the end of the peak period in 1966 and 1972.

Detailed Effects on Use

Two surveys have been made of the effects of introducing meter zones: one of a ¾-square-mile extension to an existing zone (6), the other of a ½-square-mile isolated zone (7). The following results are of interest:

1. On-street parking accumulation fell by 69 and 67 percent in the two surveys.
2. Peripheral parking can considerably reduce effectiveness of control unless controls extend at least ½ mile from the main center of attraction. In the isolated zone, increased peripheral parking compensated for 45 percent of the reduction in the zone.
3. Meter control obviously has most effect on long-term parking but can also reduce short-term parking. In the isolated zone, short-term parking at 10:00 a.m. fell by 44 percent.

Traffic Movement

The main effects of parking control to date have been seen in improved traffic conditions within the control areas. Figure 4 shows trends in journey speed, measured over 100 miles of road in Central London, in recent years, and compares these with

Table 3. Parking standards for offices and shops.

Area	Spaces per Square Foot of Gross Floor Area	
	Old Standard[a]	New (GLDP) Standard[b]
Offices		
Central area	1/2,000	1/5,000 to 1/12,000
Inner London	1/2,000	1/2,000 to 1/8,000
Outer London	1/500	1/400 to 1/2,000
Shops		
Central area	1/2,500	1/5,000 to 1/12,000
Inner London	1/2,500	1/2,000 to 1/8,000
Outer London	1/1,000	1/400 to 1/2,000

[a]Minimum standards. [b]Maximum standards.

Table 4. Parking supply in Central London.

Type of Space	1962 Number	1962 Percent	1972 Number	1972 Percent	1982 Number	1982 Percent
On-street						
Free and uncontrolled	48,000	38	5,000	4	Nil	–
Metered	12,000	9	21,000	17	21,000	16
Residents only	Nil	–	8,000	6	9,000	7
Total	60,000	47	34,000	27	30,000	23
Off-street						
Public	24,000	19	32,000	25	28,000	21
Private nonresident	35,000	28	45,000	36	48,000	36
Private resident	8,000	6	15,000	12	27,000	20
Total	67,000	53	92,000	73	103,000	77
Grand total	127,000	100	126,000	100	133,000	100
Percentage under public control	14		29		44	

Figure 2. On-street parking control zones, 1972.

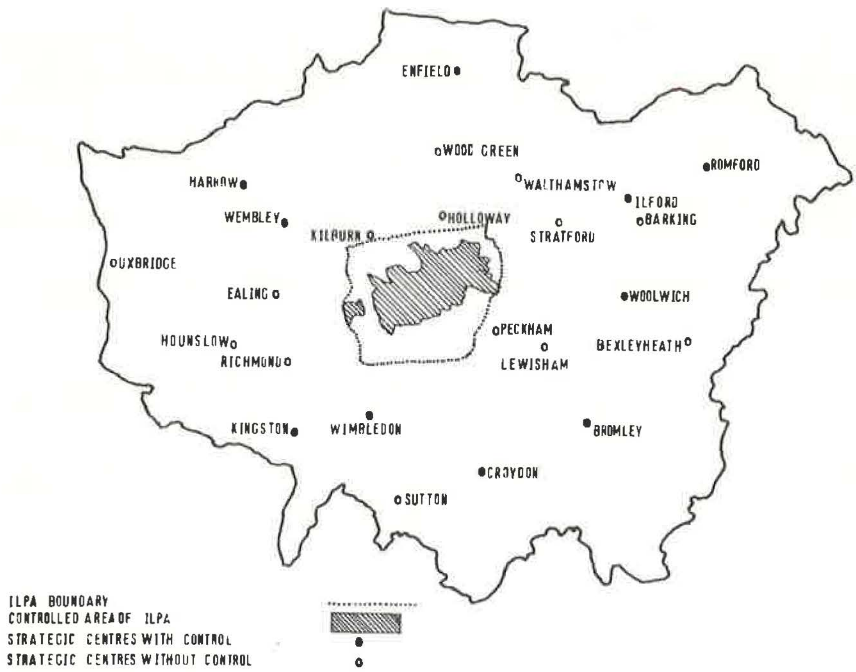


Figure 3. Trends in traffic flow, Central London.

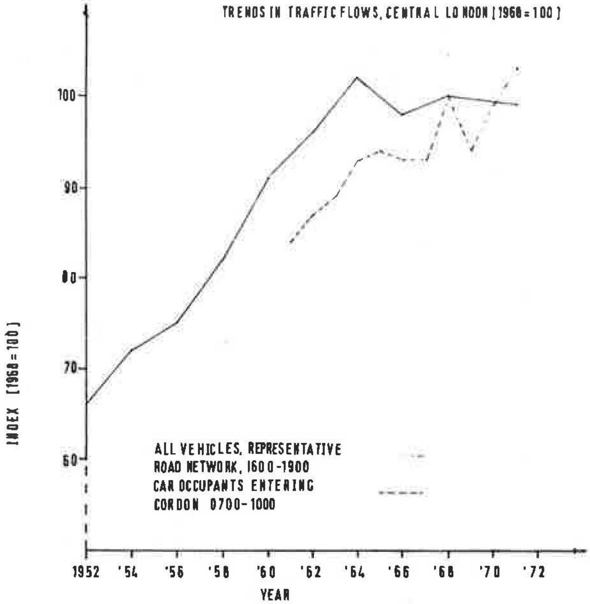


Table 5. Occupancy of parking spaces at 10:00 a.m., Central London.

Date	Type of Space	Number of Spaces	Cars Parked at 10:00 a.m.	Occupancy at 10:00 a.m.	Percentage of All Spaces	Percentage of All Cars Parked
1966[a]	On-street, free	30,000	24,900	83.1	27	34
	On-street, metered	14,500	9,400	64.9	13	13
	Total on-street	44,500	34,300	77.0	40	47
	Off-street, public	25,500	14,600	57.6	23	20
	Off-street, private[b]	40,000[c]	24,200	60.6	37	33
	Total off-street[b]	65,500	38,800	59.2	60	53
	Grand total[b]	110,000	73,100	66.5	100	100
1972	On-street, free	5,000	4,700	95	5	6
	On-street, metered[b]	21,000	14,500	69	20	20
	Total on-street[b]	26,000	19,200	74	25	26
	Off-street, public	32,000	20,800	65	31	28
	Off-street, private[b]	45,000	33,300	74	44	46
	Total off-street[b]	77,000	54,100	70	75	74
	Grand total[b]	103,000	73,300	71	100	100
1982	On-street, free	Nil	—	—	—	—
	On-street, metered[b]	21,000	13,600	65	22	22
	Total on-street[b]	21,000	13,600	65	22	22
	Off-street, public	28,000	9,200	33	29	15
	Off-street, private[b]	48,000	39,800	83	49	63
	Total off-street[b]	76,000	49,000	65	78	78
	Grand total[b]	97,000	62,600	65	100	100

[a]Source: reference 4. [b]Excludes residents' spaces. [c]Estimate revised since publication of reference 4.

the spread of on-street parking control. A steady fall in evening peak speeds up to 1958 has been replaced by a rise to above the 1952 level. A similar, though less pronounced, pattern is indicated by the off-peak speeds. In both cases, the rise has coincided with the development of on-street control. Although other factors such as traffic management measures have obviously helped, parking control has played a major part in the improvement.

ANTICIPATED EFFECTS OF PARKING CONTROL

Parking Supply

Table 4 also gives predictions of parking supply in 1982 based on the policies described in this paper. The main effects are as follows:

1. All on-street spaces will have been controlled. Although the table does not indicate it, some on-street spaces could well be removed as space in public car parks is freed of long-term parkers.
2. Public car parks will be developed only as short-term and residents' demands arise; the figure shown assumes completion only of parking lots that currently have planning permission together with closure of all temporary sites. Some addition could occur as a result of conversion of private nonresidential spaces. All public parking lot spaces would be controlled.
3. Growth in private nonresidential space would only be 3,000 as compared with 10,000 in the previous decade. This would be the direct result of introduction of the plan standards. Some reduction could in practice occur as a result of conversion of spaces.
4. Private residential space would increase by more than 50 percent.
5. The total number of spaces would rise by 7,000.
6. The proportion of spaces that were under public control would rise from 29 to 44 percent.

Similar trends would be expected elsewhere; in the remainder of the Inner London parking area, the number of spaces is expected to be about 350,000 (a reduction of about 15 percent) with about 36 percent under public control. It is hoped, too, that parking could be controlled in all strategic centers; already eight additional centers are planning on-street controls.

Parking Use

It is expected that some reduction in peak-period traffic generation can be achieved through parking control in the next decade. Table 5 also gives estimates of occupancy of parking places at the end of the peak period in 1982. The estimates are based on the following assumptions:

1. Patterns of meter use would remain as currently set up with peak occupancy kept to 85 percent,
2. Use of public parking lots would be controlled by licensing to match existing parking lots that favor short-term parkers, and
3. Peak occupancy of private nonresidential parking lots would approach 100 percent with distribution of occupancy remaining the same as is now prevalent.

If these assumptions hold true, it can be seen that the number of cars parked in Central London by the end of the peak period could fall by 15 percent in the next decade.

Effect of Control on Charges

Effects of licensing parking lots have been estimated from a survey of lot use and charging structure in nine parking lots in London's West End. Table 6 gives results that indicate that hourly charging structures attract less than half the peak-period arrivals per space found in lots with low hourly rates for long-term parking. At present, 84 percent of parking spaces in Central London have lower hourly rates for 8 hours of parking than for 2 hours of parking.

Figure 4. Trends in journey speed in Central London.

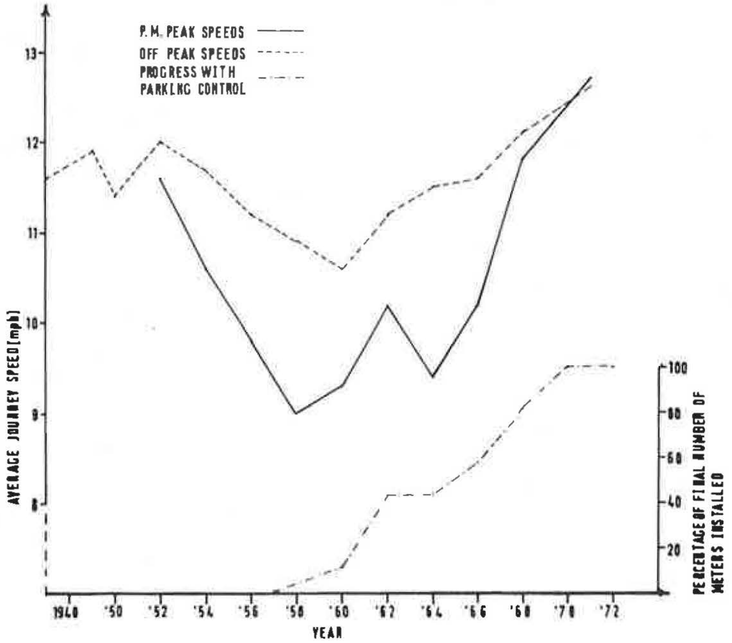


Table 6. Effect of charging structure on arrival and duration patterns at sample public parking lots.

Ratio of 8-Hour Charge to 2-Hour Charge	Sample Size	Average Ratio to Capacity of: Arrivals, 8:00 to 10:00 a.m.	Arrivals, 10:00 a.m. to 6:30 p.m.	Duration of <4 Hours	Duration of 6 to 10 Hours
1	3	0.53	0.50	0.18	0.43
2 to 3	3	0.58	0.58	0.27	0.41
4	3	0.25	0.99	0.54	0.20

Table 7. Effect of changes in charges at four parking lots.

Parking Pattern	Before	After	Change (percent)
Arrivals, 8:00 to 9:00 a.m.			
Affected parking lots	628	121	-81
Unchanged parking lots	300	309	+3
All parking lots	928	430	-60
Arrivals, 8:00 to 10:00 a.m.			
Affected parking lots	897	314	-65
Unchanged parking lots	702	685	-2
All parking lots	1,599	999	-37
Arrivals, 10:00 a.m. to 6:00 p.m.			
Affected parking lots	266	516	+94
Unchanged parking lots	478	596	+25
All parking lots	744	1,112	+49
Durations (660-space lot)			
Less than 3 hours	73	217	+200
More than 7 hours	496	116	-77
Median duration (hours)	8.9	3.2	-72
Purpose (660-space lot)			
Work	528	178	-66
Employer's business	39	94	+140
Other	64	154	+140

Further indication of the effects of charging structure was obtained when charges at four Central London parking lots were raised to 12 cents per hour from between 36 and 72 cents per day. Table 7 gives effects on arrivals at the four parking lots and at a similar number of unaffected spaces in the area. It also shows the effect on duration and trip purpose at one of the four lots, which has 660 spaces.

Peak-period arrivals at all sites combined fell 37 percent, whereas off-peak arrivals rose 49 percent because spare space was available. Work trips fell 66 percent and longer durations decreased by 77 percent. Employer's business and "other" trips increased by 140 percent, and short durations increased 200 percent.

PROBLEMS WITH PARKING CONTROL

Although parking control can greatly affect traffic generation, it does have some disadvantages. Enforcement of on-street controls is expensive and not very efficient. Problems arise because of the complexity of the regulations and the procedures involved in processing fines. These difficulties are made worse as demand gets out of step with supply, and surveys show that the level of enforcement is deteriorating (8). Some improvement can be expected from simplified procedures and unified control of on- and off-street parking.

Even if parking control is effective, it does not affect through traffic. This problem can be reduced by extending controls; only 15 percent of trips crossing the Inner London parking area cordon go through the area, whereas the figure is 25 percent for the central area. To have greater effect, supplementary licensing or road pricing would be needed, but even so parking controls would have a role as a complementary restraint measure.

ACKNOWLEDGMENT

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THE TRAFFIC ZONE SYSTEM IN THE CITY CORE OF GOTHENBURG, SWEDEN

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To achieve quick environmental improvement and better transportation without heavy expenditure, the Gothenburg City Council divided the city into five districts. Through traffic was transferred from the heavy loaded streets to the tangential streets by closing the borders to traffic other than pedestrians and public transport. No streets were closed to traffic, and transportation took place as usual though it was necessary to get into circulation routes located around the city core to reach the next zone. The public was informed of the new system by pamphlet distribution and advertising. Zone symbols helped motorists choose the shortest route. The traffic volume in the main streets has been reduced by 70 percent, there is more freedom of movement for the pedestrians, and air pollution and traffic accidents have been reduced. Private motorists have accepted the system well, but there has been protest from the taxicab organization, which asks to be treated as public transportation. Retail trade increased considerably in the residential areas and to a lesser extent in the city core. The need for increased parking facilities is being met.

•GOTHENBURG is Sweden's second largest city with approximately 500,000 inhabitants and approximately 150,000 cars. The city is 350 years old, and the oldest part, now forming the city core, was built as a fortress. Most streets are narrow, but some have been widened to serve as main arterials.

The number of cars rapidly increased after the second World War, and during the 1960's serious traffic and parking problems developed. In the 1960's, environmental problems, caused by heavy traffic, arose in the city core. Pedestrians had difficulty crossing streets, the carbon monoxide exhaust levels increased dangerously, and public means of transportation were impeded by automobile traffic. Traffic accidents and noise increased in the city core, built for pedestrians and horses 350 years ago.

During the 1960's, the Traffic Planning Department of Gothenburg studied various possibilities to solve the problem. In 1968, the City Council ordered that measures be taken to solve the most severe environment problems. In the 1959 master plan for Gothenburg, it has already been decided that the old city core plan and the scale of the buildings were of such a historical value that they could not be changed (Fig. 1).

The attempts made in the West German city of Bremen in the early 1960's to clear up the traffic conditions in the central areas of the city were of great interest for us in Gothenburg. Bremen is approximately the same size as Gothenburg and is situated at a river in the same way as Gothenburg. These attempts were studied and analyzed, and several visits were made to Bremen for first-hand observation.

The decision of the City Council in 1968 was to make necessary investigations aiming at a quick and economical improvement of the traffic situation with special attention to the Saturday traffic. The research was made with the following objectives: to improve the environment for pedestrians and those working in the city core, to increase trafficability for public transport, to ensure that proposed measures would be quickly carried out, and to realize the plan without heavy expense.

In this proposal, there was no suggestion for solving parking problems. However, this matter had been studied in other connections. The traffic count was used to determine which streets had the greatest pedestrian traffic. Certain shopping streets, which since the 1950's had been reserved for pedestrians, did not have intensive pedestrian traffic. Important through-traffic streets invariably had pedestrian congestion.

On a normal weekday prior to implementation of the plan, approximately 100,000 cars passed into the small city core at Gothenburg, a core that has a diameter of 1 km. Half of these cars were just through traffic. For example, 45 percent of the traffic over the Kungsportsbron Bridge was through traffic. The traffic in the Östra Hamngatan south of Brunnsparken could be reduced by 60 to 70 percent through use of a zone system. Streetcars and buses shared the roads with the general traffic in the streets of the city core. On Saturdays, the speed of transit vehicles was reduced to approximately 5 km/hour.

Based on the decision of the City Council and the examinations that had been made, the Traffic Planning Department suggested a division of the city core into five zones: NE, NW, SW, S, and SE (NO, NV, SV, S, and SO) (Fig. 2). The border between two zones was to be crossed only by pedestrians and public transport vehicles. This eliminated through traffic from the heavy loaded streets and transferred it to tangential streets. The tangential traffic routes and their crossings could, through some small alterations of the crossings, serve the increasing load without exceeding their theoretical capacity.

None of the streets in the city core was intended to be closed to traffic. No extra limitation was imposed on traffic or parking within the zones. Goods transportation and deliveries could, therefore, take place as previously although it would be necessary to use new routes and to drive longer distances for deliveries in different zones. The principle is that, after a visit in one zone, the vehicle must return to the circulation routes around the city core to reach the next zone.

Buses and streetcars follow the same routes as earlier but now have their own reserved public transport lanes. Buses and streetcars run through the city core in common lanes and share the stops.

The date for introduction was August 18, 1970, when most residents had returned from their summer vacations, but the schools had not yet opened. One month before implementation, literature was distributed giving all the details about the zone system. Suitable traffic routes to various destinations in the city core were given to all offices, department stores, shops, and so forth. One week before the change, a pamphlet was distributed to all households in Gothenburg and the surrounding area. Immediately before and during the introduction, the inhabitants were also informed through advertising. The total cost of this campaign was approximately $30,000 and proved to be well-spent money.

In order to make it easier for the motorists to choose the shortest route to their destinations in the city core, all signs to the city core (CENTRUM) were completed with zone symbols (Fig. 3). The borderlines between the zones were painted as an unbroken double white line or were provided with a low barrier, 5 in. high. These arrangements have cost approximately $50,000.

The traffic volume in the main streets has, as expected, been reduced by 70 percent. There has been an increase of about 30 percent on the circulation routes, which has resulted in the planned adjustments in some crossings (Figs. 4, 5, and 6).

Motorists seem to have accepted the system rather well. The expressed criticism refers to the difficulty of finding the right way to the desired sector and the way around from one sector to another. Both of these problems are the result of the shape of the circulation routes in old European towns.

Concerning public transport, no extensive changes in the traveling times can be reported. However, it can be established that the deviations from the time schedule are much less than before. The reduction of vehicle traffic within the zones has given pedestrians more freedom of movement in the city core.

A positive factor for all those who visit and work in the city core is that the air pollution has been considerably reduced. Health authorities have determined that the carbon monoxide content in the air along several streets has been reduced from 65 to 5 ppm. Furthermore, the noise level has been reduced from 74 to 67 dBA. Some sets of traffic lights have been switched off, which has also increased the comfort for pedestrians.

Figure 1. Master plan for the core of the city.

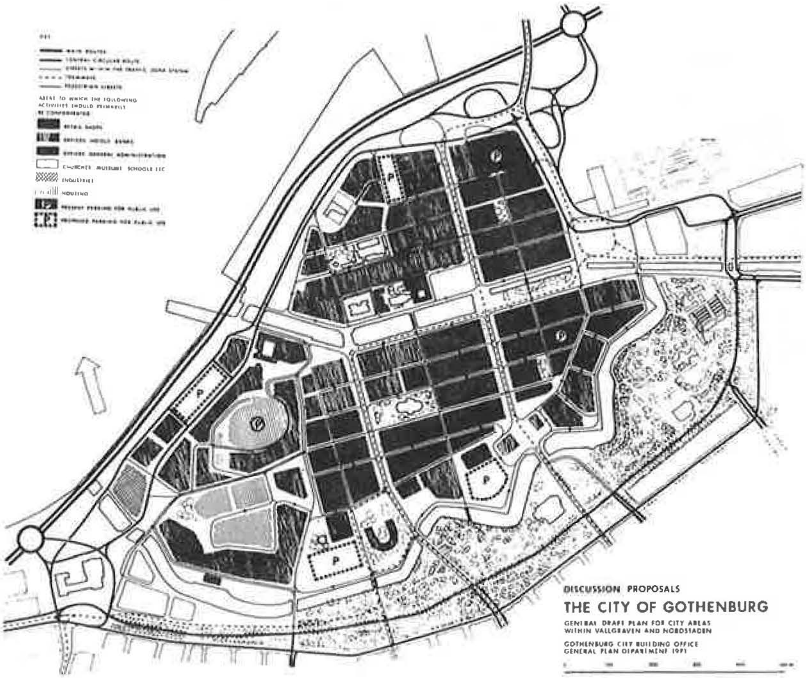


Figure 2. Traffic restraint scheme and five zones.

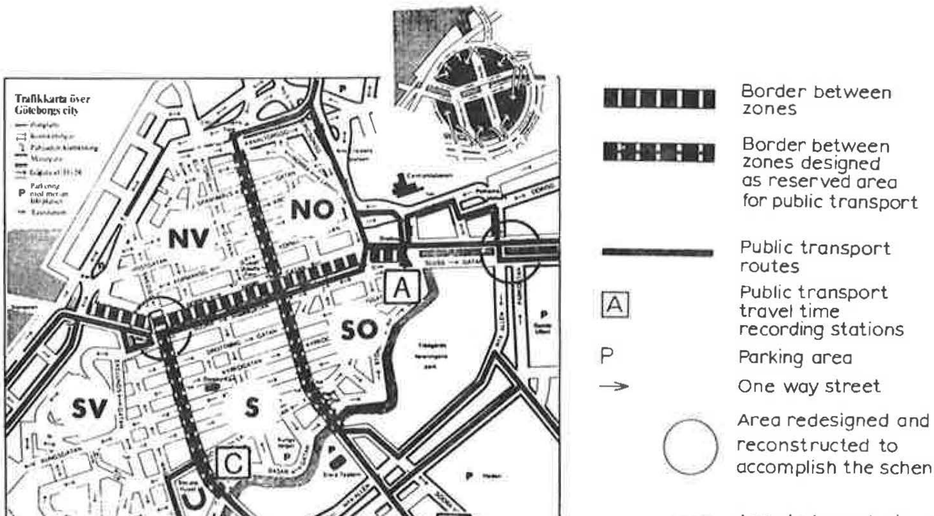
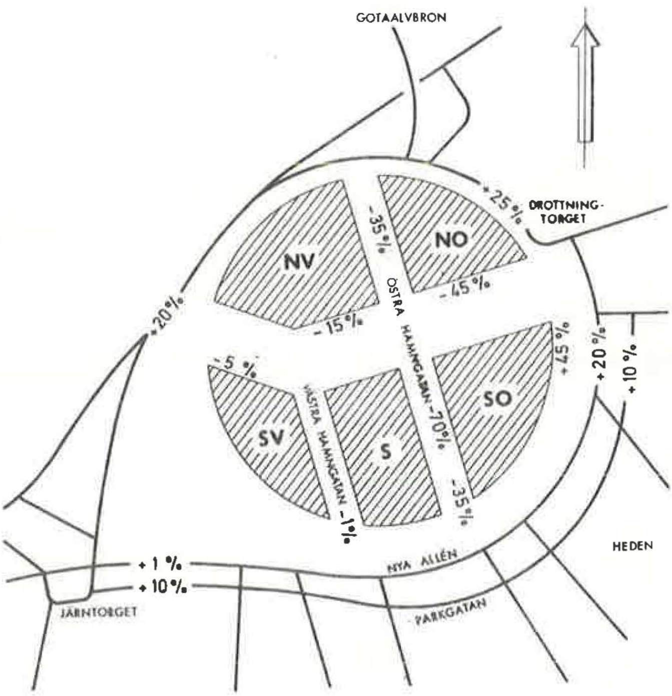
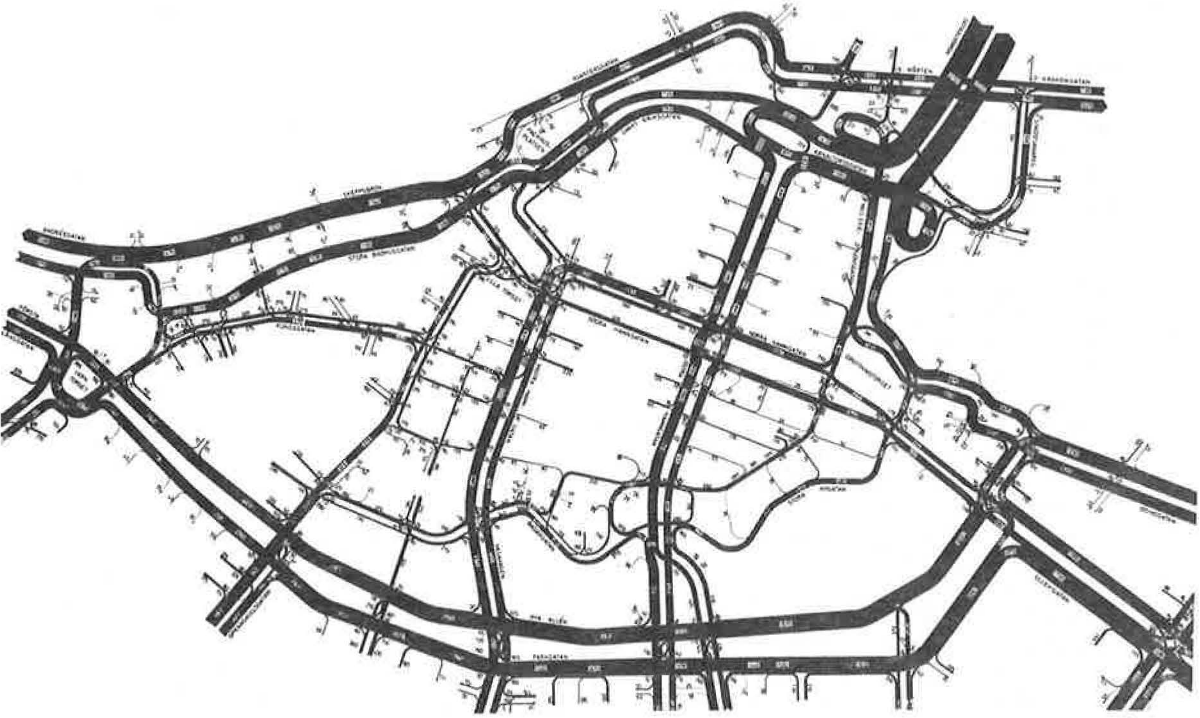


Figure 3. Route signs.

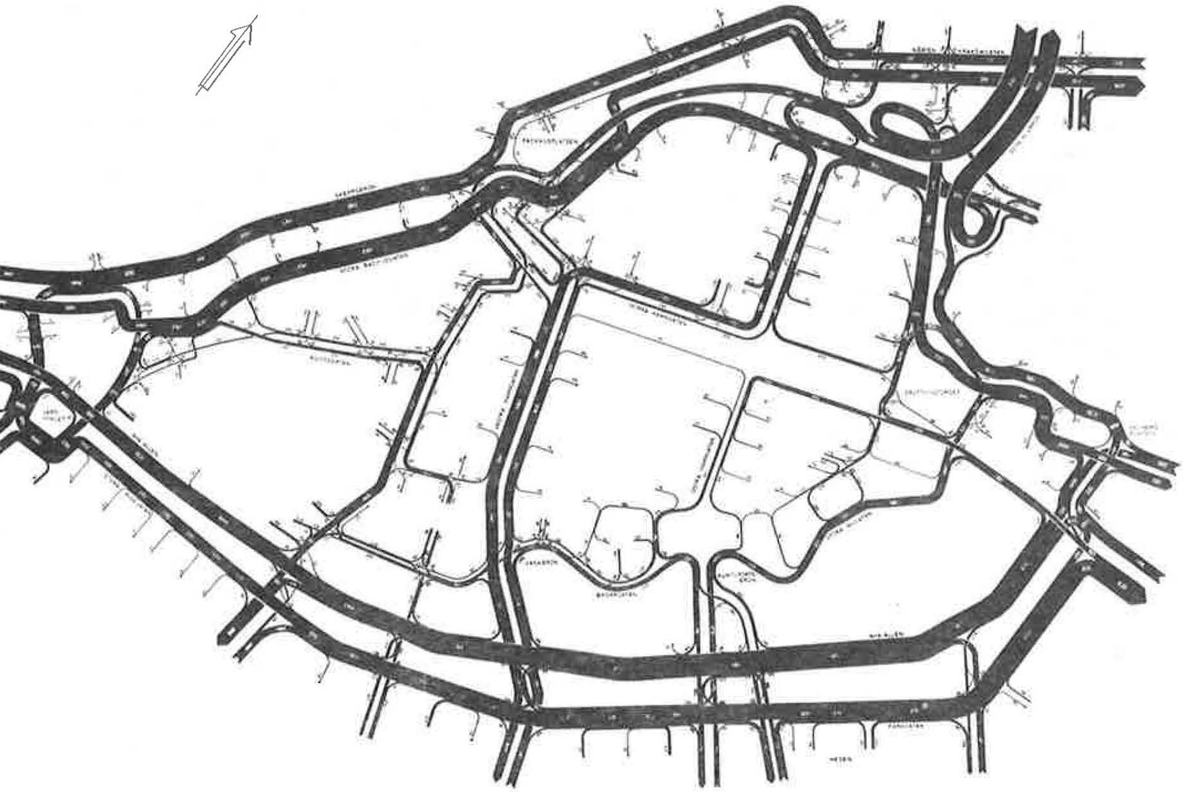
Figure 4. Percentage of change in vehicle flow after introduction of zone system.



ure 5. Vehicle flow in city core before introduction of zone system.



ure 6. Vehicle flow in city core after introduction of zone system.



The traffic accidents in the city core have been reduced by 20 percent, whereas the increase on the circulation routes is very small.

The strongest protests against the system have come from the taxicab organization. It claimed that the taxicab should be regarded as a form of public transport and should be allowed to use the public transport lanes and cross the zone limits. Taxicabs are now allowed to cross the zone limits at the points where public transport crosses, but for the rest they have to follow the same lanes as the private cars. The risk of traffic accidents is too great at the streetcar and bus stops to allow taxicabs to use the lanes that are reserved for public transport.

Retail trade problems in the city core (A-center) were already great before 1970. Whereas the turnover increased by 1 to 5 percent a year in the shops of the city core, the turnover increased by 10 to 15 percent in the B-centers (that is, shopping centers for the big residential areas) and by 20 to 30 percent per year for special supermarkets. The merchants in the city core desire such measures so that a more considerable increase in the turnover can be obtained. The zone system has resulted in only a small decrease in turnover. As a complement to the zone system, the merchants demand a considerable increase in the number of central parking places. At present, there are approximately 4,500 spaces for shopping customers in the city core, of which about 2,000 spaces are on parking lots.

Outside the circulation routes, at a walking distance of 5 to 10 min from the city core, there are approximately 6,000 spaces, most often located in open areas, for shopping customers.

The old plans for parking in the city core included 10,000 spaces for visitors, 3,000 to 4,000 spaces for people who work in the city core and need their cars for work, and 1,000 to 2,000 spaces on the streets for short stops (5 to 10 min).

Since the old plan for the city core was presented in 1959, we have carried out a study of the capacity during peak hour of the accesses to the central part of the city. The central part of the city is about 4 square miles and includes the city core. The access streets have a capacity corresponding to approximately 50,000 car spaces. In this area, we now have 35,000 spaces.

Of these 50,000 spaces, about 11,000 will be allowed in the city core. The CBD will be served by 15 spaces per 10,000 ft^2 of shop area or 800 to 2,000 spaces in each zone. About 7,000 spaces will be used for short visits (1 to 2 hours), 3,000 will be used by people working in the city core, and 1,000 will be used for short stays (5 to 10 min). Shoppers and employees will have spaces in parking garages. The parking garages in the city core are built with (or are planned to have) direct connections with the circulation routes, so that the zone streets will not be loaded by this traffic. For the zones NE and SE, this matter is solved. For zones S and SW, the construction of parking garages will start this year and the next. Furthermore, approximately 7,000 spaces at a lower rate will be available in connection to outside of the circulation routes only.

Our objective is to create a city core that functions well in all respects. The zone system is the first step to reach this goal. A well functioning road system outside the city core and adequate parking availability are a second step, and a better public transportation system is a third step.

CONSIDERATIONS IN THE DESIGN OF FRINGE PARKING FACILITIES

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The primary objective of this study was to develop a set of planning implications for the location, design, and service of transit provided at fringe parking facilities. These implications were developed through a detailed examination of five fringe parking programs currently in operation throughout the United States. The detailed case studies of the five fringe parking programs were presented in the final report for the project. This paper synthesizes the experience acquired from these five case studies and utilizes this experience to delineate the implications for the development of future fringe parking facilities.

•MANY urban transportation problems result from the temporal and geographical peaking of travel demand. Nowhere is this phenomenon more visible than during the so-called rush hours in the central business district (CBD) and the transportation corridors leading thereto. Several approaches have been used to reduce the problems affecting these highly congested areas. Most of the strategies followed by planners have a common thrust, namely, the reduction of the number of automobiles. One of these strategies is the use of fringe parking facilities located outside the CBD, with other transportation facilities being provided to the traveler to complete his trip to the CBD.

The term fringe parking refers to any parking facility located outside the CBD that serves travelers destined thereto. In this context, a wide spectrum of facilities, such as a lot in the vicinity of the CBD, a suburban shopping center, and a railroad station located many miles from the CBD, can be classified as fringe parking facilities.

The following fringe parking programs were investigated:

1. Atlanta, Georgia—Town Flyer bus service from fringe parking facilities located at the Atlanta Stadium and Civic Center;
2. Cleveland, Ohio—the Cleveland Transit System Loop Bus between the Lakeshore and St. Vincent fringe parking lots and the CBD;
3. Milwaukee, Wisconsin—Freeway Flyer express bus service between six suburban shopping centers and the CBD;
4. Philadelphia, Pennsylvania—the Lindenwold Hi-Speed Rail Line between the Philadelphia city center and six suburban fringe parking lots located in a New Jersey corridor; and
5. Seattle, Washington—Blue Streak express bus service (via an exclusive access ramp) between a fringe parking lot and the CBD.

A summary of the important physical and operational characteristics of the five fringe parking programs is given in Table 1. The transportation corridor fringe parking facilities are located between 6 and 14 miles from the CBD, whereas the CBD-peripheral fringe parking facilities are within 1 mile of the CBD. No parking fee is charged at transportation corridor facilities except for a low fee charged on the Lindenwold Hi-Speed Rail Line for those spaces that are close to the stations—about one-half of the total capacity. Parking rates for CBD-peripheral facilities (in Atlanta transit fare is included in the daily parking fee) are higher than those for the corridor facilities but lower than those for CBD facilities.

DEMAND FOR FRINGE PARKING

Characteristics of Fringe Parkers

Selected travel and socioeconomic characteristics of fringe parkers in each of the five cities are given in Table 2. Fringe parking facilities are used predominantly by travelers who work in the CBD and park all day in the fringe facilities. Therefore, the proportion of the facilities' capacities (measured in space-hours) used for work-related travel is even greater than the proportion of work-related trips, and there is little turnover associated with fringe parking facilities. Automobile occupancy at the fringe facilities ranges from 1.1 to 1.3; even the Atlanta pricing structure, designed to attract car pools, appears to have relatively little impact on automobile occupancy.

Because women constitute a significant proportion of the users, fringe parking facilities should be designed so that they are attractive to female patrons; thus, safety factors such as lighting and surveillance are particularly important. Fringe parking facilities attract users from all income categories; a majority of the users have annual household incomes greater than $10,000.

Factors Influencing Demand

Factors that influence travelers to choose fringe parking were determined by asking users in Atlanta and Cleveland to list the factors that influenced their choice of transportation mode. A free-form question (i.e., a question with no precoded responses) was used to avoid biasing the responses.

The results given in Table 3 suggest that fringe parking facilities and their associated transit service must offer significant cost and travel-time savings to the travelers. Further, the facilities must be convenient to use; that is, they must enable the traveler to avoid congested downtown streets, be easily accessible from high-speed arterials or freeways, and offer frequent transit service during peak periods. Finally, safety of the vehicle and the person may be an important factor—although this will depend on local conditions.

SUPPLY OF FRINGE PARKING

Historically, parking capacity in CBD's has been provided by municipal parking authorities, private enterprise, park-and-shop corporations, and benefit districts. In contrast, the momentum for all of the fringe parking facilities examined in this study emerged from the public transportation operator or the municipal government itself. Whether the case studies are indicative of an emerging pattern in the ownership and operation of fringe parking facilities can be determined first by examining the costs of the facilities.

General cost estimates for fringe parking facilities were developed from an analysis of self-service surface lots in a number of metropolitan areas. All of the fringe parking facilities examined in this study are self-park surface lots that require about 330 ft^2 per vehicle. Examination of investment costs, exclusive of land, for self-park surface lots with capacities ranging from 250 to 2,000 automobiles suggests that the average investment of $265 per space is essentially constant for all capacities.

Because investment cost per space is essentially dependent on the size of the facility, the remainder of the discussion is based specifically on a facility with a capacity of 500 vehicles. An interest rate of 5 percent and amortization periods of 25 years and 10 years for the land and improvements were assumed respectively for a publicly owned facility. Similarly, a land value yield of 10 percent, an interest rate of 7 percent, and an amortization period of 10 years for the improvements and equipment were assumed for privately owned parking facilities. For both public and private operation, it was assumed that operations were fully automated, and no attendants were on duty.

The case studies indicated that turnover was relatively low at fringe parking facilities and that they were not heavily used on weekends. In this sense, the use of the fringe parking facilities is similar to that of public transportation in urban areas. For this reason, it was assumed that each space would be used by about 280 vehicles per year and that the facility would be at capacity each working day. This annualization

Table 1. Summary of operational characteristics of fringe parking facilities.

	Type of Facility				
	Transportation Corridor			CBD-Peripheral	
Characteristic	Milwaukee	Seattle	Philadelphia	Atlanta	Cleveland
Number of parking spaces	800	475	8,200	1,250	4,100
Number of automobiles parked	400	475	6,600	400	4,100
Number of facilities	6	1	6	2	2
Distance to CBD (miles)	10 to 14	9	6 to 14	1	1
Daily parking fee (cents)	0	0	0 to 25	75[a]	50
One-way transit fare	50 to 55	35	40 to 60	75[a]	25
Self-parking	Yes	Yes	Yes	Yes	Yes
Attendant on duty	No	No	No	Yes	Yes
Paving	Yes	Yes	Yes	Yes	Yes
Lighting	Yes	Yes	Yes	Yes	Yes
Shelter	Yes	Yes	Yes	No	Yes

[a]Parking fee and two-way fare for all automobile occupants.

Table 2. Selected characteristics of fringe parkers.

	Type of Facility				
	Transportation Corridor			CBD-Peripheral	
Characteristic	Milwaukee	Seattle	Philadelphia	Atlanta	Cleveland
Trip purpose					
Work (percent)	99[a]	85[b]	89[c]	98[a]	95[a]
Other (percent)	1	15	11	2	5
Parking duration					
Less than 8 hours	1[a]	N/A	N/A	11[a]	2[a]
More than 8 hours	99	N/A	N/A	89	98
Occupancy of parked automobiles	1.20[a]	1.06[b]	1.16[c]	1.30[a]	1.35[a]
Sex					
Male (percent)	52[a]	N/A	60[c]	40[a]	68[a]
Female (percent)	48	N/A	40	60	32
Annual household income					
Less than $10,000 (percent)	20[a]	N/A	N/A	35[a]	53[a]
More than $10,000 (percent)	80	N/A	N/A	65	47
Travel alternative or prior mode					
Automobile (percent)	57[a]	70[b]	36 to 60[c]	81[a]	65[a]
Transit (percent)	43	30	64 to 40	19	35

[a]Data derived from Peat, Marwick, Mitchell and Company surveys, 1971.
[b]Data derived from Seattle Transit System survey, 1970.
[c]Data derived from Delaware River Port Authority surveys, 1969-1970.

Table 3. Factors influencing fringe parking.

	Atlanta		Cleveland	
Factor	Number of Responses	Percentage of Respondents	Number of Responses	Percentage of Respondents
Cost	103	74	181	70
Convenience	18	56	151	58
Travel time	15	11	62	24
Avoidance of downtown traffic	59	42	8	3
Safety	28	20	19	7
Availability of public transportation	11	8	15	6
Ecological considerations	2	1	1	—
Exercise associated with walking	—	—	16	6
Total number of responses	296	—	453	—
Total number of respondents	139	—	262	—
Average responses per respondent	2.1	—	1.7	—

factor corresponds to the one used for public transportation systems. Thus, annual costs must be allocated to 140,000 vehicles each year, yielding daily costs of \$0.49 per vehicle for a land value of \$2.50/ft^3 for a publicly owned facility and \$0.81 for a privately owned facility (Table 4). Hence, for the lowest land value considered, daily costs at a publicly owned facility are essentially equivalent to the highest daily parking fee for any of the fringe parking facilities considered in the study. In Atlanta, the \$0.75 fee per vehicle per day also includes the transit fare for all occupants of the vehicle. Clearly, exceptions could be found to each of the assumptions underlying the foregoing analysis. Nonetheless, the results of the analysis suggest that, in the contex of the current situation, revenues that could reasonably be derived from fringe parking facilities will, in most cases, not meet the fully allocated costs of constructing and operating such facilities even if they are publicly owned. If the facilities are privately owned or the cost of the land is greater than \$2.50/ft^2, the difference between potential revenues and the average daily costs will become even greater.

If this conclusion and the assumptions on which it is founded are correct, traditiona approaches for implementing parking in the CBD will be inappropriate for fringe parking. In the absence of profit, not to say sufficient net revenues to amortize bonds, it is difficult to envision that private enterprise or parking authorities would construct new facilities. Although park-and-shop corporations, benefit districts, and, occasionally, municipal parking authorities have allocated the deficits of parking facilities to merchants or property owners benefiting from the projects, this approach would not necessarily be valid for fringe parking facilities. First, these arrangements are generally oriented to shoppers, whereas the case studies strongly established that fringe parking facilities are primarily used by all-day workers. Second, the benefits from fringe parking are so diffuse that it is difficult to assess specific merchants or property owners for the costs of such facilities. Thus, the organizational and financial structures under which fringe parking programs are sponsored must be such that their fully allocated costs are not borne solely by the users of the facilities.

The case studies suggest two approaches for implementing fringe parking programs utilization of parking facilities constructed as part of other public or private projects and assumption of the investment and, in some cases, operating costs by a public agenc Fringe parking facilities have been implemented at shopping centers in conjunction wit bus programs in Milwaukee, Miami, and Washington, D.C. In most urban areas, other sites, such as civic centers and stadiums, are also available. For fringe parking to be truly effective, however, it must provide the user with good service, express bus or rail, to the CBD.

In the case of the Lindenwold Hi-Speed Line and the Seattle Transit System, fringe parking facilities were provided as part of an overall transit program. In effect, the transit operators recognized that, under certain circumstances, fringe parking was the most cost-effective means of carrying out the residential collection and distribution function. Because bus service has traditionally been more ubiquitous than rail rapid service, there have been greater opportunities for "informal" fringe parking on streets adjacent to bus lines. However, in order to increase the attractiveness of bus service by providing express service at acceptable headways on exclusive freeway lanes or ramps, it is necessary to "concentrate" bus patrons at a relatively few sites appropriately located with respect to the freeway or exclusive lane facilities to the CBD.

IMPACTS

If we consider the five operations examined in this study, it would appear that, with the possible exception of Cleveland, revenues derived from the facilities are not sufficient to meet the fully allocated costs of constructing and operating these facilities. The incentive to develop fringe parking facilities is, therefore, not necessarily financial; rather, it underscores the belief that the environmental, social, and economic benefits of the facilities are such that the general community should contribute to their development and support.

User Impacts

Fringe parking facilities offer cost savings to those who would otherwise drive and park in the CBD and travel-time savings to those who would otherwise use public transportation (Table 5). Aside from Lindenwold and possibly Cleveland, it cannot be asserted that the fringe parking program at its current scale has a measurable impact on travel congestion in the corridor served by the fringe parking facility. This assertion is not meant to be detrimental to the potential role of fringe parking. Rather, it implies that fringe parking must divert a significant portion of the home-to-work travel market to meaningfully improve travel service for those who drive to the CBD.

Impacts at the Regional Level

Insofar as it expands the market of public transportation beyond the limits set by acceptable walking distances, fringe parking facilitates the integration of fixed-route public transportation with a suburban life-style. As such, fringe parking has implications within the complex relation between a region's development pattern and the accessibility provided by a region's transportation system. Although factors other than accessibility to the CBD shape the development of a metropolitan area, particularly in multinucleated developments, there is reason to believe that differential accessibility to the CBD influences regional patterns with high-density land uses clustering along highly accessible corridors.

Because their function is to attract CBD-oriented home-to-work drivers, fringe parking facilities and their associated public transportation service can result in a measurable reduction in the vehicle-miles of travel and, consequently, air and noise pollution. For example, it has been estimated that the Lindenwold Hi-Speed Line has removed nearly 29 million vehicle-miles of travel per year, most of which is fairly peaked both temporally (i.e., during rush hours) and spatially (i.e., oriented to the CBD).

Impacts on Neighborhoods

Fringe parking facilities are less compatible with residential than nonresidential land uses; a "sea of asphalt" is not aesthetic, and entering and exiting traffic may disturb the character of residential streets. Careful attention in the design phases to issues such as drainage, lighting, landscaping, and access roads enhances the land-use compatibility of fringe parking facilities.

The issue of compatibility with adjacent land uses becomes more critical as the scale of the fringe parking facilities increases. If a highly differentiated transit service is offered, significant development pressures may occur near the transfer location. In this context, either vertically or horizontally integrated joint-use activities may provide a mechanism for allowing valuable sites within walking distances of stations to be used for fringe parking and other joint-use activities (Fig. 1). With appropriate design, such an approach can contribute significantly to ensuring that the transfer location is compatible with adjacent land uses. Staged development programs could be visualized in which transportation centers are initially exclusively oriented to fringe parking facilities and other uses are developed according to market requirements.

PLANNING IMPLICATIONS

The following locational factors should be considered in the design of fringe parking facilities:

1. Fringe parking facilities should be located in transportation corridors so that they intercept home-to-work trips destined to the CBD at a point where there is a sufficient density of transit demand that high-quality transit service may be offered.
2. To the maximum extent feasible, facilities should be located on land that is already used for parking or in a low-grade nonresidential use.
3. Fringe parking facilities should be located on sites compatible with land uses and activities in the immediately adjacent area.
4. Potential joint-use aspects of a fringe parking facility should be considered during

Table 4. Annual operational cost of 500-vehicle, self-park surface lot.

Cost Factor	Public Ownership (in dollars)	Private Ownership (in dollars)
Amortization		
Land at $\$2.50/ft^2$	29,000	41,300
Land at $\$5.00/ft^2$	58,500	82,500
Land at $\$7.50/ft^2$	88,500	124,000
Land at $\$10.00/ft^2$	117,500	165,000
Land at $\$12.50/ft^2$	145,500	206,000
Improvements and equipment	17,500	18,100
Operating costs	22,500	22,500
Taxes	–	32,000
Total annual cost		
Land at $\$2.50/ft^2$	69,000	113,900
Land at $\$5.00/ft^2$	98,500	155,100
Land at $\$7.50/ft^2$	128,500	196,600
Land at $\$10.00/ft^2$	157,500	237,600
Land at $\$12.50/ft^2$	185,500	278,600
Daily cost per vehicle parked[a]		
Land at $\$2.50/ft^2$	0.49	0.81
Land at $\$5.00/ft^2$	0.70	1.11
Land at $\$7.50/ft^2$	0.92	1.40
Land at $\$10.00/ft^2$	1.13	1.70
Land at $\$12.50/ft^2$	1.32	1.99

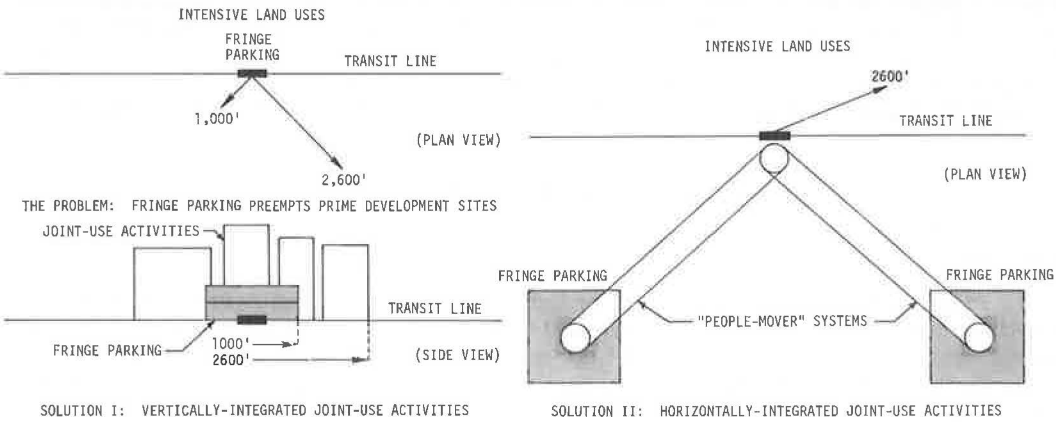
[a]At-capacity operation for 280 days per year.

Table 5. Time and cost savings accruing to fringe parkers.

Fringe Parking Transit	Cost Savings if Alternative Is Driving to the CBD (dollars/day)	Time Savings if Alternative Is Public Transportation (min/day)	Number of Automobiles per Day Parked in all Fringe Parking Facilities
Milwaukee Freeway Flyer	1.25	50	400
Seattle Blue Streak	1.05	N/A	475
Atlanta Town Flyer	0.53	22	400
Cleveland Loop Bus	1.00	20	4,100
Philadelphia-Lindenwold Hi-Speed Rail Line	2.30[a]	35[b]	6,800

[a]Assuming tolls of 50 cents and parking of \$1.75 per day. [b]Estimated time savings for all users of the Lindenwold line.

Figure 1. Fringe parking and joint-use activities.



the location process. If planners believe that joint use could be envisioned within the foreseeable future, sufficient land should be acquired so that a staged development program can be implemented.

5. Trade-offs implicit in the scale of the fringe parking facility, namely, the level of transit service as opposed to its neighborhood impacts and the ease of using the facility, should be considered.

Design considerations for fringe parking facilities are as follows:

1. To the maximum possible extent, fringe parking facilities should be designed to minimize potential impacts on the neighborhood. Areas of particular concern include the following: Available rainfall data should be used to estimate runoff and sufficient drainage should be provided, the lighting provided should not intrude on the adjacent land uses, due consideration should be given to the aesthetics of the facility, and walkways and bikeways should be developed within the facility if it interferes with established patterns of community interaction.

2. Care should be taken to ensure that access traffic to fringe parking does not overwhelm the character of residential neighborhoods. To this end, direct links should be provided, where feasible, from large facilities to high-speed roads.

3. Fringe parking facilities should be paved and lighted. Appropriate shelters should be provided so that patrons may wait comfortably for transit in those areas of the country in which adverse weather conditions may be anticipated for a significant proportion of the year. Other amenities enhancing the utility of even a small facility include telephones and newspaper stands.

4. Fringe lots should be designed to minimize labor costs required to operate these facilities, unless the intensity of use and revenues derived from these facilities are substantially different from those observed in the case studies. To this end, fringe parking facilities should be self-parking and automatic fare-collection equipment should be used.

5. Access-egress facilities and fare-collection procedures should be carefully designed to accommodate peaking.

6. As the scale of surface lots increases, care should be taken to ensure that walking distances do not become excessive. Although the definition of excessive is, to some extent, subjective and related to local conditions, it would appear that parkers having to walk more than 1,500 to 2,000 ft from their automobiles to the transit boarding point might be discouraged from using the facility. To this end, transit boarding points should be located in the center of the fringe parking facility rather than on the periphery; multiple boarding points should be used, if feasible, and, in the extreme, multilevel parking or internal people-mover systems should be considered.

7. Potential joint-use activities should be considered during the design of the facility to ensure effective integration of transportation and other functions. For example, care should be taken so that parking spaces available for transportation and other functions do not preempt one another and that the access facilities are not overburdened. Joint-use facilities should be designed to ensure that they effectively integrate the transfer location with the neighborhood. Such integration may require that additional local supportive systems be constructed in the neighborhood, e.g., walkways or bikeways.

The following fringe parking service factors should be considered:

1. High-level transit service should be provided from the fringe parking facility to the CBD. For buses, quality implies express operations, use of reserved facilities on those segments of the route on which traffic congestion would be encountered, and acceptable frequencies during the peak hours. For rail, it implies low travel times and headways during peak hours. Further, careful attention must be devoted to ensuring that an effective CBD distribution system is developed. Finally, off-peak transit service should be provided to the fringe parking locations.

2. Pricing of the fringe parking transit service should be carefully considered during the planning phases to ensure its competitiveness. Thus, the trade-off between the community objective of maximizing patronage of fringe parking and the financial objective of maximizing revenues should be carefully considered.

3. To increase neighborhood compatibility, all-day parking on adjacent streets should be discouraged. Such a policy should be implemented at the inception of fringe parking service—before such activity is observed.

SUMMARY

In the past two decades, there has been a direct correlation between the increasing dispersion of land use in urban areas and the general decline of fixed-route and -schedule public transportation. As low-density, residential areas were constructed, it would have been necessary for transit operators to extensively expand their routes to provide service within walking distance. It was economically infeasible, however, for the public transportation operator to expand service to keep pace with the expansion in the low-density residential areas.

Planners have noted that the person-carrying capacity of an exclusive bus lane or a single track of rail transit is significantly greater than that of a single freeway lane used by automobiles with typical home-to-work occupancies. On the other hand, the cost per passenger-mile of using fixed-route and -schedule modes to perform the residential collection and distribution function in less densely settled suburban areas is relatively high. The private automobile is a relatively effective means for performing the residential collection and distribution function. In this context, fringe parking can be a key component of an integrated transportation system, in which each of the modes is used most advantageously. In this sense, fringe parking has positive impacts at the individual and regional levels, and the justification to develop a fringe parking program stems from its contribution to the overall development of the community's objectives, not from a profit-making motive. On the other hand, unless care is taken in locating and designing large-scale fringe parking facilities, they could have adverse impacts on the proximate environment, i.e., the neighborhood.

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