Income and Related Transportation and Land-Use Planning Implications

HAROLD D. DEUTSCHMAN, Tri-State Transportation Commission, and
NATHAN L. JASCHIK, Monroe County, New York

•HOUSEHOLD income measures are among the most significant determinants of urban life and growth. Income is intermeshed with the location, nature, and type of housing; employment; recreation; community service facilities; and transportation systems. Moreover, it is tied to manifestations such as civic pride, community and neighborhood identity, and individual self-consciousness. Low income areas are often characterized by excessive living densities, poor social and economic conditions, and a high proportion of physical blight, while the more affluent areas commonly are associated with a higher degree of amenities and more attractive life styles.

Along with projections of such variables as population and employment, the planner must study the projection and distributional shifts of household income in order to consider the land-use and transportation plans to best serve the population. In addition, an obviously important consideration for municipal or regional planning is the economic status of the household, which is significant in financing improvements or innovations through direct costs and taxes, and more subtly, for the desire to spend public funds for a proposed plan.

Simple procedures are presented to measure the effect of income on such variables as (a) housing market, (b) auto ownership, (c) auto and transit-trip generation, and (d) time and distance separation of residence and worksite. The data source for this study was the home interview survey results from the Tri-State Transportation Commission, describing the New York metropolitan area. Methodology is presented to indicate the sensitivity of household income to these variables. Three different assumptions of the distribution of household income are presented (analogous to the different states of the world in decision theory). It is hoped that this study may serve as a starting point for needed revisions of data collection procedures pertaining to household income (as cross-classified with other variables) as well as for analytical work to systematically measure household income for its effects on transportation and land-use planning.

HOUSING MARKET VS HOUSEHOLD INCOME

Household income, along with household composition, is an important factor in the selection of a housing type and living style. Home ownership rate, a measure of living style, is a direct function of income. In the New York metropolitan area, for households earning less than $4000, only 2 in 10 own their own home, while 6 households in 10 earning $10, 000 own rather than rent. The highest home ownership is in the $25, 000 + income group with 70 percent of the households owning a home. This is, in reality, a measure of the unconstrained desire to own. The income dividing line between renting and owning is approximately $5000-6000, with the low incomes severely constrained in their selection of housing type. The joint effect of income and persons per household yields more of an insight to the actual desire expressed for home ownership (Fig. 1). Table 1 gives a comparison of households earning $5500 with those earning $8500.

Household income is a determinant of home ownership, even when holding household composition (persons per household) constant. Home ownership or the selection of a

Paper sponsored by Committee on Origin and Destination and presented at the 47th Annual Meeting.

Figure 1. Percent of households renting vs persons per household, stratified by household income.

TABLE 1

HOME OWNERSHIP (%) VS PERSONS PER HOUSEHOLD
(Stratified by Avg. Household Income)

Persons per HH	Avg. Household Income		Home Ownership Rate Ratio ($8500/$5500)
	$5500	$8500	
1	15%	19%	1.26
2	33	42	1.27
3	31	53	1.71
4	38	62	1.63
5	39	72	1.85
6	40	73	1.83
7	44	79	1.80

housing type is not just a selection of a place to live, it denotes a way of living. Associated with the selection of a house are such factors as cost of housing, relative closeness to work, residential density, tenure of residence, amount of space, degree of privacy, and type of neighbors. While income influences housing choice, once this choice is made, transportation-related variables are also influenced. To illustrate, for households of equivalent incomes, the number of autos owned per 100 households is more than twice as great in the single family units as compared to multi-unit structures.

Household income's influence on the selection of housing type must also be studied along with the racial composition of the region's households. Using the 1960 Census as a source, significant differences in home ownership rates are apparent for nonwhites vs whites in the New York metropolitan area. The rates of home ownership by race are given (Table 2) for the households in the region, stratified by household income.

TABLE 2

HOME OWNERSHIP (%) VS RACE
(Stratified by Household Income)

Race	Household Income				All Households
	(< $2999)	($3000-6999)	($7000-7999)	($10,000+)	
White	28%	37%	55%	66%	45%
Nonwhite	10%	17%	32%	48%	18%
Ratio home ownership (white/nonwhite)	2.8	2.2	1.7	1.4	2.5

Forecasting Housing Demand

A future housing demand may be simulated by studying the present relationship of household income vs home-ownership rates and then projecting the income distribution to a future year while holding the income-housing relationship fixed in time. Obviously, this is a simplified technique of estimating future housing demand. It does not implicitly consider such variables as persons per household, or age of head of the household, and does not reflect future federal policy, construction costs, or interest rates for mortgage money. Nevertheless, this technique offers a starting point to estimate the housing demands for a particular housing type, the single family unit. Furthermore, housing demands may be simulated under different assumptions or conditions of income distribution. (This is analogous to decision theory, viewing the rewards or consequences under varying states of the world. Of course, a probability must be associated or computed with each "state of the world.") Three different assumptions of income distribution are presented: (a) a uniform increase of income for each income class, (b) low-income groups gaining at a higher rate of increase than the other income groups, and (c-d) middle or high-income groups gaining at a higher rate of increase. For each assumption, the associated demand for home ownership is computed. The analytical process is as follows:

1. From survey results, the income distribution is determined for the present or survey year (in this case, 1963).

HOME OWNERSHIP RATE VS HOUSEHOLD INCOME

Household Income	Home Ownership Rate	Household Income	Home Ownership Rate
$0-2000	19.6%	$6000-7500	44.0%
2000-3000	20.5	7500-10,000	55.0
3000-4000	20.9	10,000-15,000	60.8
4000-5000	23.8	15,000-25,000	60.8
5000-6000	29.3	25,000 +	71.1

2. Associated with each income group is its calculated (also from survey) rate of home ownership per household.
3. For each income class, a percent growth of income is assigned for the survey year to forecast year.
4. The home ownership rates from item 2 are held constant, with the percent of households in each household group changing at the same rate as the real income change. An illustration of this process is as follows:

ANALYTICAL PROCEDURE TO DISTRIBUTE HOUSEHOLD INCOME

Income Class	Percent of Households in Survey Year	Change
$0-2000	7	0 -2.3
$2000-3000	6	+2.3% -6.0

Explanation: If everyone's income is increased by 50% (over 25 years) and a uniform distribution is assumed for each income class, then all households earning $1333 or more in the survey year will be propelled to the next class. Thus, ($\frac{1}{3}$) (7%) or 2.3% of the households move to the $2000-3000 income class and ($\frac{2}{3}$) (7%) or 4.7% of the households remain in the $0-2000 classification. This process continues throughout each income class and is summed up to produce a final (new) distribution.

TABLE 3

HOME OWNERSHIP VS INCOME

Condition (Assumptions)	Survey Findings (1963)	Uniform Increase In Real Income of 2% Per Year	2½% Increase for $0-5000 Income (All Others 2% Increase)	2½% Increase for $10,000 Income (All Others 2% Increase)	2½% Increase for $5-10,000 Income (All Others 2% Increase)	Uniform Increase in Real Income of 3% Per Year
Time (yr)	T_o	$T_o + 25$	$T_o + 25$	$T_o + 25$	$T_o + 25$	$T_o + 25$
Results						
(a) Home ownership demand per 100 households	40.6	50.5	51.1	50.6	50.8	53.0
(b) Autos per 1000 households	850	1096	1113	1097	1097	1166
Income Distributions—Percentage Distribution of Households						
Income Class						
$0-2000	7	4.7	4.3	4.7	4.7	4.0
2-3000	6	2.3	2.7	2.3	2.3	3.0
3-4000	9	4.0	2.8	4.0	4.0	2.9
4-5000	10	5.0	4.1	5.0	5.0	2.3
5-6000	13	6.0	8.1	6.0	6.0	6.7
6-7500	16	10.0	6.0	10.0	10.0	5.1
75-10000	17	20.2	24.2	20.2	14.6	17.1
10-15000	14	25.8	25.8	25.8	26.0	29.2
15-25000	6	15.0	15.0	14.2	20.4	19.8
25000 +	2	7.0	7.0	7.8	7.0	10.0
	100	100.0	100.0	100.0	100.0	100.0

5. The total number of home owners per 100 households is determined by multiplying the new number of households (shifted by the income growth) by the established (fixed) home ownership rate, and summing up the results for all income classes. The results of this process are given in Table 3, under Results (a).

Analysis of Results—Housing Demand

A 2 percent increase in real household income (adjusted for cost of living increases) over the next 25 years creates a new pattern or demand for home ownership. The income structure shifts to the right, producing more middle-class families, with (for the first time) sufficient income to contemplate owning a house and enjoying a life in the suburbs. Current construction rates (rate of single family home construction vs multi-family) may have to be modified for the future. To illustrate—in the period between 1957-1964 over 8, 500, 000 new dwelling units were constructed in the New York metropolitan area, of which 43 percent were single family units. (Regional Plan Association Bull. 103, Dec. 1965.) Trends indicate that this percentage of single-family construction should increase to meet the demand of the households. For example, a conservative estimate of a uniform real income increase of 2 percent per year increases the rate of single family home ownership from 40 households in 100 to over 50 per 100.

By perturbing the income distribution, causing each of the income groups to grow at different increase rates, it is possible to view the sensitivity of home ownership demands for the $0-5000, $5000-10, 000, and $10, 000+ income groups. Three cases were considered at a uniform 2 percent income increase for all groups, and with either the low, middle, or high income group increasing at a slightly higher rate of 2½ percent. The results of this analysis show that the lowest household income ($0-5000) is most sensitive to home-ownership demand with slight changes in income. The middle-to-high incomes are relatively insensitive to this same income change.

It is also noted that the increase from present conditions to a uniform 2 percent income increase (over 25 years) produces a significantly greater change of home ownership increase per year, per 1 percent income growth, when compared to the change from a 2 percent to a 3 percent income increase.

Although this analysis on household income vs housing-market demands is simplified, it is hoped that it also reveals the necessity to improve and enrich the data collection

and analytical methodology in the housing-market field. Much research is needed to describe the housing consumer, his needs, and the supply of housing to most efficiently fit his demand. The study of household income vs housing demands is but a first step in this direction. The authors of Housing, People and Cities[1] state that

> No major industry in the United States is as deficient in systematic research as the housing industry. . . . Probably the most spectacular deficiency of the housing industry is the lack of adequate market data. The census of the farm population and farm housing involves the expenditure of $1.90 per capita on the farm population. The corresponding census on urban housing and population involves an expenditure of only $0.45 per capita on the urban population. . . . Our major industries conduct systematic and detailed surveys of the buying habits, incomes, residential locations, and social characteristics of their purchases. They use all the elaborate methods of modern market research to diagnose consumer preferences and tastes. No such information is available in any city in the United States for the markets and customers of the housing industry.

Household Income vs Mass-Transit Ridership

What happens to the total number of transit trips if household income increases? Since income (along with residential density) is a strong determinant of auto ownership, it was felt that for the purpose of this analysis auto ownership may be used as a proxy variable for income. The underlying assumption for this substitution is that (holding residential density constant) income and autos may be interchanged in their relationships with total trip generation and mass-transit trip generation.

The strategy for this analysis is as follows: From survey or present conditions, construct statistical relationships between auto ownership, total trip generation, and mass transit ridership (Figs. 2-5). A simulation technique is then employed to yield the incremental change of total trips and mass-transit trips due to incremental changes in auto ownership (presumably caused by incremental changes in household income). The technique evolves as follows: With a sampling of expansion areas[2] as observation points, data were collected on (a) residential density of zone (persons per square mile), (b) autos per household (ratio), (c) number of households in each auto-ownership category (0, 1, 2+ autos), (d) total trip productions, and (e) total mass-transit trip productions. Next, auto-owership rates were related to the distribution of households in each auto-ownership class. To illustrate, an ownership rate of 1.2 autos per household (or, more realistically, 120 autos per 100 households) is equivalent to 30 households owning 2+ autos, 55 households owning 1 auto, and 15 households owning 0 autos. The next step involves the construction of a relationship between total trips generated per household vs residential density stratified by auto ownership. To illustrate, zone A has an auto ownership rate of 1.20 autos per household and an average density of 10,000 persons. Then (Fig. 3) the 100 households composing this zone will generate 672 trips (40 trips by the fifteen 0-auto households, 352 trips by the fifty-five 1-auto households, and 280 trips by the thirty 2+ auto households). The input for step 3 involves the total trip generation for this zone and the auto-ownership distribution per zone. Transit trips are then calculated as a percentage of the total trip-end densities as related to residential density and auto ownership (Fig. 5).

Analysis of Results—Transit Trip-Making

The results of this analysis may be expressed in different ways. For the purpose of this paper it was desired to illustrate the sensitivity of auto ownership as addressed to the following questions: With a constant residential density, what happens to transit-trip productions as you go from 0 to 1-auto households, and progress from 1-auto to

---

[1]Meyerson, M., Terrett, B., and Wheaton, W. Housing, People and Cities. McGraw-Hill, 1952.

[2]In expanding the Tri-State home interview survey from a 1 percent sample to its representative universe, the study area was divided into 278 expansion areas, or zones.

multi-auto households? What is the incremental change of total trips and mass-transit trips with incremental changes in auto ownership, progressing by 0.1 increases in auto ownership?

Figure 6 shows the sensitivity of transit trip generation with shifts in auto ownership from 0-1-2+ autos. The transit trip generation rate drops as much as 30 to 35 percent in high residential densities of 100,000 or more when an auto becomes available to a previously auto-less household. In relatively moderate residential densities (10,000-40,000) this drop in transit trip-making is on the order of 5 to 10 percent, while in middle-high densities the decrease is 10 to 20 percent with the availability of 1 auto.

The addition of a second auto is relatively insensitive to transit trip-making. In the residential density range from 2000-100, 000, there is a general decrease in transit trips, with the range from +5 to -5 percent. In the very high densities (over 100, 000), a sharp increase in transit trips is noted with the addition of a second auto. However, this is more of a statistical anomaly than a significant finding, as relatively few households maintain two autos at this density.

Another view of the results is made possible by studying the share of transit trips to total trips, with changes in auto ownership (Fig. 7). At high residential densities, the transit share of total trips drops 40 percent with the advent of a first auto, while at low

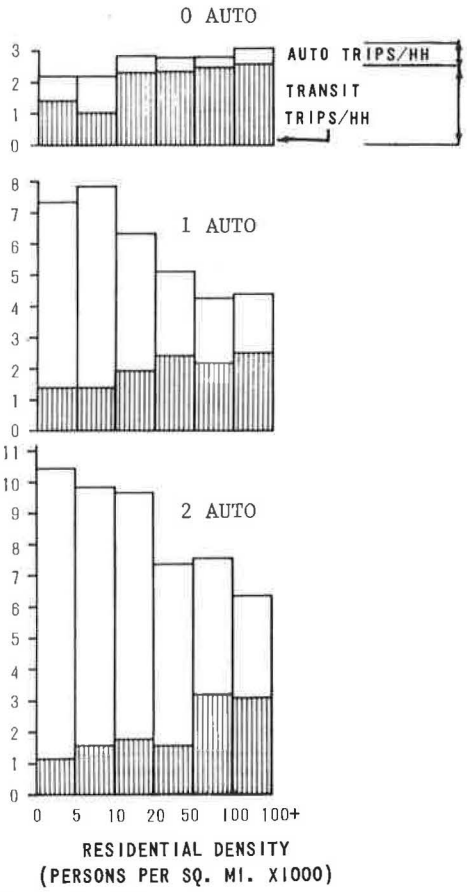

Figure 2. Trip productions vs residential density stratified by auto ownership.

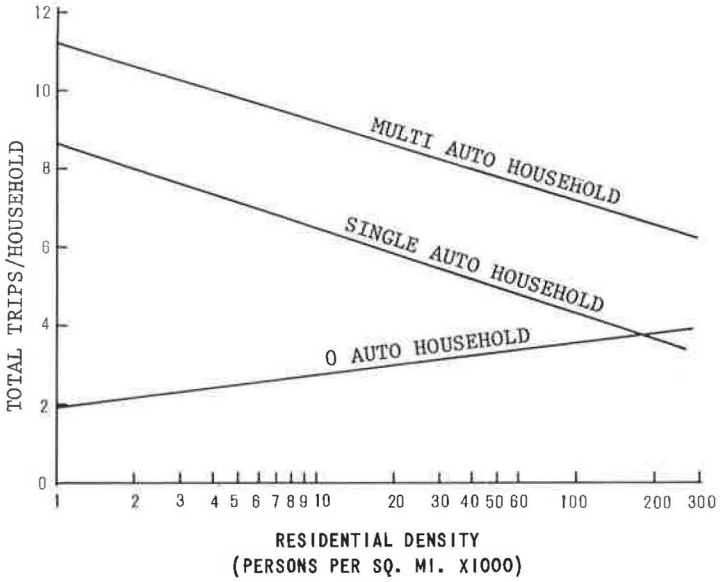

Figure 3. Trip productions per household vs residential density stratified by auto ownership.

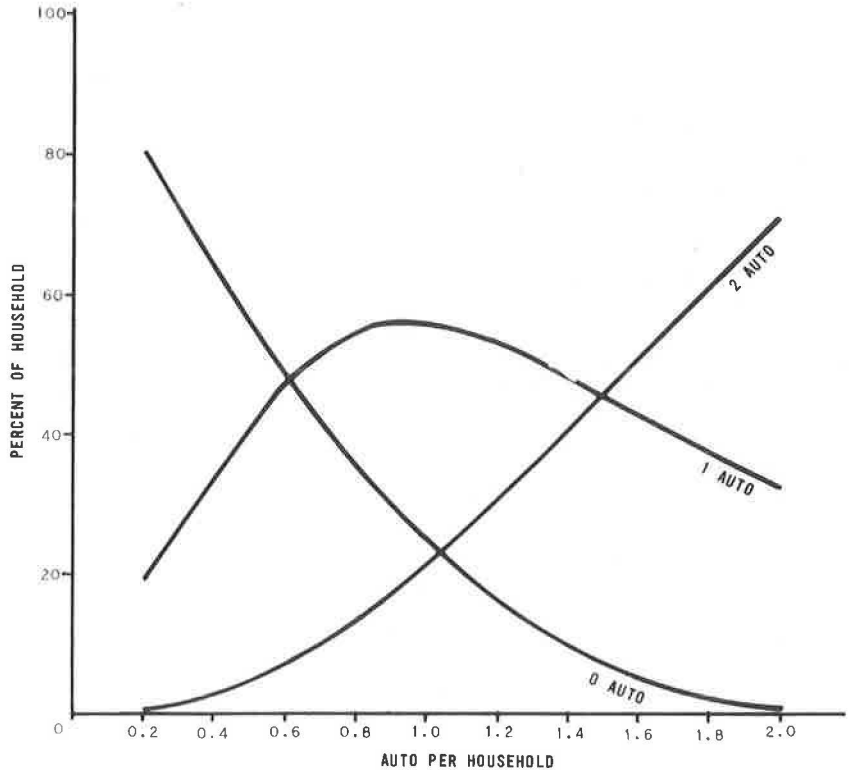

Figure 4. Percent households by ownership category vs average auto ownership.

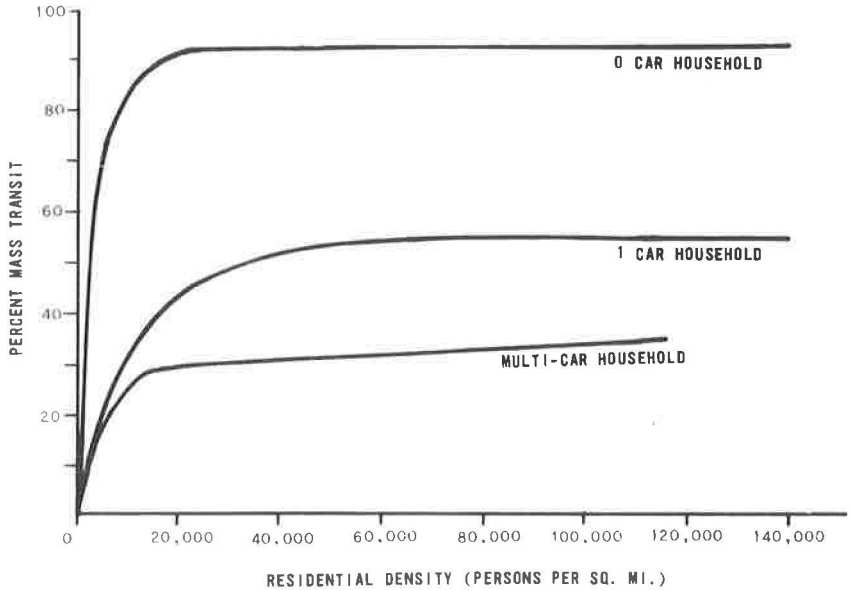

Figure 5. Percent mass transit vs residential density and auto ownership class.

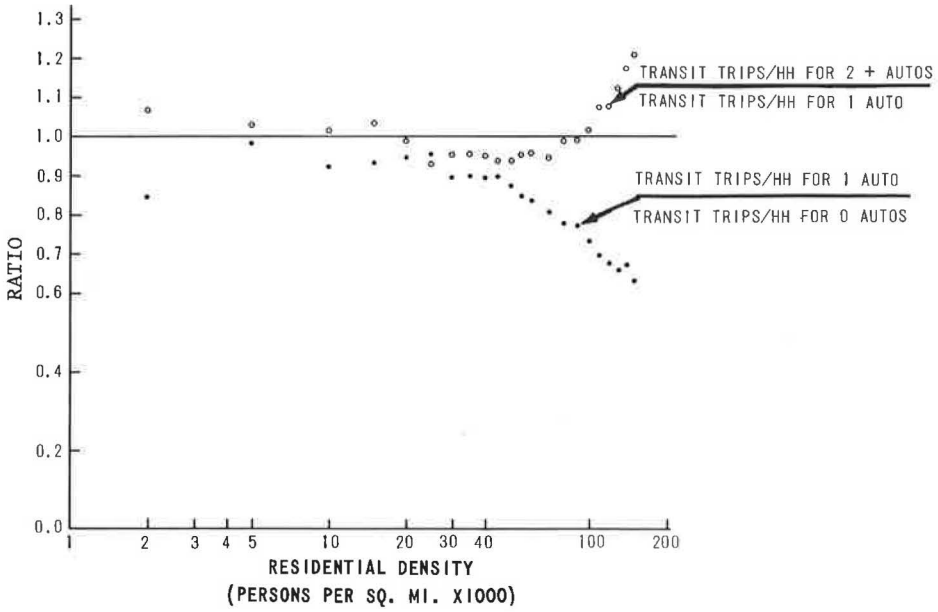

Figure 6. Sensitivity of transit trip generation with changes in residential density and auto ownership.

densities (2000) the decrease is a drastic one of 80 percent. The curve of transit share vs residential density (with change in autos available from 0-1) is curvilinear, showing an asymptotic relationship to a maximum decline of 40 percent at high densities.

Total trip generation and transit trip-making may also be studied across the entire spectrum of auto ownership (Fig. 8-9). Total trips generated is shown to vary directly with autos available and inversely with residential density. As auto availability increases, the differential rates in trip-making between different residential density measures

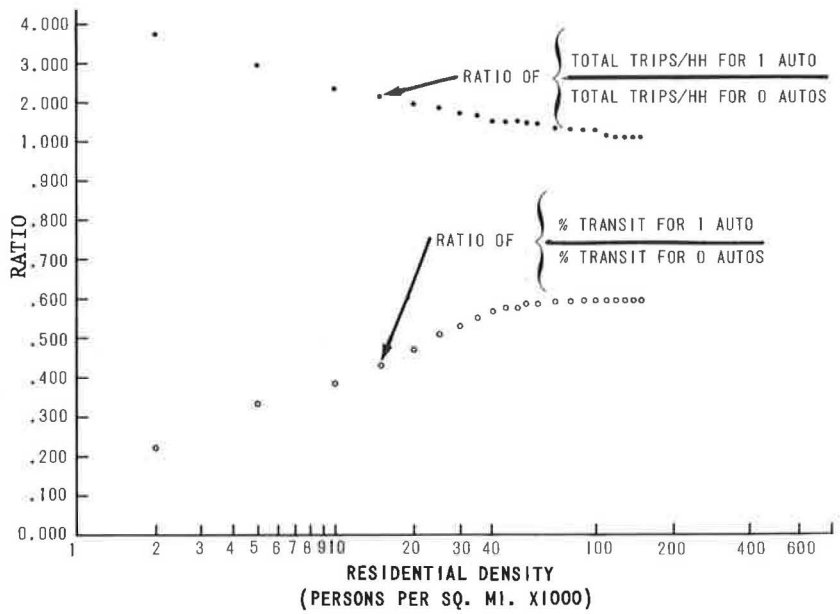

Figure 7. Sensitivity of transit trip share with changes in residential density and auto ownership.

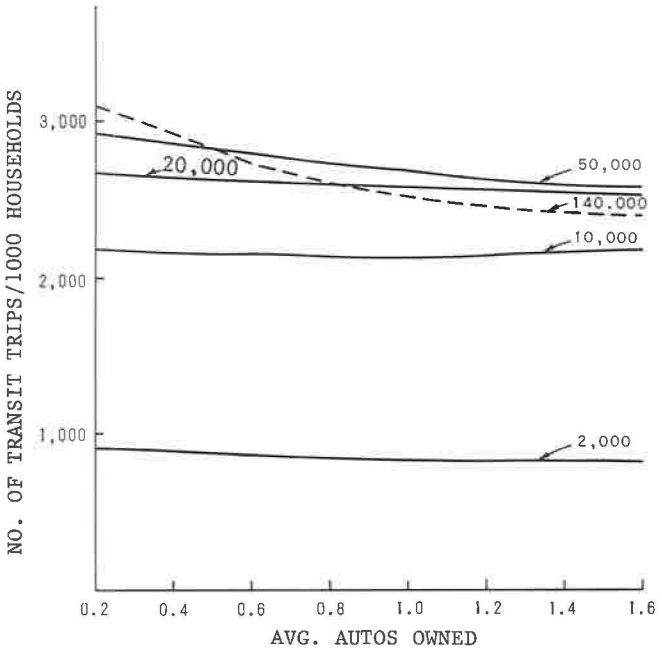

Figure 8. Transit trip production vs auto ownership stratified by residential density.

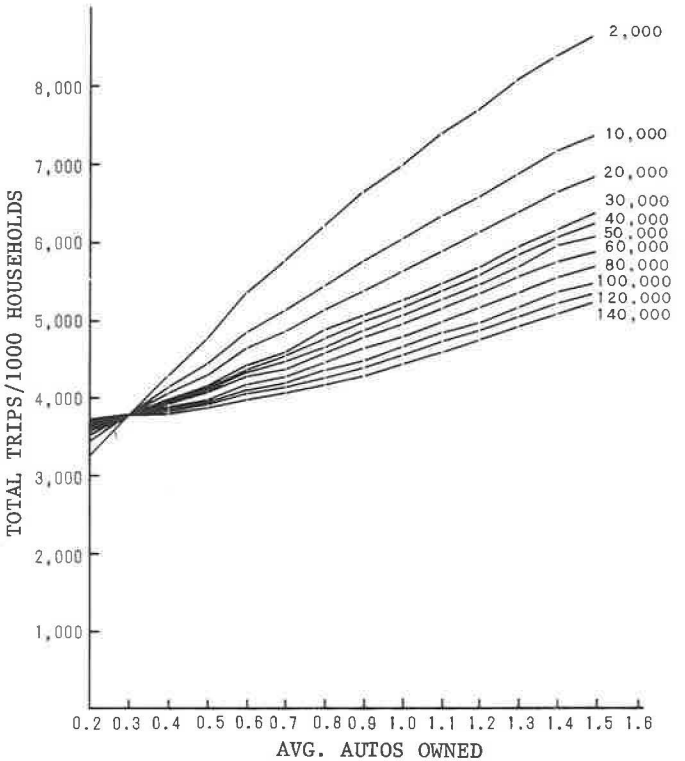

Figure 9. Total trips per household vs residential density (persons per sq mi) and auto ownership.

TABLE 4

SIMULATED TOTAL TRIPS AND TRANSIT TRIPS WITH INPUT OF AUTO OWNERSHIP AND RESIDENTIAL DENSITY

AVE AUTOS OWNED	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	
2000 PRS/SQMI	3241	3749	4282	4745	5347	5735	6204	6528	6965	7370	7691	8079	8397	8630	8935	TOTAL TRIPS
	908	896	884	874	862	854	846	840	837	833	830	827	825	825	823	TRANS TRIPS
5000 PRS/SQMI	3348	3759	4195	4572	5070	5389	5783	6142	6432	6783	7062	7403	7684	7993	8162	TOTAL TRIPS
	1621	1619	1617	1615	1613	1612	1612	1512	1512	1613	1614	1616	1617	1619	1620	TRANS TRIPS
10000 PRS/SQMI	3432	3762	4119	4425	4841	5104	5441	5753	6013	6326	6578	6888	7149	7344	7591	TOTAL TRIPS
	2192	2178	2167	2156	2147	2140	2136	2135	2138	2142	2146	2153	2160	2167	2173	TRANS TRIPS
15000 PRS/SQMI	3459	3748	4064	4334	4707	4962	5247	5534	5772	6067	6302	6594	6841	7027	7260	TOTAL TRIPS
	2432	2418	2404	2392	2379	2370	2362	2355	2351	2347	2344	2341	2340	2340	2338	TRANS TRIPS
20000 PRS/SQMI	3513	3769	4052	4293	4631	4843	5123	5389	5612	5889	6112	6389	6624	6803	7025	TOTAL TRIPS
	2666	2652	2639	2627	2612	2603	2591	2582	2574	2565	2558	2550	2544	2539	2533	TRANS TRIPS
25000 PRS/SQMI	3527	3758	4015	4234	4543	4736	4993	5238	5444	5701	5907	6165	6384	6551	6757	TOTAL TRIPS
	2748	2736	2722	2710	2692	2682	2666	2651	2638	2621	2607	2590	2575	2564	2550	TRANS TRIPS
30000 PRS/SQMI	3520	3714	3937	4124	4401	4571	4809	5041	5241	5496	5698	5956	6178	6351	6558	TOTAL TRIPS
	2788	2762	2734	2710	2679	2658	2634	2613	2596	2575	2559	2540	2524	2513	2498	TRANS TRIPS
35000 PRS/SQMI	3561	3742	3952	4128	4391	4552	4781	5004	5198	5445	5644	5896	6113	6283	6486	TOTAL TRIPS
	2852	2826	2798	2773	2742	2722	2697	2675	2658	2637	2621	2601	2585	2573	2557	TRANS TRIPS
40000 PRS/SQMI	3581	3754	3954	4122	4375	4530	4750	4967	5155	5395	5589	5834	6047	6212	6411	TOTAL TRIPS
	2886	2858	2828	2802	2769	2747	2722	2698	2680	2658	2640	2619	2601	2589	2572	TRANS TRIPS
45000 PRS/SQMI	3579	3746	3941	4106	4350	4500	4715	4926	5110	5345	5534	5774	5982	6144	6338	TOTAL TRIPS
	2898	2871	2842	2817	2784	2763	2737	2713	2694	2670	2652	2629	2611	2597	2579	TRANS TRIPS
50000 PRS/SQMI	3600	3754	3936	4088	4321	4462	4667	4870	5048	5275	5452	5694	5897	6056	6246	TOTAL TRIPS
	2930	2896	2861	2831	2791	2766	2735	2708	2686	2660	2640	2615	2595	2580	2560	TRANS TRIPS
55000 PRS/SQMI	3621	3762	3932	4072	4291	4423	4619	4813	4985	5207	5385	5613	5812	5968	6153	TOTAL TRIPS
	2964	2924	2882	2846	2800	2770	2736	2705	2681	2652	2630	2603	2581	2566	2545	TRANS TRIPS
60000 PRS/SQMI	3641	3770	3927	4056	4262	4385	4570	4757	4923	5137	5311	5533	5727	5880	6061	TOTAL TRIPS
	2991	2943	2893	2850	2796	2760	2723	2694	2657	2626	2631	2572	2550	2533	2511	TRANS TRIPS
70000 PRS/SQMI	3652	3768	3912	4030	4223	4337	4513	4692	4852	5061	5229	5446	5636	5787	5963	TOTAL TRIPS
	3021	2968	2913	2866	2807	2768	2723	2685	2655	2621	2594	2562	2537	2518	2494	TRANS TRIPS
80000 PRS/SQMI	3634	3738	3870	3978	4160	4266	4436	4613	4768	4974	5142	5358	5549	5700	5877	TOTAL TRIPS
	3014	2954	2893	2840	2775	2733	2685	2645	2615	2581	2554	2523	2500	2484	2460	TRANS TRIPS
90000 PRS/SQMI	3643	3738	3861	3961	4131	4230	4391	4556	4707	4904	5065	5272	5455	5601	5771	TOTAL TRIPS
	3029	2963	2897	2839	2769	2722	2671	2627	2595	2559	2533	2497	2472	2455	2431	TRANS TRIPS
100000 PRS/SQMI	3664	3746	3855	3943	4098	4187	4335	4491	4634	4822	4975	5173	5350	5490	5653	TOTAL TRIPS
	3056	2982	2909	2844	2767	2715	2660	2614	2581	2544	2515	2483	2459	2444	2420	TRANS TRIPS
110000 PRS/SQMI	3679	3746	3842	3917	4058	4138	4278	4426	4565	4750	4900	5095	5271	5411	5573	TOTAL TRIPS
	3084	3000	2918	2845	2761	2703	2644	2596	2563	2527	2500	2469	2448	2436	2414	TRANS TRIPS
120000 PRS/SQMI	3708	3765	3850	3917	4047	4120	4251	4392	4525	4702	4865	5035	5205	5342	5498	TOTAL TRIPS
	3115	3024	2936	2857	2765	2703	2639	2587	2551	2512	2482	2449	2425	2411	2388	TRANS TRIPS
130000 PRS/SQMI	3698	3747	3825	3884	4006	4073	4199	4336	4466	4640	4782	4969	5138	5274	5428	TOTAL TRIPS
	3116	3021	2929	2846	2752	2688	2623	2571	2536	2503	2472	2442	2422	2412	2391	TRANS TRIPS
140000 PRS/SQMI	3688	3728	3797	3848	3962	4024	4145	4277	4405	4578	4719	4905	5074	5210	5364	TOTAL TRIPS
	3114	3014	2918	2832	2735	2658	2603	2552	2519	2485	2460	2434	2419	2412	2394	TRANS TRIPS
150000 PRS/SQMI	3708	3736	3792	3832	3933	3985	4095	4221	4343	4509	4665	4825	4989	5122	5272	TOTAL TRIPS
	3145	3037	2932	2839	2734	2663	2593	2538	2503	2467	2441	2414	2398	2390	2372	TRANS TRIPS

TABLE 5

SIMULATED TRIP PRODUCTIONS BY COUNTY

VE AUTOS OWNED	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	
BERGEN	2320	2680	3080	3420	3900	4200	4600	4980	5300	5700	6020	6420	6760	7020	7340	TOTAL TRIPS
	714	731	748	762	779	790	801	809	814	819	823	827	829	830	833	TRANS TRIPS
BRONX	2320	2680	3080	3420	3900	4200	4600	4980	5300	5700	6020	6420	6760	7020	7340	TOTAL TRIPS
	1604	1725	1845	1952	2078	2163	2254	2331	2386	2448	2495	2550	2590	2617	2657	TRANS TRIPS
ESSEX	2320	2680	3080	3420	3900	4200	4600	4980	5300	5700	6020	6420	6760	7020	7340	TOTAL TRIPS
	1036	1036	1036	1036	1034	1033	1030	1027	1024	1019	1015	1010	1005	1001	996	TRANS TRIPS
HUDSON	2320	2680	3080	3420	3900	4200	4600	4980	5300	5700	6020	6420	6760	7020	7340	TOTAL TRIPS
	1186	1212	1234	1255	1272	1286	1293	1295	1292	1284	1277	1266	1253	1241	1231	TRANS TRIPS
MIDDLESEX	2320	2680	3080	3420	3900	4200	4600	4980	5300	5700	6020	6420	6760	7020	7340	TOTAL TRIPS
	584	604	622	639	658	671	684	694	701	708	714	719	723	725	729	TRANS TRIPS
MONMOUTH	2320	2680	3080	3420	3900	4200	4600	4980	5300	5700	6020	6420	6760	7020	7340	TOTAL TRIPS
	581	598	617	634	655	669	685	702	714	730	742	757	769	778	790	TRANS TRIPS
MORRIS	2320	2680	3080	3420	3900	4200	4600	4980	5300	5700	6020	6420	6760	7020	7340	TOTAL TRIPS
	341	386	434	475	531	566	611	653	687	729	762	803	838	863	896	TRANS TRIPS
PASSAIC	2320	2680	3080	3420	3900	4200	4600	4980	5300	5700	6020	6420	6760	7020	7340	TOTAL TRIPS
	688	680	675	669	666	663	664	666	671	677	683	691	699	706	713	TRANS TRIPS
SOMERSET	2320	2680	3080	3420	3900	4200	4600	4980	5300	5700	6020	6420	6760	7020	7340	TOTAL TRIPS
	681	685	692	697	710	717	732	749	765	788	807	832	854	873	893	TRANS TRIPS
UNION	2320	2680	3080	3420	3900	4200	4600	4980	5300	5700	6020	6420	6760	7020	7340	TOTAL TRIPS
	764	769	774	779	782	785	786	785	784	781	779	775	771	767	764	TRANS TRIPS
KINGS	2320	2680	3080	3420	3900	4200	4600	4980	5300	5700	6020	6420	6760	7020	7340	TOTAL TRIPS
	1652	1781	1911	2026	2166	2259	2363	2453	2520	2598	2659	2729	2784	2823	2877	TRANS TRIPS
NASSAU	2320	2680	3080	3420	3900	4200	4600	4980	5300	5700	6020	6420	6760	7020	7340	TOTAL TRIPS
	794	832	872	906	949	977	1009	1037	1059	1083	1103	1125	1143	1156	1173	TRANS TRIPS
MANHATTAN	2320	2680	3080	3420	3900	4200	4600	4980	5300	5700	6020	6420	6760	7020	7340	TOTAL TRIPS
	1697	1834	1968	2087	2223	2315	2408	2482	2531	2583	2622	2663	2689	2704	2732	TRANS TRIPS
QUEENS	2320	2680	3080	3420	3900	4200	4600	4980	5300	5700	6020	6420	6760	7020	7340	TOTAL TRIPS
	1565	1666	1774	1867	1992	2072	2172	2265	2341	2434	2508	2599	2674	2731	2803	TRANS TRIPS
RICHMOND	2320	2680	3080	3420	3900	4200	4600	4980	5300	5700	6020	6420	6760	7020	7340	TOTAL TRIPS
	1527	1651	1785	1900	2056	2155	2281	2398	2495	2613	2708	2825	2923	2996	3089	TRANS TRIPS
ROCKLAND	2320	2680	3080	3420	3900	4200	4600	4980	5300	5700	6020	6420	6760	7020	7340	TOTAL TRIPS
	658	716	779	834	907	954	1013	1059	1114	1170	1215	1270	1316	1351	1394	TRANS TRIPS
SUFFOLK	2320	2680	3080	3420	3900	4200	4600	4980	5300	5700	6020	6420	6760	7020	7340	TOTAL TRIPS
	670	733	797	853	922	967	1018	1061	1093	1130	1159	1192	1218	1236	1261	TRANS TRIPS
WESTCHSTR	2320	2680	3080	3420	3900	4200	4600	4980	5300	5700	6020	6420	6760	7020	7340	TOTAL TRIPS
	917	958	1000	1036	1082	1112	1147	1178	1202	1230	1253	1279	1301	1316	1337	TRANS TRIPS
SWESTERN	2320	2680	3080	3420	3900	4200	4600	4980	5300	5700	6020	6420	6760	7020	7340	TOTAL TRIPS
	481	482	485	488	497	502	513	526	539	557	572	592	610	625	642	TRANS TRIPS
GTR BRGPT	2320	2680	3080	3420	3900	4200	4600	4980	5300	5700	6020	6420	6760	7020	7340	TOTAL TRIPS
	602	583	566	551	536	525	517	513	512	512	514	517	521	525	529	TRANS TRIPS
SCENTRAL	2320	2680	3080	3420	3900	4200	4600	4980	5300	5700	6020	6420	6760	7020	7340	TOTAL TRIPS
	589	584	583	581	586	587	595	606	618	635	650	669	688	704	720	TRANS TRIPS
ANS-DERBY	2320	2680	3080	3420	3900	4200	4600	4980	5300	5700	6020	6420	6760	7020	7340	TOTAL TRIPS
	246	271	300	324	360	382	412	441	466	497	522	554	581	602	627	TRANS TRIPS

increases significantly. Conversely, at low auto ownership levels of 20-40 autos per 100 households, the trip propensity approaches a constant of approximately 4 trips per household for all residential density measures.

For the mass-transit trip generation, at constant residential densities, the number of transit trips is relatively insensitive to incremental changes in auto ownership. For the most part, there are slight decreases in transit trip-making as the auto ownership rates increase. Residential density, rather than auto ownership, determines the transit trip productions, with a low of about 1 trip per household at a density of 2000 to a high of 3 transit trips per household at a density of 40, 000-50, 000 (Fig. 8).

With the aid of a computer, the simulated results may be tabulated showing the total trips and transit trips per range of residential densities and autos owned (Table 4). Another way of presenting the results is to assign an average residential density to a municipality or county to see how transit and total trips vary with autos (Table 5).

In summary, perhaps too much attention was paid to the description of the results and not enough to the possible uses of the technique. The methodology presented provides a trend of trip-making projected by holding constant relationships between income, autos, density, and trip-making. It is feasible to incorporate this procedure to an overall model of population and employment growth (and related characteristics) to yield a portrait of transit and total trip demand, if these present relationships continue into the future. In addition, transit service may also be readily incorporated in the outlined procedure. The end-product of the analysis presented is a trip-demand portrait of a region if no significant region-shaping planning decisions are made. This is a starting point for viewing new transportation and land-use plans for their changes on the trend or projected plan.

HOUSEHOLD INCOME VS AUTO OWNERSHIP

Household income, along with residential density, is an indicator of auto ownership. Holding density constant (with no. of housing units in the structure a proxy for residential density) auto availability increases with increasing household income for each of the four housing types. However, this rate of increase of autos vs income is not constant

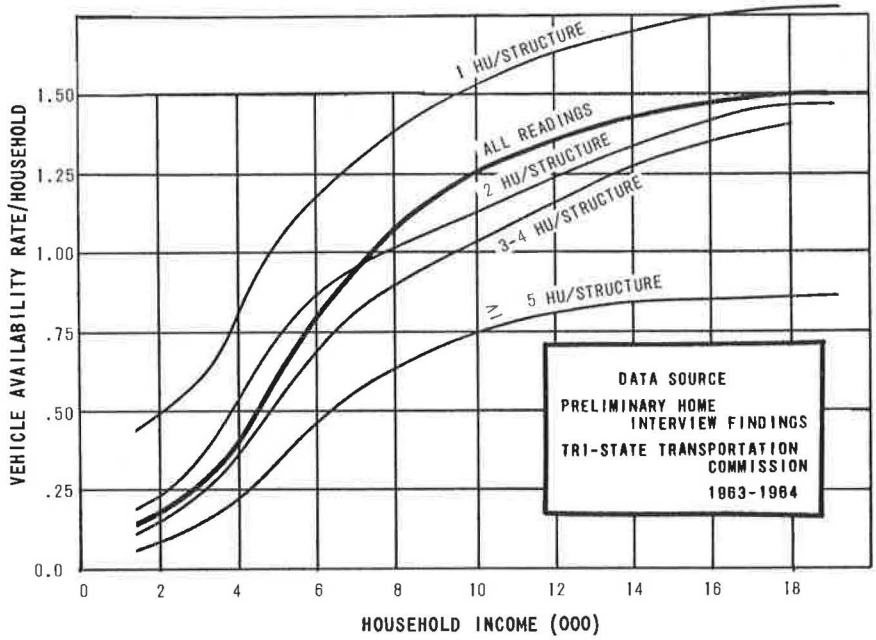

Figure 10. Vehicle availability vs household income stratified by number of housing units in the structure.

throughout the density classes. Figure 10 shows the relationship between autos and income stratified by housing type.

A rate of auto availability vs household income was determined from survey results. (The terms auto ownership and auto availability are used interchangeably.) This rate is held fixed with income forecasted to a future year. This procedure implicitly assumes that the growth in the region between the survey year and the forecast year will approximate the density configuration already intact in the region. The auto ownership rate vs household income is indicated as follows:

Income	Auto Availability
$0-2000	0.15
2000-3000	0.23
3000-4000	0.30
4000-5000	0.50
5000-6000	0.73
6000-7500	0.93
7500-10,000	1.15
10,000-15,000	1.34
15,000-25,000	1.51
25,000 +	1.51

Results of the analytical procedure used to compute the demand for auto ownership under different assumptions of income distribution are given in Table 3, under Results (b).

Analysis of Results—Auto Ownership

An increase of 2 percent per year for 25 years (or a 50 percent increase) produced a change in auto ownership from 85 autos per 100 households to 110 autos per 100 households. The actual increase in the ownership rate was 29 percent, or 14.5 percent per 1 percent increase in real income. The differential increase in auto ownership from (a) a 2 percent increase in real income to (b) a 3 percent increase in real income is less significant, producing a 12.3 percent increase per 1 percent change in real income. This is due to the saturation of autos per household (sufficient number of autos per family to accommodate household needs) regardless of household income.

With perturbations in the income-distribution process, one can view the sensitivity of each of three income groups on their effect on auto ownership. To illustrate, the household demand for autos was computed at a uniform average real increase in income of 2 percent (for all income groups). This may be compared to a 2 percent real income growth for all groups and a 2½ percent income growth in either the (a) $0-5000 income group, or (b) $5-10, 000, and (c) $10-15, 000 groups. The low income group (a) is most sensitive to changes in auto ownership with a slight change in household income. An additional ½ of 1 percent increase in auto ownership (over the uniform 2 percent increase for all groups) produces an increase of 2 autos per 100 households. The incremental growth of ½ of 1 percent to either of the other income groups produces, in effect, no change in the total autos per 100 household rate, showing the saturation effect of autos on moderate to high incomes.

TIME-DISTANCE SEPARATION OF RESIDENCE AND WORKSITE

One of the important considerations in choosing a place of residence is its relationship with the place of employment. The separation of the home and worksite, measured in time, distance, and cost, dictates to a large degree the shape a region may take. Most basic to the consideration of income and its related land-use planning implications is the relationship between income and place of residence on the one hand, and place of employment and accessibility on the other. It is commonly held that the journey to work, from this standpoint of time, distance, cost, and mode, is directly related to the level

of personal income. In essence, as a worker's income increases, he has a correspondingly wider choice as to employment location. The worker at the low end of the economic scale is severely limited in choice and opportunity.

In recent years, metropolitan areas throughout the nation have experienced a steady movement of lower-paying jobs away from the central city (especially in manufacturing). At the same time, the movement of the "middle-class" to the suburbs has left many central cities with a rapidly-increasing share of low-income families. Thus there is an apparent greater separation of home and work for each income class. This denotes a greater demand on the transportation system for the journey to work and the need for new and expanded transportation links to serve this redistributed population. In addition, viewing the average time, cost, and distance from home to work for each income class should reveal the constraints on the relative connection of residence and worksite. There is also a steady increase in distance from work as household income increases. The average trip length in miles (airline distance) and the average trip time for the journey to work as stratified by income is as follows:

Income	Trip Length	Trip Time (min)
$0-1999	2.26	23.7
2000-2999	4.60	32.7
3000-3999	6.07	34.2
4000-4999	5.62	33.4
5000-5999	7.50	32.2
6000-7499	9.16	32.8
7500-9999	11.00	33.3
10,000-14,999	12.00	32.5
15,000-24,999	14.42	32.6
25,000 and over	10.57	27.2

With the exception of the very low incomes ($0-2000) and very high incomes ($25,000 +) all other income classes have a surprisingly constant average trip time to work (about 33 min, with a range of from 32.5 min to 34.2 min for eight income classes). Of course, it is a combination of distance and time that produces the actual cost of the journey to work, such that this cost would increase as household income increases. The data above reflect the importance of the time consideration in the match-up of residence and worksite.

It is suggested that household income be studied in much greater detail in designing for more functional living-working arrangements, and for providing improved access permitting people to flow more freely between home and job.

SUMMARY

Household income is shown to be a determinant in transportation and land-use planning. Simplified procedures are presented to measure the sensitivity of household income with such variables as auto ownership, transit-trip ridership, auto and total trip-making, and home ownership. It is hoped that this paper may stir interest in the systematic evaluation of the variables that are used to simulate transportation demands (of which income is one of many). Innovations in data collection procedures should be suggested and should be designed to permit a more thorough evaluation of these variables over time.