INFLUENCE OF PARK-AND-RIDE FACTORS IN MODAL SHIFT PLANNING

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The purpose of this paper is to investigate the use of park-and-ride facilities and municipal parking policies as a means of controlling the modal split in urban areas. A discriminant model was used to examine the reasons why park-and-ride patrons shifted to that mode from a former automobile mode. An attitudinal survey was also used to substantiate the model results. The reduction in travel cost appears to be the main reason for the modal shift. The primary conclusion is that a park-and-ride facility can be used as a planning tool to adjust the modal split if the service is properly designed.

•THE purpose of this paper is to investigate the use of a park-and-ride system to change the modal split in the context of a low-cost option planning framework. This framework has two requirements:

1. A clear understanding of what characteristics a public transportation system needs to attract automobile commuters, and
2. A policy mechanism to implement publicly desirable modal shifts.

A central concept in this approach is to relate demand for new modes, or combinations of existing modes, to satisfactions gained from the attributes of the system rather than to the mode actually used or contemplated. The premise is that a traveler uses a particular mode because it provides him or her with the least undesirable combination of such attributes as travel time, travel cost, walking and waiting time, or travel comfort. If the demand for each combination of attributes can be measured, the effects of new untried systems can be tested, and modal shift predicted.

Mathematical models can be a useful means of exploring and predicting probable effects of various policy options on the modal shift. A few recently formulated disaggregated and stochastic travel demand models based on extant behavior appear to be good for simulating the modal choice of commuters. However, models based on extant behavior are somewhat restrictive because of the unavailability of behavioral data for high levels of service for transit systems. This has led to the consideration of subjective preferences as a data base for model calibration. Clearly, the effect of system changes on modal choice depends on the subjectively perceived relative service levels of the modes available. Therefore, subjective preferences, if reliably measured, can be used to understand new dimensions of transportation demand. This is the approach taken in this study.

A policy mechanism to implement mode shifts requires a philosophical change in the concept of transportation planning as practiced in the past, a change from the traditional concept of planning to meet demand for automobile travel to one of planning to adjust demand based on community objectives. One policy mechanism that can be related to the low-cost option planning framework is disjointed incrementalism, a strategy directed to the identification and solution of problems by incremental changes from the status quo. Braybrooke and Lindblom (1) described disjointed incrementalism as a realistic mechanism for solving problems through the public decision-making process. They imply that this approach is really just a formalization of the usual process of making decisions on public projects. There is no goal achievement orientation in the philosophy as documented, but Steger and Lakshmanan (2) have combined disjointed

incrementalism with a forward-seeking goal-oriented process, and these two ideas together form a systematic basis on which future transportation plans can be formulated. This process would (a) model the transportation system, (b) identify transportation problems, (c) establish problem-solving short-term transportation system objectives, and (d) generate alternative strategies to guide transportation policies toward community goals. This combination of incremental problem solving within a long range goal-oriented planning context is an appealing philosophical framework for modal split planning.

Available evidence of sensitivity to parking charges or a parking tax suggests that a policy mechanism based on parking controls conforms to this philosophical planning framework and would be successful in altering modal split on both conceptual and practical grounds. Such a mechanism should include nonprice factors because of the overall sensitivity to time and comfort aspects of system users. These include walking time at the destination and parking time as well as parking fees or a parking tax. For a park-and-ride system, walk times, overall travel times, frequency of buses leaving the park-and-ride terminal, bus fares, transfers, and waiting characteristics of the system are also factors to consider.

This planning procedure is a blend of classical demand modeling and the demonstration project, in which operational improvements are modeled and subsequent effects on the system are monitored. In this case, park-and-ride is defined as a low-cost option. If results are not in the direction desired to reach community goals on modal split, changes in the parking price, supply, or location are designed to correct the previous misallocation.

The idea of formally planned park-and-ride facilities in urban areas appears to have advantages in attracting automobile commuters because such a system provides geographic flexibility as an extension to a conventional bus, rail, or suburban mode and may create efficiencies in line-haul and downtown distribution.

INVESTIGATIVE MODEL

The potential effect of park-and-ride facilities on automobile commuting was investigated by a discriminant, policy-sensitive model applied to data collected in Vancouver, Canada.

The criteria used to define the structure of the model to study the effects of park-and-ride policies were as follows:

1. The model should be responsive to the characteristics of the transportation system, i.e., an abstract modal model;
2. The model should be structured around instrumental variables that could be represented by a realistic municipal parking policy;
3. The model should be disaggregated to account for the differential effects on different social groupings; and
4. The model should be theoretically sound and replicate a logical construct of consumer preferences.

The study used stated preferences to model the propensity of an individual to shift to a park-and-ride system. The model is called a propensity model because prediction of behavior from stated preferences for modal attributes is only possible if those who say they will shift actually do so if the perceived travel system is changed.

The model (4) postulates an indifference surface defining the combination of transportation system attributes (e.g., time, cost, and comfort) preferred by each automobile commuter. If a new set of transportation system attributes are introduced as an alternative to the automobile (in this case by a park-and-ride facility) for each commuter, the closeness of this new set of attributes to his or her travel indifference surface can be examined. The degree of closeness of the new system attributes to any individual's indifference surface defines his or her propensity to shift to the new mode. If the combination of attributes selected by all automobile drivers are considered and the points

in a Cartesian space statistically aggregated, they will form a cluster of points representing the range of attributes of automobile drivers. Similarly, a second cluster of points can be considered that consist of the preferred attributes for a park-and-ride system. Multiple discriminant analysis can be used to assess whether or not the means of the two clusters are statistically separated. If the two clusters replicate statistically two distinct modal groups, then whether or not the preferred attributes of a given individual are associated with the car-driver cluster or with the park-and-ride cluster can be determined. In this way, the effects of changes in attributes in a transportation corridor can be assessed if it is assumed that commuters have a clear perception of the alternatives available and that they in their perception and behavior act with economic rationale. In other words, they attempt to minimize their travel dissatisfactions.

This method was used to test the significant attribute changes brought about by the introduction of a park-and-ride facility that would cause a modal shift to the new facility. In other words, the approach was used to systematically investigate the reasons certain individuals shifted to the new facility. The model analysis was supplemented by a conventional attitudinal scale to test its validity.

MODAL SHIFT DUE TO PACIFIC NATIONAL EXHIBITION PARK-AND-RIDE FACILITY

The Pacific National Exhibition (PNE) park-and-ride service was introduced by the city of Vancouver and British Columbia Hydro on March 3, 1972, to service one of the most heavily used commuter corridors in the region. Agreement was made between the city and the PNE Board of Directors to use one of the exhibition parking lots as a park-and-ride terminal. Buses leave the parking lot terminal at 10-min intervals from 7:10 to 7:55 a.m., 5-min intervals to 8:10 a.m., and 10-min intervals after 8:10 a.m. The terminal is a covered stop, and the bus is express to the edge of the central business district and then follows the regular city routing. The service is also express from the same point at the edge of the CBD in the afternoon rush. The terminal parking lot is 5 miles (8 km) from the high-valued corner of the CBD, and 3 miles (4.8 km) of this is express. Buses load and unload in a bus bay centrally located in the parking lot.

The complete capital cost of the facility, including three new deisel buses and a covered bus stop shelter, was about $140,000. Vancouver provides an annual subsidy of $10,000 to the PNE in lieu of lost parking revenues.

Patronage grew quickly during the spring of 1972, leveled off in the summer at 635 daily average passengers inbound, and continued to increase to a plateau of about 900 average daily morning passengers and about 600 cars left in the lot (Figure 1).

On Friday, April 7, 1972, an on-board passenger survey (Figure 2) was made to determine why patrons used the facility and to find out some of the reasons for their shifting from their cars. Two hundred and sixty responses were received, about 48 percent of the morning rush hour patronage. Patrons were asked to fill in a questionnaire on the bus during the express portion of the trip. All answers were confidential.

The survey showed that over 77 percent of the patrons drove to the parking lot, 11 percent were driven, 10 percent walked, and 2 percent took the bus or some other mode. Almost 93 percent walked from the bus to final destinations. At least 38 percent of all patrons had been car drivers, 8 percent were car passengers, 21 percent were bus riders, and 33 percent used other modes including park-and-ride facilities. At least 12 percent of the patrons switched from a previous bus mode to the car-driver mode for the trip to the park-and-ride facility.

About 2.8 min in overall travel time were saved, walking times were decreased by about 1.2 min, and the cost was about the same both before and after the service (Table 1). The park-and-ride service had no dramatic advantages on the mean values except for the initial travel time before boarding the vehicle. When the standard deviations are taken into account we conclude the park-and-ride service is close to previous service levels.

Note the relatively long trip length for the park-and-ride patrons. Total vehicle travel time, on the average more than 40 min, is shown in Figure 3. Total pedestrian

Figure 1. Patronage trend.

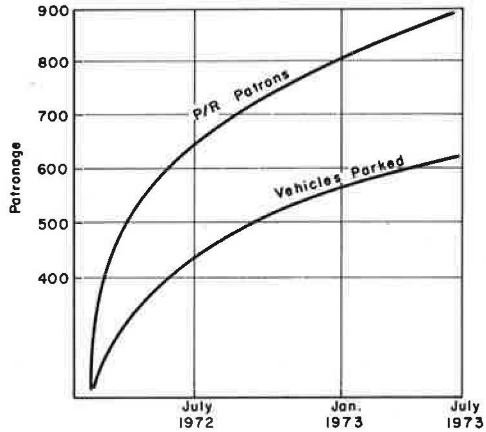

Figure 2. Park-and-ride planning survey questionnaire.

1. What is the purpose of your trip today?
   (a) work ☐ (b) personal business ☐ (c) shopping ☐ (d) school or university ☐ (e) other ______ (specify)

2. At what address did you begin your trip today? ______ (street address and municipality)

3. To what address are you going? ______ (street address or nearest intersection)

4. By what means did you get from the start of your journey to the Park-Ride bus loading area?
   (a) walk ☐ (b) car driver ☐ (c) car passenger ☐ (d) bus ☐ (e) taxi ☐ (f) other ______ (specify)

5. How will you get from the Park-Ride bus to your final destination?
   (a) walk ☐ (b) bus ☐ (c) taxi ☐ (d) other ______ (specify)

6. We would like you to estimate, as closely as you can, the following details about your complete journey today. (If you don't know the answers please write in "D.K." and continue.)
   (a) total travel time of your journey from beginning to end ______ minutes.
   (b) total travel time to get from your home to the Park-Ride bus ______ minutes.
   (c) time usually spent travelling on the Park-Ride bus to where you get off ______ minutes.
   (d) usual walking time from Park-Ride bus to final destination ______ minutes.

7. How did you make this journey before you began to use the Park-Ride bus?
   (a) all the way as a car driver ☐ (b) all the way as a car passenger ☐ (c) all the way by bus, no transfer ☐
   (d) all the way by bus with a transfer ☐ (e) by both car and bus ☐ (f) other ______ (specify)

8. Now, we would like you to estimate, as closely as you can, the following details about this same journey before you began to use the Park-Ride bus. (If you don't know the answers please write in "D.K." and continue.)
   (a) usual travel time from beginning to end of trip ______ minutes.
   (b) usual walking time from your home to a regular bus, if you used the bus ______ minutes.
   (c) usual walking time from car or regular bus to your final destination ______ minutes.
   (d) usual parking cost, if you drove your car (if no cost write in "0") by day/or ______ dollars.
   by month ______ dollars.

9. Why did you switch to the Park-Ride bus? Please indicate the importance of each of the reasons below.

	Very Important	Important	Neutral	Unimportant	Very Unimportant	Not Applicable or Don't Know
(a) makes trip faster	☐	☐	☐	☐	☐	☐
(b) avoids parking cost	☐	☐	☐	☐	☐	☐
(c) reduces walking	☐	☐	☐	☐	☐	☐
(d) buses more frequent	☐	☐	☐	☐	☐	☐
(e) reduces strain of driving	☐	☐	☐	☐	☐	☐
(f) help solve City traffic problem	☐	☐	☐	☐	☐	☐
(g) other ______ (specify)	☐	☐	☐	☐	☐	☐

10. In order to correlate results would you please tic the appropriate square below.
    Sex: (a) male ☐ (b) female ☐ Age: (a) 0-16 ☐ (b) 17-25 ☐ (c) 26-40 ☐ (d) 41-60 ☐ (e) 60+ ☐
    Household Income: (a) under $6000 ☐ (b) $6-8000 ☐ (c) $8-10000 ☐ (d) $10-12000 ☐ (e) $12-14000 ☐
    (f) $14-16000 ☐ (g) over $16000 ☐

11. In the space below please suggest any improvements you would like to see made in the Park-Ride service.

travel time is shown in Figure 4. About one-half of the patrons live within 5 miles (8 km) of the terminal. A substantial proportion (10 percent) live more than 20 miles (32 km) from the terminal.

The socioeconomic makeup of the park-and-ride patrons showed that 58.6 percent were females, 67.9 percent were under 25 years old, and almost 30 percent were between 26 and 40 years old. The median income was just under $10,000/annum. Over 25 percent of the sample was in the $10,000 to $12,000 income category.

My main concern in this paper is with the characteristics that caused automobile drivers to shift modes. Therefore, those who were not previously car drivers were removed from the sample. This left a sample of 97 or about 40 percent of the park-and-ride patrons. The propensity model was used to attempt to determine why drivers shifted modes.

Table 2 gives the means of the travel characteristics of the group as car drivers and as park-and-ride patrons. For former automobile drivers, the overall travel time was increased slightly by the park-and-ride system. As expected, travel time at the destination decreased by about ½ min. The cost of the trip dropped from an average of 82 cents for parking to 50 cents for the park-and-ride system.

When the model was tested for variable significance it showed that only the cost variable was statistically significant in separating the all-automobile commuters from the park-and-ride patrons.

The follow-up direct questions about what was important also support this finding (Table 3). Respondents were asked to indicate on a five-category Likert scale the relative importance of several reasons for shifting to the system. The categories were weighted from very unimportant to very important. In this way median values were calculated for each of the attributes and for some that were included to assess other, less quantifiable, reasons. The results show that, in this case, a reduction of the parking charge was the largest factor in the shift; the next was reduction of the strain of driving. These results are based on a park-and-ride facility that provides very little, if any, savings in travel time for the average motorist using the facility. If the park-and-ride facility provided substantial travel time savings, travel time savings would appear as a more important factor than is indicated in Table 3. The validity of this hypothesis was assessed by comparing the results of this study with results from a different commuter corridor.

COMPARISON OF TEST RESULTS

The previously tested corridor served the North Shore communities in metropolitan Vancouver that have a combined population of 107,000 (4). The data were based on a sample of 465 automobile commuters to the CBD between 7 and 9 a.m. on a weekday morning. The subsample was part of a larger sample reduced by editing out those who needed a car at work and those who said they would not shift mode regardless of the alternatives provided. The remaining sample of automobile commuters were asked to indicate, on a scale, the level of service they would require to shift from automobile commuting to a hypothetical park-and-ride facility. The assumptions about the hypothetical park-and-ride system were as follows: (a) The parking terminal would be remote from the CBD, and (b) patrons would walk from their vehicle to a sheltered bus stop, board an express bus, be deposited within two blocks of their destinations, and be guaranteed a seat.

This analysis showed that a substantial shift would occur if mean travel time were decreased by about 5 min. Total out-of-pocket expenses would have to decrease, but not substantially. The overall walking time from the parking lot of the park-and-ride station to the bus compared with the existing time at the residential end of the journey would have to be about 2 min. This implies that drivers would tolerate this amount of walking at the residential end of the trip if other desirable characteristics were provided. One characteristic that shows up dramatically in the study is a great increase in the frequency of public transit vehicles needed within the park-and-ride system com-

Table 1. Change in mean travel parameters for all patrons before and after introduction of the PNE park-and-ride facility.

Variable	Before	After	Standard Deviation
Total travel time	43.48	40.68	14.41
Residential travel time[a]	2.64	18.82	11.78
Destination travel time	4.76	3.56	2.60
Out-of-pocket expenses[b]	0.44	0.50	0.00

[a]Travel time to major vehicle (car or bus before and to park-and-ride bus after).
[b]Parking cost before and park-and-ride fare after.

Figure 3. Vehicle travel time distribution.

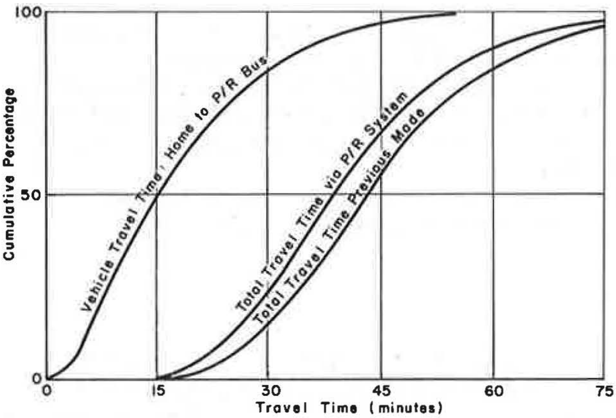

Figure 4. Pedestrian travel time distribution.

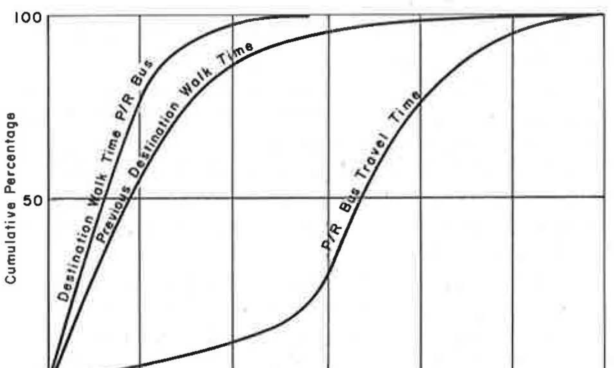

Table 2. All automobile and park-and-ride attribute means.

Variable	Group Means: All Automobile	Park-and-Ride
Total travel time	42.7	43.1
Destination travel time	4.1	3.5
Out-of-pocket expenses	0.82	0.50

Table 3. Importance of reasons for automobile drivers to shift to park-and-ride system.

Reason	Median Values[a]
Faster trip	2.67
No parking cost	4.07
Less walking	1.89
Buses more frequent	1.97
Less driving strain	3.82
Less traffic congestion	3.63

[a]Based on Likert scale: 1 = very unimportant, 5 = very important.

pared with the existing frequency of buses. The average car driver who is a potential shift patron would require about a 4.5-min headway between buses compared with the more than 17 min he or she has currently. This is close to the 5-min headways provided at the successful PNE facility.

OBSERVATIONS FROM STUDIES AFFECTING PARK-AND-RIDE PATRONAGE

Sample Validity

The two studies were done on different population samples and each, in its own way, may have had inherent characteristics that would tend to affect the results.

The North Shore sample was from an affluent population that has status occupations and a high incidence of car ownership but that is apparently positively oriented to transit. It is precisely these people who make up a fairly large proportion of the transit patronage from the North Shore to the CBD.

The PNE sample was biased toward the low-income groups of the population. This may have had something to do with the relatively high incidence of shift.

Parking Charge as a Factor

The North Shore study showed that park-and-ride system costs should be about the same as the existing parking cost. This conclusion is further emphasized because the parking cost of the sampled commuters was relatively low. About 30 percent of commuters parked free, and over 50 percent paid less than $10 per month or 50 cents per day. Therefore, any park-and-ride service would need to be fairly low cost to be patronized, and this would probably require free parking as is the case at the PNE site. It appears clear that commuters will pay only what they pay currently.

The parking charge avoidance is the main factor for the model shift in the case of the PNE study. This again attests to its influence in creating a modal shift.

This points to one fairly solid conclusion: A park-and-ride system must provide free parking or cost very little. This implies that a successful system probably would need to be subsidized for the procurement and operation of parking arrangements. This assumes that subsidized park-and-ride operations will increase social benefits or minimize social costs over the prevailing system. The degree to which these facilities should be subsidized can only be determined after social accounting of various transportation systems serving the CBD has been done.

It was found in these studies that walking distances and parking charges are complementary. Commuters will trade expensive parking spots for greater walking distances. It was shown by the North Shore study that about a 2-min walk time in the parking facility would be tolerated. If the total walking within the system (i.e., at the terminal plus the downtown distribution) is kept to 5 or 6 min, it appears that the system will be accepted by motorists. This finding is supported by other studies of parking and walking trends (5). More definitive data might also show that walking as a factor depends to some degree on climatic conditions.

Line-Haul Frequency as Factor in Modal Shift

The North Shore commuters indicated they wanted a 4.5-min frequency on the average. The successful PNE system provided 5-min frequency during the rush peak and 10 min at other times. This appears to be an important consideration in designing a park-and-ride system, and a 5-min frequency appears to be necessary.

Comfort as Factor in Modal Shift

Little is known about the level of comfort desired in any system although it appears to be important. The PNE patrons for example would wait for a later bus (5 to 10 min later) rather than board a full bus. Since discomfort is a function of the time of being uncomfortable, I suspect that for any significant trip length patrons must be able to be seated. (A second park-and-ride facility in the region was placed at the middle of a regular bus run, and a potential park-and-ride patron would have to stand for the trip downtown. This appears to have had a noticeable effect on the patronage of this facility.) Sheltered stops are also probably necessary.

Trip Length as Factor in Modal Shift

Both of these park-and-ride facilities would be defined as remote services by the break-point between remote and peripheral lots that is located 3 miles (4.8 km) from the CBD (3). Both facilities would necessitate lengthy trips by car (for North Shore commuters the mean is 31 min; for PNE commuters, 43 min). The travel time savings by the service are small for each group. However, it is obvious that the PNE facility is providing good transportation services for suburban commuters who may be attracted to it to avoid the relative congestion and parking problems they would otherwise encounter in the CBD. It is interesting that an express bus service has been initiated that serves the same market area and that has had no apparent influence on the park-and-ride patronage. This and the excess parking capacity in the system imply that market penetration for the PNE service is complete.

Although remote park-and-ride operations usually depend on a substantial saving in trip time to attract patrons, it appears that travel time savings in the case of the PNE facility are not critical to its use. This may be due to the location of the facility rather than strictly a demand factor in that it provides good access from a freeway.

POLICY IMPLICATIONS AND CONCLUSIONS

The overall objective of transportation policies should be to increase public interest benefits while social and economic costs are decreased. This implies a socially optimal modal split of transportation demand to the CBD or what is commonly referred to as a balanced transportation system. Current interest among transport planners with respect to the means of achieving this objective is to reduce automobiles and increase the use of transit. The introduction of a multimodal park-and-ride system into a transportation corridor appears to be a valid method of reducing the number of cars entering the CBD. (The estimates of diversion to the hypothetical park-and-ride system analyzed here for the North Shore may be as high as 15 percent of the corridor car commuters if the proper service is established: The PNE service is keeping a substantial portion of the 600 vehicles now parked at the site per day from downtown streets. Of course some of these parked vehicles are related to the fact that some people who now use a car to get to the park-and-ride facility were formerly bus users.) If the proper combination of walking distances, shelter design, bus frequencies and service characteristics, adequate free parking, and a similar or reduced overall travel time were provided, some motorists might shift modes (at least until the resultant reduction in congestion encourages commuters to again begin to use their cars). Parking pricing policies in the CBD would help remove worker parking from the CBD core to the fringe area.

These findings indicate the need for parking policies to be designed around several basic criteria. First, parking must be an integral part of the transportation system. Because roads and streets are public resources and there appears to be a connection between transportation services and the modal split, it follows that investment decisions about roads and streets should include parking supply and pricing considerations. This and other studies tell us that, if municipalities can exert sufficient control on parking

supply and pricing policies, the demand for the use of roads and transit may be adjusted to meet modal split objectives. This has been attempted in Vancouver by means of subsidy to provide free parking for users of the PNE parking facility. If this subsidy were combined with a parking tax or higher rates at CBD lots, the effect on the shift to park-and-ride facilities would likely be increased substantially. This might be accomplished in Canadian cities such as Vancouver by enlightened operations of quasi-public parking authorities.

Second, however, any attempt to alter modal split needs to include incentives for the use of transit. As a minimum, buses must be at least partially express, frequency must be high, and all patrons must be able to be seated. In Vancouver, buses are owned and operated by the senior provincial government, and it is possible, although difficult, to achieve coordination between parking policies and transit policies. It appears that this is a factor in the success of the PNE operation. In this way public policies can be used as instruments to adjust and plan modal split. Again, however, a full awareness of the need to produce a balanced system is required so that the provision and promotion of transit services are not counterproductive. It may be that, instead of achieving a new modal split, transit policies may encourage abandonment of certain activities from the CBD.

Third, a change in the parking rate structure, the addition or deletion of spaces, or perhaps a change in the zoning bylaw can, under usual circumstances, be implemented reasonably quickly, and the results can be monitored. Line-haul capabilities can also be adjusted by new schedules and route configurations up to the point at which a substantial increase in fleet size is needed. In this way, objectives can be met in incremental steps with, largely, noncapital investments.

Operational adjustments such as rate increases, a parking tax, rate structure controls, and minor investments in facilities are more or less reversible. Parking lot operation is considered as a holding use of land, in which a parking lot becomes a temporary revenue producer awaiting changeover to a more profitable use. Therefore, the temporary nature of parking operations could, under the right circumstances, be used to advantage by testing operational changes without large capital commitments.

Policy options aimed at parking facilities, however, face some barriers to successful implementation of modal shift. This study has shown that many car drivers park free. Therefore, rate structure changes may not affect these people significantly. In addition, it is probable that most of these employees have sufficient leverage to demand on-site parking, thus also effectively making themselves immune from location policies. There are also people who use their cars during the day and would not, in any case, be able to shift. These two groups represent the irreducible minimum car population in the CBD.

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REFERENCES

1. D. Braybrooke and C. Lindblom. A Strategy for Decision: Policy Evaluation as a Social Process. The Free Press of Glencoe, New York, 1963.
2. W. Steger and T. R. Lakshmanan. Plan Evaluation Methodologies: Some Aspects of Decision Requirements and Analytical Response. HRB Special Rept. 97, 1968.
3. G. H. Tanner and R. Barba. Park-and-Ride Transit Service: Some Guidelines and Considerations for Service Implementation. Planning and Research Bureau, New York Department of Transportation, Preliminary Rept. PRR 44, April 1963.
4. G. R. Brown. Analysis of User Preferences for System Characteristics to Cause a Modal Shift. Highway Research Record 417, 1972, pp. 25-36.
5. Parking Principles. HRB Special Rept. 125, 1971, p. 15.