Report on Analysis of Urban Work Trips

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Common to virtually all wage-earners and proprietors in cities is the daily journey from home to work and back again. An easily observable characteristic of this travel is that most of it occurs at virtually the same time: a morning period of maximum volume of travel occurs in most cities from 7 to 9, and in the evening another peak-period of traffic flow—in the opposite direction, away from the work places—occurs in the hours from 4:30 to 6:30. The massive flows to and from work places represent many vehicles which alternately speed, stop and crawl along, but more importantly, they represent thousands of people spending a considerable part of their days and of their lives in moving from one place of residence to another. These diurnal migrations are represented in the term, the "journey-to-work."

That most workers are employed away from their homes and travel between homes and work places at approximately the same times has considerable effect on capacity requirements of the circulation systems of cities. Further, the decisions made by workers and heads of families in selecting work places and in finding places to live, in the aggregate, have important effects upon the physical patterning of cities. Location decisions also influence labor force availability in various parts of the urban area. Not to overstate the case, it should be made clear that while the home-work-place relationship is clearly an operative factor at all times in providing limits for home-location decisions, it may seldom be the prime factor in location choice.

From a statistical viewpoint, trips to work constitute the largest single grouping of trips, by purpose, of all trips leaving urban residences. In metropolitan areas, trips from home to work and back again represent generally about one-third of all trips made, and up to half of the trips made to central business districts may be of work-purpose.

In a more important sense, it needs saying that for the people concerned, work-travel consumes much time and energy. The fact is that a large proportion of work-travel in metropolitan areas is arduous and long; many trips involve two or more changes of mode of travel. These two examples will help to give an idea of the scale of the journey-to-work and its costs. Estimates made for both the London Central Area and Lower Manhattan indicate that time spent in the journey-to-work lengthens the work-day by a gross amount of almost 20 percent. Thus, for the approximate figure of 3 million employed persons who travel into Lower Manhattan each weekday, over half a million man-days are consumed in travel en route.

Discernible trends in urban settlement appear to indicate, for future years, longer trips to work for many, and lengthy journies-to-work for increasing proportions of the dwellers in metropolitan areas. On the other hand, the longer trips to work mean wider areas from which employers may attract workers and a greater range of places and types of occupation for the individual wage-earners.

These considerations indicate the nature of the journey-to-work as a factor of connection between the utilization of land for circulation routes, and for residential, commercial, and industrial purposes. From this, it follows that understanding of urban life will be enhanced and planning for cities will be aided by further study of work-oriented travel (1).

Wider understanding of the relation of homes to work places will aid

in decision-making processes concerning future organization of intividual metropolitan areas. With evident trends to decentralization of industry and growth of low-density residential suburbs, decisions for renewing the central areas or cities, or for developing outlying subcenters of residence and/or employment cannot be made without assumptions concerning the work-travel of individuals.

The purpose of this paper is to present some of the findings and conclusions made in studies of the journey-to-work conducted at the Institute for Urban Studies. The present paper does not present details of the analyses of patterns of trip generation and confluence. This paper briefly describes some aspects of work-trips as a part of urban traffic, and presents some general conclusions derived from the recent studies.

●EXTENSIVE information on the journey-to-work dates from at least as far back as 1896 in Europe, while systematic consideration of urban work travel and its effect in structuring of cities and their circulation facilities was substantially begun after World War II in the United States. Despite the late beginning, however, attention is now being increasingly focused upon this important aspect of travel in the United States.

European studies on "Pendelwanderung" or "le mouvement alternant" or Japanese studies on places of work in relation to residence may be found in virtually every decade of this century. Most of these studies were based upon official census surveys in the respective countries. Journey-to-work surveys at one or more points in time may be found in many countries, including such diverse locations as Australia, Belgium, Denmark, England, Holland, Sweden, and Venezuela.

In the United States, at present, a considerable body of information on the journey-to-work is being accumulated in the urban O-D surveys and in the state-wide motor-vehicle-use surveys. The United States Bureau of the Census has cooperated on a service-contract basis with the Bureau of Public Roads in the latter type of survey. In the future, it is to be hoped that the Bureau of the Census will find the time and financing, and see the value of including a few questions on the journey-to-work in the regular decennial national census of population.[1]

The information in the O-D surveys is so extensive that special runs of cards are likely to be required to yield information relevant in specific problem analyses.

As an example, where it is desired to learn the proportional distribution of distances traveled (by the various modes) between residences and work places, the work-purpose trip-cards must be run on an area-of-origin to area-of-destination basis, with a cross-tabulation by mode. This particular information, which is not presented in the usual reports on O-D surveys, may be found to be among the most valuable parts of a major traffic survey. From this type of run may be found typical distribution patterns of residences about the major work places, or the distribution patterns, of auto-driver work trips, for instance, may be found about new housing developments. This kind of information is most useful in the study of housing markets and availability of labor force for new industrial sites.

These two major types of surveys, especially the O-D, should be regarded as virtually mines of information. Unfortunately, it appears to be often the case that little

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[1] In 1957, a committee was formed by the Population Association of America to study this matter for the Bureau of the Census. The Committee reported favorably on journey-to-work questions for the decennial census, but no action will be taken on this in 1960. The committee was chaired by Gerald Breese, and Henry O. Sheldon of the Bureau of the Census served as liaison officer. Committee members included: Nathan Cherniack, William Grigsby, Howard S. Lapin, Harlin G. Loomer, Warren Lovejoy, Chester Rapkin and Arthur Row. Organizations represented by these members were the Port of New York Authority, City of Philadelphia, Princeton University, and the University of Pennsylvania.

use has been made of the thousands of interviews and the information taken from them.

WORK TRAVEL AS A COMPONENT OF URBAN TRAFFIC

Work travel takes place in an environment where trips are made for a great variety of purposes. It is the trips of all and various purposes which have until lately been studied en masse in terms of "desire-lines" in urban traffic surveys. The present study deals with the systems of work travel only, but it is nonetheless important to observe the relationships between work travel and the total urban travel. The concept of relationship is vital for qualitative and quantitative reasons: first, to give an idea of scale to the discussion of work travel, and second, to provide data from which multipliers might be derived to expand to a more complete basis the information derived solely from systems of work travel. The latter point applies particularly in those cities where, for budgetary reasons, only work travel has been found measurable (as in Los Angeles and Toronto), but possibly elsewhere, because of the greater completeness of the work-travel measurements as compared with trips of other purposes.

The discussion following concerns numbers of trips, modes of trips, lengths in time- and mile-distance, and daily time patterns.

Number of Trips

Trips of work purpose range from one-sixth to one-third of all vehicular trips recorded in internal area surveys (2). The average volume of work trips in the internal survey is about one-fourth of the total. The largest group of trips by objective are those made to home which for 15 cities, of from 75,000 to 1,500,000 population, ranged from 37 percent to 48 percent and averaged 43 percent. There was no correspondence in these sets of figures, for either work or for home trips, between the proportions of trips by purpose and population size of city.

The group of trips "to home" include those made from work to home, as well as trips made from the great variety of other possible activity areas.

The relative scale of work-travel, in the figures above, is described in terms of the total of two systems of trips from internal-area origins: the "home-work" trips, and the "other-work" trips. These are the two systems which comprise a tabulation of internal area work-purpose trips. The relative proportions of the two are not determinable without specific referencing in the sorting process.

From consideration of the systems of trips it may be seen that the "journey-to-work," "home-work" plus "work-home"[2] trips (in the internal area) represents something less than double the proportion of work-purpose trips. The amount by which it is "less" depends upon the volume of "other-work" trips.

One of the reasons for wide variations in the reported fraction of work-trips as a part of all internal trips is that trips to home are sometimes included in the denominator and sometimes omitted. Other groups of trips which are also dealt with in inconsistent fashion are the "change-travel-mode" and "serve passenger" trips. In addition, and confusing the picture by another degree, work trips are also reported in terms of their proportion of trips to ultimate, non-home destinations. Thus, for Philadelphia-area data there are three possible proportions, as shown in Table 1. In the table it is seen that work-trips represented 24.6 percent of all trips, 38.8 percent of all trips other than those "to home," and fully 55.6 percent of trips made to an ultimate purpose, other than getting home. Again, it should be noticed that all the above data pertain only to the internal survey.

Another generality may be stated about work trips in reference to central business districts. These trips, as measured by O-D studies, represent about 40 to 50 percent of trips made to destinations in the central areas. There is variation because of differences from city to city, in importance of the CBD. For Detroit (1953), for instance, trips of work-purpose represented fully 52 percent of all daily trips to the area (3).

For Philadelphia (1947), work-purpose trips represented 236,000 of the 545,000

[2] See Glossary for definitions.

internal area trips made to or within the CBD. This represented a proportion of 43.3 percent (4). It should be noticed that the trips described are those made "to or within" the CBD. A great many trips may be made to and through the CBD. So in order to make city-to-city comparison more meaningful, only those trips are considered which have goal activities, or purposes, within the CBD. For Philadelphia, it was found that the vehicular trips of all purposes into and to the central district comprised one-half of the total vehicular trips made into, to and through the district. The latter proportion represents a strong reason for the proposed CBD circumferential loop freeway design for the Quaker City.

TABLE 1

INTERNAL TRIPS BY PURPOSE, PHILADELPHIA AREA, 1947

	All Modes, 1000's of trips	Work-trip Percentage
All trips	3,548	24.6
To home	1,305	-
All trips, less "to home"	2,243	38.8
To change-travel mode	628	-
To serve passenger	47	-
To ultimate purpose (except to home)	1,568	55.6
Work	871	-
Business	83	-
Med. -dental and school	108	-
Social-rec. and eat-meal	323	-
Shopping	183	-

Source: "Philadelphia-Camden Area Traffic Survey," Pennsylvania Department of Highways, et al. 1950.

The care taken above in qualifying data as being applicable in either internal or external surveys may leave the reader with this question: if most of the proportions given for work trips relative to total trips are for the internal area only, to what extent are these proportions changed by including the external trips? Two factors condition the answer to the question:

(a) External survey trips bear no constant relationship to the total of internal and external, but in urban areas of over one hundred thousand population, the proportion in the past has been well under one-fourth of the total. (This proportion is of course dependent on criteria of location of the outer cordon.)

(b) Trips to and from work are counted as work trips in the external survey.

From the two factors above, it may be assumed that work trips in the total of internal plus external trips will be of a somewhat higher proportion than for the internal survey trips only. Little in representativeness of data is lost in inter-city comparisons of internal work-trips proportions only, but comparability is enhanced. Table 2 shows proportional distributions of external trips as measured in two major metropolitan areas.

Mode of Travel

The mode of travel selected by an individual is a personal decision made upon such bases as the condition of available facilities, the relative times and costs of travel by the various possible modes, relative convenience (including waiting times, connections, and walking distances) and possibly, prestige (5). For individuals, the choice is important but not crucial. For cities, the choices made by large numbers of people have become crucial in recent years. The long-term trend toward use of the personal, flexible automobile mode and away from use of public transit, for example, is directly related to the increasing demands placed upon the street, highway and parking facilities of the cities. This same trend has an effect, eventually, upon freedom of choice in sites for housing, commercial, and industrial purposes. Since capacity requirements of both highway and transit facilities are conditioned by peak-period demands, and thus by the demands of primarily work-trip traffic, the modes employed in work trips are of vital concern.

Table 3 indicates the way in which usage of the various modes is distributed in the journey-to-work as measured for a number of cities of varying size in 1951. The dominance of the automobile can be seen in these figures, though the proportion of auto usage is seen to decrease with increasing city population size (where public transit service is more widely available).

Spatial Pattern of Selection of Mode

The evidence available indicates that location within the metropolitan influence area

TABLE 2

PURPOSES OF EXTERNAL TRIPS BY AUTO

Purpose of Trip	Auto Occupants St. Paul-Minneapolis			Auto Drivers Philadelphia-Camden		
	Number	Percent	Percent	Number	Percent	Percent
Work	36,151	27.0	50.2	150,433	46.6	56.5
Business	31,036	23.2		32,075	9.9	
Social-recr.	48,626	36.4		95,186	29.5	
Shop	8,012	6.0		19,151	5.9	
Other	9,910	7.4		25,799	8.1	
Total	133,735	100.0		322,644	100.0	

Sources: "Saint Paul-Minneapolis Traffic Survey," Minnesota Department of Highways, 1949.
"Philadelphia Area Traffic Survey," Pennsylvania Department of Highways, 1955.

is a strong determinant of choice of mode used in urban travel. Similarly, the measurable factors which are functions of location (net residential density, distance from city center, income, and auto ownership) are to varying degrees associated with the numbers of daily trips generated from each dwelling unit.

In a study of Philadelphia data for trips to the Philadelphia CBD, it has been reported that specific area patterns in selection of mode tend to prevail throughout the range of trips of all purposes (6). Where a single mode was emphasized, or particularly characterized a section of the city, it was found that the mode tended to predominate throughout all of the trip-purpose categories.

Thus, the purpose of an urban person-trip does not appear as a primary factor in the selection of mode, since the area patterns of mode selected tend to prevail over a number of disparate purposes. Hence, the key to the study of mode selected for trips originating from home is more likely to be found on an area basis. Area characteristics considered to be relevant to some degree in study of modes selected are: auto ownership per capita, income levels, occupation of residents, net residential densities, and location of residence relative to the major centers of destination.

A Study of Spatial Pattern of Selection of Mode

A geographic pattern of selection of public transit for work trips was studied from the specially tabulated O-D data for Philadelphia (1947). The percent of workers selecting public transit was computed for each residence area, and contours of equal percentage were drawn.

All work-trips of origin within the Philadelphia transportation survey area (except for some districts in New Jersey) were grouped according to mode selected: that is, by private vehicle or by public transit. (Taxi trips were grouped with automobile trips.)

The data when plotted turned out to be surprisingly consistent—which indicates, in this instance, that the work trips from residence were either well-reported, or at least that any errors made have geographical uniformity. Thus, it is inferred, the spatial location of residence affects the numbers of trips made per dwelling place (as has been reported elsewhere) and the choice of mode for those trips.

In the study generally, it was found that residence areas of relatively high transit usage on work trips were located radially from the center city along old, well-established transit lines. Transit usage was found to "decay" regularly with decreasing density throughout the area, but along the radial high-speed lines were noted contour

TABLE 3

MODES USED IN TRAVELING FROM HOME TO WORK
SIX STATES, 1951

Mode	Population Size of City		
	5,000 to 25,000	25,000 to 100,000	100,000 plus
Passenger Car	64.4	62.8	46.4
Public Transit	4.2	15.7	38.4
Pass. Car and Public Transit	0.9	0.9	2.2
Walk	24.2	17.2	9.9
All other means and not reported	6.3	3.4	3.1
Total	100.0	100.0	100.0

Source: Motor-vehicle-use studies. See footnote Table 4.

"fingers" of a slower rate of decay.[3] As was expected, it was found that high-transit riding for work trips occurred most often in middle- and low-income areas of quite high population density.

At present, the use of transit has declined considerably relative to private automobile transportation in the journey-to-work since the time of the Philadelphia area 1947 O-D survey. For this reason, the patterns described above have little value in terms of absolute numbers. Rather, the goals of analyzing "old" data are to provide a basis against which more recent data may be compared, and more importantly when possible, the finding of pattern and explanation of that pattern in terms of independently measured demographic, social or physical factors. Hence, the sifting and assay of 1947 data is presented with qualification but without apology.

Selection of Mode as a Function of City Size and Trip Length

Table 4 shows summary data derived from a distribution of gainfully employed workers traveling from home to work, with trips classified by mode of travel and by size of city. The original data were gathered by interview method in six states in connection with the Bureau of Public Roads motor-vehicle-use surveys. (The states were Arkansas, Louisiana, North Dakota, Oklahoma, South Dakota, and Wisconsin, and the surveys were made in the summer of 1951.) The full results of the study with data grouped by mile-distance class intervals, may be found in the source listed at the foot of Table 4.

As might be expected, the proportion of persons using transit on work-trips was found to increase with increasing size of city. But slightly surprising was the finding that the average length of transit trip was fully 1.5 miles longer for cities of 5,000 to 25,000 population than it was for cities in the next larger group, from 25,000 to 100,000 population, and one-third of a mile longer than the trips to work in the largest category of cities. Thus, of the relatively few who used transit to go to work in cities under 25,000 population there was a large proportion who took fairly long bus trips to work. The peculiar reversal in trend did not apply when the median lengths were considered. The medians, according to expectation, increased directly with city population size (or more correctly, with increasing extent of the urban area).

The reversal of trend in average trip length occurred also for the passenger automobile mode for work trips, and in the summary data for work trips of all modes. And as with the transit mode, median work-trip lengths increased regularly with city population

TABLE 4

LENGTH OF WORK TRIP AS A FUNCTION OF CITY SIZE SIX STATES[1]: SUMMER 1951

		Population Size of City		
		5,000 to 25,000	25,000 to 100,000	100,000 plus
Public Transportation	Percent of reporting workers	4.5	15.9	39.0
	Average length of trip, miles	4.45	2.93	4.12
	Median length of trip, miles	1.90	2.29	3.28
Passenger Automobiles	Percent of reporting workers	67.7	64.3	47.5
	Average length of trip, miles	4.30	3.66	5.44
	Median length of trip, miles	1.58	2.22	4.00
All Modes[2]	Percent of reporting workers[3]	100.00	100.00	100.00
	Average length of trip, miles	3.35	3.12	4.46
	Median length of trip, miles	1.20	1.89	3.31

[1] Arkansas, Louisiana, North Dakota, Oklahoma, South Dakota, Wisconsin.
[2] Includes the following mode categories: combination of auto and public transportation, walking, and "all other means and not reported."
[3] "Reporting workers" refers to those who reported length of trip. The total of "reporting workers" includes some who failed to report on modes used.
Source: Average and median data derived from information in article by T. A. Bostick, R. T. Messer, C. A. Steele. "Motor-Vehicle-Use Studies in Six States." Public Roads, Vol. 28, No. 5, December 1954. p. 111.

3 The term "decay" is used here to indicate the decrease in an ordinate value of a curve, with increasing abscissa value. The term derives from the physical science usage, for example, the "decay" of an existing electromotive force in a conductor, over time, after interruption of a previously closed circuit.

size for trips by automobile mode and those by all modes.

It might be noted that median transit trip length was less sensitive to variations in city size than was the median trip by auto. Thus, the median transit trip for the largest cities was 73 percent longer than for the smallest group (3.28 miles as compared with 1.9 miles). But the median auto work trip in the largest cities was 153 percent greater than for the smallest group (4.0 miles compared with 1.58 miles).

Amplification of these summary data is given in the original data distribution (see Source, footnote of Table 4). The distribution by distance class indicated that for the smaller cities (25,000 to 100,000 population) few persons selected transit mode for trips of over 5 miles in length. Conversely, for work-trips of over 5 miles in length in and to these cities, the auto and auto-plus-public-transit modes accounted for over 80 percent of the trips made.

The auto mode was not so popular in the larger cities. For trips of under 5 miles length in the cities of over 100,000 population (in the six-state survey), less than half of the workers utilized autos to get to work. For the work-trips of over 5 miles in these cities, the auto was selected by well over 60 percent of the work-travelers in each of the longer distance classes of trips.

Other than the reversals in average trip lengths noted above, the patterns by city size were as might be expected.

Time Characteristics

Considering that the validity of traffic surveys and projections rests wholly upon the repetitiveness of traffic patterns, very little is known of the time characteristics of traffic except for the hourly pattern throughout an "average" day. At least one study shows that the pattern of urban traffic is repetitive over a weekly cycle (7). Seasonal patterns or relation of a given survey period's figures to those for an annually averaged day are study areas requiring exploration. Perhaps even more important are changes in pattern on a long-run, yearly basis.

While not much may be known of traffic behavior over the longer time periods, the variation throughout the typical survey day are known to the point of notoriety. Work travelers themselves may be poor accountants of the time and costs of their trips on a cumulative basis, but they are all quite aware of the "crush hour."

Many are familiar with the two-peaked graph of the hourly distribution of traffic volumes passing a given point (such as a cordon station). These are the peaks which determine capacity requirements of facilities, and represent the time during the day of work-trip dominance. In Detroit, for example, it has been found (1953) that fully 90 percent of the morning peak-period traffic, and 78 percent of the evening peak-period traffic was composed of vehicles en route to or from work places (8).

The hourly peaking characteristic of work trips sets the tone of the interrelationship between vehicular traffic and the physical facilities employed. Trips between home and work in Sacramento, for instance, required 12 percent more time than trips of other purposes in traveling equal distances (1947, 9). This greater friction of peak-period congestion may be inferred from the sharply peaked hourly time distribution of the journey-to-work.

Similarly, traffic measurements made in St. Paul (September and October 1949) showed that 45 percent more distance was covered in the first 15 minutes of travel from the CBD in the off-peak as compared with the peak-period of traffic flow. The equivalent figure for Minneapolis was 18 percent (10). The retarding effect on traffic of the great volumes of workers who travel at the same time is evident in these figures.

Nature of the Data Presented

The description of this section is sparse. Omitted, for example, are discussions of time trends in selection of mode (the trend toward greater automobile usage is well known), effects of auto ownership, income, average rental, and net residential density in selection of mode. However, time and space for this presentation are limited, and materials selected for presentation here indicate some vital characteristics of the journey-to-work.

SOME CONCLUSIONS AND IMPLICATIONS

This section presents some general statements on the journey-to-work, on planning techniques, and some implications of the research study. Detailed studies from which these three topics were developed have been omitted by reason of space limitation. These studies will be available this year from the Institute for Urban Studies.

Perhaps the best general statement which has been made of the journey-to-work is the following:

"People tend to minimize their journies-to-work, maximize their employment benefits, and maximize their residential amenities" (11).

This description incorporates the Zipf concept of minimization of travel effort in regard to length of trip, and also states the operative factors which influence the specifics of home or work place selection within the distance limits imposed by the Zipf approach (12).

Again, as Renyak pointed out, the general statement above becomes an empirical theory to the extent that relationships among work place and residence areas are developed and hypothesized, and more specifically, that relationship is found among numbers of jobs in work place areas and the numbers of employed persons routinely traveling to those jobs from particular residence districts.

Generalizing about the journey-to-work is based upon assumptions concerning the statistical behavior of individuals. Considering such seemingly non-free-will behavior has a flavor of abhorrence to most people. But the probabilistic bases of generalizing about behavior assume essential freedom of choice of each individual. The financial health of the large insurance companies is a demonstration that the generalities work. That behavior is describable in this way need not be redemonstrated here. An abundant literature exists on the subject of patterns of human "interacting" over geographic space.

The literature contains several generalizations and summary statements about travel to work place destinations. Three are given below:

1. (a) "Total urban area population is residentially distributed about the central business district of the principal city. The residential distribution of persons employed in central districts tends to approximate that of the entire urban area population."

(b) "Residences of persons employed in off-center work places are concentrated most heavily in the immediate vicinity of the place of work." J. Douglas Carroll, "The Relation of Homes to Work Places and the Spatial Pattern of Cities." "Social Forces," Vol. 30, No. 3, pp. 271-282, March (1952).

2. "Each (manufacturing) plant draws workers from each of the distance zones in accordance with the number it employs—the larger the plant the greater the distance from which it attracts workers." Leo F. Schnore, "The Separation of Home and Work in Flint," Institute for Human Adjustment, University of Michigan, (1954).

3. "The dominant role of zone 1 (CBD) as the employment centre for all of Metropolitan Toronto can be seen very clearly... (from the data). From all but one of the 10 significant zones and all but two of the 7 others more than one-third of all employed residents traveled to work in this centre... In seven of the ten significant zones, over one-half, and in three, over two-thirds of all (employed) residents commuted to the central zone. The percentage appears to depend partly on the distance from the centre... and partly on the excess of (employed) residents over jobs in each zone." H. Blumenfeld, "Memorandum Re Characteristics of Work Trips." Metropolitan Toronto Planning Board, (1957).

In the current studies being reported on, regular patterns were found for the proportional distributions by mile or time-distance rings of work place destinations about residence loci and conversely of residence origins of workers about work place centers of confluence. These were studies of the relationship between a trip-origin or trip-confluence center and its surrounding field of influence.

The studies were based largely upon graphical analyses and were of two general types: one gave a proportional distribution by distance rings of the total trips leaving

or arriving at the locus of study; the second type considered the "per capita" proportion arriving at a destination from each distance ring. The first type is the easier to calculate, but is also of lesser significance. It is considered in the first four statements below. The second group of studies, employing the "per capita" approach, has meaning in terms of studies of "interacting" between centers of influence in a demographic gravity field (13, 14, 15, 16, 17). Tests of correlation and significance thereof for plotted data have not been applied in all instances. Still it is believed fair to make statement 5 below based upon partial testing and apparent uniformities in plotted data patterns.

Agreement is found between the data of the present studies and the three quoted statements above in these ways:

1. There is an apparent consistency in the decay of numbers of workers commuting to work places in a given city, with each mile-ring of increasing distance.
2. The volume scale of the work place dictates the absolute numbers of workers drawn from each distance ring, but the forms of the distribution curves in the same metropolitan area will be similar at a given point in time. Important factors affecting local variations in shapes of these curves include location of work place (central or outlying), and the consequent proportional use of transit by employees.
3. Because of the greater absolute numbers of workers drawn from each distance ring by places with large volumes of employment, the probability of drawing some workers from quite long distances increases with the volume-scale of the work place.
4. Measurable characteristics of the origin areas (net residential population density and distance from city center) relate roughly to work-trip percentile distribution patterns from origin areas.
5. Persistent patterns are discernible for the proportions of work trips bound to a particular destination of all work trips leaving origins in each mile-distance-ring about that center.[4]
6. Location of employment destinations in relation to city center and job density of destination area may be relevant to the form of the distribution function in statement 5, but neither factor has been adequately tested.

The first four statements hold interest for their descriptive value relative to housing and labor markets. They aid in description of the volumes of persons traveling varying distances between homes and work places in terms of percentile and median values.

The fifth statement has the greatest analytical value for its eventual applicability in describing the potentials for work-travel to destinations from a total residence "gravity field."

Thus, several of the statements immediately above are considered to agree with and amplify conclusions made in the past concerning patterns of distribution of residences in relation to work places, and therefore of patterns in trips between them.

Analysis and Planning Techniques

Consideration of three factors is basic to description and detailed analysis of urban transportation patterns.

1. Distribution of origin trip-ends.
2. Distribution of terminal trip-ends.
3. Distribution of trip among origins and destinations.

Until only recently, urban traffic analysis consisted primarily of study of the third item above, the distribution of trips only. Lately some attention has been focused upon

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[4] On log-log scale, distance as abscissa, curves which may be fitted to the data include straight lines, and parabolic arcs warped concave-downward. Statistically the "fit" is fair but significant for the straight-line examples tested. Curvilinear patterns appear quite consistent but are as yet untested. Data developed in this manner are for Philadelphia and Toronto.

the first aspect, origin of trips from residence areas. But consideration of special characteristics of terminal trip-ends has been given only sporadic attention, most notably in consideration of the special case of the central business district as a locus of terminal trip-ends.

As analysis techniques improve, fairly complete synthetic models of past and current systems of travel appear quite possible. Means are to be sought to explain changes between the older and the more current descriptive model. As such changes can be related to independent measures of social, economic, and urban structural change over the intervening years, means will be found for developing synthetic models of future transportation behavior. The work described in this report is largely concerned with useful description of transportation patterns at single points in recent time. From such description usable predictive techniques may be developed as travel data for more than a single point in time become available for individual cities.

A current practice in forecasting travel patterns is to multiply current trip-interchange data by various factors of expansion to obtain the relationships among future trip-origins and trip-terminations. This practice is expedient and probably necessary at present, but tends toward a perpetuation of existing travel patterns in future plans.

As more clear characteristic patterns can be found (and described) about the centers of dispersion and confluence, the possibility for a synthetic and, thus less biased, model of future travel will be increased. The most fertile field for seeking such patterns is in the journey-to-work, for reasons of scale and completeness.

A procedure may be roughly described to illustrate the application of the preceding ideas. The development of an analysis model of the future might be considered in these steps:

1. Prepare origin and terminal trip-end data for each area unit, based upon current information.
2. Develop inter-relationships of area-units through gravity formulations, utilizing varying constants, weights for individuals, and varying exponents for systems of trips, location of area units, etc. Where functions are excessively complex, apply graphical solutions.
3. Modify trip-end and trip-exchange data in terms of independent forecast measures.
4. Test work-trip production and interchange findings by means of graphical distribution analysis.
5. Test total trip-production and distribution findings by means of derived relationships between work-trip systems and other systems of travel.

In development of such tecnhiques, it is likely that graphical studies will provide the "bridge" to more detailed analyses. Graphical distribution studies have additional value in their greater likelihood of usage in local applications as compared with abstruse formulations to which research time but not applied field time can be given, other than in the exceptional examples of multi-million dollar survey and planning efforts. More importantly though, the graphical analyses can lead the way toward generalization in algebraic formulation. Where an indication of consistency of pattern can be found, and where a logical basis exists for selection of a particular type of equation, then further and more detailed study by researchers is probably warranted.

In the long-term development of this type of analysis, mathematical gravity concepts of trip interchange appear to hold the greatest promise for improving predictability of systems of urban travel. Problems in applying this formulation reside in determining multiplier constants, weights for individuals, and/or exponents. But whether or not a solution is sought in terms of varying negative exponents of distance[5] or of weights for individuals, the function of intervening distance, $f(d_{ij})$, is not to be interpreted as the same function throughout the metropolitan field. The function of distance is variable over the metropolitan field depending upon such factors as purpose of trip, and location of at least one of the two zones (origin and destination) in each combination (18).

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[5] "Journal of the American Institute of Planners, article by Carrothers (16).

Needed Data Accumulation and Research

A major need in origin-destination travel surveys is for separation among the systems of work travel in development and presentation of the data. This refinement among the three systems will aid trip-end analysis, and help in study of completeness of reporting by increasing the comparability of employment and residential labor force data with trip-production information.

Another helpful source of needed information would result from inclusion, within the decennial or special census surveys, questions concerning area of workplace, and time and mode of travel.

In cities where the building inspection program is maintained on a current basis by a consistent program of residential inspections and interviews, it may be found possible to include a question or two on work place of wage-earners to help in developing and maintaining a current file on journey-to-work patterns, and thereby indirectly cross-reference information which may aid in analyzing total travel patterns. The latter point would become more meaningful if the city area in mapped representation is divided into a number of planning analysis areas, with the boundaries of these to be regarded as cordon lines. Thus, with a continuous traffic-counting program, it could become possible, eventually, to relate current traffic counts to current trip-generation information. Given this degree of understanding of city-wide trip generation, planning for future anticipated needs could attain new levels of closeness to actuality. Similarly, better dealing with the problem situations in dense traffic areas might be made possible as control could be moved back closer to trip origins. (To get this point out of the "cloud level" of theorizing, the analogy might be made to the local check-dam approach to flood control as the sources of ground water in the water-shed areas become known, in contrast with expensive high-dam control at a point of great depth or density of flow.) Controlling traffic problems at point of maximum conflict is essentially an after-the-fact approach (19).

Careful studies of production of origin trip-ends in relation to residence indicate the present status of auto-ownership levels as the principal input data for explanation of variations in total trip generation per dwelling unit (20). In the immediate future, as suggested by authors of the HRB paper, it would appear highly desirable to improve the available information on auto ownership for travel forecasting purposes. This form of ownership is completely regulated by state governments. It should not be impossible to establish and maintain in local transportation planning offices, current information on total vehicle ownership ty type of vehicle, and by census tract of residence or place of business of the registered owner, or of registered user and partial owner (in the prevalent situation of installment purchasing). However, a very important question for transportation planning is how long the "prediction" value of auto ownership will continue into the future. As auto ownership levels become more nearly equal over time, as the physical character of cities change, it may be found that auto ownership will be relegated to the place of a transient factor in explaining trip production. The question then becomes: are auto ownership and trip production two effects of the same cause? Can one seek further into the propensity to travel in order to be prepared for saturation levels of auto ownership?

Not as a solution to the problem posed above, but as an independent consideration, another type of research is described here. It is believed to be of a lower priority as a problem than others named. The suggestion is toward development of an aid which could be helpful in improving predictability of peak-period travel. The point is that a number of indicators are available to show person-miles of travel by the several modes in all United States cities. Preliminary examination shows that variations in total urban person-miles of vehicular travel (auto, transit, taxi, railroad commutation) may be shown to be closely associated with variations in a series of annual indices of industrial production and of non-agricultural employment (21). Now in an expanding economy, some indices may be found which plot over time with startling appearances of correlation (aspirin production versus new housing starts, for instance). The point is that a logical basis must exist for a given relationship study. Nonetheless, it is reasonable to suppose that some part (at least) of urban vehicular travel, taken in summation as vehicle-miles

and/or person-miles may relate over time closely to certain measures of the level of local economic activity. It is also reasonable to suppose that the components of urban travel which would have the greatest relevance in this relationship would be the systems of work-travel. What then appears as a possible form of urban research, is a time-series analysis of total work-travel and indices of urban or regional economic activity. From this might be developed a means of roughly estimating the total future peak-period demands for urban vehicular travel, in terms of street transit, taxi, and commuter-rail capacity.

The assumptions necessary in such an approach are at present gross and the refinement difficult. The possibilities of this research avenue, even if only to supplement other and (hopefully) independent forecasts, should not be discounted, even though it represents a different approach to anticipating urban circulation requirements.

Repetition will not be made in this summary of problems posed in the previous section concerning gravity formulations of urban travel. However, one additional question is raised: that of whether or not to seek relevant "weights" for individuals by purpose of trip and zone characteristics, or to continue to seek solely for gross multiplier constants and exponents of the population and distance measures.

CONCLUSIONS

The foregoing discussion of "systems" of work-trips and their analysis, it is hoped, has awakened in the reader a wider concept of how the "ore" of available traffic data may be further sifted and refined for information useful in understanding the workings of urban circulation and in planning for its improvement.

GLOSSARY

It has been found desirable to adapt terminology and to propose a few new terms in order to deal in detail with work travel as measured in O-D and motor-vehicle-use surveys. All trips referred to are those made by individuals (person-trips) rather than those made by the vehicles.

Work-trip: A work-purpose trip as defined in connection with Bureau of Public Roads format O-D surveys. This is a trip to location of place of gainful employment, or to locations which must be visited in the course of an ordinary day's work.

Home-work trip: A trip made from residence to a work place by a person going to perform gainful employment.

Work-home trip: A trip to a person's residence from a place where his gainful employment is pursued.

Other-work trip: A trip made from work or other non-home location in connection with regular activities of a person's gainful employment.

System of movement:[6] A broad pattern of movement that is functionally related to an organized activity of business or other social action.

Journey-to-work: The two systems of movement in a city or metropolitan area, comprising all "home-work" trips and all "work-home" trips.

Work-travel: The three systems of movement in a city or metropolitan area, comprising all "home-work," "work-home," and "other-work" trips.

Central business district: [7] A district which is arbitrarily determined for planning purposes as the locus of the greater part of commercial activities within a city and constitutes an area of very high land values. In it are located many stores, service establishments, offices, hotels, and theaters. It is an area of high daily accumulation of persons and vehicles.

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[6] From Mitchell and Rapkin, op. cit., p. 218.

[7] Definition is expanded from that given in a U. S. Department of Commerce publication: "Central Business Districts and their Metropolitan Areas...," Office of Area Development, November 1957.

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