A Classification of Urbanized Areas for Transportation Analysis

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As an initial step in the development of an urban area transportation typology, 213 urbanized areas (1960) were tentatively segregated into four population size groups and then subdivided, on the basis of population density, into three density classes for each group. This approach was based on the theory that automobile availability and the mode of transport used in the work trip are functions, primarily, of population size and density.

Analysis revealed the inadequacy of population density in explaining urban area variations in most of the selected indicators of transportation and socioeconomic characteristics.

An inferential statistical method, the stepwise multiple-regression procedure, was used to analyze the interrelationship between 6 transportation variables (dependent) and 12 socioeconomic variables (independent) in each of the four population size groups. Several of the equations developed have potential use for estimating certain indicators of automobile availability and travel characteristics.

A regrouping of urbanized areas, using as the criterion a ratio of the number of automobiles available to the number of persons employed, resulted in urbanized area types which in each population size group display distinguishing transportation characteristics as well as characteristics underlying socioeconomic factors and geographic location.

THIS research was performed by division staff assigned to this task, which is one of several included in the national research project, "Underlying Factors in Urban Transportation Analysis."

One major area of concern in the development of transport requirements and the formation of new methods of forecasting demand for highway transport is the need to examine systematically the underlying factors in urban transportation. The design of this project contemplates a number of tasks at the national level which involve, primarily, a collation and correlation of significant variables and empirical values that have been associated with the demand for urban transportation.

OBJECTIVE AND SCOPE

The objective of the typology task is to develop urban area transportation types that will facilitate the analyses of urban transportation and the estimation of present and future urban travel characteristics. Segregation of urban areas by a transportation classification is to be accomplished with the aim of identifying the major factors underlying the transportation "mix" of an area. Statistical methods of analysis will be used to test the relative strength of underlying variables and the design of equations for estimating certain urban transport variables. An estimating manual or handbook will be prepared.

Characteristics of the physical elements, population, income, economic function and growth, as well as transport, are included in the scope of this task.

With its stated purpose of facilitating urban transportation analysis, the typology task is fundamental to the overall project. This task is also comprehensive in scope

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taking into account certain aspects of the other task areas: forecasting, population characteristics and change, urban economics, effects of rising income, and emerging urban form.

URBAN AND TRANSPORTATION DEFINED

To describe the scope of this project and to more easily focus on the major areas of concern, it is necessary to define the terms urban and transportation.

Urban Area

Urban generally connotes a geographic area which is "built up" or has well populated industrial, commercial and housing structures in close proximity. The measures of this condition vary somewhat among agencies involved in studying these areas as well as within individual studies prepared by the same agency.

The U.S. Bureau of the Census has the most complete and comprehensive data on population and its geographic distribution. Use of Census definitions, therefore, has the advantages of comparability and consistency.

Basic census classification of urban places are standard metropolitan statistical areas (SMSA's), urbanized areas, cities, and places with over 2,500 population.

In this report, urban area and urbanized area are the same (Fig. 1). Urbanized area was selected as the study area over SMSA and city for several reasons:

1. Urban transportation analysis should concern itself with the area in which almost all of the urban transportation problems exist.
2. The SMSA, composed as it is of whole counties, takes in much rural area.
3. City (the political entity) varies widely in the population density at its limits. New York or Philadelphia, for example, have high densities extending beyond their borders; whereas Houston and Oklahoma City boundaries take in vast areas of extremely low density.
4. Urbanized areas generally represent the thickly settled core of the SMSA's with the exception of the New York-Northeastern New Jersey and the Chicago-Northwestern Indiana urbanized areas.

It is recognized, of course, that many characteristics and relationships can often be identified whether the unit of study is the urbanized area, the SMSA, or the city.

Urban Transportation

Transportation in an urban area is thought of as the movement of people and goods from place to place. Transportation of persons may be described in terms of pedestrians, vehicle passengers, or vehicle drivers. Mode of transport may also be considered in relation to purpose of trip—work, shop, social, recreation, etc. Purpose of trip and mode of travel may be considered in relation to the numbers and types of vehicles available. Other descriptors of urban transportation are trip frequencies, distances and speed, and miles of travel by various modes during a certain period of time. Therefore, a systematic examination of the underlying factors in urban transportation should begin with a comparative analysis of urban complexes and their transportation characteristics.

THEORETICAL BACKGROUND

Choice of Transport Mode

The use of a particular mode of transport by an individual in an urban area depends initially on the choices available to him. The variety of choices available, whether on rail, road or sidewalk, vary from city to city, but some cities are similar in the combination of facilities provided. Some are equipped with extensive rail facilities but not so well equipped to facilitate motor vehicle travel.

In the largest cities the transportation spectrum runs from the elaborate rail transit system in New York to insignificant rail transit facilities in Los Angeles. Between

Figure 1. Urbanized areas, 1960.

these two extremes the transport type shifts abruptly from rail to road, after taking into account Boston, Philadelphia and Chicago.

Through the remainder of this transport spectrum are variations among the cities in the types of road facilities provided—the more adequate the road transport network, the less adequate the bus service. Design standards and extensiveness of the road structures improve as the level of bus service declines, from Washington, D.C., down through Baltimore, Pittsburgh, Milwaukee, Cleveland, Buffalo, St. Louis, and San Francisco.

Beyond this range, transport availability almost limits the choice to automobile because of the emphasis on facilities provided for this type of travel. The large areas in this category, in ascending order according to adequacy of highway facilities, are Minneapolis-St. Paul, Detroit, Houston, and Los Angeles.

The varied choice of transport has gradually shifted from the mix of rapid rail, streetcar, bus, automobile, and walking to a mix which excludes rapid rail and streetcar but with significant emphasis on bus and walking, and then to a mix in which the choice is narrowed almost exclusively to automobile.

Tomorrow's Choice—A Function of Yesterday's Investment

This description was intended to underscore the fundamental importance of the type and density of physical structures erected to accommodate social and economic activities and the transportation facilities constructed to service those structures, e.g., the location and design of buildings and rail facilities and of collector and arterial streets and highways. It is these factors which explain to a great extent the differences between areas in the relative use of private and collective passenger vehicles. Historically then, use of the private vehicle increased, relative to the use of the collective vehicle, as the road structure improved, relative to rail improvements.

The old rapid rail cities, working in the direction of providing facilities for the private car, have had some success. The transformation from rail to road, however, is very slow and becomes slower as additional portions of the skeletal system of the city are dismembered. The relatively permanent remaining portions of the skeleton, including the rail system serving it, become real "sore" spots which resist the change.

Often, the road system is superimposed on the rail system, thus providing the commuter with a choice of modes. Where one supplants the other, however, opportunity for choice has not been improved.

The relative success in changing from rail to road, or from streetcar and bus to automobile is, again, dependent on the degree of permanence of investment that was made, or is made, in the skeletal structure of the city, a key element of which is its transport system.

The structure of the core and inner ring of New York, for example, is permanently in place. Office, government, educational buildings as well as apartment houses and the subways that serve them are firmly set for a long time to come (1). The same is true in varying degrees in Chicago, Philadelphia and Boston—cities which have common backgrounds of growth.

Los Angeles and Houston, on the other hand, are heavily committed to motor vehicle transport. Areas such as these can therefore be expected to rely completely on the highway facilities that make up such an important part of their multinucleated skeletal structures (2).

Hypotheses

Initial examination of indicators of the general characteristics of an urban area and that area's reliance on various modes of transportation led to the hypothesis that a classification or typing of urban areas would facilitate analyses and make more comprehensible the data used in describing how interactions of several variables differ from one type of urban area to another.

Conceivably, a transportation classification of urban areas would be useful in conjunction with urban area transportation studies. It may be possible to estimate certain characteristics of travel patterns in a particular urban area on the basis of the findings in completed studies of other areas of the same type. Conversely, it is also conceivable that some findings of completed studies of a small sample of urban areas of a particular type may have general application to other areas of that type.

Urban areas having similar transportation characteristics may have similar socioeconomic characteristics. By establishing quantitative relationships between certain aspects of the two characteristics, a measurement is provided for forecasting future travel characteristics of an urban area type (3).

Studies of travel patterns, such as those made in origin-destination surveys, may be aided by the development of such indicators as trip frequencies, trip purpose, time of travel, and mode of travel for common use in areas of a particular type.

Data

The empirical research was carried out with the use of data provided by the Bureau of the Census. These data are available in several publications prepared by the Census Bureau. By their completeness and availability, these data satisfied the need for obtaining economically measures of both the urban transport characteristics and the factors underlying them that were judged to be best suited for this experiment and for the possible potential use of the results. For a discussion of the reasoning behind choice of characteristics and their measures see the section "Selection of Variables."

APPROACH—STATIC PHASE

Interrelationships of transportation and socioeconomic variables in each urbanized area are examined as they exist at one point in time (a static or cross-section analysis). This approach was used as a first phase of the task in order to: (a) identify existing major underlying factors; (b) measure their relative influence on currently used indicators of urban travel; (c) develop mathematical equations for estimating present travel characteristics in areas where such information is not yet available; (d) develop mathematical equations for estimating future travel characteristics in areas where current data are available; and (e) develop a classification of urban areas based on transportation indicators and underlying factors.

Examinations of the dynamics involved in the growth of an urban area and changes in its transportation requirements are being made and the results of these analyses will be covered in a subsequent report. An integration of the static and dynamic analyses will be attempted to give insight into the relative importance of factors underlying transportation requirements by urban area type, the changing importance of these interrelationships, and the probable effects on the status of transportation types and individual areas within these types.

RESEARCH PLAN

The research plan contemplates analyses of urban transportation related to general characteristics of an urban area—structure, function, form and growth, and transportation characteristics, such as automobile availability and the use of various mixes of the four general characteristics. Certain structural indicators selected from those such as population size, density and age composition, personal income, and age of the area, will be combined with selected measures of economic function, geometric form and growth.

For example, a medium-sized, rapidly expanding urban area having a youthful population, new housing, a diversified industry mix, and a circular form on flat terrain would be expected to have a high rate of automobile ownership and use.

On the other hand, a large, densely populated urban area, having low rates of increase in population and income, a manufacturing-oriented economy, a relatively old population, and a ribbon shape paralleled by rough terrain would be expected to have relatively low rates of automobile ownership and use.

Accomplishments

The work accomplishments given in this report cover correlation analyses of certain structural measures with measures of aggregate transportation use for 1960. The transportation variables are also related to one measure of an area's economic base. Growth data, i. e., data on changes in the structural and functional variables have been compiled and prepared for mechanical statistical correlation analyses.

Research Not Yet Completed

The characteristic of form has not yet been related to transportation; however, considerations of urban form led to two broad categories: (a) geometric shape of the area—circular, square, rectangular, radial, linear, oval, triangular, bowl; and (b) transportation-terminal type—seaport, lakeport, riverport, airport, railroad or highway junction, or some combination thereof.

It is expected that the shape in combination with the transportation base of an area would indicate the relative accessibility of zones within an area and that area's conduciveness to automobile transport and its potential paths of expansion.

A linear-shaped seaport, for example, indicates orientation toward the waterfront where much activity is concentrated. Its linear shape indicates topographical barriers which inhibit growth in two directions when a long waterfront is paralleled by mountainous terrain a few miles distant. High population densities usually develop with these conditions, which make rail or highway mass transit efficient. Seattle appears to fit this description.

A radial-shaped railroad and/or highway junction indicates relatively high central business district (CBD) orientation and development along the railroad lines and highways emerging from it. The degree of orientation toward the automobile for the area as a whole will depend on the population density and concentration of activity in the CBD and immediate environs. In the rest of the area, conditions of this form are amenable to automobile use. From this perspective the potential growth may be seen in the spaces between the radials. Dallas would seem to fit this description.

These and other examples of the hypothetical relationships between urban form and transportation remain to be tested. Significant results of these tests when coupled with the key indicators of population and economic growth and related to transportation characteristics should reveal the variables underlying transportation use and the relationship between changes in transportation variables and urban form.

Employment concentration in certain industries has been used to measure the economic function of an urban area. Data on employment by industry for 1950 and 1960 have been compiled in order to show changes in function. Comparative analyses are being made to determine what relationship may exist, if any, between changes in economic function and automobile availability.

Trend data, where available, are being compiled for the purpose of comparing changes in social and economic factors with changes in the transportation classification of urban areas. Supplemental reports are being prepared.

Other aspects of this task in which pilot studies and experiments have been made but in which considerable research remains to be done include the following:

1. Comparisons of social status scores of urban areas. These scores, which are composed of weighted indices of educational, occupational and income levels, are intended for use in the study of interrelationships between social status, other socioeconomic factors and transportation use.

2. Bureau of the Census data on the journey to work have been tabulated for several urbanized area for the purpose of making comparative analyses of the central city orientation of urban areas as indicated by worker commuting volumes into and out of central cities.

3. Test the usefulness of the typology in estimating certain trip characteristics for urban areas of a particular type. Data from comprehensive transportation planning studies will be used as inputs into the estimating equations developed for areas of one type or classification. It is contemplated that experimentation and modification using

these data will result in equations which may be generally applied to one type of area.

4. Investigation is continuing into the potential use of several different measures of geometric form and growth patterns of urban areas. The objective is to determine the interrelationships that may exist between changes in urban transportation characteristics and patterns of development.

A STRATIFICATION OF URBANIZED AREAS

The literature covering all facets of urban complexes suggests that features be grouped under the following general categories: urban structure (4, 5, 6), function (7, 8, 9, 10, 11), form (12, 13, 14), and growth (15, 16, 17, 18). Characteristics of the human as well as the physical agglomeration come under the heading of structure. Buildings and transport structures and the people they serve are described under this broad heading. Features of composition or makeup include the size and type of buildings and transport facilities and the magnitude of the population and its distribution. Related population characteristics, such as age composition and distribution by income groups, are also included to portray the basic physical and human attributes as they might be related to transportation.

Population Size and Density Groups

Population size is a measure of the relative magnitude of an urban area as well as an indicator of relative volumes of persons and goods movement. A comparison of population totals between areas suggests that a segregation of areas into a small number of size groups would improve their comparability.

Following this reasoning, the 213 urbanized areas were divided into four groups according to total number of inhabitants. A ratio of the largest to the smallest group population totals was used as one guide in order to get some degree of uniformity in population range (Table 1).

Population density indicates the relative compactness of an area, a second important consideration related to urban transportation (5). Whereas size is indicative of overall traffic volume, density should indicate relative congestion (19).

Each of the four size groups was then divided into subgroups based on a weighted, gross population density measure.

The number of persons per square mile in the central city was weighted by the proportion of the urbanized area's population residing in the central city at that density. The same computation was made for the urban fringe and the sum of the two weighted densities gave the measures for each urbanized area as summarized in Table 2.[1]

Areas in the two largest size groups distributed themselves rather equally among high and low densities. In the medium and smallest size groups the density distributions were not even. Areas in each of these groups tended to cluster around a moderate density.

Size and density groups were thus established for experimental purposes to determine the effect of these variables on urban transportation characteristics. Effort could then be made to identify the distinguishing transportation characteristics of each size and density group.

It was anticipated that, while size and density groups may lead to transportation types, it would probably be necessary to regroup the areas on different bases after regression analyses were made.

Population size and density indicate basic structrual characteristics of an urban area. Age of an area, i.e., the period in which it grew most rapidly, indicates the type and spatial arrangement of buildings and the type of transportation service available. Other important characteristics of urban makeup are the age composition of the

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[1]The original manuscript of this paper contained an appendix with supporting tabular data given in detail. These tables may be obtained from the Highway Research Board by special arrangement. Inquiries should refer to XS-10, Record 194.

TABLE 1

URBANIZED AREA POPULATION SIZE GROUPS[a]

Group Number	Population Ranges (thousands)			Number of Areas	Population Distribution	
	Low	High	Ratio		Total	Percent
1	1,000	14,000	1:14.0	16	51,786	54.5
2	350	999	1:2.9	36	21,154	22.7
3	150	349	1:2.3	59	13,153	12.6
4	50	149	1:3.0	102	9,755	10.2
Total	50	14,000	1:280.0	213	95,848	100.0

[a]In thousands.
Source: Adapted from U.S. Census of Population: 1960, Final Report PC(1)-1A, Table 23, U.S. Department of Commerce, Bureau of the Census.

population and the distribution of the population according to income levels. The foregoing indicators of an urban area's structure were selected in the order of their considered relative importance to analysis of urban transportation.

Size-Group Assumptions

Segregation of the 213 urbanized areas into the four population-size groups (Table 1) was based on certain assumptions and considerations.

One assumption is that the larger the area the more complicated its transportation problem; urbanized areas with populations of 1 million or more have the severest problems.

It was recognized that, although the range in size of the largest areas is broad (1 to 14 million), there are only 16 areas in the group. This number does not lend itself to being subdivided because the number of observations would then be too small to make valid correlation tests using statistical methods.

The remaining 197 areas were then divided into three groups to reduce the variance in size and the assumed related transport problems.

This experimental grouping was based on several considerations: (a) minimizing the number of groups; (b) reducing the variation in size to proportions which would

TABLE 2

URBANIZED AREA POPULATION SIZE AND WEIGHTED DENSITY GROUPS

Group Number		Weighted Population Density Range[a]		Number of Areas	Population Distribution	
Size	Density	Low	High		Total (thousands)	Percent
1	1	8,966	15,785	5	26,183	27.3
1	2	6,212	7,458	6	13,643	14.2
1	3	2,702	5,730	5	11,960	12.5
2	1	5,070	6,459	12	6,730	7.0
2	2	3,521	4,788	11	6,113	6.4
2	3	1,165	3,496	13	8,311	8.7
3	1	4,673	8,266	14	3,319	3.5
3	2	3,026	4,472	27	5,679	5.9
3	3	1,502	2,969	18	4,155	4.3
4	1	4,024	10,004	32	2,950	3.1
4	2	2,518	3,947	41	4,329	4.5
4	3	680	2,447	29	2,476	2.6
12 Group Total		680	15,785	213	95,848	100.0

[a]Persons per square mile.
Source: Adapted from U.S. Census of Population: 1960, Final Report PC(1)-1A, Table 22.

make group average characteristics more representative; and (c) making comparative analyses more meaningful.

Almost 96 million persons (53 percent of the population) lived in the 213 urbanized areas in 1960. The 16 largest areas contained nearly 52 million, almost 30 percent of the total national population. In other words, almost one-third of the population of the United States resides in 16 urban agglomerations, each having more than 1 million persons.

The 102 urbanized areas in the smallest population size group (50,000 to 150,000) contained less than 10 million persons, or 10 percent of the total urbanized area population in 1960

Table 1 gives the wide difference between the largest and smallest areas. Data on the number of areas and the population distribution among the four size groups show clearly the tendency toward population concentration.

Variations such as these, in the population size of urbanized areas, indicate the variations among the areas in the magnitudes of travel volumes. Areas such as New York, Los Angeles and Chicago in the largest size group are reasonably expected to have transportation requirements of a more complex nature than those of areas in the other size groups, because of the larger number of persons and greater expanse of land area to be served.

Density Group Assumptions

Surface movement of persons within an area is expected to be more or less congested and more or less rapid, depending largely on the density at which the people reside and work. Relative densities are given in Table 2.

Theoretically, then, population density is considered to be the major factor underlying the demand for the types and extents of urban transportation systems. Densely populated urban complexes are expected to be best served by vehicles that have a large passenger-carrying capacity, thereby providing mass movement of persons relative to vehicles. In other words, population density is closely associated in a positive way with general orientation toward persons, and in a negative way with automobile orientation.

TABLE 3

AVERAGE LAND AREA, POPULATION SIZE AND WEIGHTED DENSITY OF URBANIZED AREA GROUPS

Group Number		Number of Areas	Land Area (sq mi)	Population	
Size	Density			Total (thousands)	Weighted Density[a]
1	1	5	766	5,237	10,712
1	2	6	512	2,274	6,961
1	3	5	675	2,592	4,677
1	All	16	642	3,237	7,420
2	1	12	136	561	5,496
2	2	11	160	556	4,230
2	3	13	275	639	2,720
2	All	36	194	588	4,107
3	1	14	61	238	5,928
3	2	27	64	210	3,838
3	3	18	105	231	2,481
3	All	59	76	223	3,920
4	1	32	22	92	5,279
4	2	41	38	106	3,116
4	3	29	54	85	1,846
4	All	102	38	96	3,433

[a]Persons per square mile.

Source: Adapted from U.S. Census of Population: 1960, Final Report PC(1)-1A, Table 22.

Population density being equal, differences between urban areas in automobile orientation are often attributed to differences in income level. On the theory that relatively high income can overcome, to some extent, the congestion costs imposed by high population density (higher vehicle operating, maintenance, insurance, and parking costs), areas with relatively high income will have greater reliance on the automobile than an area of similar density but lower income.

Comparisons of Urbanized Area Size and Density Groups

The influence of New York, Los Angeles, and Chicago on the average size and density of the 16 largest areas is indicated in Table 3. An average population total of 3.24 million for the largest group is 5½ times the average size of the second largest group (588 thousand). Differences are far less between the smaller groups with the second group being over 2½ times the size of group 3, and the third group a little more than twice the size of group 4.

Averages for the density groups within each size group do not vary widely, with the exception of these in the largest size group. Population totals, for example, range from 5.24 million down to 2.59 million in the group of areas being largest in size and highest in density; whereas there is relatively little variation in size among the density groups in each of the other three size groups. Thus, similarity in population size among the density groups within each size group is necessarily reflected in the negative correlation between the square miles of land area and the population densities in each size group (again with the exception of size group 1). Population size was thereby seen as a constant within size groups 2, 3, and 4.

Selection of Variables

Automobile ownership measured by the auto-employment ratio was selected as a key dependent variable in order to overcome differences in population characteristics that often underlie urban area variations in autos per capita and autos per dwelling unit—two commonly used indicators of automobile reliance. Differences between areas in auto-employment ratios were expected to be more sensitive to factors indicating the relative personal need, desire and ability to own autos, the automobile conduciveness of areas as measured by area age, and age distribution of the population and income distribution, in addition to population size and density.

Generally, need to own an automobile is implied in the measured age of an area, its population density, and the newness of its structures. The longer an area has been established and the more time that has passed since its period of most rapid expansion, the higher will be its population density, the older will be its structures, and the less automobile oriented it will presently be. Although its newer suburbs are conducive to automobile use, its central city still relies somewhat on the older modes of mass transit and walking in many trips—automobile need is not great.

Urbanized areas of more recent development are characterized by low population densities and new buildings designed to fit into the automobile age. Little or no provision is made for the older modes of transport in these areas; therefore, need for an automobile is great.

Desire to own automobiles is indicated by the proportion of population in the age groups associated with high rates of automobile availability. Under 18, 18 to 64, and 65 and over were the three age-group distributions that are compared with rates of automobile availability. A high proportion of persons under 18 indicates a relatively large number of families in early stages of the life cycle. These families predominate in suburbia where multicar ownership is desirable, with husband and wife each wanting to own a car.

The middle-age group, 18 to 64, takes in most of the workers. People in one-person households and mature families make up this group which usually predominates in central cities where the ownership and use of an automobile is less desirable, especially where adequate mass transit is available.

Large proportions of persons in the 65-and-over group are presumably associated with both high and low auto ownership rates, depending on the size and density of an area and the availability of mass transit. In the large, dense areas, older persons in the central city would not have a high rate of auto ownership, but those in this age group who live in areas that are not very large or dense are expected to own automobiles.

In areas where there is a high proportion of persons in this age group, it was expected that the number of retirees owning cars would effect an unrealistically high rate of automobiles per 100 persons employed. Areas in which retirees owning cars would destroy the usefulness of the auto-employment criterion were expected to be few and could be readily recognized.

Where the need and desirability of owning an automobile exists, differences in rates of automobile ownership will be accounted for by differences in ability to own and operate automobiles. Ability is measured in dollars of personal income on a per capita basis and on the basis of proportions of high and low-income families ($10,000 and over and under $3,000).

It seemed logical to expect areas of similar size, density, age composition, and distribution of the population to have differences in automobile ownership rates which could be explained in almost every case by differences in the level and distribution of income.

ANALYSIS OF URBANIZED AREAS BY POPULATION SIZE AND DENSITY GROUPS

Visual Comparison

In Table 4, socioeconomic and transportation variables have been added to population size, density, and land area for each of the four size groups. The positive relationships between these three measures are shown. Income per capita is also positively related to size and age of the area. The average values were computed from tabulations of individual area data which are not included herein.

It is interesting to note the dissimilarities between the largest urban areas and those in the three remaining groups in the average values of certain characteristics. On the

TABLE 4

AVERAGE VALUES OF SOCIOECONOMIC AND TRANSPORTATION CHARACTERISTICS OF URBANIZED AREAS BY POPULATION SIZE GROUPS

Characteristic	Population Size Groups			
	1,000,000 and over	350,000 - 1,000,000	150,000 - 350,000	50,000 - 150,000
General:				
1. Total population, thousands	3,237	588	223	96
2. Population density, persons per sq mi	7,420	4,107	3,920	3,433
3. Land area, sq mi	642	194	76	38
4. Income per capita, 1959 $	2,250	2,052	1,947	1,873
5. Age of area, year	1914	1914	1919	1921
6. New housing units, %	26.6	33.2	30.9	28.5
7. Population 18-64 years, %	57.1	56.0	55.9	55.5
8. Population 65 and over, %	8.7	8.5	9.0	8.8
9. Population under 18, %	34.2	35.5	35.1	35.7
10. Family income under $3,000, %	12.5	15.9	18.1	18.1
11. Family income $10,000 plus, %	21.3	17.6	15.5	14.2
12. Persons per occupied housing unit	3.23	3.24	3.25	3.26
13. Autos per 100 employed residents	76.1	86.3	85.7	84.8
Primary work trip mode, %:				
14. Auto or car pool	61.41	70.17	71.29	72.25
15. R.R., subway, or elevated	4.48	0.16	0.34	0.25
16. Bus or streetcar	17.28	12.40	9.83	7.36
17. Walk	7.88	7.26	9.58	11.57
18. Other	1.46	1.78	2.10	2.37
19. Work at home	2.37	3.58	2.51	2.51
20. Not reported	5.13	4.66	4.35	3.70
Occupied housing units, %, with:				
21. No car available	25.0	20.1	20.0	20.3
22. One car available	56.0	56.3	57.8	57.1
23. Two cars available	16.9	20.9	19.8	20.1
24. Three or more cars	2.2	2.7	2.5	2.5

Sources: Adapted from data in the U.S. Censuses of Population and Housing: 1960; the Statistical Abstract of the United States: 1964; and the County and City Data Book: 1962.

average, population density and per capita income are higher in the largest areas than in areas making up the remaining groups.

Except for the largest areas, the average number of automobiles per 100 employed residents decreases slightly from the second largest to the smallest areas as both average population density and average per capita income decline.

Comparison of primary work trip mode shows that in the largest size group almost 22 percent of the workers rely on mass transit. In the three smaller area groups there is a gradual decline in the use of mass transit and a corresponding increase in walking. Use of the auto or car pool increases sharply from the largest to the second largest size group and then shows slight increases to the third and fourth groups. However, in the latter two groups a slight decline in the number of autos per 100 employed residents accompanies the increase in auto or car pool travel to work. Because these movements are associated with the shift from transit to walking, it may be assumed that as the size of the area becomes smaller, mass transit becomes less adequate; walking and car-pooling become more necessary. Car-pooling would, therefore, appear to be an increasingly larger proportion of the auto and car pool total.

Data on automobiles available by occupied housing units depict similarities among the three smallest size groups in all four characteristics (Table 4). The largest size group differs significantly from the other groups in the percent of households with no cars and those having two or more cars.

Density Groups

Characteristics of the urbanized areas in each of the 12 size-density groups are given in Table 5. (The areas in each of the four size groups were subdivided into high, moderate and low density groups.)

The data for each density group in the areas of the largest size group demonstrate the effect of density on the measures of availability and use of the automobile and other means of transportation. The number of automobiles available per 100 employed residents increases sharply as density drops from high to moderate to low. This negative correlation is also apparent in the data on the percentage distribution of housing units with one, two and three or more cars, but only in the areas having a population of 1 million or more.

In the second largest size group there is considerable narrowing of differences between density groups in the indicators of automobile availability. In the largest size group, as density drops from high to low the number of autos per 100 employed residents increases by 20, from 65 to 85. In the second largest group the range in the same automobile ownership indicator is reduced to approximately 12 as the number of autos per 100 employed persons increases from 82 to 94 with the reduction in population density. A similar range of 80 to 92 is given for the third largest group, whereas in the smallest size group no correlation and practically no variation is indicated between the density groups.

The effect of density on the distribution of housing units according to the number of automobiles available is reflected in the data for the largest areas, and to a much lesser extent in the two middle-sized groups, but not at all in the smallest area group.

It is significant that the urbanized areas in the lowest density group of the 350,000 to 1,000,000 population size group have the highest rate of automobile ownership (93.8), the lowest proportion (17.5 percent) of households with no car available, the highest percentages of two-car (24.5 percent) households, and households with three or more cars (3.2 percent).

Of greater significance, however, are the similarities in the percentages of workers who traveled to work by auto or car pool. Omitting the two highest density groups in the largest area class, the range in the percentages of workers using the auto in the work trip is a narrow 68 to 73 percent (rounded). When these figures are compared with those in the line of figures immediately above, the interrelationships between the two and population density are quite clear. Within each population size group, change from density group to density group in the number of autos per 100 employed residents is accompanied by a similar change in the percentage of workers using the automobile

TABLE 5

AVERAGE VALUES OF SOCIOECONOMIC AND TRANSPORTATION CHARACTERISTICS OF URBANIZED AREAS BY SIZE AND WEIGHTED POPULATION DENSITY GROUPS

Characteristic	Population Size by Weighted Population Density Groups											
	1,000,000 and over			350,000-1,000,000			150,000-350,000			50,000-150,000		
	Over 8,000	6,000 - 8,000	Under 6,000	Over 5,000	3,500 - 5,000	Under 3,500	Over 4,500	3,000 - 4,500	Under 3,000	Over 4,000	2,500 - 4,000	Under 2,500
General:												
1. Total population, thousands	5,237	2,274	2,392	561	556	639	237	210	231	92	106	85
2. Population density, persons per sq mi	10,712	6,961	4,677	5,496	4,230	2,720	5,928	3,838	2,481	5,279	3,116	1,846
3. Land area, sq mi	766	512	675	136	160	275	61	64	105	22	38	54
4. Income per capita, 1959 $	2,195	2,316	2,223	2,089	2,031	2,036	2,032	1,874	1,989	1,897	1,915	1,787
5. Age of area, year	1904	1913	1924	1905	1912	1923	1904	1921	1927	1916	1917	1932
6. New housing units, %	21.8	31.0	32.5	27.4	29.0	42.4	23.8	30.5	36.9	25.9	29.8	29.6
7. Population 18-64, %	57.7	58.6	56.3	55.5	55.9	55.9	56.5	56.3	54.8	55.5	55.8	55.3
8. Population 65 and over, %	8.8	7.1	8.6	9.3	8.4	7.2	9.2	8.0	10.4	9.0	9.0	8.2
9. Population under 18 years, %	33.4	33.9	35.3	34.3	35.6	36.3	34.2	35.7	34.8	35.6	35.2	36.5
10. Family income under $3,000. %	12.6	12.3	12.6	15.1	15.8	16.7	14.4	19.8	18.6	16.1	17.4	21.3
11. Family income $10,000 plus, %	20.3	22.9	20.2	17.5	17.9	17.5	16.3	14.9	15.7	14.7	14.5	13.3
12. Persons per occupied housing unit	3.3	3.2	3.2	3.2	3.3	3.3	3.2	3.3	3.2	3.3	3.2	3.3
13. Auto per 100 employed residents	65.1	78.1	84.5	81.5	82.6	93.8	79.8	84.4	92.4	84.0	85.6	84.7
Primary work trip mode, %:												
14. Auto or car pool	52.9	63.1	67.9	67.5	69.8	73.0	69.2	71.3	72.9	72.0	73.0	71.8
15. R.R., subway, elevated	10.8	2.8	0.2	0.1	0.2	0.2	0.2	0.1	0.8	0.3	0.2	0.4
16. Bus or streetcar	18.7	17.5	15.6	13.8	13.7	10.0	11.8	10.1	8.0	7.1	7.5	7.4
17. Walk	8.5	7.4	7.8	8.4	7.7	5.9	10.7	9.8	8.4	12.8	10.7	11.5
18. Other	1.3	1.6	1.5	1.6	1.7	2.0	1.5	2.2	2.4	2.2	2.3	2.6
19. Work at home	2.3	2.4	2.4	3.7	2.8	4.1	2.1	2.2	3.3	2.5	2.4	2.7
20. Not reported	5.4	5.2	4.7	5.0	4.2	4.8	4.5	4.3	4.3	3.4	4.0	3.6
Occupied housing units, %, with:												
21. No car available	31.4	23.9	19.8	21.6	21.5	17.5	20.7	20.6	18.5	20.0	20.3	20.6
22. One car available	54.9	56.1	57.0	58.2	56.1	54.8	59.7	56.5	58.2	58.9	56.4	56.0
23. Two cars available	12.2	17.8	20.5	18.0	19.9	24.5	17.5	20.5	20.5	18.6	20.7	20.9
24. Three or more cars	1.6	2.3	2.6	2.3	2.5	3.2	2.1	2.5	2.8	2.4	2.6	2.5

Sources: Adapted from data in the U.S. Censuses of Population and Housing: 1960; the Statistical Abstract of the United States: 1964; and its supplement, the County and City Data Book: 1962.

in the work trip. The changes are in the same direction; however, the amplitudes of change differ considerably from size group to size group.

In the largest size group, an increase of 20 in the automobile availability indicator (from 65 to 85, rounded) is accompanied by a rise of 15 percentage points in the use of the auto (53 to 68 percent, rounded). The same two series show increases of 12 autos and 5 percentage points, respectively, in the second largest group of areas.

In the third largest group, use of the auto in the work trip becomes even less responsive to change in the number of autos per 100 workers as a change of 12 in the number of autos is reflected in a change of 4 percentage points in use. There is virtually a stable relationship between the two variables in all three density groups of the smallest areas.

The relative stability in the percentage of workers using the auto in the work trip suggests the existence of a norm in this regard. In all but the largest and densest urbanized areas, where rail rapid transit plays an important role, there is wide variation among the urbanized area groups in the use of the bus or streetcar and walking to work, but there is little difference in the use of the auto. Use of the bus or streetcar shows some inverse relationship with density but a pronounced positive relationship between population size groups (see Table 4). Walking to work has a negative relationship with both density and size. The positive relationship between size of the area and the use of bus or streetcar in the work trip along with the negative relationship between size of area and walking to work explain the relative stability of the proportion of workers using the automobile in the work trip.

From the foregoing comparisons and further examination of the density group data in Table 5, it becomes apparent that within each size group most of the selected socioeconomic and transportation variables are insensitive to changes in population density.

Among the density groups within each size group, except the largest, there is little variation in the averages of such characteristics as total population, income per capita, the age group components of the population, the proportions of high and low-income families, the number of persons per occupied housing unit, the percent of workers using an automobile or car pool in the work trip, and the percent of housing units with one car available.

Characteristics which show a tendency to vary with changes in density of areas of a particular size are as follows: (a) age of area; (b) the percent of housing units built from 1950 to 1960; (c) the number of automobiles per 100 employed residents; (d) the percent of workers using bus or streetcar or walking to work; and (e) the percent of housing units with no car or two or three cars available. Areas in the small size group, however, do not exhibit this sensitivity to differences in population density.

Population density thus fails as a criterion for general use in distinguishing urbanized areas of a particular type or mix of transportation usage.

SIMPLE CORRELATION AND STEPWISE MULTIPLE-REGRESSION ANALYSES OF FOUR GROUPS OF URBANIZED AREAS

A 24-variable correlation coefficient matrix was prepared for each of the four population size groups. Intercorrelations of variables selected from the matrices are given in Table 6. Twelve of the 24 variables were indicators of demographic, social and economic characteristics. Transportation indicators comprised the other 12 variables.

Six of the 12 transportation variables were selected to be dependent variables in a 12-step (12 socioeconomic independent variables) multiple-regression analysis to be performed for each of the four population size groups (20).

Simple Correlation Analysis of Urbanized Areas in Four Population Size Groups

Results of a simple correlation analysis are summarized in Table 6. Correlation matrices of the 24 variables for each of the four size groups provided the coefficient correlations. Table 6 gives the correlation coefficients for two transportation variables related to each of 12 socioeconomic variables in each of the four population size groups.

TABLE 6

INTERCORRELATIONS OF SELECTIVE VARIABLES
(Simple Correlation Coefficients, r)

Socioeconomic Variable	Urbanized Area Population Size Groups			
	1,000,000 and over	350,000 - 1,000,000	150,000 - 350,000	50,000 - 150,000
(a) Autos Available per 100 Employed Persons				
1. Population, 1960	-0.286	0.065	0.155	-0.074
2. Population density, weighted	-0.749	-0.467	-0.320	-0.091
3. Land area, sq mi	-0.060	0.250	0.206	-0.017
4. Income per capita, 1959 $	0.127	0.218	0.099	0.138
5. Age of area	-0.493	-0.716	-0.597	-0.359
6. Housing units, built 1950-60, %	0.684	0.736	0.745	0.597
7. Population 18-64, %	-0.360	-0.234	-0.635	-0.120
8. Population 65 and over, %	-0.287	-0.187	0.235	-0.371
9. Population under 18, %	0.462	0.306	0.144	0.380
10. Families with income under $3,000, %	0.189	-0.163	0.199	-0.085
11. Families with incomes $10,000 plus, %	0.072	0.190	0.052	0.176
12. Persons per occupied housing unit	-0.148	-0.183	-0.239	0.005
Value of r at 0.05 level of significance	0.500	0.350	0.250	0.190
Number of urbanized areas	16	36	59	102
(b) Percent of Work Trips by Auto or Car Pool				
1. Population, 1960	0.576	0.180	0.131	-0.045
2. Population density, weighted	-0.808	-0.429	-0.210	-0.087
3. Land areas, sq mi	-0.412	-0.238	0.091	-0.060
4. Income per capita, 1959 $	-0.186	0.322	-0.068	0.097
5. Age of area	-0.516	-0.513	-0.354	-0.268
6. Housing units, built 1950-60, %	0.674	0.434	0.569	0.548
7. Population 18-64, %	-0.630	-0.374	-0.593	-0.148
8. Population 65 and over, %	-0.411	0.042	-0.121	-0.460
9. Population under 18, %	0.741	0.197	0.447	0.471
10. Families with incomes under $3,000, %	0.266	-0.435	0.001	-0.125
11. Families with incomes $10,000 plus, %	-0.145	0.237	-0.017	0.154
12. Persons per occupied housing unit	-0.209	-0.192	0.006	0.112
Value of r at 0.05 level of significance	0.500	0.350	0.250	0.190
Number of urbanized areas	16	36	59	102

Sources: Adapted from the U. S. Censuses of Population and Housing: 1960, and the County and City Data Book: 1962.

Number of Autos Available per 100 Employed Persons

In Table 6(a) the number of autos available per 100 employed persons has a negative correlation with population density in each size group. As the value of r drops from -0.749 in the largest group to -0.091 in the smallest group, the acceptable level of r also drops, so that only in the smallest group does r (-0.091) fall below the value at which the chances would be greater than 1 in every 20 (0.05) that the value of r could be obtained from a sample of two variables having zero correlation.

The r value of 0.745 has a high level of significance for housing units between 1950 and 1960 and autos available per 100 employed persons in the size group 150,000 to 350,000. A significant r value (0.597) for these two variables is also obtained in the smallest size group.

Age of area is significantly correlated (at the 0.05 level of significance) with automobiles per 100 employed persons in all but the largest size group.

No significant relationships are indicated between the automobile-employment ratio and population size, land area size, income per capita, the proportions of low and high-income families, or the number of persons per occupied housing unit.

In the largest population size group, the number of automobiles per 100 employed persons is significantly related in a negative way to population density and in a positive way to the percentage of housing units built between 1950 and 1960. None of the other variables is significant at the 0.05 level, although age of area and the proportion of population under 18 years of age become significant at a lower level (above 0.15 or slightly below an 85 percent confidence that the coefficient did not come from two variables having zero correlation).

Population density and age of area have significant negative correlations with the automobile-employment ratio in the 350,000 to 1,000,000 population size group. The percent of housing units built between 1950 and 1960 has a very significant correlation coefficient of 0.736, considering that an r value of 0.350 is significant.

TABLE 7

POPULATION DENSITY vs AUTOMOBILE AVAILABILITY

Automobile Availablility	Size Group			
	1,000,000 and over	350,000-1,000,000	150,000-350,000	50,000-150,000
Autos per 100 employed persons	-0.749	-0.467	-0.320	-0.091
No-car housing units, %	0.879	0.384	0.162	0.012
Two-car housing units, %	-0.684	-0.590	-0.252	-0.199

In the third largest size group, population density, age of area and the percentage of new housing units have significant r values. In addition, the proportion of the population in the 18 to 64-year age bracket assumes importance.

Population density is not an important factor underlying the number of autos per 100 employed persons in urbanized areas of the smallest size group. The proportions of the population in the young and old age groups assume importance for the first time in this group of areas.

Percent of Work Trips by Automobile or Car Pool

In all four size groups, the age of an area and the percent of its housing units that were built in the 1950-60 period have significant correlation coefficients with the percent of workers who use an auto or car pool in the work trip (Table 6(b)). The age distribution of the population becomes important, in all four groups, in relation to this work-trip mode variable. A greater proportion of persons in the 18 to 64-year age group bears a negative relationship with use of the auto in the work trip, whereas a high proportion of the young groups is positively related to auto use in the work trip. This finding is in line with the expectation that those using the auto in the work trip are largely suburbanites belonging to young families having a preponderance of children under 18. The negative correlation between use of the auto in the work trip and the percent of persons aged 18 to 64 is presumed to be due to people of this age comprising a high proportion of the central city dwellers who use mass transit or walk to work.

Another noteworthy item in Table 6 is the significance of the proportion of low-income families as a depressant on the use of the automobile in the second largest urban areas.

Summary

In summary, findings from the simple correlation experiment support the hypothetical explanations of differences in automobile orientation between urbanized areas of particular population size groups, but do not support these hypotheses for areas of other size groups.

These findings give some support to the hypothesis that high population density inhibits automobile ownership, whereas at lower densities, automobile availability is correlated with income.

Table 7 compares correlation coefficients between population density and each of three measures of automobile availability in each of the four size groups. It illustrates the declining importance of population density from the largest to the smallest size groups.

Population density is extremely high in some areas of the largest size group, and it is at this level that density becomes a strong inhibitor of highway use.

The contention that income takes over as a prime determinant of automobile availability where high population density leaves off is supported in this analysis only in a few special cases.

Income level, measured by income per capita, and income distribution, measured by the percent of high ($10,000 per year and over) and low (less than $3,000 per year) income families, bears an interesting variety of relationships to the measures of automobile availability and use.

In none of the groups does per capita income have a significant relationship with the number of automobiles available per 100 employed persons. Significant relationships were indicated, however, between income level and the proportion of housing units with no car available in areas of all but the largest size. The correlation coefficient between income and no-car households in the largest areas was a very low 0.050. Two-car households showed significant correlation with income per capita in only the smallest (50,000 to 150,000) size areas (see footnote 1).

The distribution of income assumes significance as an underlying factor in its relation to no-car households. Coefficients indicated that this is so in all but the largest size areas. In the largest areas income distribution, like income level, bears no significant relationship to any of the three measures of automobile availability.

The factor which most consistently has a significant correlation coefficient with automobile availability is the percent of housing units built between 1950 and 1960. These results are in line with expectations based on the fact that most housing construction in the 1950's was designed with the consideration that the automobile was the primary means of transportation .

Age of area is another consistently significant factor underlying differences in the rate of automobile availability, although the coefficients for this variable are always lower than those for the housing units built between 1950 and 1960. Even though there is undoubtedly collinearity between age of area and housing units built between 1950 and 1960, the fact that coefficients for recent housing construction are maintained at a similarly high level from size group to size group while age of area coefficients generally decline from the second largest to the smallest size group indicates that age of area declines in importance relative to new housing construction, as area size declines.

Numerous other comparisons could be made of the simple correlation coefficients obtained for measures of automobile availability and the several measures of urban structure. Primary mode of travel in the work trip related to the same socioeconomic variables individually produce correlation coefficients which are commonly high for housing units built between 1950 and 1960, and the age of the area—the same two variables that are important in explaining automobile availability differences.

Multiple-Regression Analysis of Urbanized Area Size Groups

Simple correlation analysis has indicated the relative importance of each socioeconomic variable in explaining differences between urbanized areas in each of six indicators of automobile availability and use. Although that analysis gives some insight into relationships between one individual transportation variable and one socioeconomic variable, it does not show the interrelations between one transportation variable and a combination of more than one socioeconomic variable. The purpose of the multiple-regression analysis is to select the combination of given socioeconomic variables that best explains variations in the transportation variable and which serves as a basis for estimating the value of the dependent transportation variable under the various socioeconomic condiditons.

All of the variables involved in the analytical phase are the same as those used in the earlier simple correlation and comparative analyses.

For each of the four population size groups, stepwise multipile-regression analysis was performed separately for each of the six dependent variables. The same 12 independent variables were used in all 24 operations (4 size groups times 6 dependent variables).

Estimating Equations

Equations for estimating the ratio of the number of automobiles available to the number of employed persons for an urbanized area in each size group are given in Table 8.

Table 9 gives equations for estimating the percent of workers using the automobile or car pool in the work trip. Each equation is the best fit for an area in the particular population size group for which the analysis was made.

TABLE 8

EQUATIONS FOR ESTIMATING THE AUTOMOBILE-EMPLOYMENT RATIO IN URBANIZED AREAS WITH 1,000,000 POPULATION OR MORE*

Step No.	Independent Variable	Estimating Equation	$S_{y.x}$	R	R^2
1	Population density (PD), 100 persons per sq mile	Y* = 0.9785 - 0.0028(PD) (0.0006)[a]	0.0800	0.728	0.529
2	Land area (LA)	Y = 0.9778 - 0.0039(PD) + 0.00011(LA) (0.0006) (0.00004)	0.0665	0.822	0.676
3	Pct. housing units built between 1950-60 (HU50-60)	Y = 0.8482 - 0.0032(PD) + 0.00009(LA) + 0.00344(HU50-60) (0.0008) (0.00004) (0.00282)	0.0653	0.827	0.684
4	Persons per occupied housing unit (POHU)	Y = 1.2252 - 0.0030(PD) + 0.00007(LA) + 0.00372(HU50-60) - 0.11908(POHU) (0.0009) (0.00005) (0.00285) (0.12699)	0.0656[b]	0.827	0.684
5	Population under 18 (P-18), %	Y = 0.8619 - 0.0025(PD) + 0.00010(LA) - 0.00245(HU50-60) - 0.44402(POHU) (0.0008) (0.00004) (0.00404) (0.20049) + 0.04457(P-18) (0.02270)	0.0585	0.866	0.750
6	Population, 1960 (P), 100,000's	Y = 0.6235 - 0.0007(PD) + 0.00035(LA) - 0.00289(HU50-60) - 0.52532(POHU) (0.0013) (0.00015) (0.00372) (0.19021) + 0.05531(P-18) - 0.0043(P) (0.02178) (0.0025)	0.0537	0.887	0.787
7[c]	Population 18 to 64 (P18-64), %	Y = 3.4923 + 0.0008(PD) + 0.00041(LA) + 0.00304(HU50-60) - 0.51888(POHU) (0.0014) (0.00014) (0.00457) (0.16836) + 0.02845(P-18) - 0.0059(P) - 0.03912(P18-64) (0.02404) (0.0024) (0.02093)	0.0475	0.912	0.831

*Number of automobiles available per employed resident: $\bar{Y}$ = 0.7606; N = 16.

[a]Standard error of the regression coefficient.

[b]The observed increase in the standard error of estimate is presumed to result from correction for the number of degrees of freedom in the estimating equation. The standard error ($S_{y.x}$) above declines from 10.5 percent to 6.2 percent of the mean ($\bar{Y}$), indicating the small variance of the dependent variable about its mean ($\bar{Y}$).

[c]Additional steps through the 11th did not improve the estimating accuracy of this equation. The 11th step resulted in the following measures: $S_{y.x}$ = 0.0548; R = 0.883; and R^2 = 0.779.

Sources: Adapted from data in the U.S. Bureau of the Census, U.S. Census of Population and Housing: 1960.

TABLE 9

EQUATIONS FOR ESTIMATING THE PERCENTAGE OF WORKERS USING PRIVATE AUTOMOBILE OR CAR POOL IN URBANIZED AREAS WITH 1,000,000 POPULATION OR MORE*

Step No.	Independent Variable	Estimating Equation	$S_{y.x}$	R	R^2
1	Population density (PD), 100 persons per sq mile	Y* = 82.3282 - 0.2819 (PD) (0.0549)[a]	6.3419	0.793	0.628
2	Population under 18 (P-18), %	Y = 2.31316 - 0.1984(PD) (0.0592) + 2.15875(P-18) (0.91092)	5.4997	0.849	0.720
3	Persons per occupied housing unit (POHU)	Y = 16.20246 - 0.1433(PD) (0.0624) + 3.78984(P-18) (1.22726) - 22.86700(POHU) (12.55461)	5.0666	0.873	0.763
4	Population 18 to 64 (P18-64), %	Y = 164.56937 - 0.1016(PD) (0.0670) + 3.58818(P-18) (1.18956) - 31.24073(POHU) (13.47753) -2.05774(P18-64) (1.46887)	4.8749	0.883	0.780
5	Pct. housing units built between 1950-60 (HU50-60)	Y = 237.01325 - 0.0865(PD) (0.0710) + 2.07349(P-18) (2.29622) - 23.30511(POHU) (17.11353) -3.03121(P18-64) (1.95187) + 0.31002(HU50-60) (0.39923)	4.9653[b]	0.879	0.772
6	Population 1960 (P) (100,000)	Y = 299.36194 - 0.0140(PD) (0.1119) + 1.24838(P-18) (2.52559) - 24.15563(POHU) (17.39143) -3.74269(P18-64) (2.15149) + 0.53571(HU50-60) (0.48502) - 0.0656(P) (0.0776)	5.0375[b]	0.875	0.765
7[c]	Land area (LA)	Y = 346.13190 + 0.1982(PD) (0.1186) + 1.94225(P-18) (1.97910) - 32.28520(POHU) (13.85564) -4.84864(P18-64) (1.72298) + 0.56483(HU50-60) (0.37684) - 0.5670(P) (0.1998) + 0.03046(LA) (0.01157)	3.9122	0.927	0.858

*Percentage of workers using private automobile or car pool: $\bar{Y}$ = 61.4062; N = 16.

[a]Standard error of the regression coefficient.

[b]The observed increases in the standard error of estimate is presumed to result from correction for the number of degrees of freedom in the estimating equation. The standard error ($S_{y.x}$) declines from 10.3 percent to 6.4 percent of the mean ($\bar{Y}$), indicating the small variance of the dependent variable about its mean ($\bar{Y}$).

[c]Additional steps through the 11th did not improve the estimating accuracy of this equation. The 11th step resulted in the following measures: $S_{y.x}$ = 5.0624; R = 0.874; and R^2 = 0.763.

Sources: Adapted from data in the U.S. Bureau of the Census, U.S. Censuses of Population and Housing: 1960.

Tables 8 and 9 indicate the changing relative importance of each independent variable from step to step. Changes in the value of a coefficient and its individual standard error measure its changing influence. In Table 9, for example, the value of the population density coefficient declined from the first through the sixth step while its standard error became greater.[2]

The equations in Tables 8 and 9 represent a best fit for the regression line within the scatter of plotted data for the urbanized areas with a population of 1, 000, 000 or more. Although these are considered the best combination of independent variables to use in estimating the dependent variable, they are only the best that could be developed on the basis of the 12 independent variables chosen for the analysis.

For other size groups, the goodness of fit of the best estimating equation is sometimes not very much better than the equation derived with half the number of steps. This has been demonstrated by detailed supporting data not reproduced herein (see footnote 1).

The first three steps of the analysis of the group of smallest areas (50, 000 to 150, 000 population) resulted in the use of the same three independent variables in the same order as for the areas in the 150, 000 to 350, 000 population size group.

An important feature of the stepwise regression method is the variety of equations it produces. In some cases this offers a choice to the user. The choice depends on two major considerations—the availability of data and the degree of accuracy desired (21).

An example of possible choices may be seen by comparing the equations for estimating the automobile-employment ratio in an urbanized area with a population of 1 million or more (Table 8). In this case it may be desirable to use the third step equation. The additional improvement in the measures of reliability may not warrant the added effort required to obtain the necessary data. Also, some variables added do not meet the desired level of significance as measured by the t test.

Limitations

Of fundamental importance in considering the value or usefulness of any of these equations is the fact that none of these model equations tells the whole story. Significant proportions of the differences between urbanized areas are left unexplained. It is obvious, therefore, that this analysis omitted some important factors underlying the urbanized area differentials in the values of the dependent variables.

Tests show that at various steps one or more regression coefficients lose significance. This occurs at different steps among the four urbanized area size groups and for estimating different dependent variables. Equations in Tables 8 and 9, which were derived from analyses of data for the largest areas (1 million or more population), have variables entering beyond step three that are not significant. In the equations for the three smaller size area groups, variables of insignificant value did not enter until the fifth or sixth step (see footnote 1).

It must be pointed out, however, that this initial experiment tested the adequacy of estimating certain transport characteristics on the basis of a limited number of socioeconomic factors and excluding other transport characteristics. The intent of this approach was to develop equations constructed of a minimum, a few perhaps, independent socioeconomic variables. Estimating tools of this nature would, it seems, facilitate the problem of estimating control totals of automobile availability, travel volumes or other highway planning guides.

Summary

In summary this initial experimental computer run, using the multiple-regression technique, has produced rather crude, static, model equations for estimating certain urban transportation variables.

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[2]Horizontal lines in the equation tables are shown after the number in the "Step No." column, which includes the last significant independent variable added, measured by comparing the regression coefficient against its standard error.

These results do, however, justify the selection of the variables chosen, and, as stated earlier, lend positive evidence to the hypothesis that the group of factors underlying urban transportation use varies among urbanized areas of different sizes.

Another finding was the lack of support for the priority, or order, in which the socioeconomic variables were selected. Income level, measured by income per capita, followed population size and density, and land area in their prejudged relative importance. Age composition of the population and distribution of families by high and low incomes were considered to be of less importance, as was the relative newness of housing units and age of the area.

As a result of this analysis, income per capita is an important factor in relation to the proportion of occupied housing units with no car available. On the other hand, the proportion of housing units built between 1950 and 1960 is closely associated with all automobile availability variables.

URBANIZED AREAS CLASSIFIED ACCORDING TO AUTOMOBILE RELIANCE

The Classification Criterion

Statistical analyses of the data in each group gave strong evidence that population density would not be useful as a basis for identifying, more closely, transportation characteristics common to a group of areas. Instead, the ratio of automobiles available to total employment was used as the criterion.

Six general types of urbanized areas result from this highway transportation viewpoint. Relative reliance on the automobile for personal mobility becomes the indicator used in segregating these classes. The number of automobiles available for every 100 employed persons, the measure of automobile reliance, is a composite of: (a) the number of automobiles available as derived from the Census data on automobiles available by occupied housing units; and (b) the total number of civilian residents employed. The number of occupied housing units reported as having one, two, and three or more cars available was multiplied by one, two, and three, respectively, to get total cars available for an urbanized area. The total number of persons employed includes all resident civilians 14 years of age and over who had a job at the time of the April 1960 Census.

Automobiles available are the only accessible data which indicate the extent of automobile ownership in all urbanized areas. These data include automobiles available for use by a member or members of an occupied housing unit, regardless of whether the automobile is owned by an occupant of the housing unit. Autos operated by persons stationed at military bases, students living in university dormitories, and other institutional persons were not included. Cars in large fleets of company-owned cars and other cars belonging to small business firms, but available to person or persons in the housing unit, are thus accounted for. Not accounted for are taxis, pickup or larger trucks, although these vehicles in many cases may serve the same purpose as a passenger car or station wagon. To the extent that this condition exists, there is a bias in the low automobile availability count for these areas. For the purpose of this study, however, it is assumed that the number of areas having these high rates of automobile substitution by other motor vehicle types would not be large enough to impair seriously the comparability of automobile availability between groups of urbanized areas.

The autos per capita ratio is hampered by variations between urban areas in the population age compositions—areas having large or small segments of persons under and over normal auto ownership age (18-65). Autos per worker narrows the population to persons who are capable of driving (with some exception, i.e., handicapped workers). It reflects ability of some workers to pay the cost of more than one automobile in a household. Effects of variance in size and composition of the household are largely overcome by using employed persons. Using employed persons as a component also avoids the necessity of estimating households with one, two, three or more, or no cars. Autos per 100 employed residents of an urban area could thus be expected to be more directly related to the underlying environmental factors, such as population size and density, age of an area, age composition of its population, and the levels and distribution of personal income.

Household members who are not employed but have automobiles available, e.g., suburban housewives and children of driving age, inflate the numerator in this ratio (autos available) without affecting the employment denominator. Inflation of the automobile figure relative to employment illustrates more clearly an urban area's relative dependence on the automobile for transportation and the relative ability of its employed residents to provide this transportation for dependents.

Unusually high numbers of automobiles relative to workers are noted in a few places, such as St. Petersburg, Fla., and Lawton, Okla. This reflects the unusually large proportion of retired persons in St. Petersburg and the large number of military personnel living off base in Lawton. These persons are not included in the total number of persons employed, although the automobiles available to them are included in the total number of automobiles available.

The abnormally high ratio of autos to workers in St. Petersburg emphasizes the degree of dependency on the automobile by both workers and retirees in that area. It also implies traffic problems of a different sort since the trip purposes and destinations of retirees would make shopping and social-recreation trips unusually high relative to work trips. Traffic should, therefore, have comparatively low peaks and be more diffused.

Auto Reliance and the Work Trip

The worker and characteristics of his trip to work best describe an urban area's degree of highway use. As a basis for estimating and predicting total highway traffic volumes for an urban area, the number of workers is preferable to the number of housing units or the total population. Highway capacity is generally designed to accommodate peak-hour traffic volumes, usually made up of vehicles being used in the work trip. Knowledge of the number of workers and their reliance on the automobile, relative to other modes of transport in their work trips, is therefore fundamental to sound decisions on highway requirements. An indication of the extent to which workers of an urban area rely on the automobile for transportation is to be found in the ratio of the number of automobiles available for the number of workers residing in the area.

Automobile availability and use of the auto in the trip to work are closely correlated. Urban areas with large numbers of automobiles available relative to the number of workers can be expected to have high proportions of workers using the automobile in the work trip. Areas with high rates of autos to workers usually have high proportions of multicar households which are outgrowths of the need for an automobile by the spouse and/or children of the worker who uses his car in the work trip.

Conversely, urban areas with lower rates of autos to workers will not be as high in the proportion of multicar households, because the need for an automobile by other members of the worker's family is not as widespread inasmuch as some of the workers leave their cars at home and use another mode of transport in the work trip.

Autos per dwelling or housing unit is not as directly connected to the work trip, since urban areas differ significantly in the number of workers per dwelling unit as well as in the number of automobiles available per dwelling unit. The correlation between the two is such that autos per dwelling unit is not a satisfactory substitute.

In areas having a similar number of workers per dwelling unit, the rates of autos per dwelling unit often vary widely. Urbanized areas in Connecticut, for example, average between 130 and 135 workers and 100 automobiles for every 100 dwelling units. In California, urban areas average approximately 115 workers and over 120 autos for every 100 dwelling units. In some urban areas, such as those in Texas, the relationship between the two data series is positive, but in many states it is a negative correlation. By relating autos directly to workers, the effect of variations in workers per dwelling unit is avoided.

Areas which have a relatively high rate of autos to workers will usually have a high proportion of workers driving the auto or riding in a car pool in the work trip. Where a relatively high rate of auto availability is associated with a relatively low rate of use in the work trip, the implication is that car pooling is more extensive than in other areas with similarly high rates of auto availability.

TABLE 10

AVERAGE VALUES OF SELECTED TRANSPORTATION AND SOCIOECONOMIC CHARACTERISTICS OF URBANIZED AREAS BY AREA TYPE

Area		Transportation Characteristics									Socioeconomic Characteristics						
		Automobiles Available per 100 Employed Residents[a]	Primary Mode of Work Trip[b]					Percent of Occupied Housing Units with		Area Age		Newness of Housing Units[d] (%)	Young and Old Age Groups (%)		Proportions of Low and High Income Families (%)	
			Auto or Car Pool (%)	Mass Transit (%)			Walk (%)									
Type	Number			Total	R.R., Subway, Elevated	Bus, Streetcar		No Car	Two Cars	Year	Years before 1960[c]		Under 18	65 Plus	Under $3,000	$10,000 Plus
A	30	106.8	78.6	4.2	0.1	4.1	7.1	13.7	27.1	1940	20	45.7	36.3	8.6	17.2	16.6
B	33	94.5	75.4	7.3	0.7	6.6	7.6	16.3	25.0	1923	37	36.4	37.0	7.7	17.2	16.7
C	65	84.7	72.2	9.0	0.1	8.9	10.1	19.5	19.4	1916	44	27.1	35.5	8.6	17.0	15.3
D	65	75.3	66.3	13.6	0.2	13.3	11.6	23.9	16.5	1912	48	24.6	34.4	9.1	17.7	15.5
E	19	65.6	62.9	15.5	2.2	13.4	13.2	29.3	13.4	1909	51	19.4	33.0	10.2	17.7	13.9
F	1	56.3	35.9	45.1	31.6	13.5	9.2	41.4	10.5	1900	60	19.5	30.6	9.6	12.4	22.7

[a]The total number of automobiles available was calculated by the BPR Office of Planning from the number of occupied housing units having one, two, or three or more cars available as reported in the Census of Housing, 1960. Total automobiles available was then divided by the total number of employed residents reported in the County and City Data Book: 1962.
[b]The principal means of transportation to work during the week prior to the 1960 Census of Population in April.
[c]The arithmetic average of the years nearest to the census year beginning with 1900.
[d]Percent of 1960 housing units in structures built between 1950 and 1960.
Sources: Adapted from data in the U.S. Census of Population and Housing: 1960; the Statistical Abstract of the United States: 1964; and its supplement, the County and City Data Book: 1962.

Transportation Types of Urbanized Areas

Selected characteristics of urbanized area types are given in Table 10 as mean unweighted averages of the data for individual areas (see footnote 1). The area types are arrayed in descending order of reliance on the automobile as measured by the number of automobiles available for every 100 employed residents. Each area type, A through F, is divided into the four population size groups.

The distribution of the numbers of areas among the types (Table 10) makes it apparent that the distribution by type is not normal, but is skewed toward the upper end of the scale where automobile reliance is greatest.

Interrelationships between the transportation characteristics are also apparent. The changes from high to low in the proportion of workers using the automobile in the work trip and in the percent of occupied housing units having two cars available show a positive relationship with the number of automobiles per 100 employed residents. The increase from Type E to Type A in the auto use data is, however, much more gradual than the increase in the auto ownership indicator. This suggests a possible ceiling or limit on use of the automobile in the work trip corresponding with what may be a floor in the proportion of workers who walk to work or use mass transit. Included in this hard core of walkers and transit users (7.1 percent walkers and 4.2 percent transit users in Type A areas) are persons who live close to their places of work and find walking the most convenient form of transport; those who for various reasons, such as age, health or desire, cannot or will not drive a car; those workers who cannot afford to own a car and for various reasons cannot or will not ride as a passenger in a car pool; those workers who own one car and prefer to leave it at home for general use by other drivers in the family rather than buy another car; those workers who have an aversion toward driving a car on congested streets or on less congested freeways where a breakdown is most troublesome and costly; and finally, those workers who cannot afford the cost of parking or for other reasons find mass transit more economical, reliable, convenient or pleasurable.

The data on social and economic characteristics reveal the close relationship between automobile availability and the proportion of housing units that were built between 1950 and 1960. In the Type A group, high rates of automobile availability are accompanied by high rates of new housing (Table 10). Change in automobile availability from one area type to another is related to area age also. The influence of the age composition of the population is less clear, although the proportion of youngsters (under 18) shows a positive relation to automobile availability while increasing old age proportions of the population are less clearly associated with declining rates of automobile availability.

TABLE 11

AUTOMOBILE OWNERSHIP, MODE OF TRAVEL TO WORK, AND RELATED SOCIOECONOMIC CHARACTERISTICS OF URBANIZED AREAS

Population Size and Area Type		Number of Areas	Transportation Characteristics								Socioeconomic Characteristics						
			Automobiles Available per 100 Employed Residents[a]	Primary Mode of Work Trip[b] (%)					Percent of Occupied Housing Units with		Area Age[c]		Newness of Housing Units[d] (%)	Young and Old Age Groups (%)		Proportions of Low and High Income Families (%)	
				Auto or Car Pool	Mass Transit			Walk									
Size	Type				Total	R.R., Subway, Elevated	Bus, Street-car		No Car	Two Cars	Year	Years before 1960		Under 18	65 Plus	Under $3,000	$10,000 Plus
1,000,000 and over-Group 1	A	1	101.6	77.3	7.8	0.0	7.8	5.0	16.0	28.0	1920	40	40.4	33.8	8.9	12.3	24.6
	B	1	89.7	74.5	11.1	0.0	11.1	4.3	17.2	26.7	1950	10	43.9	38.2	5.3	17.9	17.9
	C	4	84.6	67.4	17.3	0.5	16.8	7.1	20.1	20.5	1912	48	27.1	34.8	8.7	11.7	22.2
	D	5	73.8	61.5	21.3	0.2	21.1	8.6	24.8	14.2	1920	40	25.8	34.3	8.7	12.3	20.6
	E	4	65.5	54.4	27.1	9.2	17.8	9.0	30.0	13.0	1900	60	21.0	33.5	9.2	12.4	20.7
	F	1	56.3	35.9	45.1	31.6	13.5	9.2	41.4	10.5	1900	60	19.5	30.6	9.6	12.4	22.7
350,000 to 1,000,000-Group 2	A	5	107.9	78.1	4.9	0.4	4.4	5.7	12.4	28.7	1946	14	53.3	37.1	7.6	13.4	21.0
	B	7	94.3	72.8	10.2	0.1	10.1	5.9	18.1	24.3	1914	46	37.6	35.3	8.8	17.4	16.4
	C	11	84.5	70.6	12.7	0.1	12.6	7.0	19.9	20.3	1910	50	30.7	35.7	8.0	16.4	16.8
	D	13	75.1	65.4	16.7	0.1	16.5	8.8	24.3	16.6	1904	56	25.1	34.8	9.0	15.7	17.7
	E	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	F	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
150,000 to 350,000-Group 3	A	10	107.6	78.4	5.6	0.0	5.5	6.3	15.1	24.3	1939	21	46.4	34.6	11.5	20.1	15.2
	B	7	94.2	73.3	9.5	1.8	7.7	6.7	16.3	24.9	1923	37	37.8	38.1	7.3	18.6	18.3
	C	18	85.2	72.9	9.0	0.1	9.0	9.4	18.5	19.9	1921	39	27.8	34.9	8.0	17.0	15.4
	D	20	76.1	67.1	12.7	0.2	12.5	11.7	23.7	16.9	1910	50	24.4	34.1	8.8	18.6	14.9
	E	4	66.9	64.0	15.4	0.4	15.0	13.0	27.0	12.8	1900	60	16.8	31.0	11.8	15.2	14.2
	F	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
50,000 to 150,000-Group 4	A	14	106.2	79.1	2.7	0.0	2.7	8.3	13.1	28.5	1941	19	42.8	37.4	6.9	16.9	15.5
	B	18	94.9	77.4	5.1	0.5	4.6	8.8	15.6	25.2	1924	36	35.0	37.2	7.7	16.6	16.2
	C	32	84.6	73.1	6.8	0.1	6.6	11.9	19.9	18.7	1916	44	25.4	35.8	9.2	17.9	13.9
	D	27	75.1	67.0	11.2	0.3	11.0	13.4	23.8	16.5	1916	44	24.1	34.5	9.4	19.0	13.9
	E	11	65.1	65.6	11.4	0.2	11.1	14.8	29.9	13.8	1916	44	19.7	33.5	10.0	20.6	11.2
	F	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

[a]The total number of automobiles available was calculated by BPR Office of Planning from the number of occupied housing units having one, two, or three or more cars available as reported in the Census of Housing, 1960. Total automobiles available was then divided by the total number of employed residents reported in the County and City Data Book: 1962.

[b]The principal means of transportation to work during the week prior to the 1960 Census of Population in April.

[c]The arithmetic average of the years nearest to the census year beginning with 1900 in which the population of the central city of group 1 reached 500,000; group 2 reached 100,000; group 3 reached 50,000; and group 4 reached 25,000.

[d]Percent of 1960 housing units in structures built between 1950 and 1960.

Sources: Adapted from data in the U.S. Census of Population and Housing: 1960; the Statistical Abstract of the United States: 1964; and the County and City Data Book: 1962.

Urbanized Area Transportation Types in Each Population Size Group

In Table 11, average values are given for each urbanized area type within each of the four population size groups. Among the largest areas there is only one each of type A (Los Angeles), type B (Houston) and type F (New York).

In all size groups there is a clustering of areas in the Type C and D categories. Together, these two types include those areas having from 70 to 90 automobiles per 100 employed residents. Of the 213 urbanized areas, 130 are in the C and D classes.

Type A and B areas comprise approximately one-third of the total number of areas in each size group except the largest.

In size group 2, Type A consists of five California urbanized areas—San Diego, San Bernardino-Riverside, San Jose and Sacramento plus Phoenix, Arizona (Table 11). As a group, these areas have the highest number of automobiles available per 100 employed residents (107.9 percent) and, correspondingly, the lowest rate of households without cars (12.4 percent) and the highest rate of two-car households (28.7 percent). They are young areas, having recently experienced rapid growth as shown by the large proportions of new housing structures (53.3 percent) and the relatively large proportions (37.1 percent) of young persons under 18 years of age. Generally, they have below-average proportions of low-income families (13.4 percent) and above-average proportions of high-income families (21.0 percent). In addition, all five areas have low population densities. The preceding characterizes the type of large (350,000 to 1,000,000 population) urbanized areas in which more reliance is placed on the automobile for personal transportation than in any other area type in the same size range.

In contrast, the Type D area in the same size group is lowest in the number of automobiles available per 100 employed residents (75.1 percent), has the highest rate of no-car households (24.3 percent), and the lowest rate of two-car households (16.6 percent) for any area of similar size.

Typically, a Type D area is older, has a relatively small proportion (25.1 percent) of its housing units in new structures (built between 1950 and 1960), a relatively low proportion (34.8 percent) of persons under 18 and relatively large proportion of its population in the 65 and over age bracket (9.0). The proportion of low-income families (15.7 percent) in an area of this type is generally slightly higher than a Type A area (13.4 percent) and the proportion of high-income families (17.7 percent) is slightly lower than they are in an area of Type A (21.0 percent).

Eleven of the 13, somewhat less automobile-dependent urbanized areas in size Group 2, are located east of the Mississippi River. Five are in the New York-New England region.

Summary

Urbanized areas have been segrated into six types for the purpose of facilitating analyses of urban transportation and the factors underlying its demand. Degree of reliance on the automobile as the chief mode of personal transportation is the criterion used in establishing the six-area classification. The number of automobiles available for every 100 residents employed measures automobile reliance.

Only one of the 16 largest areas has more than 90 automobiles per 100 employed persons—Los Angeles with 102.

New York, with 56 automobiles for every 100 workers, is a type by itself, being the only area below the 60 to 70 rates of the next lowest group of areas. But then, New York is also unique in terms of the total number of residents (14 million), the size of the land area occupied (1,892 sq mi), the population density of its central city (23,000 persons per sq mi), and in the structure and use of its transportation systems (more freeway and subway mileage than any other urbanized area).

While all urbanized areas are generally auto-oriented, the urbanized areas in the class with the lowest degree of automobile orientation Type E, are all (with the exception of Chicago) located on the eastern seaboard (Fig. 2).

Reliance on the automobile is practically total in the urbanized areas in Type A. These areas are distributed geographically in the Far West, Southwest, and Florida.

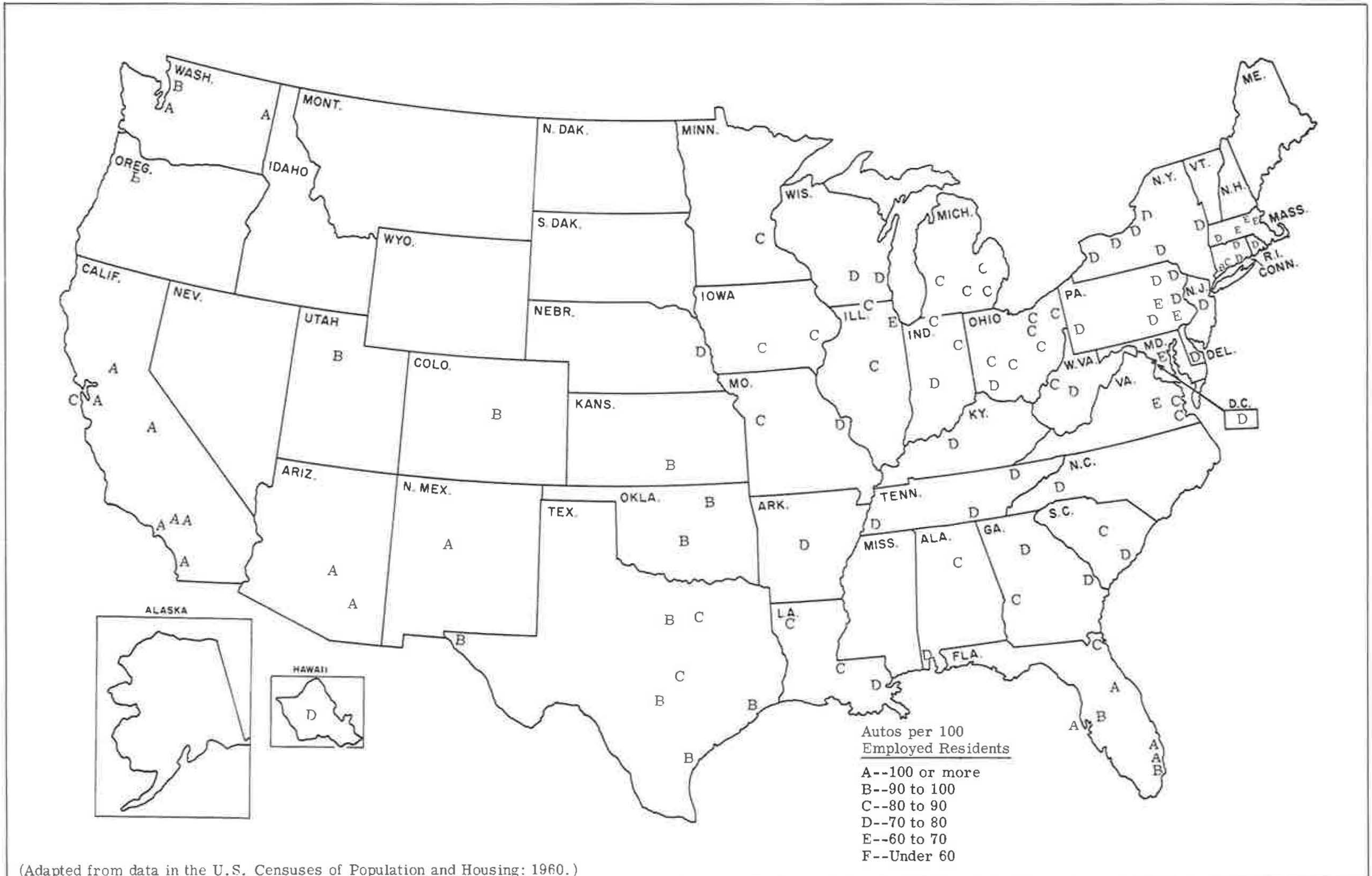

Figure 2. Geographic distribution of urbanized area types with over 150,000 population.

Nine of the 30 areas in this type are located in California, 7 in Texas, 4 in Florida, and the remaining 10 in Arizona, New Mexico, Washington, and Montana.

CONCLUSIONS AND RECOMMENDATIONS

Comparative and correlation analyses were made of the transportation and socioeconomic characteristics of four groups of urbanized areas. The four groups resulted from a stratification, by population size, of 213 urbanized areas. These analyses showed that the socioeconomic factors underlying selected transportation variables often differ between size groups. One factor, population density, was shown to be a major influencing factor only in the largest areas. Newness of housing units as measured by the percent of housing units in structures built between 1950 and 1960 was found to be significantly correlated with several of the transportation variables (Fig. 3). Measures of income (income per capita, percent of families with income under $3,000 per year and those with incomes of $10,000 per year or more) were of little or no significance.

Estimating equations were derived from a stepwise multiple-regression analysis performed on the IBM-1401 computer. The computer program was, therefore, less sophisticated than those used with later model computers. Data transformations were not made for any variables and only one computer run was made. The resulting equations have not been tested against actual data but tests of reliability indicate that the independent variables in Eq. 2 in both Table 8 and Table 9 are significantly related to the dependent variables. One or more independent variables in the remaining equations do not pass the test of significance.

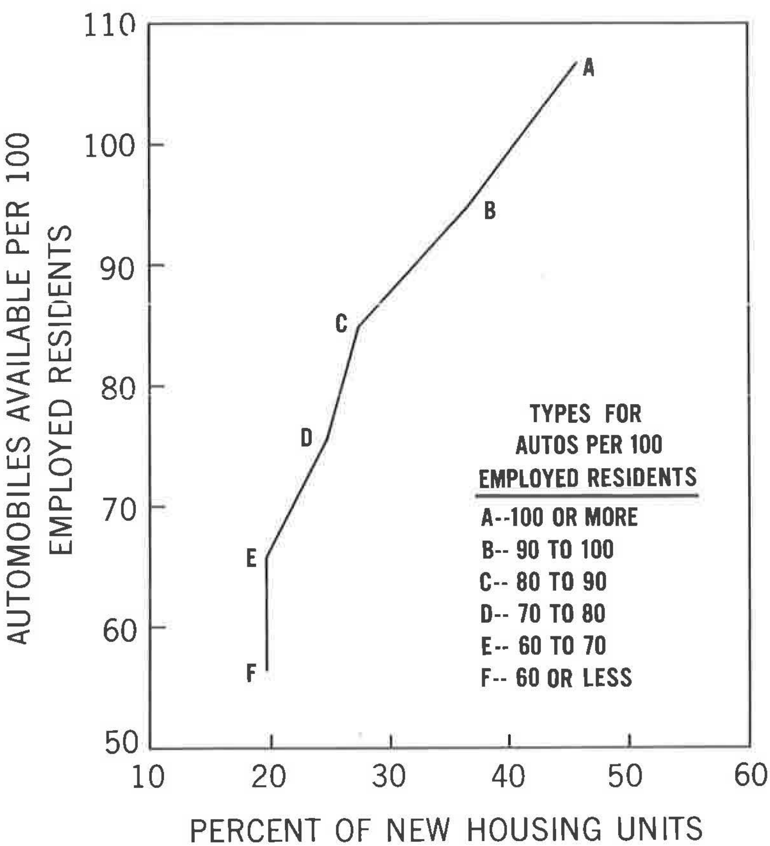

Figure 3. Age of housing units related to automobiles available by urbanized area type.

Some observations on the makeup of the equations should be of interest to persons concerned with urban road traffic estimating. Equations for estimating the automobile-employment ratio in urbanized areas are given in Table 8 (see footnote 1). For areas with a population of one million or more the multiple-regression procedure selected population density and land area for the independent variables in Step No. 2. Population density and land area did not appear as significant variables in estimating the automobile-employment ratio in areas belonging to the three smaller size groups.

Table 8 equations are for estimating the percentage of workers using private automobile or car pool in the work trip in urbanized areas with one million or more population. Other equations were derived (see footnote 1) for estimating the percentage of occupied housing units with no car available in the largest areas. In both cases, the Step No. 2 equations had the same independent variables—population density and the percentage of the population under 18—indicating the collinearity between the proportion of no car households and the proportion of workers using the automobile in the work trip.

A tentative transportation classification of urban areas has been developed based on a measure of automobile reliance (the ratio of the number of automobiles available to the number of residents employed). Grouping the urbanized areas on this basis resulted in six transportation types or classes. Generally, areas in each transportation class display similar social and economic characteristics. These similarities became stronger after the areas in each type were subdivided into the four population size groups used in the earlier analysis.

Recommendations

Research conducted in this phase of the typology task has accomplished its objective of establishing a tentative transportation classification of urban areas. This classification is tentative because the analysis has covered only structure, which is one of four general urban area characteristics—structure, function, form and growth—selected for this task. This is also a static analysis which has indicated relationships, of varying strength, between certain transportation and structural characteristics of the urban areas as they existed in 1960. It remains to be seen whether this classification, or the estimating equations developed in the process, can be of any use to persons involved in forecasting for urban highway purposes. It is recommended, therefore, that the equations given in this report and elsewhere (see footnote 1) be tested for predictability and, to improve their accuracy, adjustments or transformations be made where the need for such are indicated.

A second recommendation is that a stepwise multiple-regression analysis be made of selected variables for the urban areas in each of five area types—A, B, C, D and E.

To determine the changes taking place in the relationships between the variables studied in the static analysis, it is recommended that trend analysis be made of the areas in each tentative class and the growth dimension added to the classification criteria. Time series on economic function would be included in this phase to assess the influence of this factor on changes in urban growth and transportation requirements.

Urban form, the fourth major feature of an urban area, should be analyzed to obtain greater insight into its relationship with transportation and to determine the interrelationships that may exist between these two variables in combination with the other major variables.

In each of the recommended successive phases of research there is an implied awareness that experimentation will often be necessary to develop adequate measures of the factors involved. Also implied is the expectation that the model equations developed in each study will be tested for accuracy in estimating or forecasting certain transportation factors which would serve as controls or guides to traffic engineers and urban planners.

In the research reported here, two examples may be cited in which experimentation yielded certain measures of key variables. A weighted population density was developed to amplify central city congestion where it existed, and relative urban sprawl in areas where it existed. An experimentally developed measure of automobile availability is the automobiles-to-employment ratio which generally overcomes some of the shortcomings of the automobiles to dwelling units or the automobiles per capita ratios.

Predictability of the equations has not yet been tested against actual data, although the equations produced at the 12th step of the multiple-regression analyses had been tested. These 12th-step equations included the variables in the equations given in this report as well as others which were not significant or did not improve the standard error of estimate or the measures of correlation and determination, R and R^2. Comparisons between the actual data and the data predicted by the 12th-step equations give mixed results—close predictions for certain dependent variables in particular urban area size groups but wide differences in other cases.

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