Factors Affecting Trip Generation of Residential Land-Use Areas

GORDON B. SHARPE, WALTER G. HANSEN, and LAMELLE B. HAMNER,
Division of Highway Transport Research, Bureau of Public Roads

The present and potential trip-generating power of urban residential areas can be estimated with a reasonable degree of accuracy, dependent upon the availability and reliability of certain related information.

The major factors affecting trips by residents of an area are population and automobile ownership. With data normally developed from a home-interview-type origin and destination survey it is possible either to up-date the resident trip information or, with slightly less reliability, to forecast the trips for some future date.

It was found that the total number of trip ends in a residential area is approximately equal to the number of trips made by residents of that area between all origins and destinations. Therefore, any methods for estimating residents trips are equally applicable to estimates of total trip ends on residential land. As a corollary, the number of trips to non-residential land in an urban area can be estimated if the number of trips made by residents of the entire urban area is known.

Generally, about 80 percent of all trips made by residents of a residential area begin or end at home. Also approximately 80 percent of the total trip ends on residential land, by residents and non-residents, are "home" oriented. These proportions are greater in areas where car ownership and economic status are lower, and where population density is higher. They do not vary appreciably with distance from the central business district.

These findings are all based upon analyses of data from the two home-interview-type origin and destination traffic surveys made in the Washington, D.C., metropolitan area in 1948 and 1955. All of the results pertain to the Washington area during the time interval studied, but it may reasonably be assumed that certain aspects of the findings and methodology will be applicable elsewhere.

●COMPREHENSIVE home-interview origin and destination studies have been made in well over 100 metropolitan areas. The existing pattern of travel by different means of transportation in these areas has been developed with considerable accuracy. This information has been invaluable in determining the present need for highways and transit facilities but, in itself, does not give the answer to future needs, which must be the basis for intelligent planning.

One of the basic keys to forecasting future transportation needs is the establishment of the relationships between travel and the type, intensity, and interrelationship of land uses. When these relationships have been established and trends observed, it will be possible to determine more accurately in advance the transportation needs that will exist when anticipated urban development has taken place.

Data from a number of surveys have been analyzed to develop factors for estimating the number of trips attracted to and generated by land-use developments of different kinds, size, and intensity. These related to specific places and times. Information on trends is comparatively meager, repeat studies having been completed in only a very few of the metropolitan areas. It has not, therefore, been possible to establish relations which will permit the accurate pre-determination of the number of trip ends to be expected in different areas under conditions anticipated for some time in the future, these being dependent upon the stability of a number of factors.

In 1948 a home-interview type of origin and destination survey was in the Washington, D.C., area. A repeat study was made in 1955. In the earlier survey a 5 percent

sample was obtained by interviewing the residents of one of every 20 dwelling units. In the latter survey, the sample rate was 1 in 30 in the District of Columbia and 1 in 10 in the Maryland and Virginia suburban areas. These two surveys give a basis for a study of factors and trends relating to urban travel habits, and several research projects have been carried out with this objective.

This paper is concerned with the evaluation of methods for estimating the potential generation and production of person trips in urban residential developments. Another paper entitled "Evaluating Trip Forecasting Methods with an Electronic Computer" by Brokke and Mertz of the Bureau of Public Roads is concerned with the evaluation of methods of estimating the distribution of zone-to-zone trip movements resulting from zone growth.

There are many factors, other than size, that could be expected to affect the potential generation and production of person trips in urban residential developments. This report presents the results of an analysis of the effect that differences in population, car ownership, income per household, distance from the central business district, and population per net residential acre had on the number of person trips attracted to and generated by residential land. These factors were selected because it has been possible to establish measures that are free from personal bias and because it seems that they constitute a logical premise on which to begin an analysis of total trips generated by residential land-use areas.

Because the summarization of the 1955 data has not progressed far enough to permit a study by mode of travel, the current analysis is confined to total person trips by all modes of travel to and from residential land. It does not include pedestrian trips or trips by taxi and truck operators in the course of their daily work.

SOURCES OF INFORMATION

The trip data obtained from the Washington transportation surveys of 1948 and 1955 reflect total person trips for an average weekday of the respective survey periods. Data on population, car ownership, and distance from the central business district were also obtained from these surveys. The 1955 income information was obtained from the National Capital Regional Planning Council.

Residential acreage figures were developed jointly by the staffs of the Washington Metropolitan Area Transportation Study which made the 1955 survey and the National Capital Regional Planning Council. The figures developed were net residential acres. Streets and all non-residential land uses were excluded.

This report combines the results of a number of studies based upon travel data obtained from the two Washington transportation surveys. The basic data were summarized by groupings best suited for the objectives under consideration. For example, one very limited study utilized data for only 10 residential areas. A subsequent study was confined to the District of Columbia for which data on family income and population density were available by census tracts. Another study was based, in part, on the analysis of 118 subzones throughout the survey area that could be classed as purely residential and, in part, on 77 of the 118 subzones grouped into 48 residential areas each of which had 1,000 or more trip origins. Tests were also made using 56 of the 118 subzones grouped into 35 residential areas each of which had 2,000 or more trip origins. Finally, an analysis was made of trips by the residents of 200 zones selected so that data from the surveys would be comparable. These zones contained 96 percent of the population resident within the 1948 traffic study cordon and 93 percent of the persons living within the 1955 cordon.

FINDINGS

"Home" Trips as a Measure of Total Trip Ends on Residential Land

Any study of residential land-use trip generation must take into account the number of trip origins and trip destinations (trip ends) in a particular residential area, and the number of trips made by the residents of that area (trip production).

The present study of residential land-use trip generation and residents trip produc-

TABLE 1

RESIDENTS AVERAGE WEEKDAY TRIPS—WASHINGTON, D C , METROPOLITAN AREA, 1948

Residential Areas Studied	1 Massachusetts Avenue Park, D C	2 Wesley Heights and Spring Valley, D C	3 American University Park, D C	4 Beverly Hills, Braddock Heights, and Del Ray, Va	5 Fairlington and Parkfairfax, Va	6 Brightwood Area, D C	7 U. S. Soldiers' Home Area, D C	8 Shirley Homes, Va	9 Central City Area, D C	10 Southwest Area, D C		
Location												
Travel distance from CBD, mi	3 29	5 29	5 71	7 43	6 86	5 29	2 71	5 71	1 14	1 14		
1950 average peak-hour driving time from CBD, min	12	16	18	17	15	18	12	13	6	7		
Residential Area Characteristics												
Predominant residence type	Single family detached	Single family detached	Single family detached [b]	Single family detached [b]	Garden type apartments	Two-family semi-detached and apartments	Multi-family apartments and row houses	Government low rent row houses [b]	Row houses	Single family detached and row houses	Totals Selected areas	Totals Metropolitan area
Economic class [a]	Very high	Very high and upper high	High	Above average	Above average	Above average	Below average	Below average	Below average	Low and very low		
Dwelling units	158	712	2,375	1 426	4,826	2,497	2,101	1,352	3,270	6,596	25,313	336,181
Passenger cars owned	180	1,201	2,039	1,447	3,833	2 209	1,404	686	582	1,975	15,556	203,464
Population	518	2,896	7,975	5,176	15,658	9,354	6,913	4,805	10,977	28,657	92,929	1,109,860
Persons per dwelling unit	3 28	4 07	3 36	3 63	3 24	3 75	3 29	3 55	3 36	4 34	3 67	3 30
Passenger cars owned per dwelling unit	1 14	1 69	0 86	1 01	0 79	0 88	0 67	0 51	0 18	0 30	0 61	0 61
Auto driver trips per passenger car	2 55	3 83	4 20	4 84	4 63	3 77	2 67	4 21	1 95	1 98	3 75	3 10
Residents Trips per Dwelling Unit by Purpose—All Destinations—All Modes												
Work	1 02	2 42	1 32	1 49	1 36	1 95	1 62	1 06	1 23	1 21	1 40	1 32
Business	0 87	0 51	0 55	0 33	0 12	0 30	0 14	0 08	0 16	0 14	0 22	0 20
Medical and dental	-	0 07	0 06	0 03	0 10	0 06	0 09	0 03	0 04	0 03	0 06	0 05
School	0 15	0 36	0 25	0 34	0 33	0 24	0 12	0 09	0 03	0 08	0 17	0 12
Social and recreation	0 58	1 98	1 48	0 99	1 00	0 91	0 53	0 74	0 17	0 22	0 70	0 62
Change travel mode	0. 58	0 20	0 08	0 11	0 09	0 15	0 01	0 06	0 01	0 003	0 06	0 07
Eat meal	0 15	0 48	0 13	0 13	0 15	0. 18	0 10	0 11	0. 01	0 02	0 10	0 09
Shop	0 58	0 82	0 75	0 93	0 90	0. 80	0 28	0 63	0 08	0 11	0 50	0 33
Serve passenger	0 30	0 58	0 48	0 96	0 52	0 29	0 11	0 31	0 01	0 02	0 28	0 19
Home	2. 17	4 60	3 23	3 31	2 97	2 75	2 45	2 12	1 54	1 59	2. 40	2 13
Total trips	6 40	12 02	8 33	8 62	7 54	7 63	5. 45	5 23	3 28	3 43	5 89	5 12
Residents Trips per Dwelling Unit by Mode of Travel—All Destinations												
Auto driver	2 90	6 45	3 60	4 91	3 68	3 34	1. 78	2 14	0 35	0 59	2 31	1. 88
Auto and taxi passenger	1 75	3 36	2 89	2 25	2 22	1 57	1 11	1 52	0 47	0 40	1 42	1 22
Total auto trips	4 65	9. 81	6. 49	7 16	5 90	4. 91	2 89	3 66	0 82	0 99	3 73	3 10
Mass transit	1 75	2. 21	1 84	1 46	1 64	2 72	2 56	1 57	2 46	2 44	2 16	2 02

Economic Class [a]	1949 Estimated Income
Very high	$10,200 and over
Upper high	8,500 - 10,199
High	6,800 - 8,499
Above average	5,100 - 6,799
Below average	3,825 - 5,099
Low	2,550 - 3,824
Very low	Under 2,550

[a] Source for District of Columbia Subdivisions Economic Development Department, Washington, D C , Board of Trade, June 1954 Virginia Subdivisions (4, 5, and 8) estimated on the basis of comparable rentals, housing values, and income, reported by 1950 Census of Population and Housing

[b] Includes small number of apartment units

tion was started several years ago with an analysis of relationships of residents trips and other factors in 10 areas of varying type and income, utilizing data from the 1948 Washington transportation survey and other sources (Table 1). It was initially apparent from the developed data that residents trip production generally increased with income, except for the highest income area. It was equally apparent that the number of residents total trips varied directly with the number of passenger cars owned per dwelling unit.

To establish the degree of reliability of these findings and to evaluate the contributing influence of these and other variables on residents trip production, a series of statistical analyses was undertaken, based on 95 census tracts in Washington, D.C. The results of these studies were valuable in that they established statistically the possibility of estimating with a relatively high degree of reliability residents daily trip production.

One of the most important by-products of the analysis of the 10 residential areas was the apparent value of the study as a means of estimating traffic growth for urban redevelopment projects. For example, Area 10, the southwest area of Washington, is such an urban redevelopment area. Redevelopment plans call for the construction of apartments and row houses in the residential portion of the area. If it is assumed that data developed for Area 7, an apartment and row house area, would be representative of the redevelopment area when completed, then auto trips per dwelling unit will increase three times, while transit travel will remain relatively constant. This general method of estimating trips to a given land use should be of value, particularly to the planning and design of redevelopment projects as related to improved highway facilities.

TABLE 2

BASIC DATA FOR 118 SELECTED RESIDENTIAL SUBZONES IN THE 1955 WASHINGTON, D.C., SURVEY AREA, GROUPED BY RINGS

Rings[a]	Number of							
	Subzones	Interviews	Persons	Dwelling Units	Cars	Net Residential Acres	Residents Trips[b]	Cars per 100 Persons
2	2	46	4,689	1,820	1,182	9.5	7,574	25.2
3	3	42	4,603	1,602	881	141.8	6,853	19.1
4	16	282	17,987	6,412	5,251	487.4	32,988	29.2
5	30	379	27,014	8,817	9,305	956.3	56,973	34.4
6	25	348	18,584	5,742	6,480	782.5	39,636	34.9
7	16	454	17,735	5,190	6,242	1,041.2	39,481	35.2
8	12	279	10,727	3,007	3,657	536.8	23,386	34.1
9	12	229	9,407	2,527	3,278	1,259.2	20,793	34.8
10	2	68	3,086	798	962	215.9	6,185	31.2
Total	118	2,127	113,832	35,915	37,238	5,430.6	233,869	32.7

[a] Distance of residence from the central business district (mi). None of the selected subzones were in Rings 1, 11, 12, or 13.
[b] On an average weekday in 1955.

TABLE 3

EFFECT OF DISTANCE FROM THE CENTRAL BUSINESS DISTRICT ON THE "FROM" PURPOSE DISTRIBUTION OF PERSON TRIPS ORIGINATING ON RESIDENTIAL LAND IN THE WASHINGTON, D.C., SURVEY AREA ON AN AVERAGE WEEKDAY IN 1955[a]

Rings[b]	Distribution of Trips from[c]							
	Work (percent)	Personal Business (percent)	Serve Passenger (percent)	Change Mode of Travel (percent)	Social and Recreation (percent)	Medical, Dental, and Eat (percent)	Home (percent)	Total Number of Trips (= 100 percent)
2	2.2	1.0	2.6	0.7	5.4	-	88.1	3,672
3	4.5	4.2	2.1	-	1.5	-	87.7	3,610
4	8.2	2.0	4.4	0.5	4.8	0.6	79.5	16,598
5	4.5	2.0	5.0	0.3	7.5	0.7	80.0	28,076
6	5.8	1.3	4.7	1.5	4.6	1.3	80.8	19,684
7	4.8	2.7	4.7	0.7	5.4	0.8	80.9	18,854
8	3.8	2.0	5.3	1.0	4.8	0.3	82.8	11,263
9	5.6	2.4	4.4	0.4	5.3	0.3	81.6	9,812
10	2.8	3.9	6.1	-	0.5	0.9	85.8	2,550
Total	5.2	2.1	4.7	0.7	5.4	0.7	81.2	114,119

[a] Based on study of 118 selected residential subzones.
[b] Distance of residence from central business district (mi). None of the selected subzones were in Rings 1, 11, 12, or 13.
[c] Trips from shopping and school were not included, because they were probably the result of small amounts of non-residential land use.

The 10-area study provided an insight into residents total trip production, but as most of the areas studied included other than residential land uses, it was not possible from available data to determine definitely the actual trip generation of the residential land.

To provide accurate data for such an analysis, 118 purely residential subzones (unless otherwise specified, all subsequent references to residential areas refer to areas entirely residential) of the 1955 Washington transportation survey were selected. These subzones represented 7.6 percent of the total number of subzones in the survey area, and 113,832 persons, or 7.2 percent of the total area population, lived in these subzones. The basic data, including trip information, for these residential subzones were summarized by annular areas (rings) at varying distance from the central business district (Table 2).

In the home-interview surveys, trip purpose was designated as purpose "from" and purpose "to"; for example, from home to work and from work to shopping. For trips having one end in a given area, the number "from" a specific purpose generally equals the number "to" that purpose. For example, for each trip to work at a specific location, there is a corresponding trip from work. Correspondingly, there would be an equal number of trips "to home" as "from home" in the 118 residential subzones studied.

The average percentage trip-purpose distribution as affected by distance from the central business district is shown in Table 3. Trips from home constituted 81.2 percent of all the person trips with origins in the studied subzones, and consequently "home oriented" trips constituted the same percentage of all trips beginning and ending in these residential subzones. (From a study of trips to 210 residential blocks in the Detroit, Mich., area, it was found that 73.3 percent of the incoming trips were to home. From a study of trips to 35 residential zones in the 1948 Washington, D.C., survey area, it was found that 80 percent of all incoming trips were to home.) This is an average figure and does not reflect any variations which might be due to economic, geographic, and demographic factors.

The data in Table 3 also show that the percentage of trips which originated within these residential subzones "from home" did not vary appreciably as distance from the central business district increased. The higher percentage of "from home" trips shown for Rings 2, 3, and 10, compared to the other rings, may not be significant, as the number of interviews in these rings was comparatively small (Table 2). This variation from the pattern is reflected in the instability of trip purpose in these rings.

As distance from the central business district was not an influencing factor in the

TABLE 4

EFFECT OF FAMILY INCOME ON THE PURPOSE DISTRIBUTION OF PERSON TRIPS ORIGINATING ON RESIDENTIAL LAND IN THE WASHINGTON, D.C., SURVEY AREA ON AN AVERAGE WEEKDAY IN 1955[a]

Income Group[b]	Distribution of Trips from							
	Work (percent)	Personal Business (percent)	Serve Passenger (percent)	Change Mode of Travel (percent)	Social and Recreation (percent)	Medical, Dental, and Eat (percent)	Home (percent)	Number of Trips (= 100 percent)
2	2.5	-	-	-	7.5	-	90.0	2,040
3	4.6	1.7	4.5	0.5	4.5	0.6	83.6	39,560
4	4.5	2.7	4.0	0.8	5.5	0.6	81.9	43,671
5	7.4	1.9	6.3	0.8	6.1	1.1	76.4	28,848
Total	5.2	2.1	4.7	0.7	5.4	0.7	81.2	114,119

[a] Based on study of 118 selected residential subzones.

[b] The assignment of an income group rating to each area was made by the National Capital Regional Planning Council. The assignment was based on an analysis of average (median) family incomes which were developed for each area with the aid of local planning commissions, using 1950 census data and income statistics reported by the Washington Evening Star Consumer Survey of 1955-1956. The groups are as follows:

Income Group	1955 Family Income
1	$ 1 - 2,499 (None of the selected subzones were in this group.)
2	2,500 - 4,499
3	4,500 - 6,999
4	7,000 - 9,999
5	10,000 - over

proportion of residential-area trips having "home" as a trip purpose, an analysis was made of the effect of variation in family incomes on these "home" oriented trips. The results of grouping the 118 residential subzones into 5 categories of income are shown in Table 4. The data indicate that the percentage of total trips originating on residential land which were "from home" decreased as family income increased. Although a variety of inferences could be drawn from the data, including the apparent and reasonable increase in work opportunities at homes in the highest income group areas, there are several factors left unexplained by the data. A further classification of income of over $10,000 might help to clarify the trend.

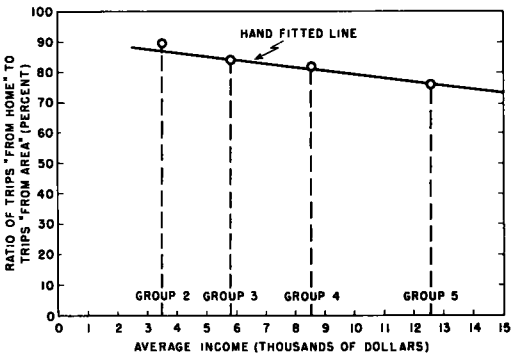

Figure 1. Income related to proportion of trip origins from home in 1955.

To obtain factors by which total trips originating in residential areas could be estimated, the proportion of trips "from home" to the total trips originating in the 118 residential subzones was plotted in relation to income (Fig. 1). By smoothing out the irregularities in the plotted data with a hand fitted line, the percentages of "from home" trips for each income group were slightly modified and expansion factors were developed as follows:

Income Group	Family Income	"From Home" Trips / Area Trip Origins	Trip Expansion Factors
	($1,000)	(percent)	(100.0/Column 3)
2	2.5 - 4.4	87.2	1.15
3	4.5 - 6.9	84.5	1.18
4	7.0 - 9.9	81.2	1.23
5	10.0 and over	76.4	1.31
Average		81.2	1.23

Prior to testing the adequacy of these trip expansion factors to duplicate total trips originating in the residential areas (from all purposes), those subzones which had less than 1,000 trip origins were eliminated, or where possible, combined, to provide greater stability to the data. This resulted in a total of 48 purely residential areas composed of 77 of the original 118 subzones, either individually or in combination, being used to test the above expansion factors.

The "from home" trips for each of the 48 areas were multiplied by (a) the applicable income group expansion factor and (b) by the average factor of 1.23, derived from the finding that an average of 81.2 percent of trip origins in residential areas were "from home" purpose. The results of these expansions compared to actual trip origins are shown in Table 5.

From a detailed study of data presented in Table 5, it appears that factoring by income groups improves the accuracy of estimating trip origins slightly over using an average factor. Two-thirds of the estimates were within ± 8 percent of the actual values when using income factors, as compared to ± 9 percent when using the average factor. The maximum error was + 19 percent when factored by income, and the maximum error was - 21 percent when using an over-all expansion factor. In appraising these results, it should be remembered that the comparisons were made for individual subzones, and that the basic trip data for any one subzone could have an appreciable error. Additional detailed study shows that the error decreases as trip volumes increase, when using either income factors or the average factor to expand "from home" trips.

From the foregoing, the conclusion may be drawn that if the number of "home" trips from any residential area is known, the total trips generated by that area can be estimated with an acceptable degree of reliability. Thus, trips generated by the residential land in any zone can be assigned to that land.

Now that trips can be assigned to residential land, it should be possible to relate these known values to the various characteristics of the residential area. It has been shown that the proportion of trips originating in residential areas that are "from home" tends to decrease as income increases. There are, however, other influencing factors which must be considered. To determine the effect that car ownership and population density had on the percentage of "from home" trips, correlations between each of the above independent variables and the percentage of "from home" trips were made for these same residential areas (Table 6). The results of these analyses are presented

TABLE 5

COMPARISON OF TOTAL NUMBER OF TRIPS ORIGINATING IN 48 RESIDENTIAL AREAS IN THE WASHINGTON, D.C., SURVEY AREA ON AN AVERAGE WEEKDAY IN 1955 WITH THE NUMBER ESTIMATED BY APPLICATION OF FACTORS TO "FROM HOME" TRIPS

Subzones	Income Group[a]	From-Home Trips	Total Trips Originating in Area	From-Home Trips Times Income Group Factor[b]	Percent Difference	From-Home Trips Times Average Factor[c]	Percent Difference
4144	2	1,161	1,334	1,335	-	1,428	7
1712-3	3	1,238	1,787	1,461	-18	1,522	-15
3143	3	2,076	2,338	2,449	5	2,553	9
3312	3	931	1,069	1,098	3	1,145	7
4752	3	1,586	1,830	1,871	2	1,950	7
4861	3	1,238	1,427	1,461	2	1,522	7
5143	3	1,852	2,006	2,185	9	2,278	14
5314	3	1,795	2,393	2,118	-11	2,208	-8
5325	3	1,089	1,395	1,285	-8	1,339	-4
5653	3	1,389	1,581	1,639	4	1,708	8
5741	3	1,201	1,318	1,417	8	1,477	12
6353	3	1,780	2,107	2,100	-	2,189	4
6469	3	1,790	2,097	2,112	1	2,202	5
6611-2-3	3	3,017	3,475	3,560	2	3,711	7
7825	3	1,101	1,244	1,299	4	1,354	9
7872-4	3	1,369	1,638	1,615	-1	1,683	3
8732	3	2,497	3,106	2,946	-5	3,071	-1
1331	4	1,102	1,195	1,355	13	1,355	13
1622-3	4	2,774	3,143	3,412	8	3,412	8
2245	4	1,079	1,117	1,327	19	1,327	19
2325	4	785	1,022	965	-6	965	-6
2333-4	4	1,040	1,365	1,279	-6	1,279	-6
2622-3	4	2,473	2,955	3,042	19	3,042	19
2643	4	890	1,055	1,094	4	1,094	4
2872	4	1,431	1,730	1,760	2	1,760	2
3434-6-7	4	1,547	1,832	1,902	4	1,902	4
3444	4	1,217	1,493	1,497	-	1,497	-
3524-6	4	1,890	2,325	2,325	-	2,325	-
3581-2	4	1,196	1,736	1,471	-15	1,471	-15
6476	4	1,194	1,487	1,468	-1	1,468	-1
7311-3	4	2,649	3,111	3,258	5	3,258	5
7452	4	1,265	1,403	1,556	11	1,556	11
7842-6-7	4	2,784	3,614	3,424	-5	3,424	-5
7911	4	784	1,098	964	-12	964	-12
8242-3	4	3,605	4,277	4,434	4	4,434	4
8426	4	913	1,247	1,122	-10	1,122	-10
1164	5	1,730	2,690	2,266	-16	2,127	-21
1322-3-5	5	1,737	2,146	2,275	6	2,136	1
2341-2-3	5	1,578	2,280	2,067	-9	1,941	-15
2421-5-7	5	1,822	2,551	2,387	-6	2,241	-12
2512	5	1,248	1,736	1,634	-6	1,535	-12
2521-2-3-5-6-7-8	5	3,077	3,900	4,031	3	3,785	-3
2531-5-6	5	1,997	2,465	2,616	6	2,456	-
2613	5	1,019	1,136	1,334	17	1,253	10
2732	5	714	1,098	935	-15	878	-20
2743	5	1,597	2,128	2,092	-2	1,964	-8
2851	5	1,241	1,411	1,625	15	1,526	8
8343	5	984	1,431	1,289	-10	1,210	-15

[a] See Footnote b on Table 4.

[b] Factor to expand home trips to total trips for each income group:

Income Group	Factor
2	1.15
3	1.18
4	1.23
5	1.31

[c] Average factor to expand home trips to total trips = 1.23.

TABLE 6

RESIDENTIAL CHARACTERISTICS OF 48 SELECTED RESIDENTIAL AREAS IN THE WASHINGTON, D.C., SURVEY AREA ON AN AVERAGE WEEKDAY IN 1955

Subzones	Cars per 100 Persons (number)	Persons per Residential Acre (number)	Trips from Home/Trips from Area (percent)	Trips to and from Home/Trips by Residents (percent)	Trips per Resident (number)
3434-6-7	14	81	84	92	1.2
3312	17	86	87	93	1.8
4144	20	184	87	94	1.0
5143	21	144	92	95	1.3
6353	23	97	84	84	1.5
3444	26	92	82	95	1.5
2421-5-7	27	21	71	78	1.9
5314	27	73	75	80	1.6
5325	27	52	78	91	1.5
5741	27	26	91	81	1.9
2512	29	49	72	76	2.5
5653	29	24	88	86	1.5
2245	30	45	97	82	2.5
6611-2-3	30	30	87	80	1.7
7825	30	61	88	93	1.8
8242-3	30	23	84	72	2 6
3143	31	286	89	81	2.2
4752	31	32	87	83	2.3
8426	31	13	73	81	2.0
3524-6	32	77	81	79	1.6
7872-4	32	11	84	82	2.2
8732	32	5	80	79	2.3
4861	33	50	87	88	1.6
6476	33	64	80	68	2.4
7311-3	33	28	85	55	2.7
1164	34	38	64	82	2.0
1622-3	34	14	88	82	2.5
2613	34	16	90	82	2.3
2872	34	12	83	71	1.9
6469	34	57	85	69	2.5
7452	34	64	90	94	1.8
2743	35	18	75	80	2.8
1712-3	36	12	69	76	2.8
2341-2-3	36	27	69	77	2.0
1331	37	29	92	68	2.8
2333-4	37	31	76	73	2.6
2643	37	31	84	78	2.2
2851	37	5	88	74	2.5
3581-2	37	29	69	80	2.0
8343	41	21	69	80	2.4
2521-2-3-5-6-7-8	42	20	79	74	3.2
2531-5-6	42	33	81	82	2.6
7842-6-7	42	17	77	89	2.1
7911	42	8	71	76	2.2
2325	45	45	77	88	2.9
1322-3-5	46	10	81	78	2.7
2622-3	46	65	84	80	2.4
2732	49	14	65	70	2.7

in Figures 2 and 3. Regression equations were fitted to the points by the method of least squares. Although these points do not exhibit a marked trend, especially those in Figure 3, related studies have shown a measurable relationship between trips and both car ownership and population density. It is believed that the sampling variability may have somewhat obscured the relationships in this case, but that these relationships should not be ignored.

Since for a given area the trips "to home" are generally about equal to the trips "from home," then 81.2 percent of all trips to and from the selected residential areas are "home" oriented. In effect, this means that on an average 81.2 percent of all trips to and from residential areas in the Washington area are made by the residents of those areas. The percentage varies with income, car ownership, and population density.

In summary, the total number of trip ends in any residential area can be determined, if the number of trips "to home" and "from home" is known, by expanding the "home" trip volumes by income, car ownership, or population density factors. An attempt will now be made to develop methods for estimating trip ends on residential land from a knowledge of total residents trips to all origins and destinations.

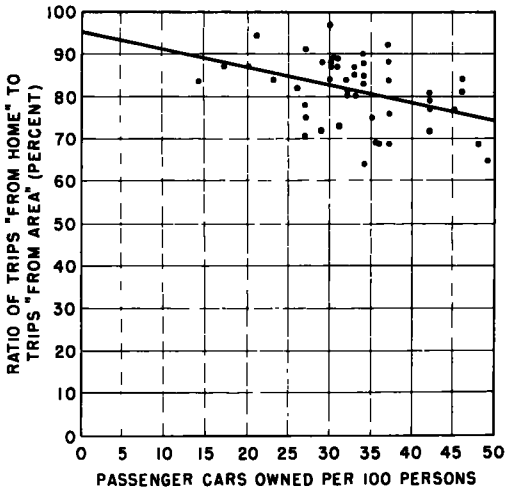

Figure 2. Car ownership related to proportion of trip origins from home in 1955.

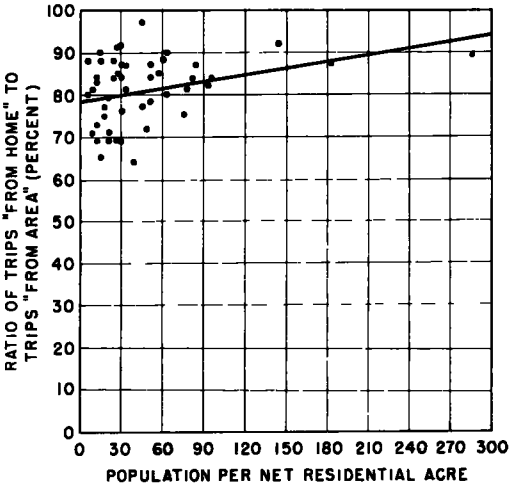

Figure 3. Population density related to proportion of trip origins from home in 1955.

Residents Trips Between All Origins and Destinations as a Measure of Total Trip Ends on Residential Land

An analysis of the data developed by the Washington transportation studies of 1948 and 1955 showed that 84 percent of all the residents internal area trips began or ended "at home" in each of the two years studied. (A study of travel patterns in 50 cities showed that an average of 82 percent of the total trips by residents had either their origin or destination at home. The range was from about 70 to 92 percent.) The percentages of residents trips which were made to and from home were computed for 48 selected purely residential areas (Table 6). Table 7 presents the percentages for 118 subzones grouped by income and distance from the central business district. Correlations were made between these percentages and the previously mentioned independent variables. The results of these analyses are presented in Figures 4 through 6, and show that the percentage of residents trips that started or ended at home tends to decrease as either income or car ownership increases, but appears to increase as population density increases. These patterns, it should be noted, have approximately the same relationship that the percentage of "from home" trips to total trips originating in a residential area had to the variables.

It may be concluded, therefore, that the ratio of "home" trips to total residents trips is related to the ratio of "home" trips to total trip ends. It follows then that the total number of trips by the residents of an area should be a useful index for estimating the total number of trip ends attributable to the residential land use in that area, by both residents and non-residents.

The factors to convert residents trips to residential land-use trip ends were

TABLE 7

EFFECT OF FAMILY INCOME AND DISTANCE FROM THE CENTRAL BUSINESS DISTRICT ON THE PERCENTAGE OF RESIDENTS TRIPS THAT WERE TO AND FROM HOME IN THE WASHINGTON, D.C., SURVEY AREA ON AN AVERAGE WEEKDAY IN 1955[a]

Variables	Number of Trips		Percent of Residents Trips to and from Home
	To and from Home	By Residents	
Income Group[b]			
2	3,670	4,071	90.1
3	66,138	82,212	80.4
4	71,558	90,280	79.3
5	44,082	57,306	76.9
Ring[c]			
2	6,474	7,574	85.5
3	6,334	6,853	92.4
4	26,398	32,988	80.0
5	44,898	56,973	78.8
6	31,794	39,636	80.2
7	30,492	39,481	77.2
8	18,662	23,386	79.8
9	16,022	20,793	77.1
10	4,374	6,185	70.7
Total	185,448	233,869	79.3

[a] Based on study of 118 selected residential subzones.
[b] See Footnote b on Table 4.
[c] Distance of residence from central business district (miles). None of the selected subzones were in Rings 1, 11, 12 or 13.

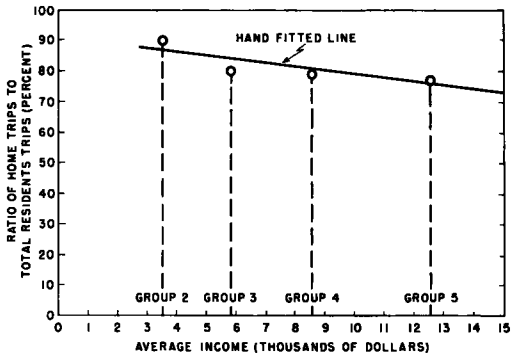

Figure 4. Income related to proportion of residents trips both to and from home in 1955.

developed for each of the selected independent variables (Table 8). As these conversion factors do not vary appreciably with any of the independent variables, a conversion factor of 1.0 was used. As previously indicated, this means that the total number of trip ends in a residential area is equal to the total number of trips made by the residents of the area between all origins and destinations.

The number of trip ends were then estimated from residents trips, using the factor of 1.0, and compared with the actual number of trip ends, as determined from the transportation survey, in 35 purely residential areas which had 2,000 or more trip ends and in which residents of 20 or more sample dwelling units were interviewed (Table 9). This comparison shows that in 3 out of 4 cases, the estimated number of trip ends was within 10 percent of the survey results. Part of the error that does exist is undoubtedly due to the small size of the areas studied, and part is due to the use of only one conversion factor.

It may be concluded, therefore, that the total number of trip ends attributable to the residential land use in an area can be estimated with an acceptable degree of accuracy from the total number of trips made by the residents of that area. The problem now is how best to determine residents trips.

Residents Trip Production. A previous analysis based on travel data obtained from the 1948 Washington metropolitan transportation study determined the influencing effect of each of four variables, individually and combined, on the number of trips made by the residents of 95 census tracts in the District of Columbia.[1] These variables were distance from the central business district, income, car ownership, and population density. A technique known as "analysis or partition of the variance" was employed to estimate the significance of each of the independent variables. It was established in

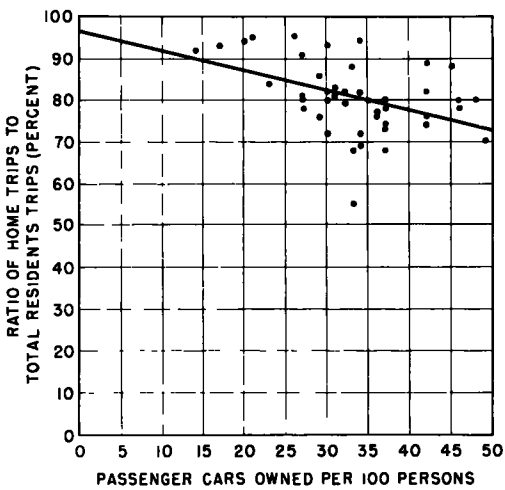

Figure 5. Car ownership related to proportion of residents trips both to and from home in 1955.

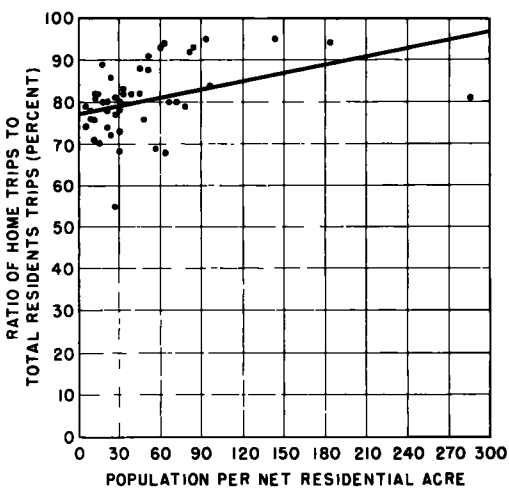

Figure 6. Population density related to proportion of residents trips both to and from home in 1955.

[1] Mertz, William L., and Hamner, Lamelle B., "A Study of Factors Related to Urban Travel." Public Roads, Vol. 29, No. 7 (April 1957).

TABLE 8

CONVERSION FACTORS FOR ESTIMATING TOTAL NUMBER OF TRIP ENDS IN RESIDENTIAL AREAS IN THE WASHINGTON, D.C., SURVEY AREA ON AN AVERAGE WEEKDAY IN 1955

Independent Variables	Trip Ends at Home as a Percentage of Total Trip Ends in an Area (percent)	Residents Trips to and from Home as as Percentage of Their Total Trips (percent)	Factors to Convert Total Residents Trips to Total Trip Ends in a Residential Area (factor)
Rings[a]			
2	88.1	85.5	0.97
3	87.7	92.4	1.05
4	79.5	80.0	1.01
5	80.0	78.8	0.98
6	80.8	80 2	0.99
7	80.9	77.2	0.95
8	82.8	79.8	0.96
9	81.6	77 1	0.94
10	85.8	70.7	0.82
Income Group[b]			
2	90.0	90.1	1.00
3	83.6	80.4	0.96
4	81.9	79 3	0.97
5	76.4	76 9	1.01
Car Ownership[c]			
5	92.6	93.7	1.01
10	90.6	91 4	1.01
15	88.6	89.1	1.01
20	86.5	86.7	1.00
25	84.5	84.4	1.00
30	82.5	82.1	1.00
35	80.4	79.8	0.99
40	78.4	77.4	0 99
45	76 4	75.1	0.98
50	74.4	72.8	0.98
Population Density[d]			
30	80 3	79 5	0 99
60	81 8	81.4	1.00
90	83 3	83.3	1.00
120	84.7	85.2	1.01
150	86 2	87.1	1.01
180	87 7	89.0	1.01
210	89.9	90 9	1.02
240	90 6	92 8	1.02
270	92 1	94.7	1.03
300	93 6	96 5	1.03

[a] Distance from the central business district (miles). None of the selected subzones were in Rings 1, 11, 12, or 13
[b] See Footnote b in Table 3
[c] Passenger cars owned per 100 persons
[d] Persons per residential acre.

this study that the use of all four variables combined did not significantly increase the accuracy of predicting trips over that which was obtained using only automobile ownership and population density combined. Furthermore, automobile ownership was found to be the most reliable single predictor with very little additional accuracy gained by combining it with population density.

Assuming that car ownership remained the most reliable single indicator of residents trips, the 1955 data on trips per person were correlated with cars owned per 100 persons to determine an estimating equation for residents total trips. Total residents trip production and information concerning car ownership are obtainable for any area where a home-interview traffic study has been made and not just those areas which are purely residential. This correlation was based on 200 areas or "zones" for which the required information was available from both the 1948 and 1955 Washington surveys. The estimating regression equation was $Y = 0.6 + 0.04 X$, where Y equals trips per person, and X equals passenger cars owned per 100 persons. The correlation coefficient is +0.71 and the standard error of estimate is 0.39 trips per person.

Using the above equation and the conversion factor developed in a previous section of this report (residents trips/trip ends = 1.0), the residents trips and, consequently, the residential trip ends were estimated for each of the 35 residential areas listed in Table 9. The estimated trip ends were compared with the actual survey values to test the accuracy for prediction purposes. Twenty-five, or 71 percent of the estimates were within ± 15 percent of the actual survey values and 88 percent were within ± 25 percent. The average error was 14.5 percent.

An intensive study of those areas with an extremely high percent of error might result in a reasonable explanation of the differences. Once again, it should be remembered that these comparisons refer to relatively small areas and the so-called actual number of residents trips is subject to error due to sample variability inherent in the basic survey.

Therefore, it is also possible to estimate, with a fair degree of accuracy, the trip ends of the residential portion of an area if the population and car ownership for that area are known. It must be pointed out, however, that these estimates are based upon a particular over-all citywide relationship between residents trips per person and car ownership.

Residents Trips as a Measure of Non-Residential Trip Ends. If, as has been shown, the number of residents trips provides a useful basis for estimating total trip ends in residential areas, it is reasonable to test its application as a measure of non-residential trip ends. Obviously, the difference betweeen total trip ends in an urban area and trip ends on residential land could be assigned to non-residential land. But, it has not been practicable to isolate each parcel of residential land to determine the trips generated thereby.

However, in this study the total number of home trips is known, and these must have been generated by residential land. It can be assumed then, that these "home" trips will represent the same proportion of total trips to all residential land as the "home" trips in the 118 selected (purely residential) subzones are to the total trips destined to these areas. In this manner, it was found that 19 percent of the trips destined to residential land were other than "to home." Also, since 58 percent of all trips in the metropolitan area were for other than "to home" purposes, it follows that 19 percent of 58 or 11 percent of all trips are generated by residential land for a purpose other than "to home." This means a total of 53 percent (42 + 11) of all trip ends are on residential land and the remaining 47 percent are on non-residential types of land. A comparison of these results with the 1948 Washington data and with that for 50 cities, similarly developed, and with data from Detroit gave the following percentage distribution of internal trip ends by land use:

Land Use	Washington Study Area		Detroit, Mich.	50 Cities
	1948	1955		
Residential				
Home	42	42	39	41
Other	11	11	14	11
Non-Residential	47	47	47	48
Total	100	100	100	100

Stability of the Relationship Between Residents Trips per Person and Car Ownership. To determine the stability of the relationship between residents trips per person and car ownership, an additional correlation between the two variables was made for the same 200 areas using data developed from the 1948 Washington area transportation survey (Fig. 8). A com-

TABLE 9

COMPARISON OF ESTIMATED TRIP ENDS AND ACTUAL TRIP ENDS IN 35 RESIDENTIAL AREAS IN THE WASHINGTON, D.C., SURVEY AREA ON AN AVERAGE WEEKDAY IN 1955

Subzones	Number of: Miles from the Central Business District	Home Interviews	Estimated Trip Ends[a]	Actual Trip Ends[b]	Percent Difference
3134	2	29	5,106	4,676	9.2
5143	3	24	3,903	4,012	-2.7
1164	4	31	4,220	5,380	-21.6
2421-5-7	4	25	4,650	5,102	-8.8
3434-6-7	4	24	3,359	3,664	-8.3
5314	4	30	4,468	4,786	-6.6
7311-3	4	124	6,365	6,222	2.3
3524-6	5	26	4,779	4,650	2.8
6353	5	20	4,234	4,214	0.5
6469	5	21	5,174	4,194	23.4
7825	5	55	2,367	2,488	-4 9
7842-6-7	5	96	6,248	7,228	-13.6
2512	6	20	3,297	3,472	-5.0
2521-2-3-5 -6-7-8	6	25	8,300	7,800	6.4
2613	6	30	2,485	2,272	9.4
6611-2-3	6	107	7,578	6,950	9.0
7452	6	47	2,689	2,806	-4.2
8343	6	24	2,460	2,862	-14.0
1622-3	7	60	6,770	6,286	7 7
2622-3	7	104	6,177	5,910	4.5
2732	7	21	2,037	2,196	-7.2
2743	7	39	3,996	4,256	-6.1
7872-4	7	37	3,350	3,276	2.2
8242-3	7	86	10,024	8,554	17.2
8426	7	26	2,244	2,494	-10 0
1712-3	8	31	3,253	3,574	-9.0
2643	8	32	2,290	2,110	8.5
4752	8	37	3,807	3,660	4.0
4861	8	45	2,824	2,854	-1.0
5741	8	32	2,965	2,636	12.5
2851	9	33	3,355	2,822	18.9
5653	9	48	3,242	3,162	2.5
7911	9	22	2,060	2,196	-6 2
8732	9	67	6,347	6,212	2.2
2872	10	48	4,041	3,460	16.8

[a] Estimated trip ends = residents trips times 1.
[b] As determined by 1955 survey study.

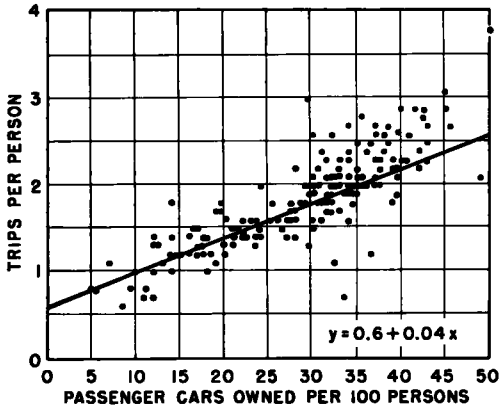

Figure 7. Trips per person related to car ownership in 1955.

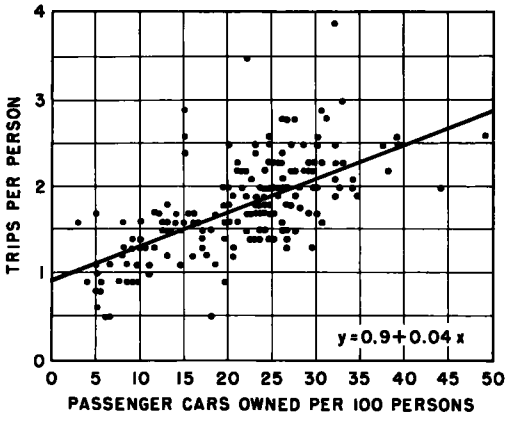

Figure 8. Trips per person related to car ownership in 1948.

parison of the regression line in this figure and the regression line based on 1955 data (Fig. 7) is shown in Figure 9. A study of these two lines indicates that the relationship between trips and car ownership has not been stable, but has experienced a measurable shift during the 7-yr period. The only difference between the two lines is the value of the constant (0.9 for 1948 and 0.6 for 1955) where the regression line intersects the Y axis. Statistical tests ("t") showed that the difference between these two constants was highly significant and could not be accounted for by sampling variability. Measures obtained from the analyses are as follows:

Year	Correlation Coefficient	Standard Error of Estimate (trips per person)	Average Trips per Person ($\bar{y}$)	Average Car Ownership ($\bar{x}$) = cars per 100 persons	Estimating Equations
1948	+0.67	0.41	1.7	21.2	$Y = 0.9 + 0.04X$
1955	+0.71	0.39	1.8	28.7	$Y = 0.6 + 0.04X$

Further analysis of the characteristics and relationship of the regression lines gives an insight into the reasons for the shift. The fact that the slope of the regression lines (0.04) remained the same during the interval between the study periods is of particular importance. Equally important is the fact that, although the average car ownership increased from 21.2 to 28.7 cars per 100 persons, an increase of 35 percent, the average number of trips per person remained relatively constant. The explanation, therefore, for the shift in the regression lines appears to be the increase in car ownership. This, in effect, means that during the 7-yr interval the numerical relationship between the two variables changed due to the increase in car ownership in 1955, but the relative association between the two variables, as indicated by the correlation coefficients, remained almost constant.

If these relationships are valid and the

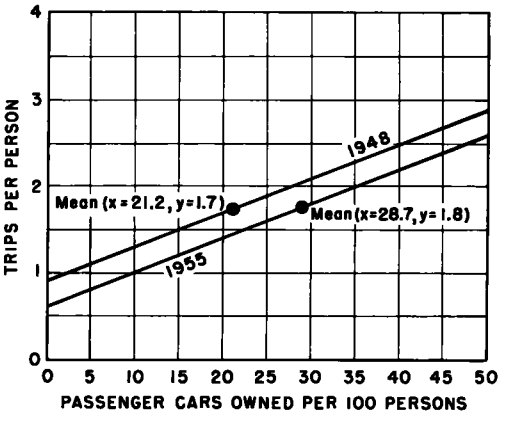

Figure 9. Comparison of the relationships between trips per person and car ownership in 1948 and 1955.

TABLE 10

INDICES FOR ESTIMATING THE TOTAL NUMBER OF TRIPS TO AND FROM RESIDENTIAL SUBDIVISIONS OF THE WASHINGTON, D.C., SURVEY AREA[a]

In Each Subdivision of Area	Number of Passenger Cars Owned per 100 Persons in Entire Survey Area										
	20	21	22	23	24	25	26	27	28	29	30
	Trips per Person										
5	1.20	1.16	1.12	1.08	1.04	1.00	0.96	0.92	0.88	0.84	0.80
10	1.40	1.36	1.32	1.28	1.24	1.20	1.16	1.12	1.08	1.04	1.00
15	1 60	1.56	1.52	1.48	1.44	1.40	1.36	1.32	1.28	1.24	1.20
20	1.80	1.76	1.72	1.68	1.64	1.60	1.56	1.52	1.48	1.44	1.40
25	2.00	1.96	1.92	1.88	1.84	1.80	1.76	1.72	1.68	1.64	1.60
30	2 20	2.16	2.12	2.08	2.04	2.00	1.96	1.92	1.88	1.84	1.80
35	2.40	2.36	2.32	2.28	2.24	2.20	2.16	2.12	2.08	2.04	2.00
40	2.60	2.56	2.52	2.48	2.44	2.40	2.36	2.32	2.28	2.24	2.20
45	2.80	2.76	2.72	2.68	2.64	2.60	2.56	2.52	2.48	2.44	2.40
50	3.00	2.96	2.92	2.88	2.84	2.80	2.76	2.72	2.68	2.64	2.60

[a] Determined from correlation of trips per person and car ownership in the Washington, D.C., survey area—1948 and 1955. To compute trips multiply population of each subdivision by appropriate index.

trend is assumed to be consistent in the future, then it should be possible to forecast residents trip production and residential land-use trip generation in the Washington area for any future year, provided that population and car ownership for that year are known or can be accurately forecasted. In fact, estimates could be readily obtained from the indices developed in Table 10, which may be taken from a family of regression curves assuming a constant average trips per person and a uniform slope, similar to those in Figure 9. The use of this table would require estimates of the citywide average car ownership for the future year plus estimates of car ownership for each zone or area for which potential trip data are desired.

Residents trip production for 1955 for each of the previously mentioned 200 areas was estimated by the indices in Table 10. The estimated trips were correlated with the actual trips as found in the survey (Fig. 10). It is readily apparent that the degree of association between the estimated and actual trips is very high. The square of the correlation coefficient (+0.98) indicates that the change in car ownership and change in population over the 7-yr period explained 96 percent of the variation in trip production (residents trips) and residential land trip generation for 1955. Two-thirds of the estimated values were within ± 15 percent of the survey results.

In the event car-ownership data are not available or are too difficult to develop, one

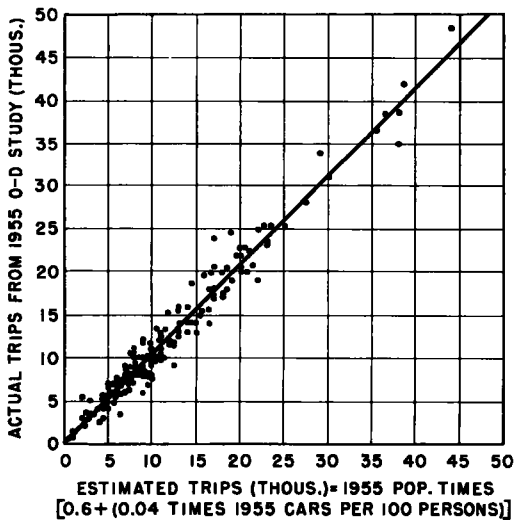

Figure 10. Actual trips related to trips estimated from relationship between trips per person and car ownership.

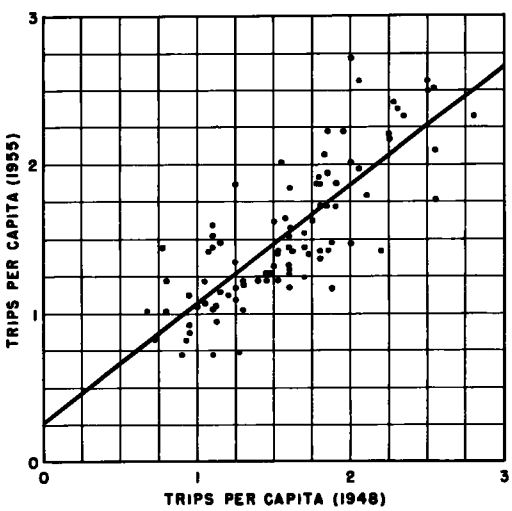

Figure 11. Trips per capita in 1955 related to trips per capita in 1948.

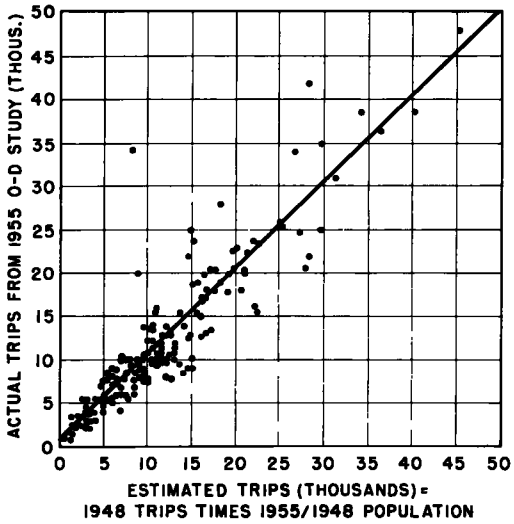

Figure 12. Actual trips related to trips estimated from change in population.

or more of the other previously mentioned independent variables could be substituted for car ownership with, of course, a probable decrease in predictability.[2]

Stability of Residents Daily Trip Production. To forecast accurately residents trip production and residential area trip generation by the method just described would require accurate estimates of population, as well as one or more factors related to trip production and generation, such as auto ownership and income, for each zone or area for which trip forecasts are desired. Admittedly, this process could prove to be more difficult and results perhaps not as satisfactory as those obtained from estimates derived from only one independent variable.

The previous comparison between 1948 and 1955 data showed that the average trips per person remained almost constant during the 7-yr period. Assuming that this consistency is not just a happy balance of plus and minus values, but rather the result of a consistency in the individual figures which comprise this average, then a second and easier method for projecting trip production and residential land trip generation to future years will be available.

To test this consistency or stability of residents daily trip production, trips per person in 1948 were compared to trips per person in 1955 for 95 census tracts in the District of Columbia (Fig. 11). The correlation coefficient is +0.80. This means that the same factors that affected persons trips in 1948 were still applicable in 1955. Therefore, it can tentatively be assumed that residents trip production in any desired area for which prior survey results are available can be forecasted by multiplying trips per person for the base year by population of the area for any future year.

Residents trips for 1955 for each of the previously mentioned 200 areas were estimated in this manner, using 1948 trip data as the base. A comparison between the estimated and actual survey values is shown in Figure 12. The results of this analysis show that two-thirds of the estimated values were within ± 25 percent of the actual values (see Method 2 in Table 11) and the correlation coefficient was +0.94. In other words, this means that the change in population alone was 88 percent effective in explaining the 1955 residents trip production and, consequently, residential land-use trip generation.

Increase in Cars Owned as an Indicator of Potential Trips. To measure the effect of cars owned, alone, as a predicting

TABLE 11

COMPARISON OF THREE METHODS FOR ESTIMATING 1955 RESIDENTS TRIPS FOR 200 AREAS IN THE WASHINGTON, D.C., SURVEY AREA

Maximum Error (percent)	Methods of Estimating		
	Method 1[a]	Method 2[b]	Method 3[c]
±	(percent of estimates)	(percent of estimates)	(percent of estimates)
5	30.9	18.5	7.8
10	51.0	39.5	15.7
15	67 2	54.5	26.2
20	79.4	63.5	33.0
25	88.7	68.5	40.3
30	91.2	78.0	47.6
35	92.2	86.0	53 9
40	94.1	88.0	57.6
45	95.6	91.0	63.9
50	96.6	93.5	68 6
55	97.1	95.0	71.2
60	97.1	95.0	75.4
65	97.1	96.5	79.1
70	98.0	97.0	82.2
75	98.0	98.5	85.9
80	98.5	98.5	87.4
85	98.5	98.5	88.0
90	98.5	98 5	89.0
95	98.5	99.0	89.5
100	98.5	99 0	92.1
Average error	±15 4	±20.9	±50.3

[a] Estimating equation = 1955 pop. [0.6 + (0.04 times 1955 cars per 100 persons)]
[b] Estimating equation = 1948 trips times 1955 pop./1948 pop
[c] Estimating equation = 1948 trips times 1955 cars/1948 cars.

[2] See Footnote 1 on page 29.

variable for estimating 1955 residents trip production and residential land-use trip generation, 1948 trips for the 200 areas were multiplied by the ratio of 1955 cars owned to 1948 cars owned. The analysis revealed that this method of estimating residents trips was not nearly as effective as the two previous methods described. In this case the correlation coefficient was +0.88. Data in Table 11 and Figure 13 compare the accuracy of three methods developed for estimating 1955 residents trips and residential trip generation for the 200 areas studied.

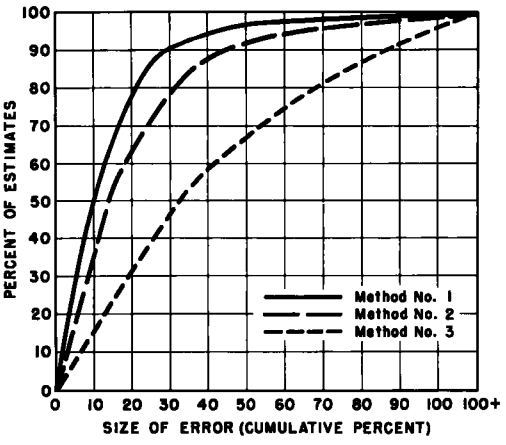

Figure 13. Comparison of three methods for estimating residents trips.

Estimating Future Traffic Potential of Residential Areas. Assuming that the travel patterns of the Washington metropolitan area are not unlike the travel patterns of other cities, the following methods and procedures have been developed for estimating with a fair degree of accuracy total residents trips for any area. As the factor to convert residents trips to trip ends on residential land was found to be approximately equal to 1.0, these methods will also give the trip generation due to any residential portion of the study area.

Method 1

Using the tabular data from an origin and destination study

1. Compute the residents trips per person for each zone in the area for which population and trip data are given.
2. Compute car ownership (passenger cars owned per 100 persons) for each zone.
3. Letting x = cars per 100 persons, y = trips per person, and n = number of zones, solve the following simultaneous equations for a and b:

$$\Sigma y = an + b \Sigma x$$

$$\Sigma xy = a\Sigma x + b\Sigma x^2$$

4. Determine estimating equation

$$y = a + bx$$

This equation provides an estimate of the trips per person corresponding to the car ownership in a particular area for an over-all citywide car ownership ($\Sigma x/n$) existing at the time of the survey. To apply this relationship to a future time, it is necessary to compute the parallel curve for an over-all car ownership estimated for the future data ($\Sigma x'/n$). This is done by assuming "y" and "b" remain constant and solving for the new "a" in the following equation:

$$\bar{y} = a' + b\bar{x}'$$

The trips per person for each area can then be calculated by substituting in the new equation ($y = a' + bx'$) for each estimated value of car ownership in the study areas. If desired, an index table similar to Table 10 could be prepared.

Although this has not been tested, instead of using car ownership data, it should be possible to utilize these techniques by substituting population density, income, distance from the central business district, or a combination of these variables.

Method 2

Using the tabular data from an origin and destination study

1. Compute the ratio of residents trips per person for each zone in the area.

2. Estimate the future population of each zone.
3. Multiply 1 times 2 for each respective zone.
4. In zones for which prior trip data are not available, estimates can be made by comparison with zones having similar characteristics.

Method 3

Using the tabular data from an origin and destination study

1. Determine the number of trips and the cars owned for each zone in the area.
2. Estimate the future cars owned in each zone.
3. Multiply the number of trips by the ratio of future to present cars owned.

The application of the most desirable method of estimating the potential trip generation in residential areas is dependent upon the availability and reliability of correlative data. For instance, although the first method appears to be the best, it must be pointed out that its accuracy depends upon the reliability of the estimated population and car ownership data. In the example above, the number of persons and the number of cars were known from origin and destination surveys. However, to forecast residential trips for a future period, the population and car ownership information is not available and must be estimated. Since the car ownership estimates are likely to be less accurate than population forecasts, Method 2, utilizing population data alone, may well be more accurate to forecast future trips.

CONCLUSIONS

1. Primarily the results of this study emphasize the fact that traffic is a phenomenon of human behavior. It is with people (and their daily travel) that there should be most concern.
2. The results of the analysis indicate means of estimating residents trips and trip ends on residential land with a reasonable degree of statistical accuracy. It appears desirable to ascertain and develop additional factors by which the accuracy of the technique could be greatly improved in each specific zone.

It would also be desirable to continue these studies, where possible, over a longer period of time to determine whether factors such as trips per person remain constant beyond a 7-yr interval. In addition, similar studies are needed in other urban areas of different sizes and with different travel characteristics, for instance, where mass transit is much less prevalent or negligible.

3. It has been shown that the use of population data as estimating factors would provide reasonable estimates of total trip ends on residential land by all modes of travel combined. However, to implement the design of transport facilities, estimates must be made of auto-driver trips, mass-transit trips, and trips by all other modes of travel, separately. It would seem necessary, therefore, to determine the degree of car ownership as a means of making these separate estimates for particular modes of travel.
4. Recognizing that a variable such as automobile ownership may only be a transient predictor of person trips, it still presents at this time rather impressive possibilities for improving traffic estimates, when known. In this regard, it is strongly urged that automobile ownership or registration records be established within urban and metropolitan areas on a basis of statistical areas, such as census tracts, police precincts, postal zones, school districts, or origin and destination zonal areas. Such a system would also enable the use of license tags in traffic analyses and many other studies, such as those connected with civil defense and market research.