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Estimating Behavioral Response to Peak-Period Pricing

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The concept of applying peak-period pricing policies to highways and other urban transportation facilities has been proposed as one means of reducing rush-hour congestion and compensating for the social costs of travel. This research was designed to assess the potential impacts of rush-hour pricing on the six toll bridges and tunnels between New York City and New Jersey that are operated by the Port Authority of New York and New Jersey. Elasticity coefficients were computed by using data obtained from 943 respondents to detailed telephone attitude surveys. Peak-period crossing patrons, categorized by market segment, were asked to give their likely behavioral responses to off-peak discounts or peak-period surcharges. Several options were identified, including ridesharing, transit, and time-of-day shift. Approximately 16 percent of all passenger-car motorists would change travel time to avoid a $1.00 toll surcharge, but less than 20 percent of these would be willing to shift time by more than one hour. Work trips were found to be less sensitive to toll changes than were nonwork trips, and a substantial cost disincentive was found to be somewhat more effective in removing vehicles than was an off-peak incentive. To avoid higher toll charges, the average motorist would react in the following order of preference: (a) switch to another crossing, (b) switch time of travel, (c) switch to transit, (d) travel less often or not at all, and (e) join a carpool.

This paper summarizes the results of a behavioral research study conducted in 1978 to determine the feasibility and impacts of adjusting toll rates during peak periods (1,2). Elasticity and cross-elasticity coefficients are developed from a detailed telephone attitude survey of motorists by using the six Port Authority vehicular crossings between New York and New Jersey for (a) peak-period toll surcharges, (b) off-peak-period toll discounts, and (c) differential tolls between vehicular crossings.

The Port Authority of New York and New Jersey operates six vehicular crossings between New York and New Jersey. These facilities include three crossings of the Hudson River into Manhattan [the George Washington Bridge (I-95), the Lincoln Tunnel (I-495), and the Holland Tunnel (I-78)] and three bridges between Staten Island and New Jersey. Together, the six facilities accommodate approximately 400 000 automobiles and 50 000 trucks and buses daily.

The eastbound traffic pattern at each crossing is similar and differs only in magnitude. Traffic starts to build up about 6:30 a.m., reaches a peak between 8:00 and 9:00 a.m., and then reduces to midday levels. At the three Hudson River crossings, demand exceeds capacity, which results in queues by 7:00 a.m. that may persist beyond 10:00 a.m. A similar pattern exists during the evening peak period.

In May 1975, the passenger-car cash toll, collected in only one direction on all six vehicular crossings, was raised from $1.00 to $1.50, and various changes were introduced relative to the reduced-rate ticket books. On November 7, 1977, the Federal Highway Administration affirmed a previous ruling that the revised toll structure was acceptable pending recommendations of a further Port Authority study. These investigations were to include an evaluation of the economic feasibility, traffic management and environmental effects, and impact on mass transit of various alternative rate structures of commuter and carpool discounts and of peak-period pricing.

PEAK-PERIOD PRICING

The concept of applying peak-period pricing policies to highways and other urban transportation facilities has been suggested as one means of reducing rush-hour congestion and compensating for the social costs of travel.

Peak-period pricing assumes that, as more vehicles use a roadway system during a given period, each additional vehicle will interfere with the free flow of others in the stream, which will cause them to reduce speed and lead to congestion. As additional vehicles try to enter the system, they further congest the total flow and impose additional costs and loss of time on vehicles that are already in the system. The total additional delay and discomfort forced on all vehicles generally exceeds the delay and discomfort to those marginal vehicles that enter a system that is approaching capacity.

In economic terms, drivers who enter a congested traffic stream do not realize the total cost to society generated by their trips because they pay only the average cost of the trip. If these drivers actually paid the true cost, each would face an economic decision as to whether or not to make the trip at that time. A driver who values traveling during a peak period sufficiently would theoretically pay for these additional costs through a surcharge or, in the case of this study, a higher toll during the congested periods. A driver who did not so value his or her travel would change travel time or mode. In theory, the surcharge or toll should vary directly in proportion to the degree of congestion.

Although there have been several instances of peak-period pricing in the transit industry, experience in highway applications is limited. The most notable example is the Singapore traffic-restraint scheme, which requires special payment to legally operate vehicles in the designated central zone during peak periods (3). This lack of precedents made it necessary to derive elasticity

coefficients for specific application in the New York area.

STUDY DESIGN AND APPROACH

Key steps in the overall study design include market segmentation, roadside and telephone surveys, analysis of results, and development of elasticity coefficients.

The population of cross-river automobile drivers includes a number of diverse groups that could differ in their responsiveness to peak-period tolls. Accordingly, six market segments were defined to facilitate a meaningful, yet manageable, level of analysis. The market was stratified by trip purpose (work, company business, or other) and location of activity [Manhattan central business district (CBD), which is defined as Manhattan Island south of 59th Street; New York non-CBD; or New Jersey].

Market Segment	Trip Purpose	Destination
A	Work	Manhattan CBD
B	Work	East of crossing (NY) except Manhattan CBD
C	Work	West of crossing (NJ)
D	Company business	Any
E	Other	Manhattan CBD
F	Other	East or west of crossing except Manhattan CBD

A two-phase survey approach was employed. A direct roadside survey at all six crossings identified a pool of candidate respondents for subsequent in-depth telephone interviews by market segment.

Initial Contact Survey

Automobile drivers were intercepted at toll plazas. Information was obtained on trip purpose, trip frequency, category of toll payment (cash or discount plans), and whether the trip began or ended in the Manhattan CBD. The vehicle occupancy and the registration number were also noted.

A total of 21 278 roadside interviews were obtained--13 014 during peak periods. Of these, approximately 8000 interviews were selected at random, distributed proportionally among market segments and split between New York and New Jersey. More than 5500 were successfully matched with motor vehicle registration data. After leased or company cars and unlisted telephone numbers were eliminated, 2471 candidates were identified for detailed interviews.

Telephone Attitude Surveys

Three study scenarios related to toll changes were tested by telephone interviews. The telephone survey questionnaire was developed to eliminate potential respondent bias, including pretesting among residents of the metropolitan New York area.

Some 943 telephone interviews were successfully completed, which represents approximately 38 percent of the available listed telephone numbers. The highest sample was obtained relative to the Manhattan CBD and New Jersey work trips (market segments A and C), and the response error terms were generally less than 10 percent based on a 95 percent confidence level.

Attitude Versus Behavior

A major shortcoming of attitudinal surveys is the frequent disparity between an individual's expressed attitude and the actual act that follows. A variety of factors may intervene, including difficulties with the accurate perception of real costs and the practical problems of actually changing travel habits.

A growing amount of literature deals with response validity and, in particular, the relationship between intended and actual behavior (4,5). Although the absolute level of response varies, the relative positions of the different population groups appear valid.

Accordingly, actual transportation-related experience in the New York area was used as a guide in discounting motorists' response. A special before-and-after survey that evaluated responses to a 1975 increase in subway prices in New York City indicated that only about 40 percent of those who claimed that they would switch travel modes actually did (6).

In recognition of this disparity between attitude and behavior, a response deflation factor of 0.5 was applied to those survey answers that indicated avoidance of the initial increment of toll surcharge. The actual response differential between toll surcharge increments was retained, again due to the theory that the relative distribution of response is accurate. All response values reported herein reflect this deflation factor.

SURVEY RESPONSE

Motorist attitudes, as reflected in the survey response to each of three scenarios, are summarized below.

Scenario 1--Off-Peak Discounts

This scenario assumes that tolls would be reduced by $0.50 and $1.00 during the off-peak period. The estimated behavioral responses (adjusted to reflect the difference between attitude and behavior) are shown in Table 1. Approximately 15 percent of all motorists who fall within the market segments defined could be expected to change their travel times to take advantage of a $0.50 toll discount during off-peak periods. If the discount were raised to $1.00, about 19 percent would shift.

As might be expected, the market segments associated with the journey to work (A, B, and C) were found to be somewhat less flexible and shifts of 11 and 14 percent, respectively, were expected. The highest potentials for time shifts were found for nonwork trips--about 25 and 30 percent for market segments E and F, respectively. This is logical because these categories deal with travel that is more discretionary and flexible in nature.

Scenario 2--Peak-Period Surcharge

This scenario assumes that tolls would be increased during peak periods by surcharges of $1.00, $3.00, and $5.00. The estimated behavioral responses are summarized in Table 2 and detailed in Table 3. Some 27 percent of the motorists interviewed would make some change in travel habits with a $1.00 toll increase; corresponding figures were 41 and 53 percent for $3.00 and $5.00 toll surcharges. With a $1.00 surcharge, almost 66 percent would change travel time, 4 percent would form carpools, 4 percent would divert to transit, and about 1 percent would not make the trip at all.

Diversion to public transit becomes much more significant at the $3.00 and $5.00 surcharge increments. Little increase in time-of-day shifts was reported. This suggests that drivers who can

Table 1. Estimated behavioral response to off-peak period discount—scenario 1.

Market Segment	No Change in Driving Habits (%) Discount $0.50	$1.00	Change Time of Day to Begin Trip (%) Discount $0.50	$1.00
A	89	88	11	12
B	88	85	12	15
C	88	85	12	15
D	84	74	16	26
E	75	69	25	31
F	74	72	26	28
All	85	81	15	19
Work only	89	86	11	14

Table 2. Estimated behavioral response to peak-period toll increases—scenario 2, all crossings.

Response	Patrons from Market Segments A-F (%) Increase $1	$3	$5	Patrons from Market Segments A, B, and C (%) Increase $1	$3	$5
Make no changes in driving habits	73	59	47	77	61	47
Changes						
Join or start carpool	4	4	5	4	4	5
Begin taking public transit	4	14	18	4	14	20
Change time of day when trip begins	16	15	15	11	13	14
Would not make trip as often	2	2	3	2	2	1
Would not make trip at all	1	6	12	2	6	13
Total	27	41	53	23	39	53
Net change in peak-period vehicle trips—assumption 1[a]	24	38	49	20	36	50
Net change in peak-period vehicle trips—assumption 2[a]	13	28	44	12	28	12
Net change in daily vehicle trips—assumption 3[a]	3	9	14	4	9	14

Note: Assumption 1 = peak period is short enough to accommodate all drivers who wish to shift (i.e., all time-of-day shifts would be to the off-peak period; assumption 2 = about one-third of time-of-day shifts would be to the off-peak period; assumption 3 = peak periods account for about 40 percent of total daily traffic in each market segment.
[a]Percentages reflect a 0.5 discount factor applied to the response of motorists who indicated they would carpool or would not make trips as often.

conveniently alter the time of trip making would do so at the $1.00 surcharge. As the penalty increases, transit becomes a more feasible alternative for those who must continue to travel during peak periods.

This is particularly true for work trips oriented to the CBD (market segment A) where bus and rail services provide good access to transit. A $1.00 surcharge would result in a 7 percent shift to transit, and approximately 23 and 27 percent would shift to transit for $3.00 and $5.00 surcharges, respectively. A somewhat similar pattern is indicated for nonwork trips to the CBD, market segment E.

Carpooling produced a steady response of about four to six percent for the various toll surcharges. This suggests that motorists who could readily carpool would do so to avoid even a $1.00 surcharge. Little or no additional ridesharing was induced by incremental pricing penalties.

The estimated net changes in vehicle trips (shown in Tables 2 and 3) were computed by assuming that those who would not make the trip as often would cut their trip making in half and that one vehicle trip would be eliminated for each carpool formed. A reduction of about 24 percent in peak-period vehicle trips would result, in theory, from a $1.00 surcharge if the critical period were limited to 1 h. Because most of the vehicular loss would result from a shift in time of day, the net reduction in daily eastbound vehicle trips within the six market segments identified would be only 3 percent.

Motorists who indicated a preference for changing the time of day when their trips begin were asked about the maximum shift in time they would be willing to make. Most drivers would be willing to change their arrival and departure time by as much as 1 h to avoid a $1.00 increase; only 20 percent would change by more than 1 h. This finding is important because it implies that reaction to peak-period pricing would be relatively small where the peak extends over several hours.

Because the peak period extends for up to 3 h at most New York-New Jersey river crossings, the actual reductions in peak-period travel would be considerably less--about 10-15 percent for a $1.00 surcharge.

Scenario 3--Peak-Period Surcharge on Specific Crossings

This scenario assumes that the peak-period toll surcharges of $1.00, $3.00, and $5.00 would be applied only at the survey respondents' crossing. Motorists were asked what course of action they would take if rush-hour tolls were raised only on the crossing they used but not on the adjacent facilities. The estimated behavioral responses are shown in Table 4.

Given the option to change routes, a slightly higher percentage of all motorists would make some change in driving habits. Specifically, assuming a $1.00 surcharge, 30 percent of the drivers would switch, as compared with 24 percent under scenario 2.

Almost half of those who change would switch routes to another bridge or tunnel. Eight percent would change the time of travel, compared with 16 percent if the penalty were imposed on all crossings. Diversion to carpools and transit would be lower.

Respondents who would change routes were asked how much extra driving time they would be willing to add to their trips to use the alternate crossing. Under the $1.00 increment, 49 percent claimed they would be willing to add 15 min to the trip, and an additional 20 percent said they would increase travel time by 30 min; the overall weighted average was 19.4 min.

ELASTICITY COEFFICIENTS

Elasticity coefficients (E) in the form of shrinkage factors were computed from the survey data, based on the following relationship:

$$E = \%\Delta Q / \%\Delta P \quad (1)$$

where $\%\Delta Q$ = estimated percentage change in vehicle trips as reported in the survey and $\%\Delta P$ = percentage change in price or trip cost.

Table 3. Detailed behavioral response to peak-period toll increases—scenario 2, all crossings.

	Market Segment A (%)			Market Segment B (%)			Market Segment C (%)			Market Segment D (%)			Market Segment E (%)			Market Segment F (%)		
	Increase			Increase			Increase			Increase			Increase			Increase		
Responses	$1	$3	$5	$1	$3	$5	$1	$3	$5	$1	$3	$5	$1	$3	$5	$1	$3	$5
Make no changes in driving habits	77	54	42	78	64	51	77	66	49	73	59	54	62	49	49	63	59	43
Changes																		
Join or start carpool	4	4	5	4	4	4	5	5	6	1	2	2	2	4	4	4	6	6
Begin taking public transit	7	23	29	3	11	16	2	8	13	3	14	14	7	18	19	4	10	14
Change time of day when trip begins	9	12	12	12	14	16	13	13	13	21	21	21	27	22	17	26	14	14
Would not make trip as often	2	2	2	1	1	1	1	1	1	1	1	1	1	1	2	3	8	10
Would not make trip at all	1	5	10	2	6	12	2	7	18	1	3	8	1	6	9	-	3	13
Total	23	46	58	22	36	49	23	34	51	27	41	46	38	51	51	37	41	57
Net change in peak-period vehicle trips[a]	20	43	54	20	34	47	20	31	48	26	39	44	37	48	48	34	34	45
Net change in daily vehicle trips[a,b]	4	12	17	3	8	12	3	7	14	2	7	9	4	10	12	3	8	12

[a]Percentages reflect a 0.5 discount factor applied to the response of motorists who indicated they would carpool or would not make trips as often. It is assumed that all time-of-day shifts would be to the off-peak period.
[b]Assumes in addition that peak periods account for approximately 40 percent of total daily traffic in each market segment.

Table 4. Estimated behavioral response to peak-period toll increases—scenario 3, individual crossings.

	Patrons from Market Segments A-F (%)			Patrons from Market Segments A, B, and C (%)		
	Increase			Increase		
Responses	$1	$3	$5	$1	$3	$5
Make no changes in driving habits	69	55	46	71	56	46
Changes						
Join or start carpool	2	3	3	2	3	4
Begin taking public transit	3	7	10	2	8	12
Change route to another bridge or tunnel	16	22	24	15	22	24
Change time of day when trip begins	8	9	10	8	7	7
Would not make trip as often	1	1	2	1	1	2
Would not make trip at all	1	3	5	1	3	5
Total	31	45	54	29	44	54
Net change in peak-period vehicle trips—assumption 1[a]	30	43	51	28	42	51
Net change in peak-period vehicle trips for specific crossing assumption 2[a]	28	37	44	22	40	46
Net change in daily vehicle trips—assumption 3[a]	2	5	7	2	5	8

Note: Assumption 1 = peak period is short enough to accommodate all drivers who wish to shift (i.e., all time-of-day shifts would be to the off-peak period; assumption 2 = about one-third of time-of-day shifts would be to the off-peak period; assumption 3 = peak periods account for about 40 percent of total daily traffic in each market segment.
[a]Percentages reflect a 0.5 discount factor applied to the response of motorists who indicated they would carpool or would not make trips as often.

Table 5. Summary of elasticity coefficients.

			Basis of Computation	
Change	Scenario	Market Segments	Total Trip Cost[a]	Toll Cost[b]
Net peak-hour traffic change	1	A-F	-1.23	-0.24
		A,B, and C	-0.81	-0.17
		E and F	-2.18	-0.37
	2	A-F	-1.55	-0.30
		A,B, and C	-1.16	-0.25
		E and F	-2.63	-0.44
	3	A-F	-1.94	-0.37
		A,B, and C	-1.62	-0.35
		E and F	-2.74	-0.47
Time-of-day shift only	2	A-F	-1.04	-0.20
		A,B, and C	-0.64	-0.14
		E and F	-1.96	-0.33
Diversion to transit cross-elasticity	2	A-F	+0.26	+0.05
		A,B, and C	+0.23	+0.05
		E and F	+0.41	+0.08

Note: Elasticities for scenario 1 based on $1.00 discount during off-peak period; scenarios 2 and 3 are based on $1.00 surcharge.
[a]Total costs for all markets = $6.47, work markets = $5.80, and nonwork markets = $7.40.
[b]Toll paid on Port Authority crossing only estimated at $1.25.

Two separate percentage changes in price were used to compute elasticities. These were the toll increase as (a) a percentage of the total trip cost and (b) a percentage of the Port Authority facility toll cost only. Results are presented in Table 5 for a $1.00 discount in scenario 1 and a $1.00 surcharge in scenarios 2 and 3. (Arc elasticities would be somewhat less than these shrinkage factors.)

The elasticity coefficients get larger as one proceeds from scenario 1 to 3. This is a logical outcome, since the elasticity coefficient should increase when a larger number of substitute actions are available to the users. That is exactly what occurs in the progression from scenario 1 to 3. In a similar context, the time-of-day coefficents are smaller than the coefficients for total peak-hour

changes, since only those who would switch time of day were included in the %ΔQ.

Trip Costs

The questionnaire included references to various components of trip cost, including expenses related to parking tolls, gasoline, and other items. The average trip cost varied between market segments from $4.71 for non-CBD work trips destined east of the crossing to $8.01 for nonwork or business destined for the CBD.

Large differentials in the estimated cost of parking were responsible for most variations among market segments. The base trip costs developed were $6.47 for all markets, $5.80 for the work markets (A, B, and C), and $7.40 for the nonwork markets (E and F).

Toll Costs

The cash toll for passenger cars is $1.50. When the discount tickets are considered, the average toll is approximately $1.25.

Net Peak-Hour Traffic Change

The first group of elasticity values in Table 5 shows the net decrease in peak-period traffic that results from various toll surcharges if the peak were limited in duration to accommodate all the time-of-day shifters.

Scenario 1

The lowest impacts would result from reducing tolls during off-peak hours. Elasticities for all market segments are estimated at -1.23 for total trip costs and -0.24 computed on the basis of toll charge alone. Again, work trips are considerably less elastic than nonwork trips.

Scenario 2

A $1.00 toll surcharge during peak periods would have a higher impact than an off-peak discount, which suggests that a substantial pricing disincentive is somewhat more significant than an incentive, at least as perceived by the telephone respondents. Elasticities for market segments are estimated at -1.55 for all trip segments and -0.30 for toll costs alone.

Scenario 3

Given the additional option of changing routes, the estimated elasticity coefficients for scenario 3 appear higher than those under scenario 2. The trip cost elasticity for all market segments combined was estimated at -1.94, and the toll elasticity was computed at -0.37.

Time-of-Day Shift

Elasticity coefficients for the shift in time of day were calculated by using the response percentage only for all drivers who said that they would switch time of day. This implies that the peak toll surcharge period would accommodate those who would shift a maximum of 30 min. The cost elasticity for all market segments is estimated at -1.03, with the associated toll elasticity computed at -0.20 for scenario 2. The coefficients shown under scenario 3 are somewhat less, because a higher proportion of diverted drivers would change routes rather than the time of the trip.

Transit Cross-Elasticities

The cross-elasticities to transit (i.e., the percentage change in automobile users who would switch to transit as a result of a 1 percent change in the price of tolls) or total trip costs are also shown in Table 5. These cross-elasticities are low relative to those for reductions in peak-hour traffic or time-of-day shifts. They suggest a very small impact of tolls on transit ridership--perhaps because transit already dominates the CBD journey-to-work market. Even though good transit accessibility is provided for many trips, the transit impact of rush-hour pricing policies would be minimal.

Comparison with Previous Elasticity Findings

To provide a basis for comparison with past experience, estimated behavioral reactions to scenario 2 were adjusted to recognize the removal of the option to shift the time of day. This was accomplished by taking the time-shift option response and distributing it over the remaining choices. Resulting elasticities for a $1.00 toll increase are as follows:

	Basis of Computation	
Market Segment	Total Trip Cost	Total Cost
A-F	-0.70	-0.18
A, B, and C	-0.62	-0.17
E and F	-0.86	-0.22

These elasticities are within the range of -0.07 to -0.29 commonly reported for increases in toll rates on bridges and tunnels. For all market segments, the toll elasticity of -0.18 conforms favorably with the toll elasticity of -0.20 cited by Kulash (7) as representative of toll increases on urban bridges.

PLANNING IMPLICATIONS

The telephone survey responses and elasticity coefficients quantify the impacts of various concepts of peak-period pricing on the six Port Authority crossings. They suggest that the average motorist would react in the following order of preference to avoid a higher toll:

1. Switch to another crossing,
2. Switch time of travel,
3. Switch to transit,
4. Travel less often or not at all, and
5. Join a carpool.

The choices of alternative route or time of travel vastly exceeded those choices that would take people out of their cars. More significantly, most motorists would make no change in their driving habits for toll increases of $3.00 or less.

In terms of reduced traffic, a $1.00 peak-hour toll surcharge would result in a 24 percent reduction in peak-hour trips if the surcharge period were limited to 1 h and if there were no other convenient facilities to use. However, there would be only a 3 percent decline in total daily vehicle trips. These benefits should be assessed in terms of additional costs, operational complexity, and public reactions associated with toll increases.

Care should be exercised in transferring these specific findings to other urban facilities. The unique characteristics of the New York-New Jersey travel market must be recognized--the high income levels, high existing trip costs, and long average trip lengths may not be representative.

It is important to recognize qualifiers for the two most frequently stated travel habit shifts--(a) to another facility and (b) to another time of day. The average time loss required for a shift to another facility was about 20 min; the maximum time-of-day shift for most users was about 60 min. In addition, Port Authority round-trip tolls are collected in one direction only. Therefore, time-of-day shifts are required during only one peak period, unlike most other urban situations.

In application of these survey findings, the Port Authority estimated that very little traffic could be shifted out of the peak period with toll surcharges because the heavy traffic demand extends over long time periods, which makes it necessary to consider peak surcharge periods of at least 3-4 h.

The use of attitudinal surveys to assess impacts of price changes and derive elasticity coefficients should be transferable; however, additional research is needed to better correlate actual behavior with reported attitudes.

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Simplified Approach to Downtown Travel Simulation

HERBERT S. LEVINSON

This paper analyzes the relation between downtown land use and travel based on a series of major generator surveys conducted in downtown Providence, Rhode Island. Trip rates obtained at nine buildings were applied to inventories of floor space and employment to provide a picture of daily trips to the city center. The surveys found 0.8 primary central business district (CBD) destinations/employee for work trips, 3.0 primary CBD nonwork destinations/1000 ft^2 of office-building floor space, and 9.7 destinations/1000 ft^2 of major retail floor space. This results in some 54 700 primary destinations in the CBD on a typical weekday (7:00 a.m.-6:00 p.m.). A small-sample home-interview survey, conducted in 1970, identified 54 100 destinations in a 24-h period. Additional studies of a greater mix of downtown land uses in other cities are suggested to further refine and validate the assumptions and methodology.

Travel to and from the city center reflects the types and intensities of downtown land use. This paper analyzes these relationships based on a series of major-generator surveys conducted in downtown Providence, Rhode Island. Trip rates obtained at various buildings applied to inventories of floor space and employment provide a picture of daily trips generated by the city center.

CONTEXT

Traditional methods of measuring travel demands in the central business district (CBD) include the downtown cordon count, postcard surveys of car occupants and transit riders, and home-interview surveys. Cordon studies do not differentiate between trips to and through the center. The other surveys are often costly and time consuming and do not provide indices for use in relation to new development. These deficiencies are largely overcome through the use of major-generator surveys at various downtown buildings. The surveys can provide a basis for developing trip rates that can be applied to new downtown land uses. They also can be used to simulate daily travel to the city center. Both of these uses were applied in downtown Providence as part of a traffic circulation and development study (1).

The comprehensive study was designed to (a) identify transportation problems and opportunities in the 350-acre CBD, (b) prepare a downtown transportation plan, and (c) develop methods to monitor and update the plan. The 1983 transportation plan applied transportation system management measures to a major urban center. It contained an integrated system of traffic, parking, pedestrian, and public transport improvements.

Key steps leading to plan preparation included the following:

1. Analysis of existing transportation conditions,
2. Surveys of existing travel patterns,