are being conducted of pedestrian movement in the Herald-Greeley Square areas, pedestrian street space in Coney Island, pedestrian mobility in the Jamaica Commercial Center, and conflicts between vehicle and pedestrians in the Midtown Manhattan area. In New Jersey, pedestrian facilities being planned include a pedestrian shopping mall in Paterson and a pedestrian mall in Jersey City. Provisions have been or are being made for bicycle parking facilities at many locations in the Tri-State area.

In the Delaware Valley region, most bikeway planning is taking place in New Jersey. Existing Pennsylvania bike paths are confined to state parks, notably the Ridley Creek, Tyler, and Valley Forge areas. Most of the existing facilities devoted to the separation of pedestrians and motor vehicles are concentrated in the Philadelphia central business district including the Underground Concourse System, which connects approximately a 2.6-km^2 (1-$mile^2$) area of downtown Philadelphia. Another prominent and relatively new addition is the Chestnut Street transitway, which was opened in November 1975. Other pedestrian facilities include new highrise commercial buildings and the University of Pennsylvania hospital complex. At the present time, there is no planned program for the provision of bicycle parking facilities.

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PARKING MANAGEMENT STRATEGIES

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This paper provides an overview of the range of parking management strategies. Particular emphasis is placed on describing the strategies and the considerations pertinent to their implementation in specific metropolitan areas. Because of the current interest in transportation system management, the paper is organized around the categories of parking management and control actions identified in the TSM regulations.

Increasing recognition is being given to the important role that the availability and quality of parking can play in shaping the overall service provided by the urban transportation system and in achieving other community objectives. The usefulness of the automobile can be impeded if the driver is unable to find convenient and reasonably priced parking in the vicinity of his or her final destination. Similarly, the ease of access to a transit station and the difficulty of driving and parking near the final destination are important factors influencing a traveler's choice of mode. Consequently, there has been an increased recognition—particularly at the federal level—that public policies influencing the availability and pricing of parking can be used to achieve air quality, energy conservation, and congestion reduction.

FEDERAL PARKING MANAGEMENT INITIATIVES

Environmental Protection Agency

Both the U.S. Environmental Protection Agency (EPA) and the U.S. Department of Transportation (DOT) have undertaken parking management initiatives. In late 1973, EPA promulgated or approved transportation control plans for 30 major urban areas. Some of these included parking management initiatives with respect to both the price and the availability of parking.

Parking surcharges were promulgated by EPA in the

transportation control plans it published in late 1973 for three parts of the country: Boston, Washington, D.C., and five metropolitan areas in California (Los Angeles, San Diego, San Francisco, Fresno, and Sacramento). The transportation control plan that was promulgated for San Diego, for example, required that persons parking automobiles in commercial parking facilities pay a parking surcharge of 25 cents/h plus the commercial rate. The plan also imposed a regulatory fee of $450/year/space on each owner or operator of more than five free parking spaces including free on-street parking spaces outside of residential areas. The plan presupposed that the owner of the space would pass this regulatory fee on to the users in some form. As a result of congressional action, EPA suspended its promulgation of parking surcharges pending a clarification of congressional intent. Local areas may still, however, implement parking surcharges at their initiative.

An important focus of EPA's Parking Management Regulations was the preparation of a plan for the control and management of parking as part of an overall transportation strategy. Potential strategies that might be incorporated into a parking management plan include parking placement strategies, zoning code revisions, park-and-ride lot development, parking freeze areas, pricing policies, on-street parking removal, vehicle travel minimization for new parking facilities, and vehicle travel minimization for existing parking facilities. Proposed new facilities would then be reviewed to determine whether they were in compliance with the pattern for future parking facility development. As an interim step before the development of a parking management plan, the Parking Management Regulations provided for an interim facility-by-facility review of new facilities to assess consistency with the regulations. Implementation of the regulations has been delayed several times by EPA; at this writing, their implementation has been indefinitely postponed while EPA awaits further congressional guidance (1).

U.S. Department of Transportation

The joint rules and regulations of the Federal Highway Administration (FHWA) and the Urban Mass Transportation Administration (UMTA) currently require an urban transportation planning process that includes development of a transportation plan consisting of a transportation system management element and a long-range element (2). The regulations describe a broad range of actions that can be taken to implement TSM; these are summarized below.

1. Actions to ensure the efficient use of existing road space through:
   a. Traffic operations improvements to manage and control the flow of motor vehicles, including channelization of traffic, one-way streets, better signalization and progressive timing of traffic signals, computerized traffic control, metered access to freeways, and reversible traffic lanes
   b. Preferential treatment for transit and other high-occupancy vehicles, including reserved or preferential lanes on freeways and city streets, exclusive lanes to bypass congested points, exclusive lanes at toll plazas with provision for no-stop toll collection, conversion of selected downtown streets to exclusive bus use, exclusive access ramps to freeways, bus preemption of traffic signals, strict enforcement of reserved transit rights-of-way, and special turning lanes or exemption of buses from turning restrictions
   c. Appropriate provision for pedestrians and bicycles, including bicycle paths and exclusive lanes, pedestrian malls and other means of separating pedestrian and vehicular traffic, secure and convenient storage areas for bicycles, and other measures to facilitate bicycle use
   d. Management and control of parking through elimination of on-street parking, especially during peak periods, regulation of the number and price of public and private parking spaces, favoring of parking by short-term users over all-day commuters, provision of fringe and transportation corridor parking to facilitate transfer to transit and other high-occupancy vehicles, and strict enforcement of parking restrictions
   e. Changes in work schedules, fare structure, and automobile tolls to reduce peak-period travel and to encourage off-peak use of transportation facilities and transit services, including staggered workhours, flexible workhours, reduced transit fares for off-peak transit users, and increased peak-hour commuter tolls on bridges and access routes to the city
2. Actions to reduce vehicle use in congested areas through encouragement of car pooling and other forms of ride sharing; diversion, exclusion, and metering of automobile access to specific areas; institution of area licenses, parking surcharges, and other forms of congestion pricing; establishment of automobile-free zones and closure of selected streets to vehicular traffic or to through traffic; and restrictions on downtown truck delivery during peak hours
3. Actions to improve transit service through provision of better collection, distribution, and internal circulation services (including route-deviation and demand-responsive services) within low-density areas; greater flexibility and responsiveness in routing, scheduling, and dispatching of transit vehicles; provision of express bus services in coordination with local collection and distribution services; provision of extensive park-and-ride services from fringe and transportation corridor parking areas; provision of shuttle transit services from CBD fringe parking areas to downtown activity centers; encouragement of jitneys and other flexible paratransit services and their integration in the metropolitan public transportation system; institution of simplified fare collection systems and policies; provision of shelters and other passenger amenities; and improvement in passenger information systems and services.
4. Actions to increase internal transit management efficiency including improvements in marketing, development of cost accounting and other management tools to improve decision making, establishment of maintenance policies that ensure greater equipment reliability, and use of surveillance and communications technology to develop real-time monitoring and control capability

Of particular importance from the perspective of this paper are the actions to accomplish management and control of parking to ensure the efficient use of existing road space; the parking actions identified are

1. Elimination of on-street parking, especially during peak periods;
2. Favoring of parking by short-term users over all-

day commuters;

3. Strict enforcement of parking regulations;
4. Regulation of the supply of parking spaces;
5. Regulation of the price of public and private parking spaces; and
6. Provision of fringe and transportation corridor parking to facilitate transfer to transit and other high-occupancy vehicles.

The mutually reinforcing relations both among the various parking strategies and between various parking strategies and the other categories of strategies identified above should be noted. The effectiveness of a given parking strategy can be enhanced by implementing another strategy. For example, actions to eliminate on-street parking or restrictions to favor parking by short-term rather than long-term users both can be enhanced through strict enforcement of parking regulations. Parking actions that tend to reduce the availability and increase the price of all-day parking for commuters in the central business district tend to encourage the use of fringe and transportation corridor parking facilities. Further, many of the parking management strategies involving regulation of the availability and pricing of public and private parking spaces are closely tied to actions to reduce vehicle use in congested areas through congestion pricing or provision for automobile-restricted areas. Provision of fringe and transportation corridor parking to facilitate transfer to transit vehicles is closely tied to various TSM actions to improve transit service. In assessing parking management strategies, one should therefore consider the effectiveness of various strategies both individually and in combination with other potential TSM actions. An underlying theme of TSM is to develop a program of mutually reinforcing actions designed to achieve a community's objectives.

UMTA and FHWA have created a strong incentive for local areas to implement an acceptable TSM element. A preamble to the joint rules and regulations (2) states that "notice is given that the inclusion in the transportation improvement program (TIP) of projects recommended from the TSM element will be a condition of UMTA program approvals." The joint rules and regulations also suggest, and UMTA and FHWA have indicated in subsequent communications, that all of the major categories should be considered for inclusion in the TSM element. Although UMTA and FHWA do not anticipate that each individual action identified in the regulations necessarily needs to be considered or included in a TSM element, they do indicate that "it is expected that some actions in each category will be appropriate for any urbanized area" (2).

OBJECTIVES OF THIS PAPER

This paper provides an overview description of the range of parking management strategies; particular emphasis is placed on describing the strategies and the considerations pertinent to their implementation in specific metropolitan areas. Because of the current interest in transportation system management, the paper is organized around the categories of parking management and control actions identified in the TSM regulations.

RATIONALE FOR IMPLEMENTING PARKING MANAGEMENT STRATEGIES

The overall goal of urban transportation system management has been described as coordinating the various elements of the urban transportation system through "operating, regulatory and service policies so as to achieve maximum efficiency and productivity of the system as a whole" (2). Within this broad objective, parking management strategies have two principal objectives:

1. To improve transportation service, and
2. To increase the "generalized cost" of using a single-occupant automobile so as to divert these travelers to higher occupancy vehicles.

To the extent that these objectives are contradictory, both would not be pursued in a specific situation. Rather, the determination of which of these objectives is paramount would be based on the particular planning circumstances and objectives of a community.

This second objective is not accepted by all planners and decision makers who have traditionally focused their attentions on improving transportation service. The argument for this approach is that the automobile driver, particularly the peak-hour, home-to-work driver, is not paying the cost of providing him or her with highway facilities (3). Further, it is argued that the peak-hour highway traveler is not charged the full cost of his or her contribution to certain externalities, such as noise, air pollution, energy consumption, and traffic congestion. Currently, the only form of control on single-person automobile use is congestion pricing; a number of economists and planners have suggested that the experienced costs of single-person automobile travel should more closely approach the social costs.

CHARACTERISTICS OF PARKING SUPPLY

An understanding of the characteristics of parking supply in different-sized urban areas is necessary to provide a background for a discussion of parking management strategies. The relation between CBD parking supply and city size is given in Table 1 (4). As the size of the city increases, the supply of CBD parking facilities also increases, but at a decreasing rate. Further, as the city size increases, the proportion of the total parking spaces provided at the curb decreases from about 43 to 14 percent, and the proportion of the spaces provided in garages increases from about 0 to 30 percent. The proportion of spaces provided in off-street lots remains essentially unchanged in the range between 55 and 64 percent.

A further classification of the CBD parking supply is given in Table 2 (4) according to whether the curb spaces are metered or unmetered and whether the off-street spaces are provided in public or private facilities. As the size of the city increases, the proportion of the off-street spaces provided in public facilities increases and the proportion provided in private facilities decreases. These are average data, however, and therefore they mask important differences among cities. The proportions of the total parking spaces in those cities in the country with a population of 500 000 or more for which such data are available are given in Table 3 (23). Spaces provided in commercial facilities range from a low of about 50 percent in Detroit and Pittsburgh to a high of about 94 percent in Atlanta.

CHARACTERISTICS OF PARKING DEMAND

An understanding of selected characteristics of parking demand is also necessary as background for a discussion of parking management strategies. Use of different types of parking facilities as a function of city size is given in Table 4 (4). Use of curb parking spaces tends

Table 1. Supply of CBD parking spaces.

Population Group of Urbanized Area	Curb Spaces		Off-Street Spaces				Avg Number of Total Spaces	Spaces per 1000 Population
			Lot		Garage			
	Number	Percent	Number	Percent	Number	Percent		
10 000 to 25 000	1090	43	1 530	57	10	0	2 630	150
25 000 to 50 000	1430	38	2 420	59	140	3	3 990	120
50 000 to 100 000	1610	35	2 790	60	260	5	4 660	70
100 000 to 250 000	2130	27	4 760	62	820	11	7 710	50
250 000 to 500 000	2450	20	7 910	64	1 940	16	12 300	30
500 000 to 1 000 000	3200	14	12 500	56	6 900	30	22 600	30
Over 1 000 000	8000	14	32 200	55	18 600	31	58 800	20

Table 2. CBD parking spaces classified by type of facility.

Population Group of Urbanized Area	Curb Spaces (%)			Lot Spaces (%)		Garage Spaces (%)	
	Metered	Nonmetered	Special	Public	Private	Public	Private
10 000 to 25 000	47	51	2	18	82	93	7
25 000 to 50 000	55	40	5	27	73	50	50
50 000 to 100 000	55	41	4	42	58	56	44
100 000 to 250 000	47	46	7	52	48	89	11
250 000 to 500 000	49	40	11	66	34	95	5
500 000 to 1 000 000	54	38	8	68	32	87	13
Over 1 000 000	27	46	27	67	33	84	16

Table 3. Total parking spaces and percentage of commercial parking for selected U.S. cities.

City	Total Parking Spaces	Percent Commercial Spaces (%)	1970 Population	SMSA Population Rank
New York	395 973	80	7 895 000	1
Detroit	35 002	50	1 511 000	5
San Francisco	55 950	54	716 000	6
Washington, D.C.	51 995	82	757 000	7
Boston	42 536	59	641 000	8
Pittsburgh	36 439	50	520 000	9
Newark	8 245	61	295 000	14
Dallas	24 354	88	844 000	16
Seattle	24 839	56	531 000	17
Milwaukee	24 710	59	717 000	19
Atlanta	33 280	94	497 000	20

Table 4. Vehicles parked in different types of CBD parking facilities.

Population Group of Urbanized Area	Curb Spaces (%)	Lot Spaces (%)	Garage Spaces (%)
10 000 to 25 000	79	21	0
25 000 to 50 000	74	24	2
50 000 to 100 000	68	31	1
100 000 to 250 000	52	42	6
250 000 to 500 000	54	34	12
500 000 to 1 000 000	33	39	28
Over 1 000 000	30	54	16

Table 5. Purpose of trip and duration of parking.

Population Group of Urbanized Area	Trip Purpose (%)		Parking Duration (h)	
	Work	Shopping and Personal Business	Work Trips	Shopping and Personal Business Trips
10 000 to 25 000	21	61	3.5	0.4 to 0.5
25 000 to 50 000	21	62	3.7	0.5 to 0.6
50 000 to 100 000	20	55	3.3	0.6 to 0.8
100 000 to 250 000	26	55	4.3	0.9 to 1.3
250 000 to 500 000	30	52	5.0	1.0 to 1.3
500 000 to 1 000 000	47	38	5.9	1.5 to 1.7
Over 1 000 000	41	40	5.6	1.1

Table 6. Automobiles used in home-to-work travel and by charge and type of parking facility.

Type of Parking	Parking Charge		Automobiles (%)
	Yes	No	
Commercial facilities	63.1	2.3	6.0
Employer provided spaces	11.3	79.6	75.6
Fringe parking	0.0	0.6	0.5
Other lots	8.5	2.8	3.1
On-street	14.6	12.0	12.1
No all-day parking used	0.5	0.9	0.9
All other	2.0	1.8	1.8
Percent of total	7.3	92.7	100.0

to decrease as city size increases, but use of off-street facilities increases. Irrespective of city size, curb facilities serve a larger proportion of the total demand than they constitute of the total supply. Whereas curb facilities constitute only 43 percent of the total supply in the smallest city size group, they serve over 79 percent of the demand. Similarly, curb facilities constitute only 14 percent of the total supply in the large city size group, but they serve over 30 percent of the demand. In general, curb facilities serve trips of shorter duration and have a higher turnover than off-street facilities.

Trip purpose and duration of parking in different cities are given in Table 5 (4). As the size of the city increases, the proportion of work-trip parkers and the duration of all trips increase. Work trips have an average duration nearly four times that of shopping and personal business parkers in nearly all city sizes. Thus, the larger the size of the city is, the greater the proportion of the parking capacity will be, where capacity is measured in terms of space-hours of usage, which is used for work-trip parking.

ELIMINATION OF ON-STREET PARKING

Elimination of on-street parking, especially during peak periods, is a well-established traffic engineering technique for increasing the capacity of existing highway facilities. Two important reasons for considering the elimination of on-street parking, especially in congested areas and during peak periods, are (a) to increase the traffic-carrying capacity of the streets and thereby reduce traffic congestion and (b) to enhance traffic safety.

The primary purpose of major arterials is to serve moving vehicles, not to serve as a parking facility. The typical arterial street with parking on both sides has only two-thirds of the capacity it would have were parking prohibited; the actual capacity reduction is related, of course, to the number of lanes and whether the location is midblock or at an intersection.

Various studies have suggested that parking activity is directly or indirectly related to approximately one out of five traffic accidents on urban streets. Factors contributing to parking-related accidents include (a) parked vehicles presenting obstacles or constraining the useful roadway, (b) vehicles leaving the parking position, (c) vehicles entering the parking position, (d) automobile occupants entering or leaving the vehicle on the side adjacent to the moving traffic stream, and (e) reduced sight distances resulting from parked vehicles. When conditions of excessive traffic congestion or excessive parking-related accidents occur on arterials with parking, consideration should be given to eliminating on-street parking (4).

The decision regarding whether on-street parking should be prohibited in an area must be responsive to the requirements of both motorists and residents of an area. The following considerations enter into such a decision.

1. Safety. The Model Traffic Ordinance (5) authorizes full-time parking prohibitions on both sides of roadways not exceeding 6.1 m (20 ft) in width and on one side of those not exceeding 9.1 m (30 ft) in width. Parking prohibitions might also be warranted if an unusual number of parking-related accidents were to occur.

2. Capacity. The maximum number of vehicles per hour per lane above which parking prohibitions should be implemented are as follows (24, Table 2):

Prohibition	One Lane	Two or More Lanes
Midblock prohibition for entire street	400	600
Intersection prohibition up to 45.7 m (150 ft) on approach and departure	300	500

3. Functional classification of street system. All other factors being equal, the greater the importance of the facility is, the greater the argument is for prohibiting on-street parking.

4. Special needs of adjacent land uses. In many areas, such as older residential and commercial areas in most cities, where the street provides the only storage area for vehicles, eliminating on-street parking constitutes a severe disservice unless alternative off-street parking facilities are concurrently provided. The importance of on-street parking facilities is emphasized by the parking supply data given in Tables 1 and 4. In all city sizes, on-street facilities serve a much greater proportion of the total vehicles parked than the proportion that they constitute of the total parking spaces. This is a result of the greater turnover and generally greater desirability of on-street spaces.

PARKING RESTRICTIONS TO ENCOURAGE SHORT-TERM USERS

The importance of parking restrictions to encourage short-term users is illustrated by data given in Table 5. The larger the size of the city is, the greater will be the proportion of the total parking spaces used for work-trip parking. Further, since the work-trip parker generally arrives earlier than the shopping-trip or personal-business-trip parker, he or she will generally obtain the most advantageous space unless some form of parking restriction favoring short-term parkers is in effect.

Several arguments are offered for implementing parking restrictions to favor short-term parkers.

1. Parking spaces located closest to commercial and shopping facilities should be reserved for those traveling for personal business and shopping reasons to encourage that kind of travel to the CBD.
2. All-day work commuters generally have low automobile occupancy, travel during peak periods, and are probably the most easily diverted of all of the urban travel market segments to higher occupancy vehicle. They should be provided with parking spaces that are less accessible to their final destinations to encourage them to divert to higher occupancy vehicles.
3. A high turnover of automobiles parked should be obtained from the limited number of parking spaces located closest to commercial and service facilities.

A number of different approaches are available for implementing restrictions on the duration of parking to encourage short-term parking. The approach used is dependent on the specific circumstances of each case including the physical arrangements of the facilities, the availability of alternative facilities for long-term parkers, the method of fee collection, and the enforcement resources available.

1. Place a time limit on the duration of parking. This approach is frequently implemented by using parking meters, although parkers may still put new money into the meters toward the end of the elapsed duration. Another technique is for an enforcement officer to uniquely identify each vehicle, for example, by a chalk mark and to ticket those that have not been moved from their original spaces.
2. Prohibit automobiles from parking before a certain hour. Automobiles can be prohibited from parking until after most all-day workers have arrived at their jobs. This technique is used in Washington, D.C., to constrain employee parking on the Mall and thereby to save the spaces for tourists and in London, England, where many parking facilities in the CBD are closed until after 9:30 a.m. The enforcement costs may be lower with this approach than with placing a restriction on the duration of parking, particularly if meters are not used to enforce the duration restriction. This approach is also effective if the duration restriction is to apply to attendant-operated garages or lots, where it would otherwise be difficult to place duration restraints on parking.
3. Change pricing structure. The parking pricing structure is frequently such that the total cost of parking per hour decreases as the duration of parking increases. Although such a pricing strategy is understandable in terms of profit maximization and the desire to rapidly recover the fixed cost of serving a given vehicle, it does not favoring short-term parkers. An alternative stragegy is for the cost of parking per hour to increase or remain constant as the duration of parking increases. Under this approach, the pricing structure could be designed to serve the needs of a particular market segment. For example, the Air and Space Museum on the Mall in Washington, D.C., has a rate structure designed to reserve the facility for tourists and to discourage all-day parking by employees. Although pricing strategies for encouraging short-term parking have not frequently been employed, they appear to offer potential for application to facilities where the fees are collected by an attendant.

ENFORCEMENT OF PARKING REGULATIONS

Enforcement of parking regulations is an essential condition if the policies on on-street and short-term parking are to be effective. Potential violators must recognize that they have a relatively high probability of receiving a traffic citation and of having to pay the fines for their traffic citations. Enforcement of parking regulations is a specialized area, and consequently transportation planners and traffic engineers have devoted relatively little attention to it and its relation to the effectiveness of parking regulations.

Enforcement of parking regulations requires personnel to patrol the streets, identify violators of parking regulations, and write citations for these violators. This is a labor-intensive function, particularly in areas where there are 2-hour parking limits. The patrol personnel can be reduced to some degree if they patrol in vehicles and have preprinted citations and if the court procedures are streamlined. In addition, patrolling can be tailored to the nature of the potential violations and randomly varied by geography and time so that potential violators cannot predict when they will occur.

In some municipalities, a specialized unit of parking enforcement personnel has been created and the regular police department has been relieved of this responsibility. This approach has two advantages: (a) highly trained and relatively expensive police personnel are freed for law enforcement duties and (b) police morale is improved, for parking regulation enforcement is generally viewed as an undesirable assignment. Creation of a specialized parking enforcement unit has the advantage of relating the enforcement function more closely to the overall parking function. Further, the incremental costs of this unit can frequently be justified by the incremental revenues and increased adherence to parking regulations that result from a more effective enforcement effort. Creation of such a unit is clearly not cost effective in all stiuations. Consequently, each community needs to assess the desirability of creating a special parking regulation enforcement unit in the context of its unique circumstances.

Adequate information systems are necessary to identify violators who have received but not paid parking citations. One approach that has been adopted in a number of municipalities is not to renew the state automobile registration or municipal vehicle identification sticker unless all outstanding parking violations for that vehicle have been paid. In those areas in which a violator parks in one jurisdiction but resides and has an automobile registration in another jurisdiction, interjurisdictional reciprocity agreements must be established.

The possible substitution of administrative hearings for court proceedings with respect to parking violators should also be considered. This approach would free the courts from the burden of adjudicating parking violations, would expedite the administration of sanctions for chronic parking violators, and might be more effectively integrated with the overall parking enforcement system. Such an approach would increase the probability that a chronic parking violator would be apprehended and would receive the sanctions associated with his or her actions.

Finally, the sanctions associated with parking violations should be closely related to the objectives of the parking program and to the anticipated rate at which violators will be apprehended. Suppose, for example, that a parker paid $3/day or $15/week to legally park but that the parking fine, were he or she to illegally park, is only $10 and, further, that the probability of being apprehended is only once per week. Illegally parking would, therefore, be economically advantageous.

REGULATION OF THE SUPPLY OF PARKING SPACES

Historically, governmental regulation of parking supply in the United States has served to increase the overall supply. In many municipalities throughout the country, the local zoning code requires that a minimum number of spaces be provided—this is generally specified as a minimum number of spaces that must be provided per unit of activity (e.g., per dwelling unit for residential facilities or per square foot of floor space for commercial or office facilities).

Recently, the U.S. Environmental Protection Agency has advocated governmental controls to reduce the volume of parking facilities provided by placing constraints on the number of new parking facilities constructed or reducing the total number of facilities currently available (1). The objective of such a program is to (a) make it more difficult for the automobile traveler to find an available parking space and (b) increase the price of parking (insofar as the equilibrium price of parking would be higher if the supply is constrained and the demand curve remains unchanged). As a result, automobile drivers would divert to higher occupancy vehicles.

A strike that closed 80 percent of the parking spaces in downtown Pittsburgh is an example of the potential favorable impacts of constraining the number of parking facilities provided. During the strike, morning peak-period traffic volumes in the CBD declined by about 6000 vehicles (or about 24 percent) and daily systemwide bus patronage increased by about 24 000 riders/day (or about 12 percent) (6). In Marseilles, France, a total ban on parking in the downtown area produced a 40 percent reduction in carbon monoxide concentrations (7).

Constraints on the growth in the supply of available parking have been implemented in Boston and in London. In Boston, the number of off-street parking spaces in the CBD has been frozen at the level of supply that existed in the 1972-73 period. As existing spaces are eliminated for whatever reason, they are placed into a "space bank" and may be allocated to new parking facility development within the freeze area; these new developments are generally oriented to upgrading the existing CBD parking inventory. This freeze is part of an overall program to encourage greater use of public transportation to the CBD; the freeze presupposes that all future increases in travel to the CBD will take place on transit. As part of this program, Boston plans a major increase in parking facilities located along rail rapid transit, commuter rail, and express bus lines (8). In London, zoning regulations place a ceiling on the maximum number of parking spaces that can be provided in new office developments (9).

Techniques for Implementing Regulation of Supply

Five broad strategies for constraining the number of parking facilities provided are discussed below.

Depleting the Existing Inventory

Depleting the existing inventory of parking facilities is the most severe of the supply constraint measures. Approaches to depleting the existing inventory include (a) immediately removing some spaces (e.g., on-street parking), (b) placing a complete moratorium on new construction of parking facilities and thereby allowing the number of parking spaces to decrease as development consumes existing spaces, and (c) removing a specified number of percentage of spaces within a specified time.

Existing on-street facilities within CBDs are generally

metered and provide a valuable service for short-duration trips; on-street facilities are generally not used for long-duration work trips.

Placing a moratorium on the construction of new facilities and allowing shrinkage to take place in the total parking inventory as development consumes existing spaces reduce the existing supply slowly over time. The rate at which the supply is reduced will, of course, be related to the rate at which new development occurs. The impact of a parking facility construction moratorium on new development within the CBD should be carefully assessed inasmuch as this approach could have an adverse impact on CBD development. In many metropolitan areas, organizations that finance new development require the provision of parking facilities in conjunction with a project as a necessary condition for their financial support. In this context, placing a moratorium on new parking facilities might actually discourage redevelopment activities within the parking moratorium area.

Removal of a specified number or percentage of spaces within a specific period of time is the most severe of the parking depletion strategies. In most urban areas, a limited number of spaces could be removed by eliminating on-street parking. If, however, a program were initiated to remove otherwise serviceable public or private sector off-street spaces from operation simply to deplete the inventory of existing parking facilities, there would appear to be a requirement to compensate the owners of the facilities for the resulting reduced value of their facilities. Private owners would be compensated for the reduced revenue that the facility would produce in other than parking uses. Since most public facilities are financed by revenue bonds, some provision would have to be made for meeting the financial obligations on the outstanding bonds.

A systematic program to deplete the existing parking space inventory would require the political support of the local decision-making community. Such a program would appear to be most applicable in mature urban centers in which relatively small growth is taking place, excess parking capacity is currently available, and environmental and energy conservation objectives are of sufficient concern to warrant such a major action.

Freezing the Number of Parking Spaces

Parking supply can be regulated by freezing the inventory of parking spaces. The existing inventory of CBD parking spaces is upgraded over time by replacing obsolete facilities with CBD peripheral garages or underground parking within structures. Spaces removed from service are placed into a parking space bank that may then be allocated to new development according to specified criteria. This is essentially the approach adopted in the Boston metropolitan area.

The freeze approach is clearly a less drastic action than depleting the existing inventory. It would appear most applicable to situations in which the CBD is experiencing some growth in travel; clearly the freeze approach would not have an effect if travel to the CBD were stable. The administrative procedures associated with a freeze, particularly the procedures used to allocate spaces from the space bank to new facilities, need to be carefully established. In this context, the parking development plan for the CBD needs to be carefully coordinated with an overall development plan. This approach may encounter the reluctance of financing organizations to support new projects that do not incorporate parking facilities.

Constraining Normal Growth in Parking Supply

A third approach is to constrain the volume of new facilities provided to less than would be provided under normal market circumstances. This approach would appear to be most applicable to areas experiencing rapid growth in traffic volumes. It recognizes that some new parking facilities should be provided but establishes a ceiling on this number to encourage use of higher occupancy vehicles. This approach requires a carefully formulated set of criteria for establishing the ceiling on the maximum number of parking spaces to be provided. Such criteria might include the availability of alternative transportation services and the environmental and energy implications of the facilities.

Requiring Residential Parking Permits

Residential parking permit programs have been advocated and implemented to reduce parking by commuters on residential streets located adjacent to a congested commercial or employment area in which either insufficient parking is available or available parking is so expensive that commuters are encouraged to park in the residential areas and walk to their final destinations. Heavy commuter parking on residential streets may also occur adjacent to a congested transit transfer point at which insufficient parking facilities are available, particularly a commuter railroad or rail rapid transit station. This situation occurred, for example, at congested fringe parking facilities on both the Lindenwold Hi-Speed Line serving the New Jersey suburbs of Philadelphia and the Bay Area Rapid Transit System serving the San Francisco metropolitan area.

Residential parking permit programs are designed to reserve the available on-street parking in these congested areas for residents. Special permits are issued to residents authorizing them to park on the streets at a time when parking by all others is prohibited. The prohibited period may be from 7 a.m. to 10 a.m. or from 7 a.m. to 6 p.m. Thus, the residential permit program increases the probability that residents of a congested area will be able to find on-street parking in the vicinity of their residences.

Understandably, residential parking permit programs are popular with residents of areas in which congested on-street facilities are being used by all-day commuters. The legality of such programs has been challenged in a number of suits questioning the constitutionality of such measures. Although the matter has not been fully resolved, the courts have permitted several municipalities to implement residential parking permit programs.

Residential permit programs are generally implemented to increase the parking available to residents and not to restrain traffic. If the residential area is located adjacent to the final destination of the all-day work parkers, however, the program will tend to increase the generalized cost of parking and will therefore tend to divert travelers to higher occupancy modes. On the other hand, if the residential area is located adjacent to a transit transfer point, the permit program may have the opposite effect, particularly if alternative transit transfer points with parking are not readily available.

Restricting Facility Use

A final approach to constraining the supply of parking is to place restrictions on the use of existing facilities, such as limiting the duration of parking. Madison, Wisconsin, for example, is converting existing facilities

from long- to short-duration spaces. Another approach is to place restrictions on the hours during which parking facilities can operate. For example, a parking facility might be able to serve only car pools of three or more persons until 9:30 or 10:00 a.m. These approaches tend to discourage the use of single-person automobiles for home-to-work travel.

Considerations Affecting the Regulation of Supply

Placing a ceiling on the maximum number of parking spaces that can be provided involves a relatively new area of governmental regulation, the implications of which are not fully understood. There has been relatively little experience with such an approach in the United States although a number of cities are exploring the use of automobile-free or automobile-restraint zones within their CBDs. The degree to which parking supply constraints can be used to reduce automobile travel and thereby achieve air quality and energy conservation objectives appears to be related to the following factors (10).

1. Placing restrictions on parking supply and thereby inhibiting the use of low-occupancy vehicles must be accompanied by the provision of transit, car pools, and van pools. Therefore, the best time to implement a parking supply constraint program is when a significant improvement occurs in alternative higher occupancy transportation services. This is difficult to achieve, particularly with respect to rail rapid transit systems that are constructed and opened to service over a period of many years. No feasible way has been devised for differentiating the service provided to parkers according to whether they reside in a portion of the region in which the transit service has been improved.
2. Parking supply constraints should be structured to impact those automobile travelers who are most likely to divert to alternative modes, particularly all-day commuters. Further, parking supply constraints should be designed so as not to adversely affect those travelers, such as shoppers, who cannot readily divert. The strategy of not allowing facilities to serve low-occupancy automobiles until after 9:30 or 10:00 a.m. is one approach that effectively focuses the parking supply constraints on commuter parking. This objective might also be achieved by placing restrictions on the duration of parking within specific facilities.
3. A significant proportion of the total parking volume within the CBDs of larger areas is provided by off-street facilities. Consequently, any program to constrain the volume of parking facilities provided must include both off-street and on-street facilities.
4. The objective of parking-restraint measures is to reduce automobile traffic to improve air quality and conserve energy. To achieve this objective, restrictions placed on the supply of parking must be sufficiently stringent to reduce the quantity of parking spaces occupied and not just reduce excess capacity, particularly in CBDs, where the overall level is stable or possibly declining over time. Since the number of automobiles that park in a CBD may vary significantly during the hours of the day, the days of the week, and the weeks of the year, particularly for shopping and personal business and to a lesser extent for work trips, "excess capacity" needs to be carefully defined.
5. Constraining the supply of parking within a portion of a metropolitan area may have long-term urban development implications. If, for example, parking supply were constrained in the CBD but not in the suburbs, new development would likely occur in the suburbs. Under these circumstances, implementation of the parking supply constraint program would appear to require concurrent implementation of development controls throughout a metropolitan area—a situation not currently existing within most U.S. metropolitan areas and one that would be extremely difficult to implement. The parking supply constraint program should be carefully assessed to ensure that it does not significantly impact the overall development patterns within the region in an adverse manner. Concurrent implementation of a parking supply constraint program and a significantly improved transit service (e.g., a regional rail rapid transit system) might have a high probability of achieving the desired objectives without adversely impacting urban development patterns.
6. In many cities, developers clear a site primed for development ahead of time and provide a parking lot until they are ready to begin construction. This allows them greater flexibility in initiating construction and provites an intermediate source of revenue. Parking supply regulations that impede or prohibit this land clearing and holding process might adversely affect CBD development, and their design should consider the role of temporary surface parking lots within the overall land redevelopment cycle.

REGULATION OF THE PRICE OF PARKING FACILITIES

Actions to increase the price of parking are designed to make driving an automobile relatively more expensive and thereby encourage automobile travelers to divert to high-occupancy vehicles. Parking pricing actions that might be taken include parking tax, parking surcharge, increased parking rates, and restructured rate structure.

Techniques for Implementing Regulation of Price

Parking Tax

Although a parking tax is viewed by most municipalities as a revenue-raising device, it also has the effect of increasing the cost of parking and thereby encouraging travelers to divert to high-occupancy modes. Cities that have a parking tax include Pittsburgh, which has a 20 percent tax; Washington, D.C., which has a 12 percent tax; and San Francisco, which levied a 25 percent tax from October 1, 1970, to June 30, 1972, and then lowered it to 10 percent. A further advantage of these taxes is that a significant portion of them are paid by suburban residents. The constitutionality of the Pittsburgh parking tax was upheld by the Supreme Court in Pittsburgh versus Alco Parking Corporation (June 11, 1974):

> By enacting the tax, the city insisted that those providing and utilizing non-residential parking facilities should pay more taxes to compensate the city for the problems incident to off-street parking. The city was constitutionally entitled to put the automobile parker to the choice of using other transportation or paying the increased tax.

Parking Surcharge

A parking surcharge is an additional fee that is added to the existing or regular parking charges as a result of governmental action. Whereas parking taxes can only be applied to situations in which a fee is regularly paid for the use of parking, parking surcharges can also be applied to employer provided parking, free parking at commercial centers, and even free or metered on-street parking. The nature of the surcharge with regard to its

level, the geographical area of application, the hours during which the surcharge applies, the facilities to which the surcharge applies, and the duration of parking to which the surcharge applies can be varied, although the selected approach must be administratively feasible. Consequently, the parking surcharge approach offers the potential for carefully targeting the group that is to be impacted by an increase in parking prices. If this group is, for example, all-day work commuters to the CBD, the group most divertible to transit, then the parking surcharge might be applied only to vehicles having a parking duration greater than 4 h or to vehicles arriving between the hours of 7 and 10 a.m.

Parking Price Increase

A number of actions, other than a parking tax or surcharge, can be taken to increase the overall price of parking. These actions include increasing the rates at municipally owned and operated on-street parking meters, installing meters at additional locations, increasing the parking rates at facilities operated by the city or the municipal parking authority, and placing restrictions on the duration of parking at various facilities. Such actions would indirectly tend to increase commercial parking rates insofar as the municipal or authority operated parking facilities constitute a significant proportion of the total parking supply available within the area. Direct municipal regulation of the rates charged by the commercial parking industry might also be undertaken, although this approach has not yet been implemented anywhere in the country and would probably be subject to a test of its constitutionality.

Parking Rate Structure Revision

The current parking rate structure in many metropolitan areas results in a lower effective rate per hour for long-duration parkers. Although the parking industry practice of charging a higher fee for the first few hours than for subsequent hours is partially related to recovering the incremental costs of serving an additional automobile (irrespective of its parking duration), it also reflects a realistic profit assessment strategy of the parking industry. Revising the parking rate structure so that the parking cost per hour is the same irrespective of the duration of parking or even increases with the duration of parking has the effect of increasing the overall parking cost for all-day work commuters and possibly decreasing the parking costs for short-term shopping and personal business parkers. Such an approach could reduce automobile travel during peak periods by those travelers who are potentially the most divertible to high-occupancy vehicles.

Although revising the parking pricing structure at municipally owned or operated facilities is presumably a matter of municipal policy, revisions at commercially operated or public authority operated facilities require explicit municipal authority. As noted above, regulation of commercial or public authority conditions of parking is a power not currently being exercised by any municipality within the United States, and municipal assertion of such a power would probably be subject to a court test.

Considerations Affecting the Regulation of Price

Potential Desirable Aspects of Price Regulation

Use of parking price regulation to achieve automobile congestion reduction, air quality, and energy conservation has a number of appealing features. If the strategy is implemented in the form of a parking tax, the approach is generally considered to be within the recognized powers of the municipality, its implementation is administratively straightforward, additional revenues are obtained for the municipal treasury, and the incidence of the tax falls on suburban commuters to the CBD and not just the residents of the city (a factor of some importance to elected officials of the central city of a metropolitan area). Further, this approach directly increases the out-of-pocket cost of using an automobile and can be designed to impact those urban travel market segments that are most divertible to high-occupancy vehicles. Some of the limitations of parking price regulation are describe below.

Proportion of Automobile Drivers Who Pay for Parking

Most people who drive to work in the United States pay no parking charges (14). The type of parking facility used and the charge paid by a sample of all U.S. home-to-work commuters are given in Table 6 (14). Only about 7 percent of those who drive an automobile to work pay any parking charge whatsoever; the other 93 percent park for free. Further, only 6 percent park in commercial parking facilities, and nearly 76 percent park in employer-provided spaces. Consequently, on a national basis, a parking price regulation strategy that used parking taxes superimposed on existing parking fees would affect only about 7 percent of the total home-to-work travelers. In some of these cases, parking fees are employer subsidized and consequently any increase in the cost of parking would not directly affect behavior of the home-to-work commuter.

Since the data given in Table 6 represent all automobile commuters within the United States, it might be expected that travelers on radial freeways to the CBD may pay parking fees to a greater extent. A survey of automobile commuters in the Shirley Highway corridor (a major radial freeway from the CBD of Washington, D.C., to the Virginia suburbs) found that 56 percent of the automobile users park for free and that more than 80 percent of the automobile users pay $1/day or less for parking (11). Yet the prevailing commercial parking rates in the Washington CBD were $2/day or greater at the time of the survey. Thus, a majority of the automobile travelers on a major freeway radial to the CBD were either parking for free in employer provided spaces, obtaining reduced rate parking, or obtaining employer subsidized parking. This suggests that the effectiveness of a parking price regulation program would be significantly enhanced if the program could be designed to impact employer provided and subsidized parking in such a manner that travelers perceive an increase in the out-of-pocket parking costs they must pay.

Proportion of Automobile Drivers Destined to the CBD

Most of the parking facilities in the United States in which the user must pay a fee are located in the CBDs of metropolitan areas. Many of the proposals for implementation of a parking price regulation strategy have

therefore focused on increasing parking prices within the CBD. The CBDs of most urban regions within the United States generally attract less than 5 percent of the total travel undertaken in metropolitan areas. Thus, a CBD parking price strategy implemented to achieve energy conservation or regional air quality objectives would impact a relatively small proportion of the regional travel. Such a policy might, however, beneficially affect local air quality (CO concentrations) at key locations within the CBD.

Inelasticity of Parking Demand

Empirical studies suggest that parking usage is suprisingly insensitive to increases in parking prices and that parking revenues are relatively sensitive. A study of the impacts of the San Francisco parking tax on parking demand, gross revenues, and overall traffic levels (12) found that the demand elasticity for parking for all trip purposes was about -0.3. There was some evidence that all-day commuters were more likely to discontinue parking than were shoppers. Gross parking revenues, on the other hand, were found to be quite elastic, that is, the increase in price was more than offset by the decrease in dollar sales volume. A revenue elasticity of about -1.6 was estimated on the basis of the revenue change. Thus, the parking tax caused both a reduction in the number of automobiles parked and a reduction in the net revenues per automobiles parked. This latter change was caused by (a) a tendency to continue using parking but for shorter durations than before the tax and (b) a relatively greater reduction in commuter parking than in shopping and other short-term parking.

The parking tax had relatively little impact on traffic in the city as a whole, causing perhaps a 2 percent reduction in the number of vehicles using the streets of San Francisco—equivalent to about 3 months of secular growth. Further, the tax had a relatively nominal impact on the level of downtown retail activity. Finally, the tax had a major impact on the gross revenues and profits of the parking industry; gross revenues were estimated to be 36 percent below the level projected under normal growth and 31 percent under those observed the year before the tax. These losses exceeded somewhat the revenues that the city and county government collected from the tax. To the extent that the San Francisco tax appears to have affected all-day work commuters to a greater extent than shoppers, it did contribute to reducing peak-period traffic congestion.

Proportion of Traffic Traversing the CBD

If the area in which the parking rate increase is applied is defined as the CBD plus immediately adjacent areas, the available empirical evidence suggests that through travel probably accounts for about 15 to 30 percent of all of the automobile trips currently made into the area (13). If parking restraints were implemented within the area, changes in travel might occur that would increase the proportion of through travel: (a) As congestion is reduced by parking controls, trips formerly routed around the CBD might now be routed through it; and (b) if parking restraints were severe enough, travelers might divert to other modes such as taxi and serve-passenger trips.

Urban Development Implications

If a parking price regulation strategy is implemented in selected portions of a metropolitan areas, such as the CBD, a greater amount of development might occur outside the area in which the parking rate (or supply) regulations are applied. As a practical matter, it would be extremely difficult to control such development through development controls currently available within the United States. Further, competition for development exists at a subregional level in most metropolitan areas within the United States, and the development controls available are generally applied at a subregional level. Consequently, potential development effects need to be considered as part of the overall process of planning a parking price regulation strategy.

Reference was previously made to the role of surface parking lots as an important intermediate stage in the land redevelopment cycle. To the extent that such facilities enable developers to maintain a readily available land bank for new projects, they may facilitate urban redevelopment. Parking price regulation strategy should ensure that the land redevelopment process is not significantly adversely affected.

FRINGE AND TRANSPORTATION CORRIDOR PARKING

The provision of fringe and transportation corridor parking offers a particularly attractive parking management strategy because it focuses on providing improved transportation service and not on increasing the generalized cost of travel. Although fringe and transportation corridor parking currently only provides 0.5 percent of the total parking used in the country (14), this parking management strategy appears to offer some potential for further development. Fringe and transportation corridor parking facilities allow each of the transportation modes to be used to its best advantage; low-occupancy automobiles are used to travel between dispersed residential sites (particularly in low-density areas) and fringe parking facilities, and high-occupancy vehicles (e.g., public transit bus, van pools, and car pools) are used to travel between the fringe parking facilities and the final destinations. To date, fringe parking facilities exist primarily at rail transit and bus routes oriented to the CBDs of large metropolitan areas. Connecticut has, however, been quite successful in developing well-used fringe parking facilities to serve dispersed employment sites and the CBDs of smaller metropolitan areas (15).

An analysis of the cost of operating a 500-vehicle, self-park, surface fringe parking lot is given in Table 7 (16). Turnover is relatively low at fringe parking facilities, and they are not heavily used on weekends. In this sense, the usage of 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 280 vehicles/year and that the facilities would be at capacity each working day (this annualization factor corresponds to the one used for public transportation systems). Thus, the annual cost for the facility must be allocated among 140 000 vehicles/year, yielding a daily cost for a land value of \$26.90/m^2 (\$2.50/ft^2) or \$0.49/vehicle for a publicly owned facility and \$0.81/vehicle for a privately owned facility. Hence, for the lowest land value considered, the daily cost of operating a publicly owned fringe parking facility is essentially equivalent to the highest daily parking fee for any of the fringe parking facilities considered.

Although exceptions to the above assumptions could be found, these results suggest that in the context of the existing situation the revenues that can reasonably be derived from fringe parking facilities will not meet the fully allocated costs of constructing and operating such facilities even if they are publicly owned. When the facilities are privately owned or the cost of the land is greater than \$26.90/m^2 (\$2.50/ft^2), the differences be-

tween the potential revenues and the average daily cost are even greater. If this analysis is correct, traditional approaches—such as municipal parking authorities, private enterprise, park-and-shop corporations, and benefit districts—for implementing parking facilities in a CBD will be inappropriate for fringe parking. 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 experience to date suggests that there are two approaches for implementing fringe parking programs: (a) use of parking facilities constructed as part of other public or private projects and (b) assumption of the investment and, in some cases, operating costs by a public agency. Fringe parking facilities have been implemented at suburban shopping centers in a number of metropolitan areas; such sites are available in most metropolitan areas. A fringe parking facility should be provided with good transit service to the CBD, if possible by an express bus service. This implies a parking facility with a minimum capacity of 500 automobiles. Such facilities could only be located at relatively large regional shopping centers where use of about 500 spaces for commuters during regular work days would not adversely affect the overall parking capacity of the shopping center. Civic centers and stadiums also have a substantial amount of parking that is generally not heavily used during normal working hours and could be made available for a fringe parking program.

Many fringe parking facilities are currently being constructed and operated by public transit operators, particularly rail rapid transit systems. The Lindenwold Hi-Speed Line has approximately 8000 parking spaces, and the Bay Area Rapid Transit (BART) System has approximately 17 000 parking spaces. Significant amounts of fringe parking are being planned for the systems under construction in Washington, D.C., Atlanta, and Baltimore.

Based on recent experiences with fringe and transportation corridor parking (16), several conclusions can be drawn about the usage of fringe parking facilities and planning guidelines for locating, designing, and providing transit service to these facilities. A summary of the important physical and operational characteristics of five selected fringe parking programs is presented in Table 8 (17). The programs in the five cities are described below.

1. In Milwaukee, the Freeway Flyer express bus service is provided between six suburban shopping centers and the CBD;
2. In Seattle, the Blue Streak bus service is provided between a fringe parking lot and the CBD via an exclusive access ramp;
3. In Philadelphia, the Lindenwold Hi-Speed Line provides rail rapid transit service between the Philadelphia CBD and six suburban fringe parking lots located in a New Jersey corridor;
4. In Atlanta the Town Flyer bus provides service between fringe parking facilities located at the Atlanta Stadium and Civic Center on opposite sides of the periphery of the CBD; and
5. In Cleveland, the Cleveland Transit System Loop Bus provides service between the Lakeshore and St. Vincent fringe parking lots located on opposite sides of the periphery of the CBD.

The transportation corridor parking facilities are located between 9.7 and 22.5 km (6 and 14 miles) from the CBD, and the CBD-peripheral parking facilities are located within 1.6 km (1 mile). No parking fee is charged at transportation corridor facilities, except for a low fee charged on the Lindenwold Hi-Speed Line for those spaces that are closest to the stations. Although higher than those charged at corridor facilities, parking rates at CBD-peripheral facilities are significantly lower than in the core of the CBD. On the other hand, transit fares are lower for the CBD peripheral facilities than for the transportation corridor facilities. All of the facilities are self-parking, lighted, paved, and provide shelters (except for Atlanta, where the climate is pleasant for the entire year). Attendants are provided at the Atlanta and Cleveland facilities to ensure the security of the vehicles; such provisions have not proved necessary at the other facilities, where security is provided by transit police, municipal police, or the private security service of the shopping center owner.

Selected travel and socioeconomic characteristics of the fringe parkers in each of these five cities are given in Table 9. Fringe parking facilities are used predominantly by workers, who generally park more than 8 h. Consequently, there is relatively little turnover associated with fringe parking facilities. Automobile occupancy at fringe facilities ranges from 1.1 to 1.3, which is about the national average. Even the Atlanta price structure, designed to attract car pools, appears to have had relatively little impact on automobile occupancy.

Inasmuch as women constitute a significant proportion of the users, fringe parking facilities should be designed so they are attractive to female patrons. Safety factors such as lighting and surveillance appear to be particularly important. Fringe parking facilities attract users from all income categories; most have annual household incomes greater than $10 000, suggesting that fringe parking facilities can, under the proper circumstances, offer a sufficiently high level of service to attract travelers who have a realistic option of using their automobiles. The ability of fringe parking facilities to divert automobile users is also reflected in the fact that about 35 to 80 percent of the respondents at the various facilities surveyed reported that their prior travel mode or the alternative mode they would use was the automobile.

Based on these syntheses of the literature, it is possible to identify the following implications for the location, design, and operation of fringe and transportation corridor parking facilities (16). Further summaries of existing experience and planning guidelines are provided in other research reports (17, 18, 21, 22).

Locational Aspects

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 good transit service may be offered.
2. To the maximum extent feasible, facilities should be located on land that is already devoted to parking or to low-grade nonresidential use. This objective is more achievable for facilities with bus service than it is for those with rail inasmuch as bus is a more ubiquitous mode and the scale of facilities required to serve rail is inherently larger.
3. Fringe parking facilities should be located on sites compatible with the land uses and the activities in the immediately adjacent area.
4. Potential joint-use aspects of a fringe parking facility should be considered during the location process. If planners believe that joint use can occur in the near 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 during the planning phase.

Design Considerations

1. To the maximum feasible extent, fringe parking facilities should be designed to minimize potential impacts on the neighborhood. Areas of particular concern are as follows: Available rainfall data should be used to estimate runoff and sufficient drainage should be provided; lighting provided should not intrude on the adjacent land uses; due consideration should be given to the aesthetics of the facility; and walkways 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 are substantially different from those observed in the case studies. To this end, self-parking and automatic fare-collection equipment should be used.

5. Access and 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 subjective and related to local conditions, it would appear that parkers having to walk more than 450 to 600 m (1500 to 2000 ft) from their automobiles to the transit boarding point might be discouraged from using the facility. To this end, transit boarding points should

Table 7. Annual operating cost of a 500-vehicle, self-park, surface fringe parking lot.

Cost Category	Land Value ($/m²)	Public Ownership ($)	Private Ownership ($)
Amortization of land	26.9	29 000	41 300
	53.8	58 500	82 500
	80.7	88 500	124 000
	107.6	117 500	165 000
	134.5	145 500	206 000
Amortization of improvements and equipment		17 500	18 100
Operating costs		22 500	22 500
Taxes		–	32 000
Total annual cost	26.9	69 000	113 900
	53.8	98 500	155 100
	80.7	128 500	196 600
	107.6	157 500	237 600
	134.5	185 500	278 600
Daily cost/vehicle parked[a]	26.9	0.49	0.81
	53.8	0.70	1.11
	80.7	0.92	1.40
	107.6	1.13	1.70
	134.5	1.32	1.99

Note: 1 m² = 10.8 ft².
[a]At-capacity operation for 280 days/year.

Table 8. Operational characteristics of typical fringe parking facilities.

Characteristic	Milwaukee	Seattle	Philadelphia	Atlanta	Cleveland
Number of parking spaces	800	475	8200	1250	4100
Number of automobiles parked	400	475	6600	400	4100
Number of facilities	6	1	6	2	2
Distance to CBD, km	16.1 to 22.5	14.5	9.7 to 22.5	1.6	1.6
Daily parking fee, cents	0	0	0 to 25	75[a]	50
One-way transit fare, cents	50 to 55	35	40 to 60		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

Note: 1 km = 0.6 mile.
[a]Parking fee and two-way fare for all automobile occupants.

Table 9. Selected characteristics of fringe parkers.

Characteristic	Milwaukee	Seattle	Philadelphia	Atlanta	Cleveland
Trip purpose, %					
Work	99[a]	85[b]	89[c]	98[a]	95[a]
Other	1	15	11	2	5
Parking duration					
Under 8 h	1[a]	NA	NA	11[a]	2[a]
8 h or more	99	NA	NA	89	98
Occupancy of parked automobiles	1.20[a]	1.06[b]	1.16[c]	1.30[a]	1.35[a]
Sex, %					
Male	52[a]	NA	60[c]	40[a]	68[a]
Female	48	NA	40	60	32
Annual household income, %					
Under $10 000	20[a]	NA	NA	35[a]	53[a]
Over $10 000	80	NA	NA	65	47
Travel alternative or prior mode, %					
Automobile	57[a]	70[b]	36 to 60[c]	81[a]	65[a]
Transit	43	30	64 to 40	19	35

[a]From Peat, Marwick, Mitchell and Company surveys in 1971.
[b]From Seattle Transit System, 1970 data.
[c]From Delaware River Port Authority surveys in 1969-1970.

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 unusual situations 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 are not preempted by 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 within the neighborhood. Such integration may require that additional local supportive systems be constructed in the neighborhood, e.g., walkways or bikeways.

Service Considerations

1. High-level transit service should be provided from the fringe parking facility to the CBD. For buses, such a quality implies express operations, use of reserved facilities on those segments of the route in which traffic congestion is 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 given 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 objectives 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.

SOME PLANNING GUIDELINES

This paper emphasizes the diversity of the parking management strategies that are available and the planning considerations that must be taken into account with regard to specific strategies. Because of this diversity, it is neither possible nor desirable to develop a universal parking management program applicable to all metropolitan areas. Rather, each metropolitan area needs to develop its own program responsive to its unique local circumstances. Within this context, there are several broad guidelines for planning a parking management program for a specific local area.

1. Approaches to parking management range widely with regard to the nature, areas of application, levels, and implementation aspects of the actions. Local areas need to explore the full range of alternative strategies available to them.

2. Local areas should place considerable emphasis on developing an integrated parking management strategy that includes the different types of facilities available (metered and nonmetered on-street facilities, off-street lots, and off-street garages); commercial, employer provided and subsidized, and developer provided parking facilities; and the enforcement program needed to ensure the effectiveness of the other elements of the parking management program.

3. The parking management strategy should be carefully designed to serve the needs of the metropolitan area and to achieve its objectives with regard to improving transportation service, reducing traffic congestion and transportation-related accidents, achieving ambient air quality standards, and conserving energy. Further, the planning program needs to carefully integrate consideration of local and metropolitanwide community objectives.

4. Parking management strategies that focus on improving transportation service are generally the most desirable. Strategies that improve service for some but increase the generalized cost for others are next most desirable. Strategies that focus on increasing the generalized cost are less desirable, although these may be necessary in specific instances.

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MANAGING TRANSPORTATION DEMAND BY ALTERNATIVE WORK SCHEDULE TECHNIQUES

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The management of urban transportation demand involves a number of techniques to reduce congestion by altering peak demand patterns. This paper discusses several transportation system management elements and focuses on alternative work schedule techniques such as staggered and flexible work hours and the shortened workweek. Alternative work schedules are deemed to be the most promising approach to managing transportation demand since such techniques are usually highly cost effective, are popularly received, entail nontransportation societal benefits, and can be implemented quickly. The effectiveness and state of practice of various alternative work schedule techniques are discussed, and a recommended approach for studying, implementing, and evaluating such techniques is presented. Brief case studies are given of programs in urban areas.

A primary function of many urban transportation professionals is to determine the demand for transportation and then design and implement systems to serve that demand. The traditional procedure is to analyze the characteristics and quantity of the demand with respect to parameters such as peak-hour flow, trip purpose, directionality, and peaking and to provide a wide variety of facilities to handle the current and forecast demand. Since such facilities usually require high capital and are, in many cases, controversial, increasing emphasis in recent years has been placed on devising ways to alter the demand patterns themselves in order to operate existing systems more efficiently.

TECHNIQUES TO MANAGE DEMAND

A number of techniques are available to alter demand. They vary in their relative effectiveness and ease of implementation. The most common can be classified as alternative work schedules or pricing incentives or disincentives. Each of these is discussed in this paper. Some specific techniques in these areas are contained in the listing of transportation system management (TSM) actions to be considered (1):

Changes in work schedules, fare structures and automobile tolls to reduce peak period travel and to encourage off-peak use of transportation facilities and transit services, such as:
- Staggered Work Hours
- Flexible Work Hours
- Reduced transit fares for off-peak transit users
- Increased peak-hour commuter tolls on bridges and access routes to the city

Alternative Work Schedules

The use of alternative work schedules to manage urban transportation demand is given primary emphasis in this paper. Among the reasons for this are that work schedules are directly correlated with peak-period travel patterns and that a number of feasible concepts can be implemented quickly at little cost, are widely popular, and promise other nontransportation benefits. The fact that the movement away from the rigid 8-h workday is growing in this country behooves the transportation professional to understand and take the lead in directing the acceptance of such concepts so that they are dovetailed with the interests of efficient use of urban transportation systems. In later sections of this paper, a number of alternative work schedule concepts are discussed with respect to their impact on transportation systems and the status of their acceptance. Also discussed is a recommended approach for designing alternative work schedule concepts for an urban area, and a number of case studies of efforts throughout the country are presented.

Pricing Incentives or Disincentives

In a straightforward analogy to the economic theory of demand, the amount of transportation demand varies inversely as the price of the service. Thus, managing demand can be achieved by raising or lowering the price of the service provided. Incentives to use certain public transportation modes or to travel at less-congested off-peak times can take the form of reduced fares or tolls as appropriate. Conversely, disincentives of higher fares or tolls would reduce volumes of certain modes, for example automobiles during the congested peak hour.

Although it is difficult to generalize the wide area of pricing schemes, alternative work schedules are usually more effective than pricing in altering peak transportation demand for work trips. This is because there is a direct impact on such demand when the times that people commute to and from their jobs are changed. In addi-