Some Considerations in Appraising Bus Transit Potentials

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•WHEN public transportation systems in all of the more than 200 urbanized areas in the United States are examined, only a few of the largest are found to have extensive private right-of-way public transport facilities. In the great majority of these communities, motor buses operating in the general traffic stream provide the basic transit services. Often, this service is limited in coverage, speed, and other performance characteristics, with bus patrons constituting only a small fraction of area-wide tripmakers.

More effective utilization of bus transit facilities would reasonably be expected to reduce the number of private vehicles which traverse major urban travel corridors, provide relief to congested conditions (extend the time when relief facilities will have to be built), and extend the useful life of existing streets and highways. Means to achieve this represent a major challenge to transportation planners. It was with this possibility in mind that the U. S. Bureau of Public Roads authorized a study to develop guidelines and procedures whereby both minimum need and maximum potential for bus transit could be ascertained for the middle-sized urban area. The following study goals were set forth:

1. To define the latent (unrealized) travel potentials of urban residents, and to consider the implications as they may apply to transportation planning;
2. To describe household characteristics and community relationships which relate to urban travel and choice of mode;
3. To develop concepts and criteria for desirable bus service;
4. To predict probable bus "ridership" related to both conventional and unconventional concepts of service and costs; and
5. To estimate potential reduction of street and highway capacity requirements by maximizing bus transit.

A principal goal of these investigations is the definition of procedures which can be used to estimate an "optimum" or "maximum" amount of travel that residents of an urbanized area are capable of making. The definition is based on population characteristics, amounts and intensities of land use, the extent and capabilities of the main alternative forms of personal transport, and the costs and special benefits associated with each.

OVERALL STUDY DESIGN

In a broad context, the development of a study framework for maximizing bus potentials must consider four basic interrelated components.

First, it is necessary to estimate the total market for urban travel; i. e., to appraise the cross-elasticity of urban travel demands. This is the trip-generation phase of the analysis. Second, having defined the potentials for urban travel, this travel must then be allocated to the different urban transport modes. This is commonly termed "trip diversion"; most current modal split analyses fall into this category. Third, and more evasive, are the land-use impacts associated with urban transport improvements. Would, for example, a radically new form of bus transport exert a centrifugal, or

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centripetal influence on urban development? Finally, the role of public policy in regard to each of the preceding factors must be evaluated.

The present paper places emphasis on the trip-generation phase of the problem, with special attention given to the latent travel potentials of urban residents.

Some Basic Dimensions

The heaviest concentrations of travel in most urbanized areas are, and will continue to be, in the corridors which serve the central business district (CBD). This does not preclude the possibility or even the likelihood that other centers of activity can develop large concentrations of demand. It seems reasonable that a transport plan designed to effectively serve travel generated by the CBD should also be readily adaptable to traffic needs in other parts of the urbanized area.

Much argument revolves about the selection of a mode and system (or combination of modes and systems) of personal transport to provide optimum service in the urbanized area. A large part of today's residential community in every urbanized area has been built to very low densities. Even the largest urbanized areas incorporate much low-density residential development. For example, over 30 percent of the dwellings within the Cordon Area of the Penn-Jersey Transportation Study (1960) were detached units averaging three structures per net residential acre. More than half of these were built during 1945 to 1960, accounting for more than 60 percent of all nonresidential units constructed in that period (1). Travel by the occupants of these areas is presently oriented toward use of the personal car. New concepts in public transport are needed if they are to be provided with effective mass transportation.

The competitive aspect of travel by automobile and bus mainly relates to travel between the CBD and the places where people live. The CBD attracts a large proportion of all public transport use within most urban areas, partly because it represents the most intensive concentration of travel demand in any community and therefore offers the best target for frequent, efficient service. Bus services in many communities are totally oriented to the city center, and there are strong interrelationships between service frequency and intensity of downtown land use.

Depending on the number of CBD approaches which serve the urbanized area, the principal corridors of travel will develop critical intensities of traffic demand under different conditions of population growth and downtown employment density. A relatively small population spread along a narrow valley bottom or hemmed in between mountains and a body of water can generate, in the few available corridors, CBD approach volumes equal to those which occur in symmetrically developed urban areas only when they have reached much greater overall size.

For example, Honolulu (population about 300, 000) occupies a very restricted site on the shore and in the foothills of the Koolau Mountains and principal traffic flows must parallel the ocean. The 1960 traffic survey found 18-hour traffic of 125, 000 vehicles per day on a screenline northwest of CBD and 144, 000 vehicles in the corridor southeast of the center. Parallel express highways have been built which provide two large-capacity routes for the flow of traffic in each corridor. In contrast, a large, symmmetrical urban area, such as Washington (population 1, 569, 000 at time of 1956 survey) has developed about a dozen traffic service areas radial to the CBD in which corridors of heaviest demand develop traffic volumes somewhat less (1956 data) than the two principal corridors in Honolulu.

Typical examples of peak-hour traffic on the approaches to the CBD in medium-sized cities are shown in Figure 1. These examples, detailed in Table 1, were derived from analyses of CBD cordon counts and origin-destination data obtained from many sources (2). Figure 2 shows the relationship between travel mode and city size at the CBD cordon.

These models assume that one-fourth to one-sixth of the total CBD cordon crossings use the principal corridors. In some cities, individual corridors might actually accommodate a larger proportion of the daily CBD travel, particularly where cities front a body of water.

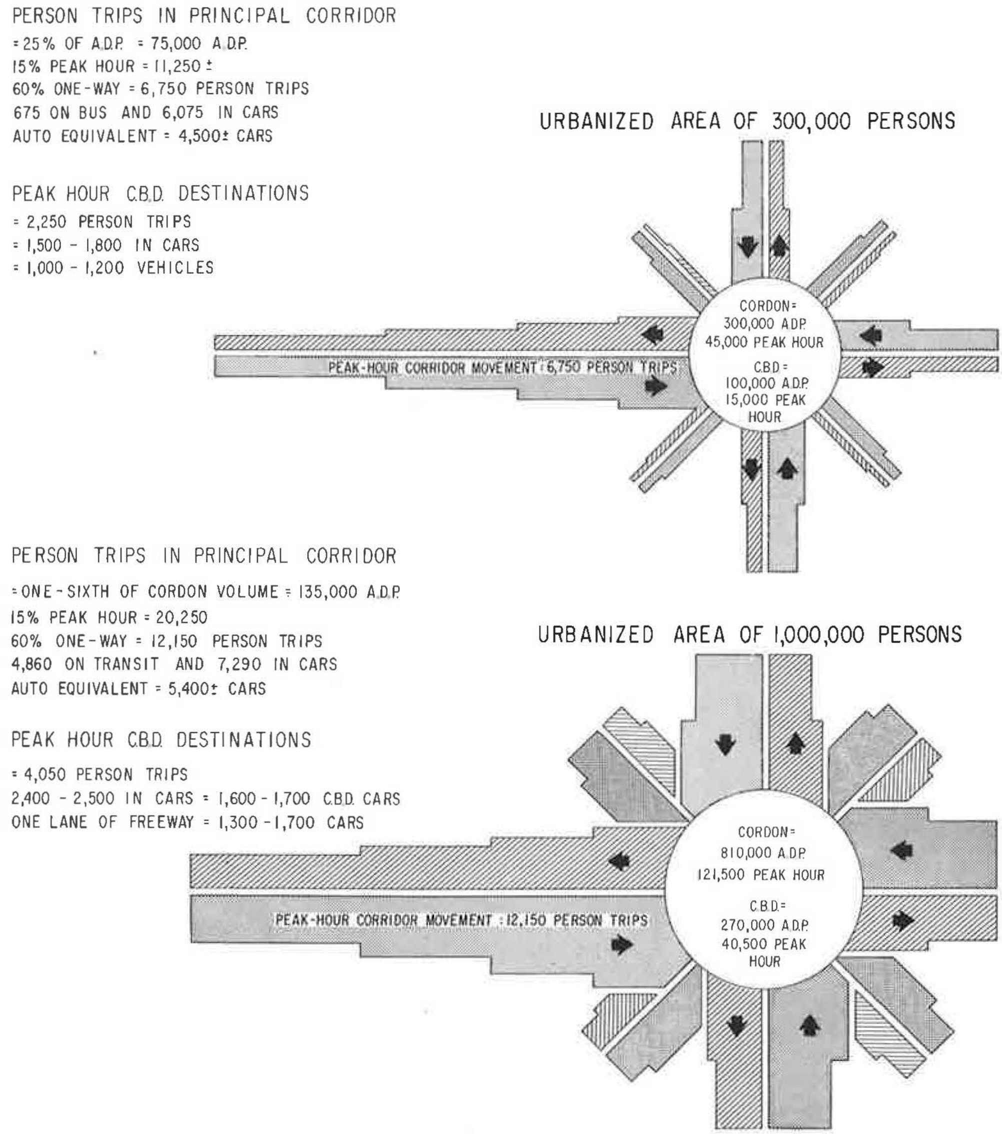


Figure 1. Peak-hour directional traffic flows in principal corridors—middle-sized urban areas.

In the first example, it is assumed that the CBD generates about 100, 000 trips, origins and destinations, each day (see Fig. 1 and Table 1). If the urbanized area is symmetrically developed, the corridors of most intensive use would accommodate about 25 percent of the total volume (i.e., 25, 000 trips). About 15 percent of these trips would occur in the peak hour (3, 750 trips). Trips generated in the CBD represent only about one-third of all peak-hour corridor traffic at the CBD cordon (the remainder are through trips), so that the total corridor volume at peak hour would amount to about 11, 250 person trips. About 60 percent, or 6, 750, would constitute the traffic flow in the heaviest direction of travel. Of this flow, about 10 percent are person trips in transit, as shown for areas with "centralized" CBD in Figure 2. The remainder, at 1. 5 persons per car, would require some 4, 050 private vehicles. Cars used by residents of the urbanized areas average about 1. 5 persons per trip, overall, according to

TABLE 1

PEAK-HOUR TRAVEL DEMAND IN HEAVILY TRAVELED CORRIDORS ON APPROACH TO CENTRALIZED CBD

Item	Typical Centralized CBDs		
Urban area population	300, 000	500, 000	1, 000, 000
Daily person trips generated in CBD	100, 000	160, 000	270, 000
Percent in heaviest corridor	25	20	17
Number in heaviest corridor	25, 000	32, 000	45, 000
Peak hour = 15 percent	3, 750	4, 800	6, 750
Corridor = 3 × CBD peak	11, 250	14, 400	20, 250
One-way person trips (60 percent)	6, 750	8, 640	12, 150
Percent ride transit	10	25	40
Number ride transit	675	2, 160	4, 860
Number in cars	6, 075	6, 480	7, 290
Number cars at 1. 5 occupancy	4, 050	4, 320	4, 860
Total one-way vehicles[a]	4, 500	4, 800	5, 400

[a]Trucks and buses in heavy direction of flow at peak hour assumed to constitute an "auto-equivalent" equal to 10 percent of all vehicles in traffic. (Trucks and buses have an effect on traffic capacity equal to two or more times the same number of cars (5).)

published data. These cars, plus trucks and buses, increase the "auto-equivalent" one-way flow of vehicles to about 4, 500 peak-hour corridor volume.

In the typical urban complex of one million persons (see Fig. 1, also third example in Table 1), the CBD would generate about 270, 000 daily person movements. In a symmetrical environment, the corridor of heaviest travel would have to accommodate about one-sixth of the cordon volume, or 45, 000 person trips. Peak-hour travel would consist of about 6, 750 CBD trips plus 13, 500 through trips at the cordon, with approximately 60 percent in one direction, for a total of about 12, 150 one-way person trips. Under present conditions, about 40 percent of these trips would be expected to use transit across the cordon of a centralized CBD. This would leave 7, 290 persons in 4, 860 cars in the heaviest direction of flow at the CBD cordon. With adjustment for trucks and buses, the auto-equivalent one-way volume would amount to about 5, 400 cars.

Alternatively, in a "decentralized" CBD only about 25 percent of the 12, 150 one-way person trips would be expected to use transit, leaving about 9, 100 persons in 6,100 cars in the heaviest direction of flow at the CBD cordon. With adjustment for trucks and buses, the auto-equivalent volumes of vehicular traffic would be approximately 6, 800 cars.

Assuming that corridor volumes at the CBD cordon had reached levels (or would soon do so) which, in a car-oriented city, would require major new improvements—extensive street widening, construction of a freeway, or additional lanes on existing freeways—what conditions would have to be met in the design of a bus system to entice a sufficiently large voluntary diversion of car riders to transit so as to defer or supplant the need for this improvement?

A modern 6-lane freeway, designed for heavy central-area traffic in an urbanized area under half-a-million people, would handle 4, 000 to 4, 500 vehicles (passenger car "equivalents") in the direction of heaviest flow at the peak hour. A 4-lane freeway, designed for similar conditions, would provide efficient service for 2, 800 to 3, 000 vehicles (car-equivalents). The difference (1, 200 to 1, 500 vehicles or 1, 800 to 2, 250

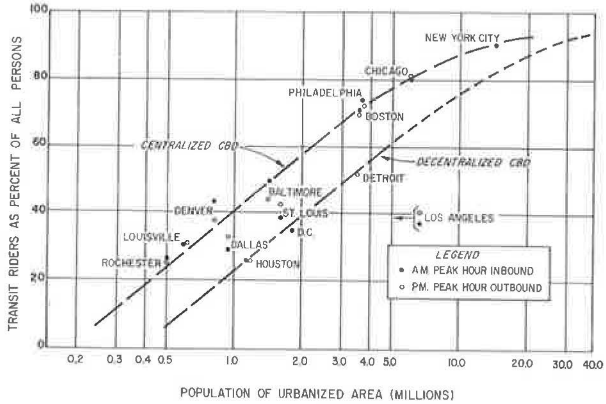


Figure 2. Transit riders as percent of persons entering or leaving central business district at peak hours (typical weekdays).

TABLE 2

TRANSIT TRIPS AT CBD CORDON: ONE-WAY PEAK HOUR AS PERCENT OF DAILY TWO-WAY TRIPS
(Typical Weekday, Selected Urban Areas)

Urbanized Area			Transit Trips at Cordon (thousands)		
Central City	1960 Population (thousands)	Year of Count	Peak Hour (one-way)	All Day (two-way)	Percent Peak Hour
New York City	14, 115	1960[a]	762	4, 790	15. 9
Los Angeles	6, 489	1957[b]	49	344	14. 2
Chicago	5, 959	1961[b]	180	1, 018	17. 7
Philadelphia	3, 635	1955[b]	127	948	13. 4
Boston	3, 584[c]	1954[b]	105	674	15. 6
Detroit	3, 538	1956[b]	34	304	11. 2
St. Louis	1, 608	1957[b]	26	184	14. 1
Baltimore	1, 419	1955[b]	29	238	12. 4
Houston	1, 140	1953[b]	16	146	11. 0
Dallas	932	1958[b]	21	144	14. 6
Denver	804	1962[a]	13	64	20. 3
Louisville	607	1957[b]	15	118	12. 7

[a]Morning peak hour.
[b]Evening peak hour.
[c]Population of 152-town Boston region, 1962.
[d]Transit riders entering CBD at cordon have been doubled to develop two-directional flows.

Note: Definition of CBD varies, determined locally by persons in charge of cordon count survey.

person trips) represents the magnitude of travel which, if diverted from car to transit, would provide substantial relief to the highway construction program by enabling the designer to scale down a projected freeway from 6 to 4 lanes.

For a larger urbanized area, the design capacity relationships are slightly modified. The difference between a 4- and 6-lane facility approximates 1, 500 to 1, 600 vehicles (2, 250 to 2, 400 person trips), again representing the substantial relief required to achieve a practical saving in new freeway construction (one lane each way).

Peak-hour one-way transit rides at the CBD cordon represent 10 to 20 percent of the two-way daily transit movement entering and leaving that area, averaging about 12. 5 percent in urban areas under two million persons (Table 2). If transit service is improved sufficiently to achieve the substantial relief by attracting riders away from private cars, diversion on a daily basis in the particular corridor under study would range from about 14, 000 to 20, 000 riders in urban areas under a million persons.

These values assume that transit service improvements adequate for peak-hour diversion would attract the same proportion of riders away from cars at all hours of the day. It might, of course, prove more feasible to divert riders to transit on a selective basis, concentrating on peak hours and the principal purposes of travel at those hours.

In the larger cities, the potential savings on freeway construction or on other new highways are significant, provided that bus operations of a practical nature can be devised which will achieve the levels of performance needed to divert travel. This is especially true in asymmetrical cities, where a few corridors must serve the vast bulk of centrally oriented travel. The advantage of high-volume transit riding is presently realized in cities such as Philadelphia, Washington, and New Orleans, where buses carry more than 50 percent of all peak-hour person movements on selected streets (for example, Connecticut Avenue in Washington). Bus services are also important in serving the 15-min peaks within the rush hour, or in helping reduce the duration of the peak period.

In smaller communities, the bus travel volumes required for effective freeway reduction would represent virtually the entire corridor traffic flow. In these situations the potentials for highway relief generally must be thought of in terms of special situations—restricted sites with heavier-than-average corridor volumes, or smaller scale savings, such as relief equivalent to (or taking the place of) street widening, grade separations, etc.

Mobility and Trip Generation

The potentials for bus transit may also be viewed in another context. Perhaps the goal should be to optimize mobility rather than increase capacity. This suggests that

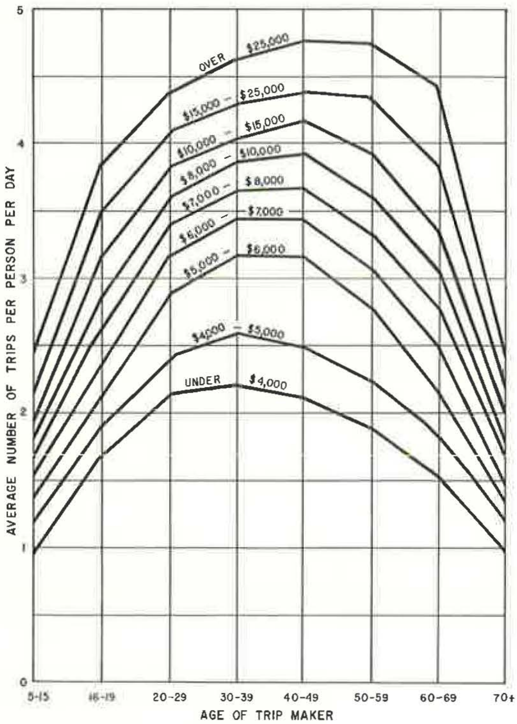


Figure 3. Trip rates related to age and household income of trip-makers (Springfield urbanized area, 1964-65).

the latent travel demands—trips not now being made—constitute a source of additional bus riders.

Research has centered on cross-sectional analysis of trip behavior in four middle-sized communities and one larger metropolitan area. These communities and their cordon area populations at time of the field surveys were: (a) Baltimore, Maryland, 1,600,000 population; (b) Springfield, Massachusetts, 531,000 population; (c) Richmond, Virginia, 418,000 population; (d) Allentown-Bethlehem-Easton (Lehigh Valley), Pennsylvania, 345,000 population; and (e) Columbia, South Carolina, 200,000 population.

Current trip-estimating techniques are usually designed to predict the numbers of trips that resident populations are likely to make under conditions similar to those that presently exist. These are almost always stratified to some degree (according to the trip-maker's purpose or income). The present analyses attempt to estimate the number of trips people might make, if constraints to travel were minimized or eliminated. It is recognized that the desire to make a trip for a certain activity, the selection of a particular activity center for the trip destination, and the choice of mode to be used are all parts of one decision-making process. The wish to make a trip is modified by a host of circumstances before it becomes a decision to make a trip. In appraising the alternatives, the trip-maker is constrained by the amount of time-loss he is willing to accept in traveling to and from a given activity, the out-of-pocket costs of his trip, and the availability of facilities for travel. His appraisal of each factor will relate directly to the urgency of his motive.

Age and Income Variables—The age and income of trip-makers have important bearing on the number of trips they perform. These interrelationships for Springfield, a typical urban area, are shown in Figure 3, and are summarized in Tables 3 and 4.

The average number of daily trips, regardless of age, was found to increase from less than 1.6 per person at lowest family income to more than 3.6 trips per day at the highest. The effects of age show a different, but equally consistent story. Travel increases from 1.5 daily trips at ages 5 to 9 years to nearly 3.6 trips at ages 40 to 49, then declines to about 1.3 trips for persons 70 and older. Within the matrix of Table 4, the pattern is nearly as consistent for each age grouping and income class as for the overall totals. Some discrepancies show up, but these may relate to differences in household size (number of persons in each dwelling unit).

Eligibility to drive affects trip-making in many households, particularly as it relates to age. About 31 percent of the Springfield area population is too young to drive, including about 10 percent under 5 years of age; another 8 percent is 16 to 19 years of age (old enough to drive) and, for the most part, still living at home; 13.4 percent is over 60 years of age (with more than two-fifths of the people in this stratum over 70 years old).

The age distribution of trip-makers provides insight into living patterns in the middle-sized cities. More than 45 percent of persons in the lowest income households are over 60 years of age. Most of these are no longer employed. The combination of old age, low income, and no jobs has resulted in very low rates of trip production,

TABLE 3

NUMBER OF PERSONS BY GROSS HOUSEHOLD INCOME AND AGE[a]
(Springfield, Urbanized Area, 1964-65)

Age (years)	Annual Household Income ($)									
	Under 4, 000	4, 000-5, 000	5, 000-6, 000	6, 000-7, 000	7, 000-8, 000	8, 000-10, 000	10, 000-15, 000	15, 000-25, 000	Over 25, 000	All Persons
5-9	4, 108	4, 690	7, 604	8, 311	7, 024	6, 224	4, 723	1, 540	402	44, 626
10-15	4, 555	4, 024	7, 415	7, 171	7, 264	8, 057	6, 250	2, 134	624	47, 494
16-19	3, 869	2, 906	3, 745	4, 325	3, 932	4, 500	4, 558	1, 952	134	29, 921
20-24	2, 335	2, 959	3, 802	2, 956	2, 240	2, 951	2, 693	931	25	20, 892
25-29	1, 604	2, 829	4, 066	4, 056	2, 805	2, 536	1, 976	484	14	20, 370
30-39	3, 542	5, 241	9, 496	8, 635	7, 885	7, 997	6, 077	1, 712	688	51, 273
40-49	4, 182	4, 817	7, 657	8, 127	8, 550	9, 353	10, 106	3, 910	392	57, 094
50-59	5, 827	5, 020	6, 364	5, 925	4, 868	5, 855	6, 049	2, 797	574	43, 279
60-69	11, 993	5, 341	3, 936	2, 821	2, 422	2, 163	1, 522	627	474	31, 299
70+	13, 740	3, 635	1, 793	1, 612	863	862	1, 028	341	238	24, 112
All ages	55, 755	41, 462	55, 878	53, 939	47, 853	50, 498	44, 982	16, 428	3, 565	370, 360

[a]This table contains data only on those persons who occupy households which reported annual income (about three-fourths of all interviewed households).

particularly by persons over 70. Nearly half (46. 5 percent) of all persons over 60 years of age in the study area are in the lowest income group.

At higher income levels, the very old (over 70 years) perform a substantial amount of travel, those from households with incomes over $7, 000 averaging slightly more than 2 trips a day, or about twice as much travel as those with very low incomes. This implies that the lower income elderly may be constrained by lack of funds, although it is not clear whether such constraint might relate to their inability to pay for travel, or lack of money to purchase goods and services at the points of activity which attract travel.

At the other end of the age scale, children and adolescents (ages 5 to 19) are a substantial proportion of the persons who occupy the lowest income households. Some of these, of course, are dependents of underprivileged and/or unskilled parents, abandoned mothers, and broken homes. The trips performed by these young people reflect the incomes and travel patterns of their parents. In general, the adult population, ages 20 to 60, constitutes the parent group to whose households the dependent children's income classifications are related.

Travel by young people increases with rising family income, much like the patterns recorded for elderly persons. Within the dependent groups there are distinct differences which relate to the pecularities of each age. It may be inferred that most of the travel by persons under 10 years of age is made in company with adults; some of this travel is incidential to the parent's motive, although many of the parents' trips are

TABLE 4

TRIPS PER PERSON (ALL MODES) BY GROSS HOUSEHOLD INCOME[a] AND AGE
(Springfield Urbanized Area, 1964-65)

Age (years)	Annual Household Income ($)									
	Under 4, 000	4, 000-5, 000	5, 000-6, 000	6, 000-7, 000	7, 000-8, 000	8, 000-10, 000	10, 000-15, 000	15, 000-25, 000	Over 25, 000	All Incomes
5-9	1. 06	1. 31	1. 39	1. 30	1. 51	1. 76	1. 90	2. 10	2. 21	1. 49
10-15	0. 87	1. 20	1. 59	1. 59	1. 85	1. 81	1. 94	2. 28	3. 16	1. 67
16-19	1. 71	1. 92	1. 87	2. 38	2. 79	2. 90	3. 40	3. 55	3. 10	2. 62
20-24	2. 41	3. 02	3. 21	2. 96	3. 30	4. 82	3. 87	3. 03	—	3. 38
25-29	2. 85	2. 20	3. 22	3. 42	3. 47	3. 83	4. 67	3. 50	—	3. 35
30-39	2. 24	2. 59	3. 20	3. 82	3. 89	3. 90	3. 92	4. 21	4. 63	3. 53
40-49	1. 91	2. 39	3. 18	3. 30	3. 70	4. 40	4. 24	4. 39	3. 54	3. 58
50-59	1. 93	2. 25	3. 11	2. 76	3. 09	3. 92	3. 76	3. 69	4. 82	3. 06
60-69	1. 80	2. 01	1. 85	2. 45	2. 81	3. 06	3. 27	4. 56	2. 90	2. 27
70+	1. 04	1. 28	1. 75	1. 82	2. 34	1. 76	1. 96	2. 37	1. 65	1. 32
All ages	1. 58	2. 02	2. 57	2. 62	2. 89	3. 28	3. 40	3. 52	3. 61	2. 66

[a]Trips per capita for persons living in households with the designated level of income.

Note: Tables 3 and 4 contain data only on persons and trips from households for which income data were reported (about three-fourths of all households interviewed).

TABLE 5

DAILY TRIPS PER HOUSEHOLD RELATED TO CARS OWNED, NUMBER EMPLOYED, INCOME
(Springfield, Massachusetts, 1964-65)

Cars Owned	Persons Employed		Annual Income ($)								
			Under 4,000	4,000-5,000	5,000-6,000	6,000-7,000	7,000-8,000	8,000-10,000	10,000-15,000	15,000-25,000	Over 25,000
0	0	Trips	15,135	2,220	140	95	–	100	25	–	–
		Households	12,520	1,590	115	70	–	35	25	–	–
		T/H	1.21	1.40	–	–	–	–	–	–	–
0	1	Trips	10,535	6,800	2,635	1,560	335	310	–	105	–
		Households	4,905	2,215	900	630	190	70	–	15	–
		T/H	2.15	3.07	2.93	2.48	–	–	–	–	–
0	2+	Trips	345	1,275	1,225	1,635	940	105	990	–	–
		Households	80	295	390	400	255	25	110	–	–
		T/H	–	4.33	3.14	4.08	3.68	–	–	–	–
All 0		Trips	26,015	10,295	4,000	3,290	1,275	515	1,015	105	–
		Households	17,505	4,100	1,405	1,100	445	130	135	15	–
		T/H	1.49	2.51	2.85	2.99	2.87	–	–	–	–
1	0	Trips	27,065	7,930	5,385	1,515	700	770	310	185	285
		Households	6,255	1,580	790	285	65	80	125	50	85
		T/H	4.30	5.02	6.82	5.32	–	–	–	–	–
1	1	Trips	27,400	47,060	84,880	68,875	52,384	44,300	28,710	8,630	2,150
		Households	4,400	7,980	10,970	8,615	5,780	4,470	3,055	790	210
		T/H	6.23	5.90	7.73	8.00	9.05	9.93	9.40	10.90	10.20
1	2+	Trips	3,380	10,690	21,035	33,620	37,230	50,315	31,525	7,605	270
		Households	420	1,120	2,410	3,400	3,505	4,650	2,680	715	40
		T/H	8.05	9.53	8.74	9.90	10.30	10.82	11.75	10.65	–
All 1		Trips	57,845	65,680	111,300	104,010	90,314	95,385	60,545	16,420	2,705
		Households	11,075	10,680	14,170	12,300	9,350	9,200	5,860	1,555	335
		T/H	5.22	6.15	7.86	8.45	9.66	10.36	10.31	10.55	8.07
2+	0	Trips	1,355	340	710	–	–	–	415	190	–
		Households	180	95	65	–	–	–	50	30	–
		T/H	7.53	–	–	–	–	–	–	–	–
2+	1	Trips	2,430	3,730	13,100	16,620	19,670	24,575	26,845	14,730	7,380
		Households	305	480	1,355	1,355	1,570	1,685	2,030	1,065	560
		T/H	7.98	7.78	9.68	12.26	12.55	14.55	13.20	13.82	13.17
2+	2+	Trips	2,030	2,705	14,745	16,795	26,085	44,650	63,730	26,065	2,900
		Households	165	270	1,285	1,520	2,205	3,470	4,655	1,830	215
		T/H	–	10.00	11.50	11.05	11.80	12.87	13.70	14.25	–
All 2+		Trips	5,815	6,775	28,555	33,415	45,755	69,225	90,990	40,985	10,280
		Households	650	845	2,705	2,875	3,775	5,155	6,735	2,925	775
		T/H	8.95	8.02	10.55	11.60	12.10	13.42	13.50	14.00	13.25

made to accommodate needs of the child. Much the same can be said about 10-to-15-year-olds, although they are shown to average slightly higher rates of travel. The upper-teen group is distinctly more mobile, generating trips at rates which exceed those of the younger dependents by 50 percent or more.

Highest rates of travel are performed by the adult population (family heads and workers) between the ages of 20 and 60. Their lowest trip rates are about twice as high as those of children and teenagers on the one hand and the senior citizens on the other hand. They maintain something like this differential at each level of income, with trip rates by upper income residents nearly twice as high as rates at the low end of the income scale. Work travel accounts for a very high proportion of trips at low incomes and is a substantial part of travel at higher incomes.

Car Ownership and Employment Variables—The age-income-trip-making patterns are further modified by differences in car ownership, and the presence or absence of employed persons in households. Accordingly, Table 5 gives data on how these variables affect trip production in households with different incomes.

Nearly a fifth of all households in the Springfield area did not have cars. These households generated less than 4.8 percent of the trips made by the area's residents. About 60 percent of all dwelling units in the Springfield urbanized area had one car, and more than 61 percent of the trips in the area (all modes) were made by persons in this group. The remaining 21 percent of all occupied units were each provided with two or more cars, and they accounted for more than a third of all the trips made by area residents.

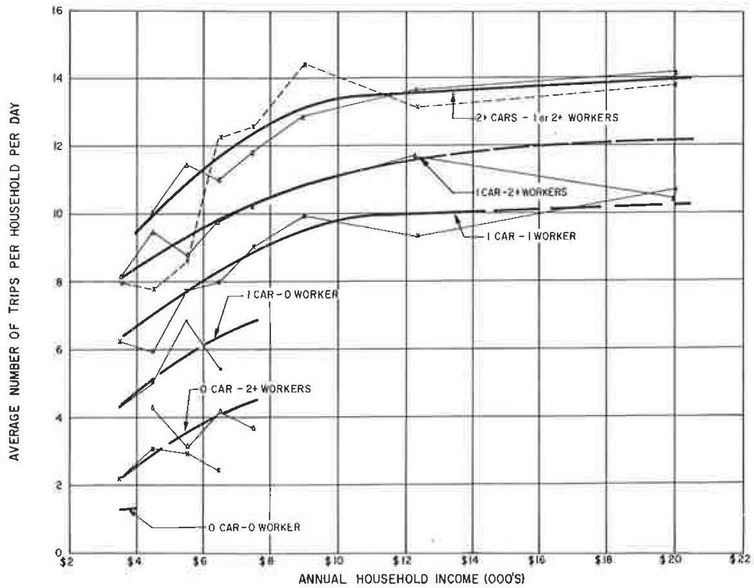


Figure 4. Daily trips per households vs workers, cars owned and income (Springfield urbanized area, 1964-65).

Trip generation in households which had one car ranged from about 4.3 trips per day, where no one was employed, to nearly 12 trips, on the average, where two or more persons worked outside the home. Very low incomes typified homes without workers, and the highest incomes were reported for households supported by one or more workers.

The pattern was the same for two-car dwellings, except that there were virtually no homes in this class without at least one working member. The majority of all two-car households were supported by one or more employed persons, and the two-worker dwellings dominated the upper end of the income scale. Average daily trip production exceeded 14 in high-income, two-worker households.

The stratification of household trip generation according to income, employment and car ownership is shown in Figure 4. (This figure has been prepared by plotting the average household trip rates listed in Table 5. Freehand curves have been fitted to the various sets of data according to number of cars and number of workers in the households.) Again, it is apparent that large increments of trip generation are associated with each of the cars in a household. At all levels of car availability, trip production rates are modified by the number of workers in the household. Size of household is not taken into account here, but households must consist of two or more adults to make use of two or more cars or have more than one worker.

Data for one-car families are the most stable, because nearly 60 percent of all households reporting their incomes fall in this category. Trip generation is shown to increase steadily with rising income in all classes under $10,000, and to level off above that value. Households without cars show distinct differences in the trip-generating characteristics of those without workers and those with one or more workers. A curve which generally fits the slope for two-car households has been fitted to data for families with one or more workers. Very few households with two workers are without cars; similarly, hardly any families with two cars are without workers.

Family Composition—At any level of household employment, car ownership, and income, the number of household occupants influences the number of trips that the household can be expected to produce. In general, per capita trip production declines with each increase in family size. Although the aggregate number of trips generated by each household increases as households get larger, the rate of increase generally slows down.

TABLE 6

OVERALL TRIP GENERATION RATES
(Springfield Urbanized Area, 1964-65)

Household Size	Number of Workers	Cars in Household 0	Cars in Household 1	Cars in Household 2+	Remarks
(a) Trips Per Person Per Day (All Modes)					
1 person	0	0.80	3.00	–	Average per capita trips in one- and two-person households.
	1	1.50	3.75	–	
2 persons	0	0.50	2.25	2.50	
	1	1.00	2.75	4.00	
	2	1.50	3.75	4.00	
3 persons	0	+0.80	+1.50	+1.50	Increments of travel by each person in excess of two, as indicated by household size. Add to travel by both members of two-person families to develop household rates.
	1	+1.40	+1.50	+2.00	
	2+	+1.40	+1.50	+2.00	
4 persons	0	+0.80	+1.50	+1.50	
	1	+1.00	+1.50	+2.00	
	2+	+1.00	+1.50	+2.00	
5+ persons (based on average of 6 persons in 5+ households)	0	+0.80	+1.50	+1.50	
	1	+0.60	+1.50	+2.00	
	2+	+0.60	+1.50	+2.00	
(b) Trips Per Household Per Day (All Modes)					
1 person	0	0.80	3.00	–	
	1	1.50	3.75	–	
2 persons	0	1.00	4.50	8.00	
	1	2.00	5.50	8.00	
	2	3.00	7.50	8.00	
3 persons	0	1.80	6.00	6.50	
	1	3.40	7.00	10.00	
	2+	4.40	9.00	10.00	
4 persons	0	2.60	7.50	8.00	
	1	4.00	8.50	12.00	
	2+	5.00	10.50	12.00	
5+ persons (based on average of 6 persons)	0	4.20	10.50	11.00	
	1	4.40	11.50	16.00	
	2+	5.40	13.50	16.00	

Typical stratifications of per capita trip-making by size of household, number of workers and car ownership are shown in Table 6 and Figure 5. (Appendix A contains the data on which these exhibits were based.) It is apparent that, for every given family size and number of workers, an increase in car ownership results in increased trip generation.

OPTIMUM AND MAXIMUM TRIP GENERATION IN URBANIZED AREAS

The foregoing empirical investigation reaffirms many previous findings. Numerous studies of urban travel have indicated that residents without cars make fewer trips than those who have cars and that the travel generated by the average household increases when the household acquires a second (or third) car. These relationships are interesting for another reason: they provide a basis for estimating an optimum amount of mobility within the urban area. They indicate that there are various degrees of mobility within the urban environment. Those persons who have the exclusive use of a car seem to have achieved the maximum level of mobility, those without cars have the least.

Examination of "car-saturated" households—those with as many cars as members—shows a wide variation in trip generation; however, it is to be expected that maximum mobility would vary from person to person in a given population. Some persons and households need to make more trips than others, depending on the number of persons in the household, the number who work outside the household, the level of income on which the household subsists, the ages of the residents, and possibly such environmental factors as residential densities (persons per acre) and proximity to non-home activity centers (work, shopping, recreation, school, etc.).

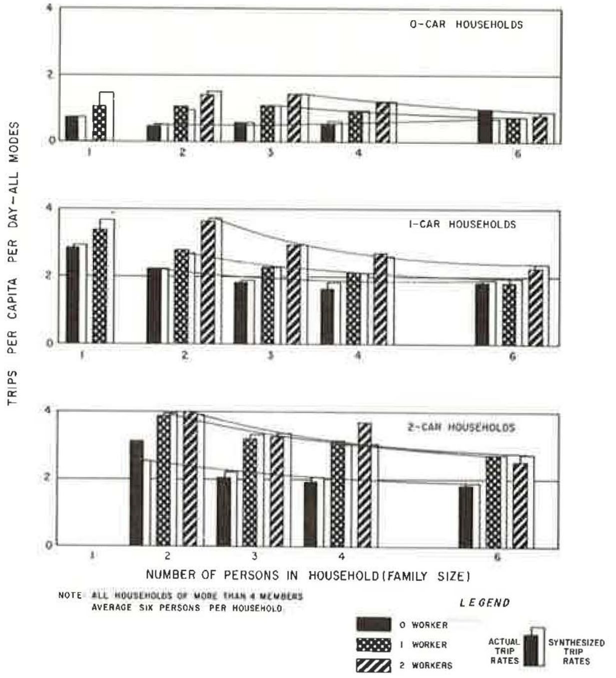


Figure 5. Urban trip generation related to family size, number of workers, number of cars owned (Springfield urbanized area, 1964-65).

The Basic Concept

Car ownership related to family size, employment and income characteristics provides a means of estimating the optimum and maximum rates of trip generation by the residents of households within an urban area.

Optimum Trips—The average trip rate computed for households with a specified number of workers and a saturated level of car ownership might be said to represent an optimum level of trip production in a community as it now exists. These people perform more trips than are generated in households without as many cars; in other words, they have the highest degree of mobility that contemporary standards can provide.

Maximum Trips—The maximum trip rates for any stratum of the mentioned population are found among those who experience no income constraints.

These definitions provide a framework for establishing ceilings on urban trip production, based on the behavior of car-saturated adults. In this regard, it is interesting to speculate on how much more travel would take place throughout a typical urbanized area if all residents were provided with an optimum degree of mobility equal to that achieved in car-saturated households. Such a computation might be regarded as a trip production ceiling, and would be useful in developing better appreciation of present mobility and its deficiencies.

It might further be postulated that this optimum level of trip production could only take place if the households were provided with a level of mobility equivalent to that of car-saturated households. Conceivably, public transport, if able to accommodate the urban citizenry at the same speed, comfort, availability, privacy, etc., afforded by the car, would generate travel at similar rates from persons who are not presently eligible to drive a car.

The conditions for optimum trip generation as defined herein do not incorporate an income variable, but relate to trip averages for households within all strata designated by family size and number of workers. Thus, a second intriguing question arises. How much travel would people perform under the conditions of maximum mobility if income

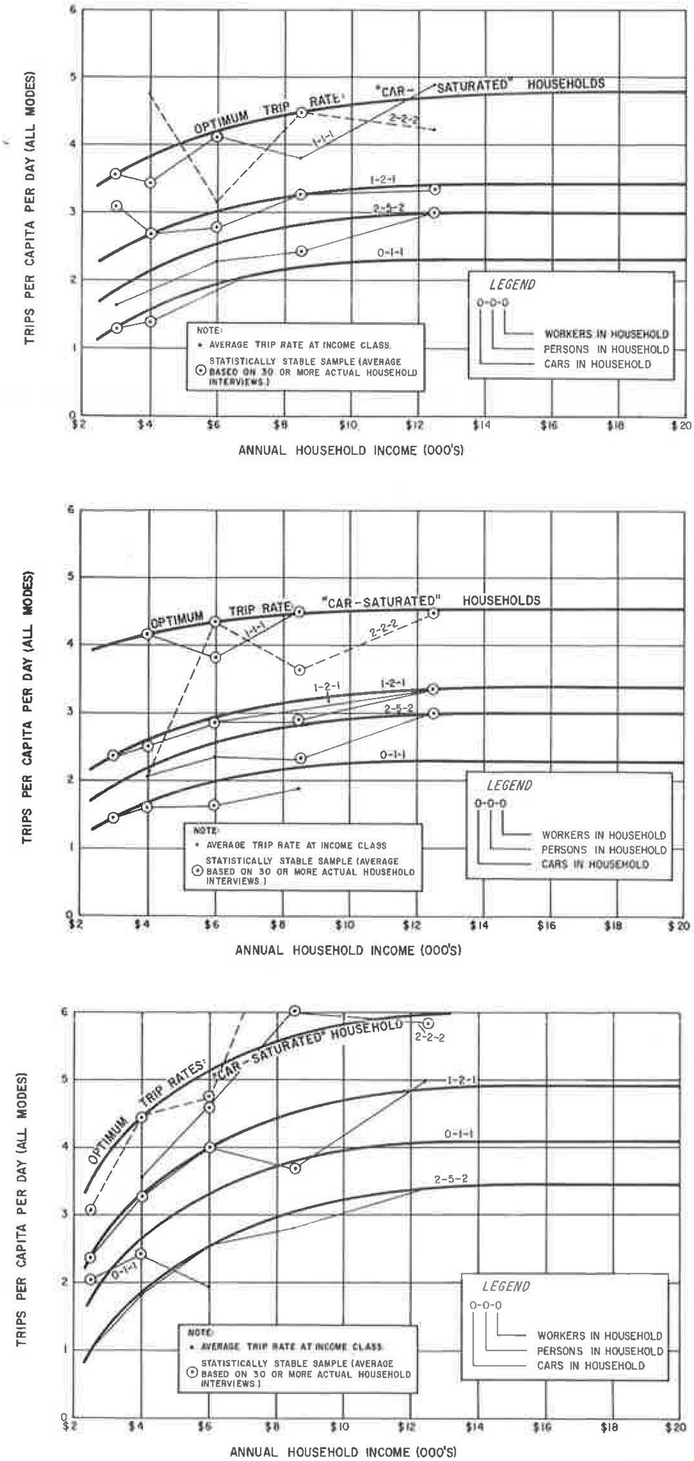


Figure 6. Trips per capita by family size, income, number employed, cars owned: (a) Springfield urbanized area, 1964-65; (b) Richmond urbanized area, 1964-65; and (c) Columbia urbanized area, 1964-65.

TABLE 7

OPTIMUM AND MAXIMUM[a] TRIP GENERATION RATES PER HOUSEHOLD
(Four Urbanized Area Surveys)

Persons in Household	Workers in Household	Baltimore Area[b] Optimum	Springfield Area Optimum	Springfield Area Maximum	Richmond Area Optimum	Richmond Area Maximum	Columbia Area Optimum	Columbia Area Maximum
1	0	2.0	3.0	3.65	3.0	4.0	3.0	4.0
1	1	3.0	4.0	5.2	4.0	6.0	5.0	6.0
2	0	4.0	6.0	7.0	6.0	6.0	8.0	9.0
2	1	6.0	9.0	8.25	7.0	7.75	9.0	10.5
2	2	6.5	8.5	9.5	8.0	9.0	10.0	12.0
3	0	6.0	6.5	8.0	9.0	10.0	12.0	14.0
3	1	8.0	10.0	11.0	10.5	11.25	12.75	15.5
3	2	8.5	10.0	11.2	11.0	11.5	13.5	16.0
3	3	9.0	—	—	12.0	12.25	15.0	16.5
4	0	6.0	8.3	8.3	11.5	13.5	15.0	16.0
4	1	9.0	12.3	13.0	13.5	14.25	16.75	18.0
4	2	9.5	14.7	15.8	14.0	14.5	17.5	19.0
4	3	10.0	—	—	16.0	17.0	19.0	19.5
4	4	10.5	—	—	—	—	—	—
5	0	8.0	12.5	12.5	14.0	15.0	16.0	17.0
5	1	11.0	16.0	17.5	16.5	16.7	20.75	22.0
5	2	11.5	17.0	18.0	17.5	18.0	21.5	22.0
5	3	12.0	—	—	18.0	18.5	23.0	24.0
5	4	12.5	—	—	—	—	—	—
5	5+	13.5	—	—	—	—	—	—
6	0	—	—	—	15.0	16.0	22.0	22.0
6	1	—	—	—	18.0	19.0	24.75	25.5
6	2	—	—	—	20.0	21.0	25.5	26.5
6	3+	—	—	—	24.0	25.0	27.0	28.5
7	0	—	—	—	17.75	18.5	—	—
7	1	—	—	—	20.5	21.0	—	—
7	2	—	—	—	25.5	26.0	—	—
7	3+	—	—	—	32.0	33.0	—	—

[a]Optimum trip generation rates were taken from the original data tabulations, rather than the "smoothed" matrix shown in Table 6. Maximum trip generation rates relate to travel by the upper-income households in each stratum.
[b]Detailed estimates of maximum trips not made for Baltimore, since income data were not collected in the O-D Survey.

limitations did not inhibit trip-making? Stated another way, how much travel would be made in today's city if every household had purchasing power equal to those whose residents presently generate the most trips? This is not an entirely irrelevant consideration, because average purchasing power, and purchasing ability within the lower economic strata of the urban population, has grown rapidly in recent years.

Accordingly, optimum and maximum rates of trip generation have been computed for the Baltimore, Springfield, Richmond, and Columbia urbanized areas and provide insight into these questions. These trip rates are shown in Figure 6 and given in Table 7. The data are stratified by household according to size, number of workers, number of cars owned, and income. Maximum trip rates are shown for households earning over $10,000 per year. These rates are substantially higher than the optimum averages for households without regard to income, which points up the significance of an adequate income in maximizing the mobility of people who have cars. Thus, the asymptotes in Figure 6 serve as a ceiling, incorporating the equivalents of both car saturation and high purchasing power.

TABLE 8

OPTIMUM AND MAXIMUM TRIP GENERATION WITH FULL POPULATION MOBILITY: YEAR OF STUDY
(Four Urbanized Area Surveys)

Item	Baltimore	Springfield	Richmond	Columbia
Population	1,608,000	531,000	418,000	196,000
Reported trips	2,675,452	1,200,016	972,958	580,721
Optimum trips	3,603,000	1,561,000	1,386,000	811,000
Maximum trips	3,963,300	1,755,100	1,485,700	901,200
Reported trips/person	1.66	2.26	2.33	2.96
Optimum trips/person	2.24	2.94	3.32	4.14
Maximum trips/person	2.47[a]	3.30	3.55	4.60
Increase over reported trips:				
Optimum rates (%)	35	30	43	40
Maximum rates (%)	48[a]	46	53	55

[a]Maximum rates estimated for Baltimore, based on difference between optimum and maximum rates in other three areas.

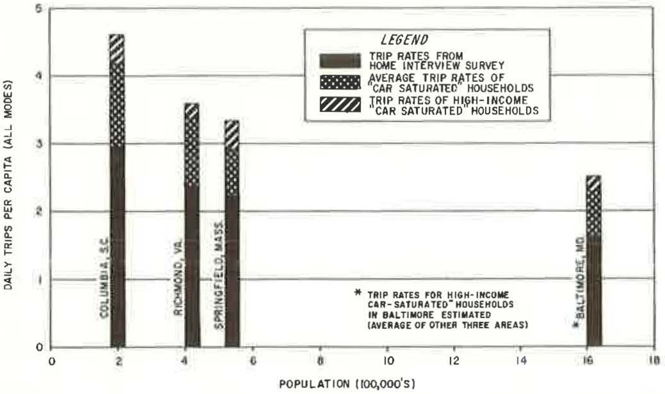


Figure 7. Trips per capita in four urbanized areas (survey data vs maximum potentials).

The trip rates (Table 7) have been applied to the population of households in each of the four study areas to develop estimates of trip-generation ceilings for the two extreme conditions described. The results of these computations are shown in Table 8 and have been plotted in Figure 7. (Detailed computations are shown in Appendix B.) Since data were not available for household incomes in Baltimore, optimum trip generation has been arbitrarily increased by 10 percent to develop an estimate of maximum trip potentials. This is based on the finding that maximum trip rates in the three areas for which income data were reported averaged about 10 percent greater than the optimum rates in those areas.

When trip rates for the four cities are examined for similarities, they are seen to vary in regular fashion, the smaller populations consistently generating trips at higher rates than the larger populations in every combination of family size and number of workers. This may, in part, relate to net residential density; in general, trip-making is inverse to the number of persons per net residential acre. Another possible explanation reflects the rise in average trip lengths as city size increases; fewer long trips can be accomplished in the time available for trip-making. Finally, social customs in an area also influence trip generation. (In Columbia, for example, many workers return home for the noon meal.)

Perhaps the most intriguing aspect of this analysis is the relatively small overall increase which results from the application of two such extreme sets of conditions. When the Springfield data were developed to show the constraints on travel by persons who do not have cars, it was noted that persons who had exclusive use of a car perform more trips than those without. Only about a fifth of the Springfield area population had access to cars which they did not have to share with other drivers. However, three-fourths of these drivers shared households with non-drivers and were, of course, called on for travel on behalf of the non-drivers—another form of constraint which results in the driver with dependents making more than the optimum amount of travel, as compared to patterns of trip-making by persons in households whose members all have cars. (Average per capita trip-making in these households is much lower than the optimum rate, of course.) From these studies, it was determined that fewer than 5 percent of the area residents were free to make as many trips (or as few) as needed to fulfill their wants.

It is somewhat astonishing, then, to realize that, despite the numerous constraints on travel which have been identified in these studies, the urban populace seems to come reasonably close to realizing its "theoretical" travel potentials under existing conditions. The optimum estimate of trip potential, according to the data given in Table 8, ranges between a 30 to 40 percent increase over the number of trips performed at the time the travel surveys were made, whereas the maximum rates under the assumptions of ideal income and mobility would lead to only 42 to 55 percent more trips. It is probable that even these trip rates overstate actual trip potentials for reasons noted earlier, because they are based on the most travel-oriented stratum of the population.

There are, of course, many other considerations which affect trip rates: some of the reasons why households within a given range of income are "car saturated" and others have no car at all relate to the personality and education of the householder and the relative importance he places on alternative uses for his money—purchasing a home, buying a boat, traveling abroad, sending a child to private school. The importance of mobility is also influenced by occupation (a traveling salesman must have a car), proximity to parks, shopping centers (which may allow participation in various activities without any vehicular transport), physical handicaps, and so on.

Potential Urban Travel—The discussion of optimum and maximum travel affords a basis for making estimates of the changes which very well may occur in urban trip-making as purchasing power continues to rise. (Most projections of urban development anticipate very real increases in purchasing power, and the analysis which follows can be used to approximate the effect of a given amount of change in purchasing power in each stratum of the urban population.)

Assume, for example, that the trip rates given in Table 5 are applied to a typical community of 500, 000 persons. Assume further that, on the average, median family income (purchasing power) is increased by $1, 000 (except for incomes over $15, 000). About 10 percent more trips would be expected to result. If incomes were increased $2, 000 (except in the highest increase category), an 18 percent gain in trips would probably result.

This analysis merely assumes that the average person from a household in a given income range, making the average number of daily trips for that income level, can be expected to increase his trip-making to the average levels associated with greater wealth as his income rises. Other aspects of this study have found that higher incomes are related to the number of workers in the household. They show, too, that the higher degree of mobility enjoyed by members of the richer households is achieved by use of the cars they own and that the extent of car use increases with income.

Travel, however, is not usually an end in itself, but is incidental to activities in which the trip-maker participates; his trips are usually made to bridge the distance between one activity and another. For activities such as the place of work, the costs of travel reduce net earnings but not enough to seriously offset the gains. However, participation in most nonwork activities requires expenditure of funds other than the cost of travel so that the number and variety of trips may be restricted by lack of resources to purchase desired goods or entertainment; travel costs may play only a minor role in the curtailment of travel. As incomes rise, power to travel and to purchase goods and service does result in more travel, and the foregoing relationships are general indicators of what to expect.

Transit Riding and Urban Travel Potentials

The significance of the foregoing discussion of urban travel potentials in relation to future bus transit patronage becomes apparent from a brief review of transit rider characteristics, and attitudes within the various study areas.

Aggregate Travel by Bus—The numbers and proportions of bus trips in the five study areas are given in Table 9.

Excluding the use of buses by school children, the number of trips made on buses was a very small portion of the travel performed in each area. Nonschool trips by bus accounted for a little over 10 percent of all person-travel in Baltimore, 7. 5 percent in Richmond, 2. 7 percent in Springfield, and less than 2. 5 percent in the Lehigh Valley and Columbia. When school trips are included, about 7 percent of all trips in Columbia, 9 percent in Lehigh, 10 percent in Springfield, 14 percent in Richmond, and 17 percent in Baltimore were made by bus.

A further analysis of travel mode and age of bus riders in Springfield (Table 10) reaffirms another well-known fact. Most adults traveled as auto drivers. More than three-fourths of all trips by persons 20 to 60 years of age were made as drivers (over

TABLE 9

TRIPS BY MODE
(Five Urbanized Areas)

Mode	Baltimore	Springfield	Richmond	Lehigh Valley	Columbia
			(a) Total Trips		
Public bus	332, 056	43, 351	80, 793	22, 781	14, 582
Public bus to school	(61, 305)	(11, 069)	(7, 552)	(7, 277)	(1, 094)
Nonschool	(270, 751)	(32, 282)	(73, 241)	(15, 504)	(13, 488)
School bus	122, 672	76, 916	46, 454	36, 264	25, 874
Auto driver	1, 467, 389	756, 112	570, 007	442, 028	363, 566
Auto, truck, taxi, pass.	753, 335	323, 637	275, 704	187, 013	176, 699
All modes	2, 675, 452	1, 200, 016	972, 958	688, 086	580, 721
			(b) Percentages of Trips by Mode		
Public bus	12. 4	3. 6	8. 3	3. 3	2. 5
Public bus to school	(2. 3)	(0. 9)	(0. 8)	(1. 0)	(0. 2)
Nonschool	(10. 1)	(2. 7)	(7. 5)	(2. 3)	(2. 3)
School bus	4. 6	6. 4	4. 8	5. 3	4. 5
Auto driver	54. 8	63. 0	58. 6	64. 2	62. 6
Auto, truck, taxi, pass.	28. 2	27. 0	28. 3	27. 2	30. 4
All modes	100. 0	100. 0	100. 0	100. 0	100. 0

80 percent by those in their 30's), whereas bus transit accounted for less than 2½ percent. Almost 60 percent of trips by persons over 70 years of age were made as drivers.

The largest relative use of bus was by people over 70 and in the age bracket between 16 and 19. However, the older persons made only 6 percent of the total bus trips, whereas persons in the 16 to 19 age bracket made nearly a quarter of all public bus trips. The teenage group was very mobile, considering that a relatively small proportion were employed, many were not licensed to drive, and those so licensed usually shared the family car. The bus was often the obvious alternative when others were using the car, and their per capita travel by bus was nearly twice that of the next ranking group (adults in the ages 40 to 60). Yet, although teenagers performed a major share of all bus travel in the Springfield area, it did not appear that special efforts had been made to market bus service to them.

The influence of walking distance on bus patronage is given in Table 11. More than a third of all homes in the 12-town Springfield "transit service area" were located

TABLE 10

NUMBER OF TRIPS BY MODE AND AGE OF TRIP-MAKER
(Springfield Urbanized Area, 1964-65)

Mode of Travel	Age								
	5-15	16-19	20-29	30-39	40-49	50-59	60-69	Over 70	Total
				(a) Number Trips					
Car driver	—	36, 855	136, 395	173, 530	204, 590	126, 810	59, 065	18, 150	755, 395
Car, truck, taxi, pass.	88, 915	39, 430	39, 825	37, 065	48, 785	36, 600	21, 590	10, 665	322, 875
Public bus	5, 675	9, 195	4, 140	2, 605	6, 425	6, 310	5, 440	2, 800	42, 590
School bus	58, 625	17, 525	—	—	—	—	—	—	76, 150
All modes	153, 215	103, 005	180, 360	312, 200	259, 800	169, 720	86, 095	31, 615	1, 197, 010
				(b) Mode as Percent of Trips in Age Bracket					
Car driver	—	35. 8	75. 6	81. 4	78. 7	74. 6	68. 6	57. 4	63. 1
Car, truck, taxi, pass.	58. 0	38. 3	22. 1	17. 4	18. 8	21. 7	25. 1	33. 7	27. 0
Public bus	3. 7	8. 9	2. 3	1. 2	2. 5	3. 7	6. 3	8. 9	3. 6
School bus	38. 3	17. 0	—	—	—	—	—	—	6. 3
All modes	100. 0	100. 0	100. 0	100. 0	100. 0	100. 0	100. 0	100. 0	100. 0
				(c) Percent of Trips in Each Mode by Age of Trip-Makers					
Car driver	—	4. 9	18. 1	22. 9	27. 1	16. 8	7. 8	2. 4	100. 0
Car, truck, taxi, pass.	27. 5	12. 2	12. 4	11. 5	15. 1	11. 3	6. 7	3. 3	100. 0
Public bus	13. 3	21. 6	9. 7	6. 1	15. 1	14. 8	12. 8	6. 6	100. 0
School bus	77. 0	23. 0	—	—	—	—	—	—	—
All modes	12. 8	8. 6	15. 1	17. 8	21. 7	14. 2	7. 2	2. 6	100. 0

TABLE 11

HOUSEHOLDS USING BUS VS WALKING DISTANCE TO BUS ROUTE
(Springfield Urbanized Area, 1964-65)

Distance, Home to Bus Line	All Households at Distance	Make Only Bus Trips	All or Some Trips by Bus	Households, Make No Trips	
				Number	Have No Cars
(a) Number of Households					
0 ft- 200 ft	47, 317	1, 989	4, 915	9, 092	6, 790
200 ft- 400 ft	21, 595	1, 069	3, 513	4, 913	3, 585
400 ft- 800 ft	24, 162	1, 151	3, 396	5, 306	4, 084
800 ft-1, 500 ft	25, 008	697	2, 450	7, 888	6, 322
Over 1, 500 ft	17, 479	180	1, 139	2, 306	1, 501
Total	135, 561	5, 086	15, 413	29, 505	22, 282
(b) Percent of Households Use Bus Within Each Increment of Distance to Bus Route					
0 ft- 200 ft	100	4. 2	10. 4	19. 2	14. 4
200 ft- 400 ft	100	4. 9	16. 3	22. 8	16. 6
400 ft- 800 ft	100	4. 8	14. 1	22. 0	17. 0
800 ft-1, 500 ft	100	2. 8	9. 8	31. 6	25. 3
Over 1, 500 ft	100	1. 0	6. 5	13. 2	8. 6
Total	100	3. 7	11. 4	21. 8	16. 5
(c) Percent of Households Use Bus According to Walking Distance to Bus Route					
0 ft- 200 ft	34. 9	39. 2	31. 9	30. 8	30. 5
200 ft- 400 ft	15. 9	21. 0	22. 8	16. 7	16. 1
400 ft- 800 ft	17. 8	22. 6	22. 0	18. 0	18. 3
800 ft-1, 500 ft	18. 5	13. 7	15. 9	26. 7	28. 4
Over 1, 500 ft	12. 9	3. 5	7. 4	7. 8	6. 7
Total	100. 0	100. 0	100. 0	100. 0	100. 0

Note: Data are for all households in a 12-town "transit service area" centered in Springfield.

within 200 ft of a bus route, more than half within 400 ft of transit service; nearly 70 percent were closer than 800 ft. Of the 30 percent of all dwellings more than 800 ft from a local bus route, about two-fifths were beyond 1, 500 ft (more than a quarter of a mile from bus service).

Considering households which use only the bus, 39 percent were within 200 ft of a bus route, 60 percent within 400 ft, and 83 percent within 800 ft. Nearly all bus riders lived within 1, 500 ft of a bus route. (There is good correspondence between the distribution of dwelling units and bus travelers by distance from the bus line. The "index of concentration" between the percent of dwelling units, p_1, and the percent of people who make bus trips, p_2, was 85 percent. This index is defined as $100 - \frac{1}{2} \Sigma | p_1 - p_2 |$. Perfect concentration or correspondence would equal 100.)

Data were also examined to see if car ownership was a factor in determining the proportion of households which generated no trips at all. Households from which no trips were made accounted for 19 to 23 percent of all dwellings within 800 ft of a bus line and nearly a third of the homes at 800 to 1, 500 ft; only 13 percent of the homes located more than a quarter mile from the bus produced no travel.

TABLE 12

AVERAGE DAILY CHOICE AND CAPTIVE PUBLIC TRANSIT (BUS) TRIPS

Urbanized Area	All Transit Trips		Choice Trips		Captive Trips				
	Number	Percent of All Trips	Number	Percent of Bus	Number Potential Drivers	Percent of Bus	Number No Driver Potential	Percent of Bus	All Bus
Columbia, S. C.	14, 582	2. 5	630	4. 3	1, 190	8. 2	12, 762	87. 5	100. 0
Lehigh Valley, Pa.	22, 781	3. 3	2, 040	9. 0	2, 320	10. 2	18, 421	80. 8	100. 0
Richmond, Va.	80, 793	8. 3	7, 280	9. 0	7, 940	9. 8	65, 573	81. 2	100. 0
Springfield, Mass.	43, 396	3. 6	2, 600	6. 0	4, 825	11. 1	35, 971	82. 9	100. 0
Baltimore, Md.	332, 056	12. 8	24, 020	7. 2	26, 220	7. 9	281, 816	84. 9	100. 0

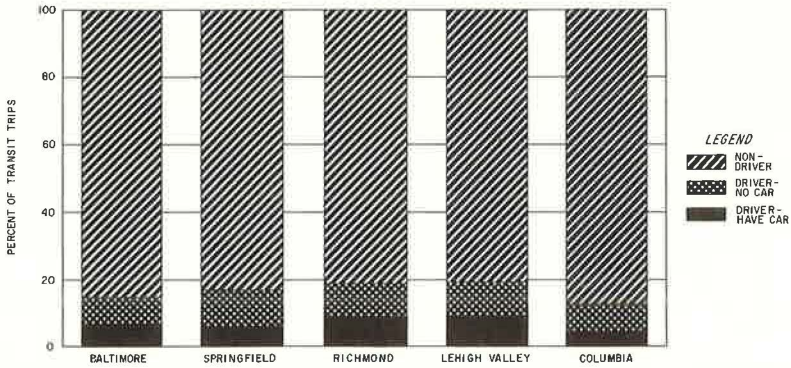


Figure 8. All bus transit trips classified as: captive (non-drivers and drivers without cars) and choice (licensed drivers with cars), five urbanized areas.

About three-quarters of the households which made no trips were without cars. This proportion ranged from 71 to 77 percent of the dwellings within 800 ft of a bus route, increased to 80 percent of those 800 to 1, 500 ft from bus service, and decreased to only 65 percent of those over a quarter of a mile away. Thus, areas over 1, 500 ft from bus routes contained the smallest proportion of homes which generated no trips, and households which made no trips at that distance were more likely to have a car than those closer to the bus route.

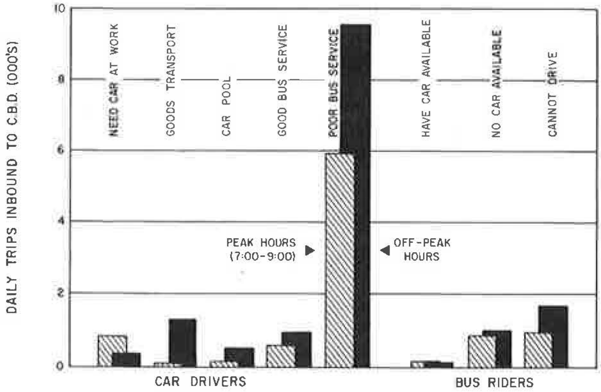
Choice and Captive Transit Riders—Efforts were made to class bus travelers as "choice" and "captive" in the study cities. The classification was based on stratification of origin-destination data according to car ownership and eligibility to drive. "Choice" transit riders were defined as those bus riders who (a) had a car available for use, and (b) had a driver's license. "Captive" riders included (a) those who were not licensed drivers, and (b) those potential drivers who were licensed but did not have a car available at the time of travel (Table 12, and Fig. 8). In this study, "choice" bus riders included only persons who drove a car to the bus line, then completed the trip by bus, or those bus riders whose car remained at place of residence during the entire time they were away from home.

Choice riders accounted for 9. 0 percent of all bus trips in the Richmond and Lehigh Valley areas, 7. 2 percent in Baltimore, 6. 0 percent in Springfield, and 4. 3 percent in Columbia. When related to overall person trips by all modes, however, choice bus riders accounted for a very small fraction of all urban trips, ranging from about 1. 0 percent of the trips in Baltimore to only one-tenth that proportion in Columbia. The proportion of choice riders in Baltimore appears to be less than that found by other investigations for cities of comparable size; this may be the result of different definitions of choice riders (10, 11).

The significance of city size is also apparent in Table 12. The Baltimore urbanized area, with a population equal to all four smaller cities, generated more than twice as many transit trips as the other four areas combined. Springfield and Richmond urbanized areas, at first glance, appear to be reversed in terms of transit travel, but about a third of the Springfield area population was oriented toward outlying town centers and had no direct transit service to Springfield. (Springfield is a polynucleated urban region.) Richmond, therefore, had a larger service area and, by virtue of a more concentrated business center, supported a much larger transit operation.

Those persons who chose to ride the bus in place of the car available to them, definitely exhibit characteristics and behavior patterns which differ in some degree from other bus riders. In Richmond, for example:

1. More than half of the choice riders had a car available for their exclusive use. (Either the bus rider was the only household member with a driver's license, or there were as many cars in the household as persons eligible to drive.)



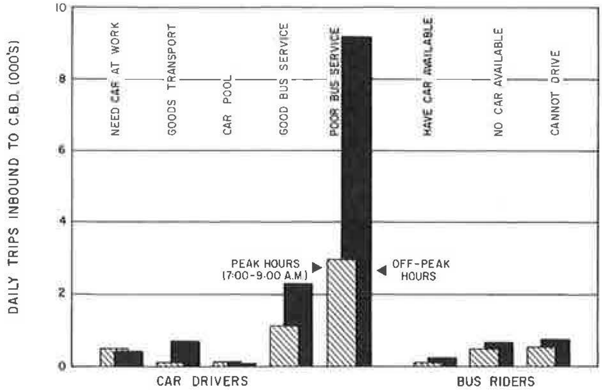


Figure 9. Attitudes of persons traveling to CBD: drivers—need for car and availability of bus; bus riders—car availability and eligibility to drive. (a) Springfield urbanized area, 1964-65, and (b) Allentown CBD - Lehigh Valley urbanized area, 1964-65.

2. About one-fifth of the choice riders were "park and ride" patrons; i. e., they drove to bus stops and parked, continuing their trips on the bus. (The proportion of park and ride trips was much less in Baltimore and other study areas than in the Richmond area, suggesting that there may have been special aspects of the bus service in Richmond which had a positive influence on choice riding.)

3. More than 80 percent of the choice bus riders were from households of middle and upper incomes. (Only 18 percent of the choice riders were generated in the third of households with incomes under $5, 000.)

4. More than 90 percent of the choice bus riders were engaged in travel to work, whereas 48 percent of the captive riders were traveling to or from nonwork activities.

5. Nearly two-thirds of all bus riders in Richmond were women, and this proportion holds true for both choice and captive trips. In car-owning households, the disproportionate number of women using the bus was not a matter of the male head-of-household preempting the family car. The ratio of men to women was virtually the same among choice riders, whether they came from households where cars equaled the number of licensed drivers, or from households where there were fewer cars than qualified drivers.

To summarize, the use of buses in the study areas was largely by persons who had no ready alternative. Of those who appeared to have made a choice (a car was at home during the time they were away), there is strong likelihood that some, perhaps most, did not really have access to a private vehicle; although they were qualified to drive, the car was not theirs, it was not in operable condition, or they did not have permission to use it. This is especially probable of the junior members of households.

The aparent conclusion, then, is that the quality of bus transit available in the study cities was relatively unattractive when compared with the car so that most who used it were captive to it. The clearly defined exceptions were few (213 actual trip reports in the 5 percent sample of dwelling units in Richmond, made by about half that many different persons from households with as many cars as licensed drivers), making it difficult to derive a meaningful service-responsive formula for computing choice of mode between alternative forms of transport in these cities.

Attitudes Toward Bus Use—The validity of this assertion was confirmed in an independent analysis of questions directed to respondents in home interviews concerning the availability of alternatives to the modes used in travel, whether performed in car or bus.

Results of attitude studies in the Springfield, Massachusetts, and Lehigh Valley (Allentown), Pennsylvania, areas are shown in Figure 9. In both areas, respondents expressed similar attitudes. Most respondents preferred to drive; however, a small number of transit riders preferred the bus to the car. Data for Springfield are based on over 1,000 direct-interview trip reports relating to trips which had Springfield CBD destinations. Data for Allentown are based on about 2,000 trip reports.

In both Springfield and Allentown, the majority of drivers reported that bus service was not frequent enough to suit their purposes, especially during off-peak hours. Many drivers admitted they could have used the bus and had no special need for their cars other than for the trip from home and return, which may be interpreted as a negative attitude toward the bus. This attitude was most evident in the large proportion of drivers (78 percent of CBD drivers in Springfield, 69 percent in Allentown) who regarded bus service as "infrequent or lacking" when confronted with present transit service levels.

Most of these drivers originated within 15 min driving time of Springfield CBD and 10 min of Allentown CBD. These central areas were the focus of transit service in both communities. Thus, it seems likely that factors other than transit service frequency also discouraged bus patronage. Some of the drivers lived a considerable distance from the bus route, and this probably affected their choice.

The attitude studies suggest that those persons who traveled to the CBD as drivers did not prefer to use bus transit as it existed at the time of the surveys. These findings reflect attitudes in middle-sized urban areas without major problems of street congestion to delay the car, and no separate rights-of-way which might permit transit to provide a rapid service. Under the circumstances, these attitudes are probably typical of inhabitants in similarly sized urbanized areas throughout the country.

SOME IMPLICATIONS FOR MAXIMIZING BUS TRANSIT POTENTIALS

The purpose of the study has been to identify some of the potentials for bus transport in medium-sized American cities in terms of today's travel market. Within this context, wherein lies the significance of the analyses?

The following implications arise from the work done to date:

1. In the lower range of middle-sized cities (under 250,000 population), increases in transit usage on approaches to the CBD would have relatively small effects on reducing peak-hour highway lane requirements.
2. In cities near the upper limit of the size range (750,000 to 1,000,000 population), street and highway improvements might be substantially reduced by retaining and increasing bus transit patronage. Corridors of travel are typically near vehicle saturation levels on the CBD approaches and relatively small increments of vehicular traffic can make the difference between congestion and free-flow at periods of peak travel demand.
3. Improvements in income or mobility levels tend to increase trip-making within the urbanized area. If this mobility increase could be achieved through improvements in public transport operations, it might afford a substantial new market for transit patronage. It is even conceivable that new travel might exceed diversion from automobile travel. Most of the added travel would be for nonwork purposes at off-peak hours.

4. Some of the benefits that might result from improved transit would be increased mobility for underprivileged or deprived strata of the population. These potentials may possibly exceed those resulting from relief to highways. A revitalized bus transit service might also relieve drivers of trips which are primarily motivated to accommodate non-drivers. In all of the study areas, large numbers of auto driver trips were made to "serve-passenger" rather than to attend to an activity of the driver. Such trips ranged from 18 to 23 percent of the driver trips in all urbanized areas except Richmond. In Richmond, "serve-passengers" accounted for less than 11 percent of the drivers in the Richmond urbanized area (and resulted in higher percentages of trips for other purposes). This difference probably relates to the high level of transit use in the Richmond area.

5. Most transit riding in small- and medium-sized cities is performed by people who are essentially "captive" to this mode. Studies related to the attitudes of persons who use their cars rather than the bus, when they have a choice, show that bus service is not as satisfactory as the car in the opinion of trip-makers in the areas chosen for study. This does not mean that public transit cannot be an attractive and preferred mode of travel, but simply that it does not now present this appearance.

6. Stated in other terms, conventional transit media have difficulty competing with the car when travel by bus requires substantially more time. To achieve gains in transit riding, it is likely that new concepts in transit will be required. These may involve more extensive use of jitney services as well as consolidation of public bus, school bus, and taxi operations.

7. In larger cities, where transit seems to have potential for substantial peak-hour capacity relief, further attention might be given to improved line-haul and downtown distribution facilities (viz. central-area bus subways or transitways through urban renewal projects).

REFERENCES

1. Penn-Jersey Transportation Study, Volume 2, U. S. Dept. of Commerce, pp. 34-36, Sept. 1964.
2. Transportation and Parking for Tomorrow's Cities. Wilbur Smith and Associates, 1966.
3. 1960 Honolulu Metropolitan Area Traffic Survey. Volume 1, Historical Data and the Design of the Study. State of Hawaii and U. S. Dept. of Commerce, Sept. 1962.
4. Mass Transportation Survey, National Capital Region, 1958: Traffic Engineering Study. Wilbur Smith and Associates, Jan. 1959.
5. Highway Capacity Manual, 1965. HRB Spec. Rept. 87, 1965.
6. Wynn, F. Houston. Studies of Trip Generation in the Nation's Capital, 1956-58. HRB Bull. 230, pp. 1-52, 1959.
7. Detroit Metropolitan Area Traffic Study: Part I, Data Summaries and Interpretations, July 1955; Part II, Future Traffic and a Long-Range Expressway Plan, March 1956.
8. Chicago Area Transportation Study: Volume I. Survey Findings, December 1959; Volume II, Data Projections, July 1960; Volume III, Transportation Plan, April 1962.
9. Pittsburgh Area Transportation Study: Volume I, Study Findings, November 1961; Volume II, Forecasts and Plans, February 1963.
10. Land Use—Transportation Study: Volume I, Inventory Findings, 1963. Southeastern Wisconsin Regional Planning Commission, May 1965.
11. Keefer, Louis E. Characteristics of Captive and Choice Transit Trips in the Pittsburgh Metropolitan Area. HRB Bull. 347, pp. 24-33, 1962.

Appendix A

TRIP GENERATION RATES RELATED TO FAMILY SIZE, NUMBER OF WORKERS AND CAR OWNERSHIP
(Springfield Urbanized Area, 1964-65)

No. of Persons	No. of Workers		No. of Cars		
			0	1	2+
1	0	Trips	10, 886	10, 702	–
		Households	13, 550	3, 734	–
		Trips/households	0. 80	2. 87	
		Trips/persons	0. 80	2. 87	
1	1	Trips	7, 021	23, 502	–
		Households	6, 505	6, 868	–
		Trips/households	1. 08	3. 43	
		Trips/persons	1. 08	3. 43	
2	0	Trips	7, 659	30, 706	1, 873
		Households	7, 825	7, 137	299
		Trips/households	0. 98	4. 30	6. 26
		Trips/persons	0. 49	2. 15	3. 13
2	1	Trips	6, 753	74, 067	21, 601
		Households	3, 219	13, 242	2, 831
		Trips/households	2. 10	5. 63	7. 64
		Trips/persons	1. 05	2. 81	3. 82
2	2	Trips	1, 723	59, 668	24, 911
		Households	621	8, 012	3, 086
		Trips/households	2. 77	7. 46	8. 08
		Trips/persons	1. 39	3. 72	4. 04
3	0	Trips	1, 566	7, 066	472
		Households	864	1, 192	78
		Trips/households	1. 81	5. 93	6. 05
		Trips/persons	0. 60	1. 98	2. 02
3	1	Trips	3, 952	68, 083	26, 803
		Households	1, 166	9, 746	2, 851
		Trips/households	3. 39	7. 00	9. 40
		Trips/persons	1. 13	2. 33	3. 13
3	2+	Trips	3, 010	53, 328	40, 712
		Households	691	5, 818	4, 185
		Trips/households	4. 36	9. 15	9. 73
		Trips/persons	1. 45	3. 05	3. 24
4	0	Trips	1, 772	2, 820	552
		Households	772	426	72
		Trips/households	2. 30	6. 61	7. 67
		Trips/persons	0. 58	1. 65	1. 92
4	1	Trips	3, 513	88, 668	43, 394
		Households	885	10, 566	3, 450
		Trips/households	3. 97	8. 40	12. 57
		Trips/persons	0. 99	2. 10	3. 14
4	2+	Trips	2, 268	46, 826	52, 333
		Households	447	4, 235	3, 608
		Trips/households	5. 07	11. 06	14. 50
		Trips/persons	1. 27	2. 77	3. 63
5+	0	Trips	4, 274	7, 861	918
		Households	785	689	86
		Trips/households	5. 45	11. 40	10. 68
	(Avg. = 6 Pers.)	Trips/persons	0. 91	1. 90	1. 78
5+	1	Trips	6, 270	183, 873	74, 366
		Households	1, 461	17, 131	4, 620
		Trips/households	4, 30	10. 73	16. 10
	(Avg. = 6 Pers.)	Trips/persons	0. 72	1. 80	2. 68
5+	2+	Trips	1, 487	62, 215	51, 180
		Households	305	4, 803	3, 400
		Trips/households	4. 88	12. 94	15. 05
	(Avg. = 6 Pers.)	Trips/persons	0. 81	2. 16	2. 51

Appendix B

ESTIMATES OF "OPTIMUM" AND "MAXIMUM" TRIP GENERATION

BALTIMORE URBANIZED AREA
(O-D Survey, 1961-62)

No. of Persons	No. of Workers	Actual Trips	No. of Households	Optimum Trips[a]	
				Trip Rate	No. Trips
1	0	20, 240	30, 381	2. 0	60, 762
1	1	67, 531	31, 531	3. 0	94, 593
2	0	40, 381	24, 605	4. 0	98, 420
2	1	245, 176	63, 702	6. 0	283, 212
2	2	203, 567	37, 704	6. 5	243, 126
3	0	13, 892	6, 093	6. 0	36, 558
3	1	265, 405	49, 258	8. 0	394, 064
3	2	194, 881	29, 604	8. 5	250, 634
3	3	42, 436	5, 687	9. 0	51, 183
4	0	7, 596	3, 577	6. 0	21, 462
4	1	330, 675	49, 058	9. 0	441, 523
4	2	178, 370	22, 532	9. 5	214, 054
4	3	52, 915	5, 898	10. 0	58, 980
4	4	9, 742	1, 091	10. 5	11, 456
5	0	13, 439	5, 378	8. 0	43, 024
5	1	458, 197	62, 913	11. 0	692, 043
5	2	230, 893	27, 352	11. 5	314, 548
5	3	96, 233	9, 889	12. 0	118, 668
5	4	29, 575	2, 678	12. 5	33, 475
5	5	8, 223	726	13. 5	9, 801
Total		2, 509, 002	469, 357		3, 603, 042

[a]Detailed estimates of maximum trips not made for Baltimore, since income data were not collected in the O-D Survey.

SPRINGFIELD URBANIZED AREA
(O-D Survey, 1964-65)

No. of Persons	No. of Workers	Actual Trips	No. of Households	Optimum Trips		Maximum Trips	
				Trip Rate	No. Trips	Trip Rate	No. Trips
1	0	21, 588	17, 284	3. 0	51, 852.	3. 65	63, 087
1	1	30, 543	13, 373	4. 0	53, 492	5. 2	69, 540
2	0	40, 238	15, 261	6. 0	91, 566	7. 0	106, 827
2	1	102, 421	19, 292	8. 0	154, 336	8. 25	159, 159
2	2	86, 302	11, 719	8. 5	99, 612	9. 5	111, 331
3	0	9, 104	2, 134	6. 5	13, 871	8. 0	17, 072
3	1	98, 838	13, 763	10. 0	137, 630	14. 0	192, 682
3	2	97, 050	10, 694	10. 0	106, 940	11. 2	119, 773
4	0	5, 144	1, 270	8. 3	10, 541	8. 3	10, 541
4	1	135, 575	14, 901	12. 3	183, 282	13. 0	193, 713
4	2	101, 427	8, 290	14. 7	121, 863	15. 8	130, 982
5	0	13, 053	1, 560	12. 5	19, 500	13. 5	21, 060
5	1	264, 509	23, 212	16. 0	371, 392	17. 5	406, 210
5	2	114, 882	8, 508	17. 0	145, 136	18. 0	153, 144
Total		1, 120, 674	161, 251		1, 561, 013		1, 755, 121

RICHMOND URBANIZED AREA
(O-D Survey, 1964-65)

No. of Persons	No. of Workers	Actual Trips	No. of Households	Optimum Trips		Maximum Trips	
				Trip Rate	No. Trips	Trip Rate	No. Trips
1	0	8, 613	5, 732	3. 0	17, 196	4. 0	22, 928
1	1	24, 553	7, 722	4. 0	30, 888	6. 0	46, 332
2	0	21, 879	7, 721	6. 0	46, 326	6. 0	46, 326
2	1	83, 943	16, 142	7. 0	112, 994	7. 75	125, 100
2	2	102, 743	14, 363	8. 0	114, 904	9. 0	129, 267
3	0	5, 662	1, 398	9. 0	12, 582	10. 0	13, 980
3	1	92, 231	12, 939	10. 5	135, 860	11. 25	145, 564
3	2	87, 442	9, 804	10. 5	102, 942	11. 50	112, 746
3	3	18, 667	1, 704	12. 0	20, 448	12. 25	20, 874
4	0	3, 723	460	11. 5	5, 290	13. 5	6, 210
4	1	121, 053	12, 378	13. 5	167, 103	14. 25	176, 387
4	2	81, 452	7, 469	14. 0	104, 566	14. 50	108, 300
4	3	29, 473	2, 549	16. 0	40, 784	17. 0	43, 333
5	0	2, 501	480	14. 0	6, 720	15. 0	7, 200
5	1	86, 496	7, 977	16. 5	131, 621	16. 7	133, 216
5	2	42, 462	3, 563	17. 5	62, 353	18. 0	64, 134
5	3	16, 131	1, 285	18. 0	23, 130	18. 5	23, 772
6	0	886	213	15. 0	3, 195	16. 0	3, 408
6	1	42, 132	3, 856	18. 0	69, 408	19. 0	73, 264
6	2	20, 257	1, 747	20. 0	34, 940	21. 0	36, 687
6	3	10, 316	835	24. 0	20, 040	25. 0	20, 875
7	0	1, 316	272	17. 75	4, 828	18. 5	5, 032
7	1	22, 451	2, 335	20. 5	47, 867	21. 0	49, 035
7	2	17, 485	1, 489	25. 5	37, 970	26. 0	38, 714
7	3	12, 020	999	32. 0	31, 968	33. 0	32, 967
Total		954, 432	125, 432		1, 385, 923		1, 485, 651

COLUMBIA URBANIZED AREA
(O-D Survey, 1964-65)

No. of Persons	No. of Workers	Actual Trips	No. of Households	Optimum Trips		Maximum Trips	
				Trip Rate	No. Trips	Trip Rate	No. Trips
1	0	12, 417	8, 389	3. 0	25, 167	4. 0	33, 556
1	1	14, 070	3, 627	5. 0	18, 135	6. 0	21, 762
2	0	12, 713	2, 601	8. 0	20, 808	9. 0	23, 409
2	1	49, 802	6, 727	9. 0	60, 543	10. 5	70, 634
2	2	46, 524	5, 114	10. 0	51, 140	12. 0	61, 362
3	0	5, 582	1, 089	12. 0	13, 068	14. 0	15, 246
3	1	56, 267	5, 743	12. 75	73, 223	15. 5	89, 017
3	2	51, 980	4, 402	13. 50	59, 427	16. 0	70, 432
3	3	9, 668	770	15. 00	11, 550	16. 5	12, 705
4	0	2, 099	336	15. 00	5, 040	16. 0	5, 376
4	1	65, 189	5, 175	16. 75	86, 681	18. 0	93, 150
4	2	54, 245	3, 641	17. 50	63, 718	19. 0	69, 179
4	3	11, 567	777	19. 0	14, 763	19. 5	15, 151
5	0	1, 931	258	16. 00	4, 128	17. 0	4, 386
5	1	51, 632	3, 606	20. 75	74, 825	22. 0	79, 332
5	2	22, 309	2, 241	21. 50	48, 181	22. 0	49, 302
5	3	10, 343	582	23. 00	13, 386	24. 0	13, 968
6	0	2, 496	346	22. 00	7, 612	22. 0	7, 612
6	1	41, 629	3, 075	24. 75	76, 106	25. 5	78, 413
6	2	30, 799	2, 146	25. 50	54, 723	26. 5	56, 869
6	3	14, 623	1, 066	27. 00	28, 782	28. 5	30, 381
Total		567, 885	61, 711		811, 006		901, 248