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.

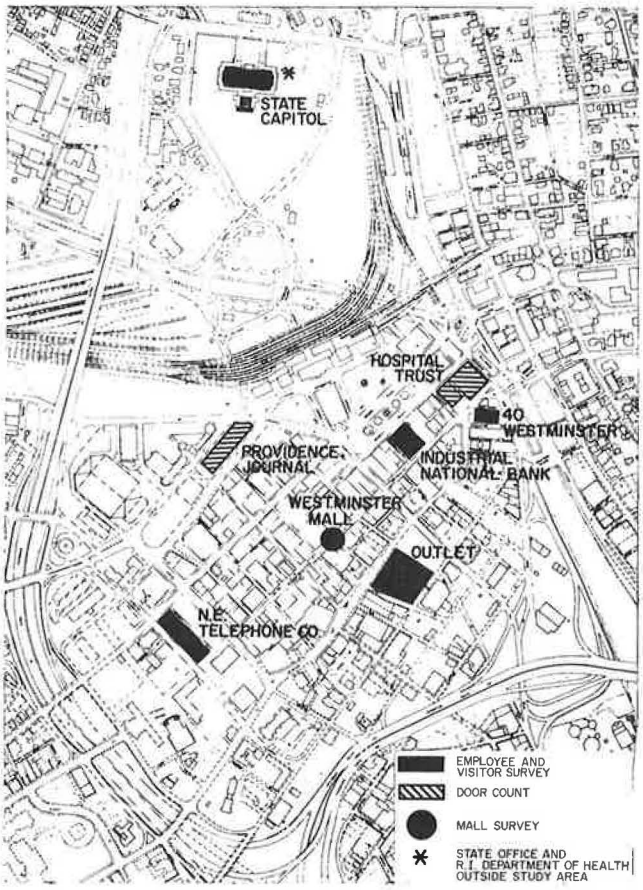
Key steps leading to plan preparation included the following:

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

3. Forecasts of future travel patterns based on anticipated changes in downtown land use,
4. Analysis of alternative circulation concepts, and
5. Development of a 1983 transportation plan.

The major-generator surveys described in this paper were used to develop existing travel patterns and to forecast future requirements of the transportation system. Trip rates derived from the surveys were applied to anticipated future land uses to estimate the travel and traffic generated by planned land use. Estimates were made of the additional daily and peak-hour person trips by mode. The peak-hour vehicular trips were superimposed on the existing flow and assigned to the downtown street system on a block-by-block basis to assess the impacts of alternative circulation concepts.

Figure 1. Downtown Providence survey locations.



TRAVEL SURVEYS

Door counts and travel-pattern surveys were conducted at nine major buildings during June and July 1977. Figure 1 shows the location of the buildings within the downtown area, and Table 1 (2) gives the location, floor space, door counts, and size of the survey sample for each building.

The nine buildings surveyed contained more than 2.3 million ft^2 of floor space and employed 9000 people. Collectively, they account for about 25 percent of the total floor space (9 633 500 ft^2) and 35 percent of the total employment (25 600 people) in downtown Providence.

Employee and visitor surveys were conducted at seven of the nine locations: two general-purpose office buildings, a restricted-use office building, two government office buildings, the state capital, and the major department store. Approximately 4700 travel surveys were completed by some 2700 employees and 2000 visitors. Although 472 of the government employees interviewed work outside the study area in the state office building and Rhode Island Department of Health, the interviews are used for statistical purposes. Information was obtained for 10 percent of all downtown workers. The proportions of various types of CBD employees interviewed are shown in the table below (1).

Type of Employment	Total Employment	Interviews	
		Number	Percentage of total
Office and business	11 574	1642	14.2
Retail	4 400	426	9.7
Government and institution	5 195	621	12.0
Other	4 462		
Total	25 631	2689	10.5

The surveys obtained information on characteristics of respondents (age and sex), car

Table 1. Interview and door-count sample size.

Place in CBD	Primary Function	Occupied Floor Space 1976-1977 (ft^2)	Employment 1976-1977	Total No. of Persons Entering	Visitor Survey Patterns	Employee Survey		Travel Surveys as Percentage of Reported Employment
						Attitudes	Patterns	
40 Westminster	General office	285 597	1015	2 936	135	36	551	54.3
Industrial National Bank	General office	350 000	1500	4 791	310	83	646	43.1
New England Telephone Company	Restricted office[a]	407 847	931	1 578	12[b]		445	47.8
Outlet	Retail sales	431 249	583	8 732	735		426	73.0
State capitol	State office	146 139	300	1 295	97		149	49.7
State office building[c]	State office	NA	600	4 225	350		275	45.8
Rhode Island Department of Health[c]	State office	NA	500	1 340	80		197	39.4
Subtotal		1 620 832	5429	24 897	2041	119	2689	49.5
Hospital Trust	General office	537 940	2321	7 030				
Providence Journal	Special office	161 616	1250	2 299				
Total		2 320 388	9000	34 226	2041	119	2689	29.9

[a] Authorized visitors only.
[b] Only 12 nonemployees entered this building; this sample is too small for meaningful evaluation.
[c] Lies outside of study area on far side of street that bounds study area.

ownership status, trip origin, mode of travel, purpose of visit to building, purpose of visit to downtown, and trip frequency. Table 2 summarizes some of the planning data obtained from the surveys. Comparisons of trip purposes to the buildings and to the CBD provided a means of estimating the number of primary trip destinations at various buildings. This information was then expanded to represent the total daytime downtown population.

PEDESTRIAN TRIP RATES

Pedestrian trip characteristics at the nine buildings are given in Table 3 (2). Approximately 34 000 people entered the buildings on a typical weekday. Some 5600 were within these buildings by 9:00 a.m. and about 7300 by midday. Overall, about 4.7 persons entered the buildings during the day per peak person accumulated (i.e., a turnover of almost 5).

Pedestrian trip rates for the four general office buildings and the major department store are summarized below.

1. The number of people who entered the office buildings averaged 12.8 persons/1000 ft^2 of floor space or 2.7 persons/employee. If each employee makes a trip at lunchtime, this figure suggests 0.7 visitor/employee. The maximum accumulation approximated 0.7 person/employee or 3.2 persons/1000 ft^2 of floor space. The turnover (entrants per peak accumulant) averaged 4.

2. The number of people who entered the department store totaled 20.2 persons/1000 ft^2; however, the maximum accumulation was 2.3 persons/1000 ft^2 of floor space or 1.7 persons/employee, which resulted in a turnover of 8.8.

PRIMARY CBD DESTINATIONS

The strength of the CBD stems from its compactness and the interaction among its various activities. Many people visit several buildings in the course of a single trip to the area (for example, lunchtime shopping trips by employees). The extent of this interaction is, in many respects, a measure of the vitality of the CBD. Therefore, in simulating travel to the city center, it was necessary to identify the number of primary destinations in each building as well as the total number of daily arrivals (entrants).

The primary destination is defined as the reason for making the trip to the city center. This is not necessarily the same as the reasons for visiting a specific building. In effect, it is the beginning end of an interzonal trip with the CBD viewed as a single zone. More specifically

1. Workers were assumed to have their primary destination in the buildings where they work and
2. The trip purposes of visitors to downtown Providence were compared with reasons for visiting specific buildings. Where the two trip purposes were identical, it was assumed that these trips represented primary destinations to the city center.

Table 4 summarizes the number and proportions of primary visitor trips at each building. Overall, approximately 61 percent of the visitors made primary destinations, usually for personal business or for shopping. The state office buildings located on the perimeter of the downtown area had the highest percentages of primary visitors (76-91 percent). Primary destinations to the two downtown general-purpose office buildings represented about 43 percent of the total visitors and they accounted for slightly more than 50 percent of the total trips to the major department store. [A similar study conducted during October 1957 reported that about 60 percent of all people in downtown stores throughout the day came primarily to shop (3).]

DERIVING TRIP ATTRACTION RATES

Attraction rates for trips to the downtown areas and the procedures used to derive them are shown in Table 5 (2). The basic steps were as follows:

Table 2. Illustrative travel characteristics.

Place	Percentage Who Live in Providence		Percentage Who Traveled by Bus		Percentage From Households That Have No Cars Available	
	Visitors	Workers	Visitors	Workers	Visitors	Workers
40 Westminster	34.8	24.3	6.7	21.6	2.2	3.8
Industrial National Bank	44.2	36.1	32.6	26.2	13.5	2.9
New England Telephone Company	NA	28.5	NA	14.2		5.2
Outlet	51.0	33.3	40.7	30.8	22.2	10.6
State capitol	27.8	28.2	8.2	4.7	7.2	4.0
State office building	31.7	27.3	2.6	7.6	3.7	5.4
Rhode Island Department of Health	40.0	27.9		1.1	5.0	2.0

Table 3. Door counts and pedestrian generation rates.

Place	Accumulation of Persons		Daily Turnover of Entrants	Persons Entering		Maximum Person Accumulation	
	At 9:00 a.m.	Maximum		Per 1000 ft^2 of Floor Space	Per Employee	Per 1000 ft^2 of Floor Space	Per Employee
40 Westminster	654	815	3.6	10.3	2.9	2.9	0.8
Industrial National Bank	842	1097	4.4	13.7	3.2	3.1	0.7
New England Telephone Company	618	655	2.4	3.9	1.7	1.6	0.7
Outlet	392[a]	992	8.8	20.2	15.0	2.3	1.7
State capitol	237	407	3.2	8.9	4.3	2.9	1.4
State office building[b]	467	538	7.9		7.0		0.9
Rhode Island Department of Health[b]	338	388	3.5		2.7		0.8
Hospital Trust	1655	1923	3.4	13.1	3.0	3.6	0.8
Providence Journal	400	515	4.5	14.2	1.8	3.2	0.4
Total	5603	7330	4.7	12.4	3.8	2.8	0.8

[a]Person accumulation at 10:00 a.m. [b]Lies outside study area.

1. The number of different employees who entered each building was estimated based on the number of people accumulated between 9:00 and 9:30 a.m. In the case of the Outlet department store, the number of employees was based on the people who used the employee entrance.

2. The nonwork trips to each building were assumed to equal the total number of persons who entered the building minus twice the number of different employees entering the building. This assumes that each employee leaves the building for lunch and subsequently returns. The number of employees at work at about 9:15 a.m. was about equal to the number of people who left major office buildings [the figures for employees' entrances and departures, respectively, were 40 Westminster = 720, 770; Industrial National Bank = 970, 1210; Rhode Island Department of Health = 380, 360; Hospital Trust (Bank 1) = 1780, 1760].

3. The primary nonwork destinations as a percentage of the total reflect the results of the visitor surveys.

4. The primary nonwork destinations were computed by applying the percentages shown in column 4 to the values shown in column 3. The results are shown in column 5.

5. The total primary destinations represent the sum of columns 2 and 5.

Steps 1 through 5 can be expressed analytically as follows:

$$D = W_1 + P(E - 2W_1) \quad (1)$$

where

W_1 = estimated number of different work trips,
E = total number of persons who enter building, and
P = primary nonwork destinations as percentage of the total.

Table 4. Estimated number of primary visitor trips by building.

Place	No. of Persons Interviewed	Estimated Primary Visitor Trips Based on Survey		Approximate 95 Percent Confidence Limits[a]	
		No.	Percent	No.	Percent
40 Westminster	135	59	43.7	35.3	52.1
Industrial National Bank	310	132	42.6	37.1	48.1
Outlet	735	388	52.8	49.2	56.4
State capitol	97	74	76.3	67.8	84.8
State office building	350	317	90.6	87.6	93.6
Rhode Island Department of Health	80	72	90.0	83.4	96.6
Total	1707	1042	61.0	58.7	64.7

[a]Confidence limits approximated by formula $\hat{p} \pm (1.96\sqrt{pq/n})$.

Table 5. Person-trip generation rates for primary destinations.

Place	Person Accumulation 9:00-9:30 a.m.	Estimated Employees Entering Building for Primary Work Destinations	Estimated Nonwork Trips to Building[b]	Primary Nonwork Destinations		Total Primary Destinations	Primary Destinations per 1000 ft² of Floor Space			Primary Destinations per Employee		
				As Percentage of Total	No.		Work	Non-Work	Total	Work	Non-Work	Total
40 Westminster	720	720	1 496	43	643	1 363	2.5	2.3	4.8	0.7	0.6	1.3
Industrial National Bank	970	970	2 851	43	1 226	2 196	2.8	3.5	6.3	0.6	0.8	1.4
New England Telephone Company	630	655	268	43	115	770	1.6	0.3	1.9	0.7	0.1	0.8
Outlet	390[a]	440	7 852	53	4 162	4 602	1.0	9.7	10.7	0.8	7.1	7.9
State capitol	320[a]	240	815	76	619	859	1.6	4.2	5.8	0.8	2.1	2.9
State office building	520	520	3 185	90	2 866	3 386	NA	NA	NA	0.9	4.8	5.7
Rhode Island Department of Health	380	380	580	90	522	902	NA	NA	NA	0.8	1.0	1.8
Hospital Trust	1780	1780	3 470	43	1 492	3 272	3.3	2.8	5.1	0.8	0.6	1.4
Providence Journal	420	800[b]	699	43	300	1 100	5.0	1.9	6.9	0.6	0.2	0.8
Total	6130	6505	21 216		11 945	18 450						

[a]10:00 a.m. for outlet; 9:00 a.m. for state capitol. [b]Estimate based on two effective shifts.

Table 6. Major categories of Providence floor space.

Zone	Office or Business (ft²)	Major Retail (ft²)	Other Retail Services (ft²)	Total Retail Space (ft²)	Government or Institution (ft²)	Other Nonresidential (ft²)	Total Nonresidential (ft²)	Residential (ft²)	Total (ft²)
390	72 884		1 400	1 400	519 127	162 843	756 254	81 035	837 289
391	45 000	30 000		30 000			75 000		75 000
392	112 493		55 400	55 400	235 792	598 720	1 002 405		1 002 405
393	1 569 205	22 621	222 358	244 979	148 557	136 416	2 099 157		2 099 157
394	165 000	35 000		35 000			200 000		200 000
395	252 769	9 603	74 111	83 714	274 199	404 840	1 015 522	343 095	1 358 617
396	128 951	373 430	100 899	474 329	168 039	54 948	826 267		826 267
397	198 089	179 511	195 570	375 081	90 413	239 263	902 846	800	903 646
398	595 589		4 266	4 266	18 111	148 215	766 181	29 004	795 185
399	37 901	43 888	47 455	91 343	201 614	185 417	516 275	221 750	738 025
400	171 130	413 856	17 603	431 459	94 398	369 956	1 066 943		1 066 943
401	192 458	34 915	72 912	107 827	33 579	72 773	406 637	2 481	409 118
Total	3 541 469	1 142 824	791 974	1 934 798	1 783 829	2 373 391	9 633 487	678 165	10 311 652

Table 7. Primary destinations by analysis zone.

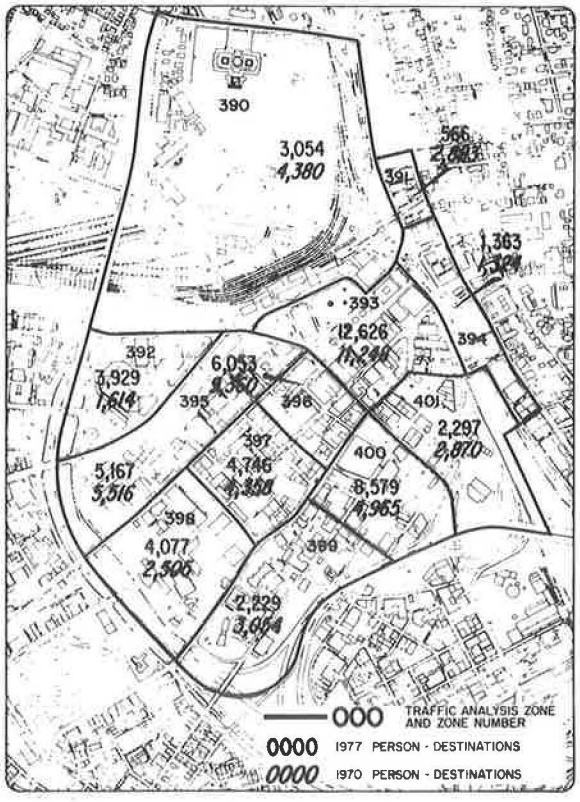
Zone	Employment	Work Trips (0.8 x Employment)	Office, Government, and Other Nonresidential Floor Space	Other Nonwork Trips at 3.0/1000 ft^2	Major Retail Floor Space (ft^2)	Shopping Trips (9.7/1000 ft^2)	Total Nonwork Trips	Total Destinations
390	986	789	754 854	2 265			2 265	3 054
391	175	140	45 000	135	30 000	291	426	566
392	1 360	1 088	947 005	2 841			2 841	3 929
393	8 555	6 844	1 854 178	5 563	22 621	219	5 782	12 626
394	660	528	165 000	495	35 000	340	835	1 363
395	2 849	2 279	931 808	2 795	9 603	93	2 888	5 167
396	1 719	1 375	351 938	1 056	373 430	3 622	4 678	6 053
397	1 778	1 422	527 765	1 583	179 511	1 741	3 324	4 746
398	2 238	1 791	761 915	2 286			2 286	4 077
399	660	528	424 932	1 275	43 888	426	1 701	2 229
400	3 323	2 659	635 484	1 906	413 856	4 014	5 902	8 579
401	1 328	1 062	298 810	896	34 915	339	1 235	2 297
Total	25 631	20 505	7 698 689	23 096	1 142 824	11 085	34 181	54 686

Table 8. Comparison of 1970 and 1977 downtown trip destinations.

Zone	Work Trips			Nonwork Trips			All Trips		
	1970[a]	1977[b]	Difference	1970[a]	1977[b]	Difference	1970[a]	1977[b]	Difference
390	805	789	−16	3 575	2 265	−1310	4 380	3 054	−1326
391	1 189	140	−1049	1 694	426	−1268	2 883	566	−2317
392	921	1 088	167	693	2 841	2148	1 614	3 929	2315
393	6 165	6 844	679	5 083	5 782	699	11 248	12 626	1378
394	652	528	−124	672	835	163	1 324	1 363	39
395	3 037	2 279	−758	2 479	2 888	409	5 516	5 167	−349
396	2 804	1 375	−1429	6 556	4 678	−1878	9 360	6 053	−3307
397	1 302	1 422	120	3 056	3 324	268	4 358	4 746	388
398	1 289	1 791	502	1 216	2 286	1070	2 505	4 077	1572
399	66	528	462	2 988	1 701	−1287	3 054	2 229	−825
400	1 221	2 659	1438	3 744	5 920	2176	4 965	8 579	3614
401	1 090	1 062	−28	1 780	1 235	−545	2 870	2 297	−573
Total	20 541	20 505	−36	33 536	34 181	+645	54 077	54 686	+609

[a]Based on Rhode Island Statewide Planning Program 1970 origin-destination study.
[b]Based on Wilbur Smith and Associates field surveys, June-July 1977.

Figure 2. Comparison of persons and destinations in downtown Providence by analysis zone for a typical weekday, 1970 versus 1977 data.



Trip attraction rates based on these analyses are summarized in the table below.

Item	General Office	Government Office	Major Retail
Work trips			
Per employee	0.7	0.8	0.8
Per 1000 ft^2 of floor space	2.9	2.1	1.0
Nonwork trips			
Per employee	0.7	1.0-1.8	7.1
Per 1000 ft^2 of floor space	2.9	3.6	9.7

APPLICATION TO DOWNTOWN LAND USE

By using these rates as a guide, the following rates were applied to the various downtown land uses listed in Table 6 (2):

For work trips--all nonresidential uses = 0.8 destinations/employee.
For nonwork trips = 3.0 destinations/1000 ft^2 for office, business, governmental, and other; 9.7 destinations/1000 ft^2 for retail.

To derive Table 6, it was necessary to differentiate between major retail and secondary retail space. It was assumed that major department stores and general apparel-furnishing stores would attract trips to the city center. Other stores and service establishments would depend almost entirely for trade on the downtown's daytime population. Restaurants and bars, office supply stores and stationers, drug stores, dry cleaners and laundries, newsstands and smokeshops, and many other small

shops and repair services are in this category.

Distinction was made, therefore, between types of retail activities that attract customers on their own and those that are essentially satellites to the work force and shoppers attracted by the larger-scale retailing establishments (i.e., primary versus secondary destinations). Analysis of block-by-block land-use data found that major retailing space constitutes about three-fifths of the floor space devoted to retail and service uses in the CBD. It was assumed that the Outlet department store, which accounts for about 35 percent of the floor space used for major retailing, generates trips in a way that is representative of all major downtown retailing. The percentages of land use in the CBD are 34.3 percent for office or business, 11.1 percent for major retail, 7.7 percent for other retail services, 17.3 percent for government or institutions, 23.0 percent for other nonresidential purposes, and 6.6 percent for residential.

The computations derived from the above are shown in Table 7. Overall, there were 54 700 primary person destinations during the working day. Of this total, about 20 500 were work trips, 11 100 were shopping trips, and 23 100 were other nonwork trips.

COMPARISON WITH 1970 SURVEY

Downtown work and nonwork trips by traffic zone are compared with travel data obtained in a 1970 home-interview sample in Table 8 and Figure 2. The 1970 data show 54 100 total destinations (24 h) as compared with 54 700 in 1978. Both sets of data appear to provide consistent estimates of the total travel to the center, although there are major differences in many analysis zones. In zone 390 there was little or no change; however, the estimate may understate the state capitol. Much of zone 391 has been cleared since 1970. In zone 392 an arena and some other improvements have been added. New office towers are located in zone 393. Zone 394 shows little change except for the addition of some East Side offices. In zone 395 new apartments have been built and the Biltmore closed. In zone 396 Shepards and Grants have been closed. A new telephone company annex, housing, and other improvements have been added to zone 398. Zone 399 shows some change due to new housing.

Many of these differences can be rationalized by changes in land use during the seven-year period, clearance of areas, closing of department stores, or construction of new office buildings. However, the 1977 data represent an 11-12 h period; when expanded to a 24-h period, there is some overstatement of nonwork trips. Relative to the 1970 sample data, this is further denoted by the reported decline in the maximum number of people accumulated downtown from 30 000 in 1968 to 25 600 in 1976.

SUMMARY AND SIGNIFICANCE

The major-generator surveys produced important information on the dimensions and characteristics of travel to buildings in downtown Providence. Trip rates obtained from these surveys provided a basis for estimating total travel by analysis zone to the CBD and for assessing the impacts of changes in land use. The results seem reasonable when compared with travel-pattern data obtained from conventional home-interview surveys, but they can be obtained more quickly and economically.

Additional research is needed to refine and further verify the assumptions and methodology. These efforts should focus on the following:

1. Determining the lunchtime travel behavior of downtown employees;
2. Extending the analysis to other cities to encompass a greater variety of land uses, including personal business and recreational generators;
3. Verifying the relationships between primary and secondary destinations; and
4. Establishing more definitive criteria to differentiate between major and secondary downtown land use.

Additional data on a cross section of cities would provide a valuable reference source on downtown trip generation and pedestrian rates.

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