# Critique of Home-Interview Type O-D Surveys in Urban Areas

NATHAN CHERNIACK, Economist, Comprehensive Planning Office,
The Port of New York Authority

● IT HAS BEEN STATED (1) that "it has now been 15 years since the home-interview method of making origin-and-destination surveys in urban areas was developed. The method has now been used in 126 urban areas and repeat surveys have been made or started in 10 of these. The field methods and the information obtained have been changed very little since the earliest surveys. Present emphasis is on the improvement of analysis methods."

It has been said that where a method has been in use for 5 years, it should be reviewed; if it has been in use for 10 years, it is ready for drastic revision; if it has been used for 20 years, it should be presumed to be obsolete. On the basis of this rule of thumb, the home-interview method of collecting O-D data is rapidly approaching obsolescence, if it has not already reached it.

## INHERENT DEFECTS OF HOME-INTERVIEW SURVEYS

A home-interview survey of the origins and destinations of trips, in any given study area, does reveal a fairly faithful picture of all trips made in the course of a 24-hr weekday, for all purposes, by all modes of travel. Such a survey does also have the advantages that 5 percent sample interviews, conducted at randomly selected homes, can be tied to a known universe of homes and an intercensal estimate for the year of the survey, of total population in each of the O-D zones of residence in the study area. But having said all this, the remaining characteristics of the home-interview method of assembling O-D trip data, for purpose of planning limited-access highways, and mass transportation, particularly in urban areas, are replete with inherent defects which are practically incurable with any statistical methods, or by electronic computers.

For one thing, only a fraction of the usual 5 percent sample of the primary trips (those originating at or destined for homes in any given zone in the study area), consist of journeys to and from work or business or other trips that would utilize existing arterials or expressways, or would utilize proposed expressways in the future. Substantial portions of such primary trips are usually made on local streets—picking up and delivering children at schools, visiting local shopping areas, friends and homes, and for other local area chores. Other large portions of the sampled trips are made along directions crosswise to existing arterials or proposed expressways. Consequently, of the expanded 5 percent home samplings of primary trips, only fractions can actually be utilized to the base year trip potentials for proposed expressways of the future.

Lynch further states that "throughout the past 10 years, much research has been conducted on trip production and trip attraction in relation to land use." For purposes of measuring the drawing powers of different types of land-use generators, like sites of employment in the study area, the numbers of inter-zonal trips actually recorded in an over-all 5 percent home-interview sampling, are so few and inadequate as to make them rather crude instruments for such measurements. But to make matters worse, before such meager samplings can be used to correlate with land-use data, they must first be broken down by significant trip purposes, such as journey-to-work trips, business trips, trips for shopping, recreation, amusement, etc. In some instances, such as journey-to-work trips, the fraction of the sample must be further reduced to reflect only the significant morning and evening rush hour travel. These types of breakdowns often reduce some samplings of inter-zonal trips, to such small numbers as to be wholly worthless for research purposes.

Nor does the "fattening up" of sample zonal trips, by combining trips in several

zones into larger areas, to counteract the trip purpose and rush hour breakdowns, for example, serve to cure the inherent defects of the original meager zone samplings. The pairs of combined zones now become areas too large to be characterized by average travel times, distances and costs, between their centroids. Lynch states that "it is necessary, however, to smooth out the reported times because of the small number of reported trips between some pairs of zones." Correlations with average travel time, distance and cost determinants thus become blurred and blunted, evidenced by the wide scatters on correlation graphs. Imagination must often be stretched to the elastic limit to glean the types of quantitative relationships between zonal trips and some of the factors of trip generation. Then, to explain exceptions to the derived relationships, a number of additional factors, quite unpredictable in the future, have usually been introduced.

But that is not all. In any study area, zonal trip ends as usually tabulated, constitute a kind of "chemical mixture" that consists of (a) primary trips originating in or destined for homes in individual zones and produced by residents domiciled in those zones, plus (b) trips attracted to those same zones to non-residential land uses located in those same zones, for purposes of work, shopping, etc. Consequently, as a result of these "chemical mixtures" of primary and attracted trip ends, correlations between these mixtures of zonal trip ends and the autos domiciled in the corresponding zones, could not possibly yield satisfactory relationships. The trips generated by non-residences in the zones are definitely not related to either households nor autos domiciled in those zones. Lynch apparently realizes this when he says, "difficulties have been encountered because of mixed land uses within zones and lack of precise knowledge as to the character of the establishments at the end of each trip."

Before any meaningful correlations could be derived between trip determinants and trips they produced, it is therefore essential, first, to break down this "chemical mixture" of primary and attracted trip ends into "elemental" primary trip ends. To break down such mixtures, it is necessary to go back to the original home-interview schedules and distill out of them the pure "elemental" primary trips for each zone—that is, trips of one or all purposes, originating in or destined exclusively for residences in those zones. Only such "elemental" primary trip ends could yield meaningful correlations with autos domiciled in those zones. This step has now actually been taken in the analysis of the National Capital Region, by retabulating original trips. The category of trips with the ludicrous "purpose," "to home" has been mechanically eliminated; in its place, the more realistic category of "work trips to and from homes" has been substituted.

Where "elemental" primary trip ends could be made available, such trips which began or ended at homes may be expected to yield excellent correlations with autos domiciled in the corresponding zones.

Car densities in small areas (expressed as cars per acre) are intimately related to the corresponding household densities (expressed as households per acre). In suburban sparsely settled communities cars are absolute essentials. In more densely populated communities, auto densities are also higher but not proportionately so, because in such areas car ownerships become less essential by reason of convenient public transportation and of cars being more costly to own and operate.

Auto ownership densities thus increase with household densities, not in proportion but rather at declining rates. In the New York-New Jersey Metropolitan District for example, as of 1955, in Somerset County, N.J., the average household density for the county was around 2 households per acre, auto density was about 3 autos per acre; in Bergen County, N.J., where household was about 4.5 households per acre, auto density was about 5.5; in Essex County, N.J., the corresponding figures were 8 and 8.5; in Hudson County they were 15 and 13; and in Manhattan there were 52 households per acre and about 21 autos per acre.

Because autos per acre do not increase in proportion to households per acre, autos per household in densely populated areas usually constitute, currently, less than a car per household. In Somerset County, with 2 households per acre, there were 140 autos per 100 households; in Bergen County with 4.5 households per acre 120; in Hudson with 15 households per acre 80; in Manhattan with 52 households per acre only 40 autos per 100 households.

Household densities would appear to constitute far more stable indicators of auto ownership than are such other indicators as groups of income levels. Besides numbers of households and residential acreage for small areas are far more predictable, in the future, than income levels.

Also, distances from the CBD are not good fundamental determinants of either car ownerships or trips. Distance from the CBD is only a space parameter, akin to a time parameter. Mere distance from the CBD, which itself has been changing significantly in character, like mere passage of time, are both generally weak and, at times, unreliable determinants for forecasting purposes. More fundamental and considerably more predictable determinants, like household densities, are needed to measure zonal auto ownerships which in turn, are the determinants for generated zonal trip ends. The urban area is never a homogeneous continuum that spreads out in circles from a center, like the centroid of the CBD, out to the suburbs, in all directions. There are dense zones in the distant suburbs and less dense zones in close-in areas near the CBD. In any given urban study area, individual residential zones of widely varying household densities make for correspondingly widely varying auto ownership densities, and thus for widely varying volumes of auto ownerships at similar distances from the CBD. The last, in turn, generate widely varying volumes of zonal trip ends. Aggregate households in the study area and the spacial distribution of widely varying household densities, thus determine, to a large extent, the aggregate absolute number of trip ends in any given urban area.

Also in any given urban area, every O-D zone is not only a residence but also a non-residence zone. The same type of "chemical breakdown" is thus equally essential, in order to obtain trip ends in every O-D zone as non-residence zone—that is, trips originating in or destined for work places, shopping areas, recreational, amusement and cultural areas, but excluding homes as origins or destinations. If such a breakdown were actually made, by going back to the original schedules, such "elemental" trip end data to and from non-residence zones, could then be correlated with such correlative land-use data as, gainfully employed at sites of employment for journey-to-work trips, floor space in commercial buildings for business trips, floor space in retail establishments for shopping trips, and floor space in other buildings for amusement and other trips, etc. These types of land-use data have only very recently become available in connection with the home-interview O-D trip surveys, and in only a few cities. And yet these are some of the fundamental determinants of the relative number of trip ends in non-residence zones, just as households and household densities are the fundamental determinants of the absolute number of trip ends in residential zones.

The final group of essential fundamental data (in addition to land use data) that should have been, but which were not, usually assembled in the past, in conjunction with and, where possible, also simultaneously with, the collection of home-interview O-D data, are the travel impedances some of which must be obtained through test runs between residence and non-residence zones. Test runs should have been made between every pair of zones in any given study area and along various alternate routes and modes of travel, by riding autos, buses and railroads, where the last are important. In connection with such test runs, data should have been assembled, on travel distances and travel times along actual routes, tolls at bridges, tunnels and highways, parking fees in non-residence zones, and on annoying, irritating and potentially hazardous aspects of routes, like direct left turns, clover leaf left turns, parked cars, pedestrains crossing, etc.

## HOW SHOULD O-D TRIP DATA BE ASSEMBLED IN THE FUTURE?

Having criticized the home-interview O-D survey, it is fair to ask whether there is a better method of assembling trip data.

There are really only three possible methods of assembling O-D trip data. One is to interview persons enroute from origins to destinations, at roadside stations. The second method is to interview persons at home about trips made in a recent period by members of the household. The third method is to interview persons (and to obtain,

by other means, other correlative data) at non-residence locations, where there are large concentrations of persons, with respect to their trips for the specific purposes which brought them there.

It would seem to this researcher that, for planning future urban expressways, sample trip and correlative data on trip determinants should really be assembled, not in the homes but in areas where people are concentrated during the day. Such areas are: central business districts, large commercial and industrial sites of employment, shopping areas, amusement and recreation areas, and in general, sites of public assembly. Those are the areas on which traffic converges, where traffic is concentrated on approach highways and where consequently additional vehicular capacities are usually urgently needed on peak weekdays, in peak leisure time periods, and in peak hours.

Trip data to and from non-residences, if assembled at these sites, could at the same time, just as readily include correlative data on modes of transportation that were used to reach areas of concentration, travel distances, times and travel costs, as well as the conveniences and inconveniences of alternate routes and modes of travel between homes and such areas of concentration. Thus, for example, data on journey-to-work trips could be assembled at selected sites of employment, together with the correlative data on locations of employee residences, travel times, distances and costs to and from employees' homes. Such work trip data could then be correlated with data on employed labor forces residing in small residential zones, whence employees had been drawn. Such correlations would, at the same time, disclose the varying strengths of selected and stratified sample sites of employment in their ability to draw different classes of employees from different types of residential zones located at varying travel distances, times and costs from these sites of employment. The varying power of attraction of any given site, zone or area of concentration of persons, whether it be a large or small traffic generator, for trips from different resident zones, measured by the varying proportions of zonal employed labor forces which it draws, would be, to a large degree, inversely proportional to the travel distances, times, costs and other travel impedances between that site, zone or area and the residences scattered over the study area.

This type of inverse relationship is often referred to as the "gravity model." However, it is believed that this inverse relationship does not follow the so-called "gravity formula," which is a power function, but rather an inverse exponential type of mathematical function.

But to validate any hypothesis, which postulates inverse relationships with travel impedances, sample O-D data are, of course, essential. To establish adequate confidence in any proposed hypothesis which sets forth the fundamental determinants of trip generation, sample O-D trip data, plus the correlative supplemental data on determinants, must be quite substantial. Sample O-D trip data should therefore be assembled at locations, not where people are diffused over the study area as in their respective homes, but where people are concentrated, as at sites of employment. Trip data should therefore be assembled at work places, in retail establishments, in office buildings, in manufacturing plants, at recreational and amusement areas, and at cultural centers. In short, O-D trip data, to be useful for research and for the application of the relationships for planning purposes, whether for future expressways or for the revitalization of CBD's, or for the planning or replanning of commercial and industrial areas, must be assembled at sites where people are concentrated; also O-D trip data should reflect travel in rush hours, whether to or from work on weekdays, or to or from recreational areas in peak leisure time periods.

## A SUGGESTED PROGRAM FOR THE FUTURE

Three types of research projects suggest themselves for the future: (1) re-analyze O-D trip data, which have been assembled over the years by the home-interview method, in relation to minimum fundamental trip determinants which prevailed at the time of the O-D surveys; (2) in the future assemble O-D trip data, together with correlative data on travel distances, times, modes and costs, at locations where people are concentrated; and (3) inaugurate the collection and compilation of a minimum of

data on independent fundamental trip determinants, for small zones in the study area on a continuing basis.

Today there is a wealth of trip volume data between small areas in more than 100 cities, for which millions of dollars have been spent to assemble by the home-interview method and more millions for analyses of these data. Some of these original data should be "exhumed" and repunched on new cards. Some fundamental supplemental data, on trip determinants, reflective of the time of the survey period, should be punched into those cards. They should be retabulated. They should be re-analyzed, with a view of establishing quantitative relationships between trips and the minimum number of fundamental factors of trip generation that prevailed in different cities at the time of the O-D surveys.

Then after such quantitative relationships had been established, but before they are applied to estimate future changes in trip volumes, these relationships should be tested to see how close the differences in trip determinants in various zones of the study area actually account for significant differences in trip generations in those zones as of the survey period.

At this point, it would also have to be realized that a philosophical step would have to be introduced between the current trip determinants and their use for estimating future travel patterns. It is this: Currently, a unit difference in any trip determinant like distance, time or cost would be associated with a related difference in generated trips, as between two locations in the study area. It would have to be assumed that a corresponding unit change between two points in time, in any trip determinant, would be associated with an equivalent change in generated trips.

A great wealth of understanding would flow from such re-analyses of home-interview O-D trip data. Minimum real and essential trip determinants would be identified; the most effective methods of assembling the types of data required for planning purposes would be revealed.

Such re-analyses would, on the one hand, point to a serious consideration in the future for tapering off home-interview O-D surveys and on the other hand, point to the need for assembling future O-D trip data (together with correlative data on travel distances, times, and travel impedances, as well as cost via various modes of travel used to and from homes), at sites and areas of concentrated economic, social and recreational activities in urban areas.

In addition, the need to collect and compile a minimum of supplemental fundamental determinants for small zones on a continuing basis would become evident. These trip determinants would consist of the following data: population, households, autos, numbers of gainfully employed at sites or zones of employment, net residential acreages, floor space at industrial, commercial, management, office, amusement and recreational sites.

By assembling O-D trip data in areas where people are concentrated, a much richer body of data would thus become available for identifying the minimum underlying fundamental determinants of urban transportation and for the forging of more powerful tools for planning. Realistic and understandable relationships between generated trips and fundamental trip determinants that would be predictable, to a large extent, could indicate which determinants of trip generation could be controlled, through land-use planning, for example, and which changes in determinants must simply be anticipated. Such relationships could thus become effective aids and even powerful tools for the formulation of city planning and transportation policy decisions.

## REFERENCE

1. Lynch, J. T., "Home-Interview Surveys and Related Research Activities." HRB Bul. 224, pp. 85-88 (1959).

## *Discussion*

E. WILSON CAMPBELL, Assistant Director, Chicago Area Transportation Study—

The writer agrees with Mr. Cherniack that the home-interview method has inherent defects. However, little else is found in his paper with which the writer can agree. The fact that there are defects in the technique does not prevent the home-interview method from becoming a useful tool for urban transportation planning. There are defects in the way steel structures are designed and constructed, in the way cars are driven, in relations with people; in fact, there is hardly a process which is free from defect. However, the fact that there are defects does not prevent these processes or relationships from being useful when handled properly.

The author states that only a fraction of trips collected with the usual 5 percent sample consist of journeys that would utilize existing arterials and expressways, and that substantial portions of these primary trips are usually made on local streets. The Chicago Area Transportation Study home interviews are based on a sample rate of 1 in 30 (3.3 percent). The vehicle-miles of travel accounted for by these reported trips have been calculated, and through a system of sample on the ground counts, vehicle-miles of travel in the study area for the same year have been estimated. The total vehicle-miles of travel estimated by the two techniques agree within 10 percent of this total mileage. Eighty percent is on streets classified as arterial or expressway. The close correlation of these results certainly explodes the theory that trips resulting from interviews at home account for a small portion of the travel on arterials or expressways.

Mr. Cherniack's next point is that in a 5 percent sample, the number of interzonal trips reported are so few and inadequate as to make them rather crude instruments for purposes of measuring drawing powers of different types of land use. In Chicago this was not the case. As a result of the home-interview survey, a record of over 350,000 trips was obtained. Thus, it was possible to group trips by purpose and by land use at the destination and still have enough trips in a group to analyze the variation of attractiveness or drawing power of the same type of land use in 45 different geographic areas.

The author's next major point is "in any study area, zonal trip ends as usually tabulated constitute a kind of 'chemical mixture' that consists of (a) primary trips originating in or destined for homes in individual zones and produced by residents domiciled in those zones, plus (b) trips attracted to those same zones to non-residential land uses located in those same zones, for purposes of work, shopping, etc." His concerns are several. First that relationships of autos domiciled in the zone to population or to net residential density or other variables could not be determined accurately. Second that correlations of trips to various land uses which are indicators of trip generation are clouded by this chemical mixture. What he says is true if the kind of land at which the trips begin or end on cannot be identified.

This problem has been eliminated in Chicago. Four years ago when the home-interview data was collected the kind of land use at each end of the trip was determined from the respondent. This information, along with the trip purpose, tells a great deal about the trip. For example it is not only known that a trip ends in a zone, but that it is going to a residential, a commercial, an industrial use, etc. In addition it is known that a person going to a residential land use is going "to home" thus he is domiciled there. Or conversely it is known that a person is going to a residential area "to work." He is a carpenter, or painter, or domestic servant, etc. He is not domiciled there. Similar examples can be made for trips to all kinds of land uses. This precision helps to pull out information required to sharpen the relationships of auto ownership, traffic generation, etc.

Next, Mr. Cherniack says that to complete the essential fundamental data, "test runs should be made between every pair of zones in any given study area and along alternate routes and modes of travel." This is an impossible task in an area as large as the Chicago Metropolitan area. More important, however, is that this type of information is all but useless for planning purposes. The planning period is some distant target year 20 to 30 years in the future. Twenty years from now the travel speeds on arterial and expressway, train, or bus will bear no resemblance to the speeds inventoried on today's roads under today's traffic conditions.

It is the feeling in Chicago that a sampling of speeds on different types of streets in

different areas during the peak hour under today's conditions is useful. These sample speeds related to net residential density or trips per square mile might be useful in estimating average speeds on facilities which have the same characteristics predicted for the future.

Next Mr. Cherniack suggests that the way to proceed in obtaining trip data is to go to the areas where people concentrate during the day, such as a CBD, industrial sites, shopping centers, etc. First, these are the areas where the predictions from the home-interview study are best. For example, in Chicago checks were made on the reported trips to work at several industrial plants of varying size. Based on the trips reported "to work in" at these plants from the home-interview study, it was possible to check within 95 percent the number of people reported at work by the plants for these same time periods.

The great disadvantage of interviewing at place of concentration is that there is no total frame of reference which can be used as a guide. That is, what is the total universe of trips per day? How many vehicle-miles of travel are driven in the area each day? This information cannot be obtained by this type of survey. The importance of knowing the total scale should not be underestimated.

Information about the household, which is useful in projecting future trips and other related trip information cannot be obtained by interviewing at the work end of the trip. The influence of "home" in organizing the travel in an area cannot be overlooked. Eighty percent of all trip ends are at home. That is to say, 80 percent of all trips begin or end at the home. This is a substantial indicator that trips inventoried at the home produce a good sample of the total trip pattern.

Mr. Cherniack states that the gravity formula which is a power function does not adequately describe the power of attraction of any given site. He feels that an inverse exponential relationship would produce better results. The writer heartily agrees with Mr. Cherniack on this point. Using a formula of this kind and 1956 trip ends and assigning to the existing arterial and expressway network we have been able to duplicate the vehicle-miles travelled in this system within 5 percent of the estimated vehicle-miles travelled in 1956.

In summary, the writer cannot agree with Cherniack that the home-interview study because of its inherent weaknesses is valueless. Nor can he agree with Mr. Cherniack's statement that the proper way to obtain this data in the future is by collecting trip information at points where people concentrate. On the contrary, the writer feels that the home-interview study is and has been a useful tool. The field of urban studies is relatively new and the tools are being developed. The home-interview technique is a stepping stone to the development of new tools. In the near future trips may be estimated based on land-use forecast, coupled with population and economic projections. This synthesis of trip data would result in great economies in data collection. This new tool would not have been possible without utilizing data collected by the home-interview method.

JOHN T. LYNCH, Chief, Planning Research Branch, U.S. Bureau of Public Roads—The writer agrees with Mr. Cherniack that the home-interview type of O-D surveys, as now conducted in urban areas, may become obsolete in the not too distant future. It is hoped that the analyses being made of the extensive data that have been collected, and particularly the study of changes in the travel pattern over periods of ten years or more, will make possible the development of a cheaper and more accurate method of forecasting future travel. This is the objective of much of the research now under way. But without the benefit of the data from these statistically controlled surveys, and especially from the repeat surveys now being conducted in a number of cities, the development of a sound and proven method would not be possible.

The home-interview method of conducting O-D surveys was adopted after a careful study of numerous shortcut methods previously used. Although some of these had provided satisfactory answers to specific problems of limited scope, they had proved to be entirely inadequate for the planning of extensive urban highway networks. In most of the cities where they had been tried, comprehensive home-interview type surveys have subsequently been undertaken.

One of the shortcut methods that was found to be inadequate was the assembling of data "at locations where people concentrate," a procedure now advocated by Mr. Cherniack. This was tried in Washington in 1939-40, in Cleveland and in Detroit about 1944, and also in other places. The difficulties encountered were numerous and the results of limited value.

For one thing, information was obtained about only a fraction of the traffic that would use a freeway or arterial network. Even for those routes that lead to the CBD, much of the traffic has neither origin nor destination in that district. In cities of about one million population, not more than one-quarter of the trips by all modes of travel have been found to have either origin or destination in the CBD. Most of the remaining trips were on arterial routes for a portion of their length. How can a freeway or arterial route be planned and designed properly if information is lacking for an unknown and relatively large portion of the travel that would use it?

Aside from the omission of important segments of the travel, such surveys were found to be unsatisfactory for other reasons. Among the most important of these were inability to obtain information from a scientifically selected sample, lack of a satisfactory universe for expansion purposes, and inability to evaluate the accuracy of the results. There were varying degrees of cooperation from different establishments, resulting in undersampling for some types of work trips and oversampling for others. It was impossible to obtain representative information for travel other than work travel, even that occurring during the peak hour. Information about shopping trips to the big department stores could sometimes be obtained, but not about those to the innumerable smaller establishments. There was no satisfactory method of accounting for the many duplications where shoppers went from store to store.

In the home-interview type of survey, the sample is selected on a systematic area-wide basis, a procedure developed by the highly competent statisticians of the Bureau of the Census and advocated by them for this purpose. This is the only type of survey of which the writer has knowledge where information is obtained about all of the travel, by all modes; where the sample is selected on a sound statistical basis; and where the results can be reliably appraised. In addition to internal checks of statistical reliability, there are many checks that can be made with independent data such as population, automobile ownership, and screenline counts.

As Mr. Cherniack points out, the sample is much too small (generally about 5 percent in the larger cities) to permit an accurate determination of the zone-to-zone movements. If the true number of trips between a certain pair of zones is 50, for example, the number of such trips included in a 5 percent sample might, by chance, be 0, 1, 2, 3, 4, 5, or even more, which would be expanded to 0, 20, 40, 60, 80, 100 or more, with a high percentage error in most cases. But in estimating traffic volumes, concern is not with individual zone-to-zone movements, but rather the accumulation of a large number of such movements on an expressway, arterial, or transit line. Tests have shown that the errors for such accumulation are generally acceptable. One test that has been made is to determine from the O-D data the number of trips that would have been expected to use certain bridges or highway sections and compare the results with actual ground counts. Another more comprehensive, if somewhat more theoretical method has been to establish a grid on a map of the entire area by drawing lines, say 1 mi apart in a north-south direction and 1 mi apart in an east-west direction, and calculate from the original sample and a number of subsamples the number of zone-to-zone movements that would cross different sections of this grid if made in an airline. From the variations of the results obtained from the different subsamples, the errors in the original sample can be estimated by the use of a statistical formula. A report on a test of this kind is included elsewhere in this Bulletin (see p. 114).

Mr. Cherniack is quite right in saying that the combining of zones into larger ones to increase the number of trips in the zone-to-zone movements introduces too great an inaccuracy in such factors as distance and travel time to be an acceptable procedure for the purpose of determining traffic movements. The accumulation of the smaller number of trips between smaller zones, as discussed previously, is much better for the purpose of assigning trips to highway and transit facilities. For purposes of

determining trip production in relation to land use, a different procedure is available. Information is now being obtained concerning the land use at each end of a trip, and trips to like land use can therefore be combined to obtain an adequate sample for different areas of the city. The availability of electronic computers makes the task a relatively simple one.

Another source of error, not mentioned by the author, is probably considerably more important than the error due to the smallness of the sample. This is a "response" error, due to the fact that the interview often must be conducted with someone other than the person who performed the travel—usually the housewife. An attempt is being made to correct this in the more recent surveys by a double-interview procedure. On the first call a form is left with the request that all persons making trips on the following day record the origin and destination of each trip, the time of departure and arrival, the mode of travel, and the trip purpose. The forms are picked up and the other desired information is obtained on a subsequent day.

The writer certainly agrees with Mr. Cherniack that the mass of data collected in the numerous O-D surveys should be correlated with other data and extensively analyzed in order to establish fundamental facts that will aid in forecasting future travel. This is being done, with the aid of electronic computers, to the extent that funds and personnel permit. Data from the two surveys in Washington, D.C., in 1948 and 1955, the two in Phoenix, Arizona, in 1947 and 1957, and the two in St. Paul-Minneapolis in 1949 and 1958 are being used for this purpose. In Detroit, a continuing organization is reanalyzing the data from the original survey, and is collecting and analyzing data from a few zones on a continuing basis, as Mr. Cherniack suggests. As the results of these studies become available, it is hoped that improved methods of determining the future travel pattern in relation to urban development can be devised.

C.A. STEELE, Chief, Highway Economics Branch, Highway Needs and Economy Division, U.S. Bureau of Public Roads—These comments are prompted by the impact that this paper might have on the motor-vehicle-use and other similar interview-type studies. Although the urban O-D studies and the motor-vehicle-use studies are made for widely different purposes, many of the basic sampling and analysis techniques employed are the same or nearly the same.

The home-interview method of collecting data for the motor-vehicle-use studies and their predecessors, the so-called road-use studies, has now been in use for nearly 30 years. On the basis of the "rule of thumb" cited in the paper this method should now be presumed to be obsolete. However, during the 30-yr period so many fundamental changes have been made in the selection of the sample, the design of the interview forms, the nature of the data collected, and the methods of collecting them, that motor-vehicle-use study interviews obtained today bear only a superficial resemblance to those obtained 25 or 30 years ago. For example, the statistically supportable "probability" sampling method has replaced the old "purposive" sampling method originally employed. Furthermore, in designing modern motor-vehicle-use study samples, stratification is used wherever possible to improve the coverage of certain types of areas or characteristics that it is desired to represent, and to reduce the size of the over-all sample that it is necessary to obtain. As a result, the motor-vehicle-use studies home-interview samples taken today are not obtained on a flat across-the-board percentage basis as was formerly done, but a separate sampling rate is set for each stratum that it is desired to sample which will be sufficient to reflect with reasonable accuracy those characteristics that it is desired to analyze most completely.

In the design of stratified samples due consideration is given to the matter of household densities mentioned by Mr. Cherniack. The point he makes that auto ownership densities increase with household densities, but at declining rates rather than in proportion, is a good one, and has been given at least indirect recognition in the design of motor-vehicle-use study samples in several states. It is to be hoped that the decennial census of 1960 will provide much more complete information on housing and households than has been available from previous censuses, although the information obtained in the 1950 census was extremely helpful in the design of samples for the motor-vehicle-use studies.

Mr. Cherniack's concern throughout his paper seems to be with the collection and analysis of O-D travel data to aid in the design of specific facilities. It has long been recognized that the purpose for which a travel study is to be made will have an important bearing on the type of data collection to be employed, and the design of the sample to be used in obtaining the information. The U.S. Bureau of Public Roads and the state highway departments have had recourse to all of the three methods mentioned in Mr. Cherniack's paper, or to combinations thereof, in the many studies that they have made.

In addition to the more common applications of these sampling methods there are a few which are not so well-known but in each of which the specific method employed was best adapted to obtaining the desired information. Thus, roadside interviews were used to obtain information for rural road-service studies in Oregon and Washington in an attempt to define the radius of "access" and "neighborhood" trips for a relative-use analysis of highway benefits. The interviewing of travelers at their destinations—places of work, department stores, etc.—was done extensively in connection with the war industry transportations studies made during World War II for the purpose of developing information basic to the rationing of motor fuel and motor vehicle tires.

For the purposes of the studies just described these methods of interviewing were the best available. For the purposes of the motor-vehicle-use studies, however, there is as yet no known substitute for the home-interview type study where it is desired to obtain characteristics of motor vehicle ownership and use, especially the use of passenger cars. Inasmuch as it has been found that the use of commercial trucks is often not directly related to households, a fourth method of sample selection and interviewing has been developed and applied in a number of states within recent years. Here the sample of trucks on which interviews are to be made is obtained from the registration lists and the interview itself is made either with the owner of the vehicle or, if he is not the principal driver, with both the owner or his representative and the principal operator.

Each of the interviewing methods listed above has its particular virtues but each also has its shortcomings. Although the destination type of interview mentioned by Mr. Cherniack can be used to good advantage for certain types of studies, such as determining how the workers at a given plant travel to and from work, such interviewing, especially when conducted at retail establishments, is likely to produce extensive duplication in the information reported through the interviewing of the same person at several locations, and is also likely not to give a good distribution of sources from which the travel originated.

ROBERT T. HOWE, Associate Professor of Civil Engineering, University of Cincinnati—A casual reading of this paper does not do justice to the importance of the author's basic ideas. Unfortunately he implies, but does not specify, what appears to be his fundamental objective. This discussion first considers what appears to be this basic goal, and then comments in detail on three of the author's suggestions.

It would seem that what Mr. Cherniack wants is a completely bounded study of origins and destinations. Inasmuch as he does not refer to this objective specifically, many of his same comments about the weaknesses of present home-interview O-D surveys may be turned on his suggested "destination-interview" survey. It is assumed, therefore, that the data, which he proposes to collect from samples of workers at places of employment, shoppers in business districts, and recreation-seekers at places of amusement, would be expanded on the basis of the numbers of households in the actual zones of residence of the interviewers. Actually, it would be possible to expand existing home-interview data on a comparable basis, rather than on the ratio basis usually used. Censuses of business, and various state employment publications, combined with information from a city directory, can give a comprehensive picture of the actual distribution of jobs in an area as a control for expanding work-trip patterns from a statistical sample of such trips originating in homes.

All centers of entertainment must keep attendance records for tax purposes, and these would form a control on the expansion of recreation trips. Department stores and chain drug and food stores may not have records of the number of customers served in each store each day, but at least they have some record of the number of sales made

each day, and this information could be used to control the expansion of shopping trips.

Mr. Cherniack fluctuates in his use of the term "trip" from total trips (including walking), to auto plus transit trips, to auto trips alone. It is inconceivable to the writer that the number of households per acre in any way influences the total number of trips generated per household in any way. The figures given on automobile and household densities are most interesting, and are certainly significant in the generation of automobile trips.

To check the author's contentions concerning the relationships between auto density and household density, the writer analyzed ten zones of the 1954 O-D Survey of Cincinnati and calculated household densities from the 1950 Census data and auto densities from the 1954 registration figures. The particular zones were chosen because the census tract and O-D boundaries coincided. Table 1 summarizes this analysis and seems to confirm the data given in the paper.

TABLE 1

DATA ON AUTO REGISTRATION AND HOUSEHOLD DENSITY IN TEN ZONES OF CINCINNATI, OHIO

| Suburb | Area (acres) | Distance from CBD (mi) | Households per Acre | Automobiles per Acre |
|---|---|---|---|---|
| California | 1,250 | 7.2 | 0.2 | 0.2 |
| Winton Place | 1,860 | 5.1 | 0.9 | 0.3 |
| Riverside | 875 | 6.0 | 0.5 | 0.5 |
| Reading and Lockland | 3,100 | 9.5 | 1.4 | 1.7 |
| College Hill | 2,120 | 7.2 | 1.4 | 1.8 |
| Clifton | 1,350 | 3.4 | 2.3 | 2.2 |
| Avondale | 1,960 | 3.6 | 4.5 | 3.8 |
| Norwood | 1,950 | 5.1 | 5.8 | 5.1 |
| Westend (south) | 360 | 1.0 | 20.5 | 6.5 |
| Westend (north) | 340 | 1.1 | 26.4 | 8.9 |

In their report on the Baltimore study, Voorhees and Morris (HRB Bull. 224) state that they used the numbers of employees in business districts as a measure of attraction of such areas for shopping trips, because employment data, and no others, were readily available. The writer believes that the number of employees in places of shopping, recreation, etc., is the only valid measure of attraction of such centers. Employment can usually be varied appreciably in the short term, and therefore, reflects changes in attraction with much greater sensitivity than does floor space, which can only be altered substantially in the long term.

An excellent example of the difference between number of employees and floor space as measures of attraction is the situation in a major suburban shopping district in Cincinnati. About 1940, a large, local grocery chain, built a "supermarket," Store A, in this district. About 1946, another large grocery chain built a competing unit, Store K, almost directly across the street from Store A. Both buildings are of similar size, and have similar facilities. Both chains carry on major advertising campaigns, and both give trading stamps. Neither side of the street has obvious shopping advantages or disadvantages, although Store K has a much better parking lot. Both stores have four check-out lanes. In the autumn of 1958, Store A was employing two check-out clerks on Saturday afternoons, and these were not too busy. At the same time, Store K was employing four such clerks, and they appeared to be very busy. In October of 1959, Store A closed and completely vacated its building. The floor areas of these buildings has not been changed since they were erected, but the numbers of employees and the powers of attraction have changed greatly.

As another example, consider the fact that a gasoline service station, occupying a 100- x 200-ft lot and employing four men in a 16-hr day, is not likely to attract many more customers than a specialty shop employing four persons for a total of 10 hr a day in a 10- x 20-ft room.

From another point of view, if employment data are gathered to control the expansion of work-trip patterns, as suggested previously, the same data can be used to control the expansion of shopping and similar trip patterns.

At one point in his discussion of future trip patterns, the author says "The power of attraction of any given site—would be found to be inversely proportional to the travel time—and the residences scattered over the study area." This appears to be a slip, because it is inconceivable that the number of trips between zones of residence and zones of non-residence could vary inversely as the populations of the residence zones.

The exponential-type function suggested in place of the "gravity model" has a serious disadvantage if Eq. 1 is approximately what the author has in mind.

$$A_j = k \frac{P_i}{e^x} \tag{1}$$

in which

$A_j$ = number of trips attracted to a non-residence center j from residence center i;
$P_i$ = population of residence center i;
$k$ = constant of proportionality; and
$x$ = a measure of the distance from i to j.

When there is no impedance to the movement, and x reduces to zero, Eq. 1 assigns the total population to the co-terminous non-residence center, and this is scarcely a defensible assignment.

In summary, that which seems to be the author's goal, to completely bound the conditions for a given type of movement, in order to more accurately expand the O-D trip pattern for that type of movement, is completely valid and desirable. It appears, however, that some of his specific suggestions for achieving this goal are of dubious merit.

NATHAN CHERNIACK, Closure.—In supporting his disagreements with the author, Mr. Campbell has leaned heavily on the Chicago study data and experience. The Chicago and Detroit studies have taken long strides in meeting some of the author's criticisms leveled against the home-interview type surveys which have preceded those in Detroit and Chicago. But there is still a long way to go toward improving present methods of collecting data on urban travel and its determinants, as well as improving present methods of analysis.

For example, the author has brought together (Table 1) selected data from the Appendix to the Chicago Area Transportation Study (CATS), Volume One, for 77 districts in Chicago on total dwelling places and autos owned (Table 19, page 108), for residential land use expressed in acres (Table 21, page 110) and all residential person trip destinations (Table 23, page 113). From these basic data, the author calculated for each of the 77 districts, dwelling places per acre, autos per acre, and trips per acre.

Plotting autos per acre versus dwelling places per acre, yields a "scatter diagram" (Fig. 1) which demonstrates what the author had suggested in his paper; namely, "auto ownership densities thus increase with household densities not in proportion, but rather at declining rates." In fact, a simple parabola through the origin, used as a fast first approximation, indicates that autos per acre in the Chicago Study Area increase as dwelling places per acre, raised to a power of about 0.66. Autos per acre for any one of the 77 districts can thus be estimated from this simple first approximation to within a standard deviation of 15 percent of recorded autos per acre in each of the 77 districts in Chicago. (Much closer relationships could, of course, be obtained with more careful mathematical analysis.)

Also, a "scatter diagram" of person-trips per acre versus autos per acre (Fig. 2)

TABLE 1

DWELLING PLACES PER ACRE AUTOS OWNED PER ACRE PERSON TRIPS PER ACRE IN CHICAGO 1956-57

| District | Total Dwelling Places[1] | Autos Owned[1] | Person-Trips Destination Residential[2] | Residential Acreage[3] | Dwelling Places Per Acre | Autos Owned Per Acre | Person-Trips Per Acre |
|---|---|---|---|---|---|---|---|
| 01 | 12,756 | 1,298 | 24,524 | 11.4 | | | |
| 11 | 137,811 | 48,871 | 240,179 | 1,071.5 | 128.6 | 45.6 | 224.2 |
| 21 | 59,631 | 29,455 | 130,577 | 866.6 | 68.8 | 34.0 | 150.7 |
| 22 | 38,723 | 23,175 | 87,552 | 750.8 | 51.6 | 30.9 | 116.6 |
| 23 | 53,564 | 29,987 | 122,120 | 960.1 | 55.8 | 31.2 | 127.2 |
| 24 | 28,832 | 17,732 | 66,747 | 569.3 | 50.6 | 31.1 | 117.2 |
| 25 | 19,825 | 11,931 | 41,859 | 396.2 | 50.0 | 30.1 | 105.7 |
| 26 | 13,842 | 8,673 | 34,353 | 359.2 | 38.5 | 24.1 | 95.6 |
| 27 | 42,577 | 15,061 | 82,836 | 545.7 | 78.0 | 27.6 | 151.8 |
| 31 | 71,830 | 40,976 | 156,397 | 1,135.7 | 63.2 | 36.1 | 137.7 |
| 32 | 56,559 | 41,955 | 169,230 | 1,825.0 | 31.0 | 23.0 | 92.7 |
| 33 | 50,347 | 36,803 | 149,316 | 1,574.7 | 32.0 | 23.4 | 94.8 |
| 34 | 32,631 | 23,070 | 89,319 | 894.9 | 36.5 | 25.8 | 99.8 |
| 35 | 22,592 | 15,933 | 62,988 | 884.9 | 25.5 | 18.0 | 71.2 |
| 36 | 30,670 | 19,474 | 87,182 | 1,001.0 | 30.6 | 19.5 | 87.1 |
| 37 | 81,787 | 37,332 | 174,061 | 1,052.8 | 77.7 | 35.5 | 165.3 |
| 41 | 72,092 | 58,668 | 214,166 | 2,282.8 | 31.6 | 25.7 | 93.8 |
| 42 | 59,889 | 50,078 | 182,776 | 3,174.5 | 18.9 | 15.8 | 57.6 |
| 43 | 68,558 | 62,669 | 243,255 | 4,505.0 | 15.2 | 13.9 | 54.0 |
| 44 | 39,692 | 37,995 | 143,746 | 2,805.7 | 14.1 | 13.5 | 51.2 |
| 45 | 24,386 | 21,769 | 89,145 | 1,895.3 | 12.9 | 11.5 | 47.0 |
| 46 | 67,524 | 54,141 | 221,899 | 3,031.6 | 22.3 | 17.9 | 73.2 |
| 47 | 103,975 | 68,297 | 302,674 | 2,771.8 | 37.5 | 24.6 | 109.2 |
| 51 | 37,371 | 33,509 | 145,845 | 2,511.9 | 14.9 | 13.3 | 58.1 |
| 52 | 38,676 | 41,952 | 163,705 | 4,312.5 | 9.0 | 9.7 | 38.0 |
| 53 | 32,152 | 34,952 | 137,777 | 3,748.6 | 8.6 | 9.3 | 36.8 |
| 54 | 29,306 | 23,548 | 86,985 | 2,632.2 | 7.7 | 8.9 | 33.0 |
| 55 | 19,595 | 20,040 | 81,071 | 2,045.9 | 9.6 | 9.8 | 39.6 |
| 56 | 35,778 | 38,510 | 158,752 | 4,092.3 | 8.7 | 9.4 | 38.8 |
| 57 | 42,232 | 37,106 | 169,175 | 2,615.1 | 16.1 | 14.2 | 64.7 |
| 61 | 20,145 | 25,148 | 116,513 | 4,630.2 | 4.4 | 5.4 | 25.2 |
| 62 | 26,552 | 32,303 | 135,244 | 4,560.4 | 5.8 | 7.1 | 29.7 |
| 63 | 33,023 | 38,434 | 147,178 | 5,902.7 | 5.6 | 6.5 | 24.9 |
| 64 | 22,499 | 27,815 | 120,288 | 4,810.2 | 4.7 | 5.8 | 25.0 |
| 65 | 12,988 | 16,298 | 62,550 | 2,757.1 | 4.7 | 5.9 | 22.7 |
| 66 | 41,101 | 43,416 | 196,282 | 4,559.4 | 9.0 | 9.5 | 43.0 |
| 67 | 31,356 | 26,883 | 141,321 | 2,293.5 | 13.7 | 11.7 | 61.6 |
| 71 | 16,709 | 20,649 | 85,163 | 3,581.1 | 4.7 | 5.8 | 23.8 |
| 72 | 22,174 | 26,443 | 105,950 | 5,917.2 | 3.7 | 4.5 | 17.9 |
| 73 | 16,838 | 20,025 | 84,285 | 5,314.6 | 3.2 | 3.8 | 15.9 |
| 74 | 17,086 | 19,987 | 79,084 | 5,042.6 | 3.4 | 4.0 | 15.7 |
| 75 | 3,801 | 4,239 | 17,020 | 1,359.9 | 2.8 | 3.1 | 12.5 |
| 76 | 35,176 | 38,126 | 181,946 | 6,117.2 | 5.8 | 6.2 | 29.7 |
| 77 | 15,015 | 16,920 | 73,492 | 2,403.7 | 6.2 | 7.0 | 30.6 |
| Total | 1,730,666 | 1,341,646 | 5,606,527 | 115,574.8 | 15.0 | 11.6 | 48.5 |

[1] Chicago Area Transportation Study, CATS, Vol. 1, Table 19, p. 108.
[2] Chicago Area Transportation Study, CATS, Vol. 1, Table 23, p. 113.
[3] Chicago Area Transportation Study, CATS, Vol. 1, Table 21, p. 110.

indicates that equally good approximations of person-trips per acre could be estimated from autos per acre. Another first approximation, this time a straight line through the origin, indicates that there are about 4.2 person-trips per acre for every auto per acre. Person-trips per acre can thus be computed from autos per acre from this simple first approximation to within a standard deviation of about ± 15 percent of recorded person-trips per acre, in each of the 77 districts in Chicago.

These two diagrams for the Chicago Study Area thus confirm the author's expressed judgment that "household densities would appear to constitute far more stable indicators of auto ownership than are such indicators as group income levels. Also, distances from the CBD are not good fundamental determinants of either car ownerships or trips. Distance from the CBD is only a space parameter akin to a time parameter." That is exactly what Figure 32, page 61, of Volume One (CATS) illustrates. Examining Figure 32 carefully, the author is firmly convinced of this judgment also expressed in his paper, that "mere distance from the CBD, which has been changing significantly in character, like mere passage of time, are both generally weak and at times unreliable determinants for forecasting purposes. More fundamental and considerably more predictable determinants, like household densities, are needed to measure zonal auto ownerships, which in turn are the determinants for generated zonal trip ends."

One need but compare the author's two scatter diagrams derived from the basic

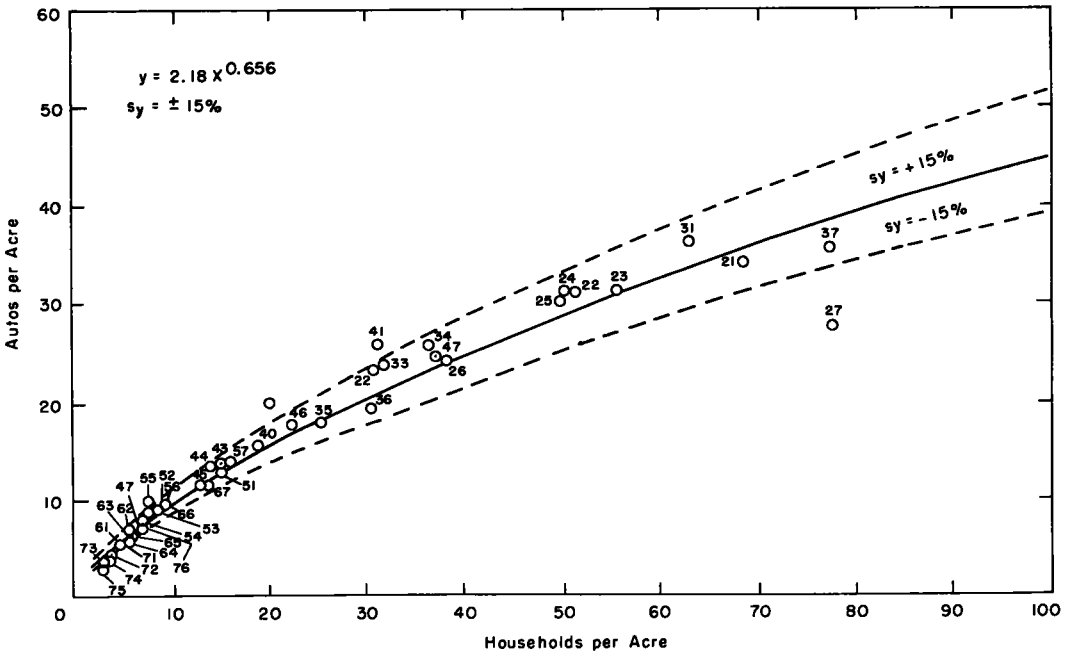


Figure 1. Relation between autos per acre and households per acre for 77 districts in Chicago, 1956-57 (from Table 1).

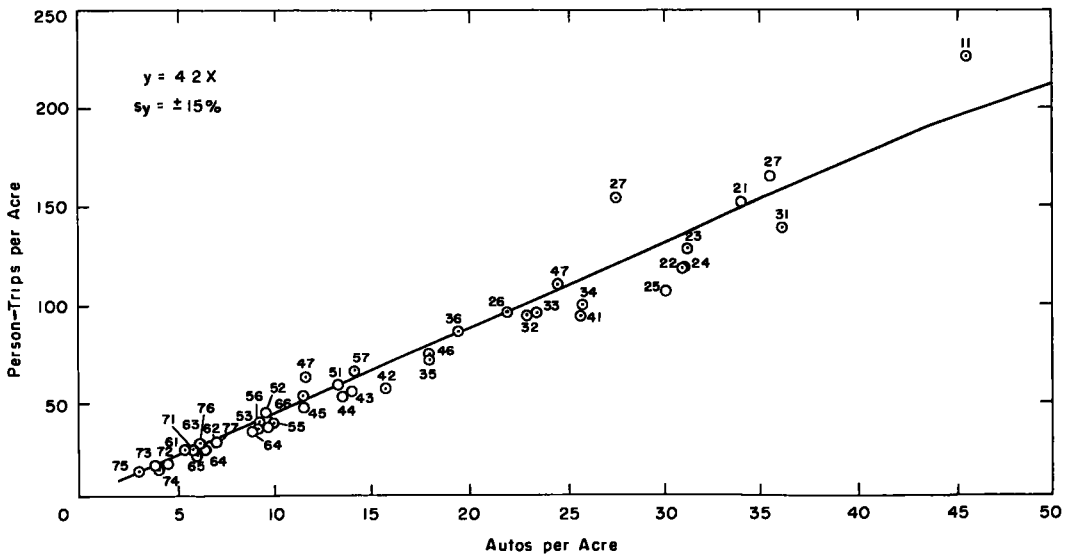


Figure 2. Relation between person-trips per acre and autos per acre for 77 districts in Chicago 1956-57 (from Table 1).

data in the Chicago Area Study—autos per acre versus dwelling places per acre, and person-trip destinations per residential acre versus autos per acre—with Figure 32, page 61 of Volume One, CATS, as well as the formulas in Appendix Table 37, to

determine for one's self which are the simpler, more fundamental, more accurate determinants of person-trips in the 77 individual districts in Chicago. These simple determinants of dwelling places and residential acreages may readily be kept up-to-date in the continuing study. Also, auto ownerships in selected districts could be sampled from time to time and thus trips per residential acre estimated. A continuous check can thus be had of both the end results and the relationships established on the basis of 1956 data.

Although such forecasts will yield total person trips in the 77 districts in the study area, they do not pinpoint the journey-to-work trips, most of which occur in peak periods, built up on arterials close to concentrations of sites of employment, and absorb substantial portions of highway capacities. Accommodating journey-to-work trips close to concentrations of sites of employment is and will be the critical urban transportation problem. Consequently, the author insists that eventually O-D surveys will have to be made at locations where people are concentrated.

At the outset of his discussion, Mr. Campbell states that he "would agree with Mr. Cherniack that the home-interview method has inherent defects. However, little else is found in his paper with which the writer can agree." The author is happy to find that the "little else" with which Mr. Campbell can agree with the author is in a highly important research area, and is also supported by the results of the Chicago study. Mr. Campbell phrases his agreement with the author as follows: "Mr. Cherniack states that the gravity formula, which is a power function, does not adequately describe the power of attraction of any given site. He feels that an inverse exponential relationship would produce better results. The writer heartily agrees with Mr. Cherniack on this point."

It is kind of Mr. Lynch to express agreement with the author on several of his criticisms of the home-interview type of O-D surveys, which Mr. Lynch has pioneered and which he has been personally instrumental in improving continuously over some 15 years.

Nevertheless, there still remains a large area of disagreement. The author, therefore, feels impelled to speak out on the need for continuing to assemble essential data, and by methods which would be most effective and most adequate for a deeper understanding of the urban traffic pattern. Understanding of urban travel patterns and urban transportation needs, is still largely in the astrology stage and just beginning to show glimpses of the astronomy stage. Yet there is a tendency to speak and write on this subject as if the astronautical stage has been reached, and that all that is now needed are the proper electronic computers and all transportation problems would be solved.

The author's suggested procedure for assembling data at locations where people concentrate (which is the heart of his paper) is described by Mr. Lynch as "one of the short-cut methods that was found to be inadequate... The difficulties encountered were numerous and the results of very limited value." The author's suggested method is far from being just another "short-cut method." It requires considerable thought to design such surveys properly. Consequently, there are many difficulties to be anticipated in conducting such surveys. But does the fact of difficulty of a given type of O-D survey necessarily preclude its use if this procedure is, in fact, an effective means for acquiring a deeper understanding of the major facets of the urban traffic and transportation problem? The author is not ready to concede Mr. Lynch's opinion that the results of data collected at locations where people concentrate would have "very limited value."

Mr. Lynch reveals the weaknesses of the data actually assembled in Washington (in 1939-40), and in Cleveland and Detroit (about 1944), by pointing out that the data thus obtained revealed "only a fraction of the traffic that would use a freeway or arterial network. Even for those routes that led to the Central Business District (CBD), much of the traffic has neither origin nor destination in that district." Apparently in the Washington, Cleveland and Detroit tests the data assembled at the sites of employment and business were located only in the CBD's. The author, however, did not suggest the "short cut" of limiting the assembly of such data only to CBD locations where people were concentrated. He suggested such locations everywhere within the study area (at the Pentagon, for example, as well as the Treasury Building in Washington, D.C.).

So, when Mr. Lynch asks how a freeway or arterial route can be planned and designed properly if information is lacking for an unknown and relatively large portion of the travel that would use it, the author answers that of course it cannot, on the basis of the short-cut methods that were used and with such incomplete and inadequate data as were assembled at the CBD sites of employment in Washington. No wonder "the results were of very limited value."

If, however, one recognizes the now commonly known facts that sites of employment and concentrated shopping areas have become quite diffused over urban areas, and that CBD's are not the only such areas of concentration of people in metropolitan districts, one would proceed to assemble sample data at all locations where people are concentrated. He would thus obtain data that would reveal all actual and potential locations within urban areas where traffic concentrations occur on the arterials and which could be anticipated in the future on proposed expressways.

Mr. Lynch objects to the assembly of data at locations where people concentrate on several other technical grounds, such as "the inability to obtain information from a scientifically selected sample, the lack of a satisfactory universe for expansion purposes, and the inability to evaluate the accuracy of the results." To the author, these reasons smack of statistical idolatry. Are we so engrossed in making sacrifices to statistical idols as to forego the pursuit of a better understanding of urban traffic and transportation through the medium of pure statistical explorations without benefit of published, detailed theoretical statistical maps? What if outer space scientists took that same attitude? They do not. They send up missiles costing millions to explore outer space. We as social scientists should also do some exploring. Even where a precise value cannot be put on the entire universe (although not being altogether naive about its size), data should still be assembled at locations where people concentrate, obtaining their travel habits and correlating them with data on land uses and travel impedances, to obtain a better understanding of people's travel habits than is now possessed.

Mr. Lynch dredges up a number of other difficulties encountered in the collection of data at locations where people were concentrated. "There were varying degrees of cooperation from different establishments resulting in under-sampling for some types of work trips and over-sampling for others." To detect this under- and over-sampling statistically, one had to have some approximations of the respective universes; and if there were such approximations, the estimated under- and over-samplings could be statistically corrected, at least approximately.

Mr. Lynch goes on to say that "it was impossible to obtain representative information for travel other than work travel, even that occurring during the peak hour." But a well-known slogan says, in part, "The impossible takes a little longer." It can be done.

Mr. Lynch continues: "Information about shopping trips to the big department stores could sometimes be obtained, but not about those to the innumerable smaller establishments." The author's procedure would be to assemble the data available and analyze what is at hand. In this way, exploration will have been made further into the dark and light sufficient to outline the whole will have been shed.

Continuing, Mr. Lynch says: "There was no satisfactory method of accounting for the many duplications where shoppers went from store to store." Each store or group of stores would constitute a small, statistical universe for the study of such travel behaviors. However, when it came to adding the universes to other segments which contained duplications, there would be set up an approximate control on the aggregates so as to eliminate most of the duplications, numerically.

Mr. Lynch continues: "In the home-interview type of survey... in addition to internal checks of statistical reliability, there are many checks that can be made with independent data such as population, automobile ownership and screenline counts." Checks of statistical reliability are highly theoretical and are based on the assumption that the sample is purely random, whereas in actual practice it may be far from being random.

Data on population in intercensal years are, at best, extrapolated "guesstimates" based on the previous decennial population census data, supplemented by recorded births and deaths since the census year plus guesses as to net migrations into or out

of the area. "Checking" expanded sample person trips with such population "guesstimates" is like the blind leading the blind.

Few urban areas have current auto registrations tabulated by small areas, that could be used to check the expanded 5 percent samplings of autos registered in the O-D zones. To be sure, data on individual addresses of car owners are available at the vehicle registration bureaus of the respective states. But in how many home-interview studies have the auto registrations as of the year of the survey, been tabulated by O-D zones to check the expanded 5 percent samplings of car ownership in these zones?

Screenline vehicle traffic counts are, in fact, excellent checks on expanded vehicle trip samplings obtained from home interviews, but only for a fraction of the total trips generated in the total study area. Besides, such vehicle counts have invariably revealed under-enumerations in the aggregates, particularly in off hours. Moreover, if roadside O-D interviews had been made at the screenline (as they have not been), it would have been discovered that errors in the expanded vehicle trip samplings from individual O-D zones would be quite large. Also, if O-D surveys were simultaneously made at sites of employment they would probably reveal, quite dramatically gross errors in certain expanded home-interview zone-to-zone movements.

Mr. Lynch does agree that 5 percent samples are "much too small to permit an accurate determination of the zone-to-zone movements." But, he continues, "In estimating traffic volumes, concern is not with individual zone-to-zone movements, but rather with the accumulation of a large number of such movements on an expressway, arterial or transit line. And tests have shown that the errors for such accumulations are generally acceptable." Again the author must disagree on two grounds. On the first, the author maintains that concern is with zone-to-zone movements, which are the elements of the trip aggregates that impinge upon proposed expressways at their various entrance and exit ramps. Mr. Lynch makes the implicit assumption that in the accumulation of a large number of such zone-to-zone movements, the individual errors will be compensating and the algebraic sum of the individual errors will be smaller than the error in any individual zone-to-zone movement. This is not necessarily so: the errors may be cumulative, not compensating. Besides, the theoretical tests described by Mr. Lynch are not completely satisfying.

The second ground of disagreement is that, again, concern is with zone-to-zone movements because these movements must be utilized to obtain sound relationships with trip determinants such as land uses, as well as distances, times, costs and other impedances between pairs of zones, which relationships can eventually be fed into electronic computers so that there would be some degree of confidence that the computer answers will be realistic. And the individual expanded zone-to-zone movements, which are known to contain large errors, cannot be cured statistically by merely combining trips between small zones into those between large zones and thereby reducing the size of the errors.

It is gratifying that Mr. Lynch admits that the author is correct in maintaining that "the combining of zones into larger ones, to increase the number of trips in the zone-to-zone movements, introduces too great an inaccuracy in such factors as distance and travel time to be an acceptable procedure for the purpose of determining traffic movements." He goes on to say, however, that "the accumulation of the smaller number of trips between smaller zones... is much better for the purpose of assigning trips to highway and transit facilities." They would be better if the original bases for assignments that were established from the individual zone-to-zone movements were in fact valid, but these bases are themselves weak because, for correlation purposes, the original samples of the individual zone-to-zone movements were so anemic.

Mr. Lynch goes on to say that "information is now being obtained concerning the land use at each end of a trip, and trips to like land use can therefore be combined to obtain an adequate sample for different areas of the city. The availability of electronic computers makes the task a relatively simple one." A beginning is just being made on assembling data on areas devoted to residential, commercial and industrial uses, in an effort to obtain approximations of the trips generated by significantly different types of land use. Such land-use data for small O-D zones, together with the corresponding data on the trips that focus on locations where people concentrate, in the urban areas

where O-D data have been assembled, constitute a veritable mine of urgently needed researchable data. Such assembled land-use and travel-impedance data, even without benefit of electronic computers, would be far more valuable than the availability of electronic computers without such data. If a deeper understanding of urban traffic patterns is to be acquired and sound bases for an intelligent appraisel of the needs for urban transit facilities are to be established, it is the simultaneous collection of such land-use and travel-impedance data for the O-D zones in urban areas where trip data will be assembled, which is now the crying need, rather than availability of electronic computers.

Mr. Lynch volunteers a serious source of error in the home-interview type of O-D surveys which the author had not mentioned in his original paper. "This is a 'response' error due to the fact that the interview often must be conducted with someone other than the person who performed the travel—usually the housewife." In assembling trip data at locations where people concentrate, such as at sites of employment, the data for, say, 100 journey-to-work trips may be obtained not by ringing 5 home doorbells but by ringing just one doorbell—the personnel officer's. The data on 100 journey-to-work trips would thus be obtained with no "response" error of the type that would result from multiplying by 20 the responses from the wives of the 5 workers. Besides, a sample questionnaire distributed among the workers at sites of employment would also yield individual journey-to-work distances, times, costs and modes of travel between homes and work places.

The author has taken time to spell out his disagreements with Mr. Lynch in order to call attention to the fact that there is still a far way to go in developing a profound understanding of urban travel patterns sufficient to plan wisely for urban transportation needs. This results from the fact that despite all the voluminous trip data that have been collected by home-interview surveys over some 15 years, there is still a lack because of not having contemporaneously collected data on trip determinants. Short-changed trip determinants consist of such data for O-D zones as areas occupied by residences, commercial and industrial establishments, as well as travel impedances for individual zone-to-zone movements, both of the type that are directly measurable (highway distances, travel times and costs) and those that are only indirectly measurable (travel irritations and annoyances) by recording traffic lights, left turns, parked cars, and other known and suspected travel irritants.

In his discussion Mr. Steele places the home-interview type of O-D survey in its proper perspective and in the light of all the sampling techniques which have been used by the U. S. Bureau of Public Roads for various data collection purposes. He also sets forth some effective fundamental principles on sampling techniques and data collection. Consequently, the author must necessarily agree with most of Mr. Steele's discussion. In fact, the author wishes to take the liberty of using certain of Mr. Steele's statements of sampling principles and practices to underline the author's own suggestion for collecting O-D data at places where people concentrate.

Mr. Steele first points out that "so many fundamental changes have been made in the selection of the sample, the design of the interview forms, the nature of the data collected, and the methods of collecting them, that motor-vehicle-use study interviews obtained today bear only a superficial resemblance to those obtained 25 or 30 years ago." Excellent! These changes are all to the good. Obsolescence of the methods of collection is thereby postponed.

But Mr. Steele goes on to point out that in certain types of sampling, stratification has been used, and for good reasons. To the author's knowledge, however, home-interview surveys have still been based on random, rather than stratified samplings. Under random samplings, it is implicitly assumed that homes are distributed in a study area much like the molecules of a gas are in a receptacle. It is known, however, that household densities vary widely in different sections of the study area and are not randomly distributed. Sampling of households stratified on the basis of household density, for example, would improve coverage, as Mr. Steele suggests. The author, however, is not aware that home-interview samplings had been stratified except for special types of dormitories.

Assuming that a parallel system of sample interviews were also made in areas

where people are concentrated, such as in CBD's as per the author's suggestion, one would not adopt the naive attitude that there is no awareness that clusters of sites of employment exist. It would have to be recognized that there were financial, theatrical, shopping and other such clusters. Stratification of sample interviews in areas where people are concentrated would thus be a sine qua non of sampling in such areas, because as Mr. Steele indicates, stratification under those conditions would improve coverage immensely.

Mr. Steele hopes that the decennial census of 1960 will provide much more complete information on housing and households than has been available from previous censuses. It probably will. But the acreages necessary to calculate household densities expressed as households per residential acre are still lacking. Residential acreages will still have to be compiled by the local planning agencies in the respective study areas.

Mr. Steele states a fundamental canon of statistics when he says: "It has long been recognized that the purpose for which a travel study is to be made will have an important bearing on the type of data collection to be employed and the design of the sample to be used in obtaining the information." Then he goes on to say: "For purposes of motor-vehicle-use studies, however, there is as yet no known substitute for the home-interview type study where it is desired to obtain characteristics of motor-vehicle ownership and use, especially the use of passenger cars." Here the author disagrees with Mr. Steele that the essential purpose of current travel studies is to obtain characteristics of passenger car ownership and use. Instead, the purpose of the travel study is to obtain quantitative measures and a thorough understanding of urban traval patterns in study areas, on the basis of which transport systems may be conceived that would adequately meet current and future needs of urban travel, particularly in peak periods when the capacities of existing and proposed transport facilities will be largely absorbed. Consequently, it is essential to interview especially those who travel in peak periods (workers on weekdays) and to interview them at their destinations which are closest to locations where the capacities of transport systems are and will usually be largely absorbed in peak periods.

Mr. Steele states: "Mr. Cherniack's concern throughout his paper seems to be with the collection and analysis of origin-destination travel data to aid in the design of specific facilities." Instead, the author's concern is with urban transportation systems, including existing rail as well as highway facilities, existing rail transit where available, and mass transit by express buses, and not just with ownership and travel by autos on the highways. That is why the author desires as accurate a quantification of the characteristics of the journey-to-work pattern as possible.

The War Industry transportation studies made during World War II for purposes of motor fuel and tire rationing, to which Mr. Steele refers, are exactly the types of studies the author has in mind in connection with his suggestions contained in the paper. Such studies, when amplified with supplemental data, would yield valuable "isochron lines" which would indicate how far away, timewise, various sites of employment drew 50 percent or 75 percent, or other percentages, of their employees. These studies would also reveal the varying percentages of the labor pools in small residential areas which different sites of employment drew at varying travel times between plants and homes. These are the types of travel data for which there is presently a great need, for the purpose of planning urban highway transport systems of the future to handle particularly the journey-to-work travel in peak periods.

It is refreshing to have Professor Howe say: "To check the author's contentions concerning the relationship between auto density and household density, the writer analyzed ten zones of the 1954 survey of Cincinnati and calculated household densities from the 1950 Census data and auto densities from the 1954 registration figures," and incidentally that "Table 1 summarizes this analysis and seems to confirm the data given in the paper."

Professor Howe did just what the author recommended in his paper; namely, to "exhume" home-interview data, to retabulate them and to re-analyze them, and then discover some significant relationships previously not revealed.

Table 2 and Figures 3 and 4 were prepared on the basis of the data dredged up by

TABLE 2

AUTOS PER ACRE AND HOUSEHOLDS PER ACRE IN 10 ZONES OF CINCINNATI, OHIO, AND 18 N.Y.-N.J. COUNTIES

| New York - New Jersey Counties | | | | Locations in Cincinnati, Ohio | | | |
|---|---|---|---|---|---|---|---|
| | County | Households[1] per Acre | Autos[2] per Acre | Suburb | Households[3] per Acre | Autos[4] per Acre | Distance From CBD (mi) |
| 1 | Suffolk, N.Y. | 1.3 | 2.2 | 1 California | 0.2 | 0.2 | 7.2 |
| 2 | Morris, N.J. | 1.8 | 2.3 | 2 Winton | 0.9 | 0.3 | 5.1 |
| 3 | Somerset, N.J. | 2.2 | 3.0 | 3 Riverside | 0.5 | 0.5 | 6.0 |
| 4 | Middlesex, N.J. | 2.7 | 3.4 | 4 Reading and Lakeland | 1.4 | 1.7 | 9.5 |
| 5 | Rockland, N.Y. | 2.7 | 3.6 | 5 College Hill | 1.4 | 1.8 | 7.2 |
| 6 | Richmond, N.Y. | 3.0 | 3.5 | 6 Clifton | 2.3 | 2.2 | 3.4 |
| 7 | Monmouth, N.J. | 3.2 | 4.0 | 7 Avondale | 4.5 | 3.8 | 3.6 |
| 8 | Nassau, N.Y. | 3.3 | 4.3 | 8 Norwood | 5.8 | 5.1 | 5.1 |
| 9 | Westchester, N.Y. | 3.9 | 4.8 | 9 Westend (South) | 20.5 | 6.5 | 1.0 |
| 10 | Bergen, N.J. | 4.5 | 5.3 | 10 Westend (North) | 26.4 | 8.9 | 1.1 |
| 11 | Union, N.J. | 4.6 | 6.0 | | | | |
| 12 | Passaic, N.J. | 5.3 | 5.5 | | | | |
| 13 | Essex, N.J. | 7.8 | 8.5 | | | | |
| 14 | Queens, N.Y. | 8.4 | 7.2 | | | | |
| 15 | Hudson, N.J. | 15.4 | 13.0 | | | | |
| 16 | Bronx, N.Y. | 22.9 | 9.5 | | | | |
| 17 | Brooklyn, N.Y. | 38.1 | 16.5 | | | | |
| 18 | Manhattan, N.Y. | 52.0 | 20.9 | | | | |

[1] Estimated for 1955.
[2] Registrations as recorded in 1955.
[3] As of 1950.
[4] Registrations as of 1954.

Professor Howe. In Figure 1b the center of the CBD has been plotted on the right, and distances therefrom to the left, in order to make this plot visually comparable to Figure 1a. It will be seen that households per acre is a much superior determinant of autos per acre than is the distance from the CBD. Also, from any curve fitted to the relationship of autos per acre versus households per acre, a derivative equation may be readily obtained of autos per household by dividing both sides of the equation by households per acre.

Figure 4 shows autos per acre versus households per acre in 10 zones in Cincinnati and 18 New York and New Jersey counties in the New York-New Jersey metropolitan district. The similarity is marked for two such widely separated urban areas.

When Professor Howe says: "It is inconceivable to the writer that the number of households per acre in any way influences the total number of trips generated per household," he apparently does not realize that households per acre is only an indicator of autos per acre, and that, in the same manner, autos per acre then also becomes an indicator of not only auto trips but also of person-trips both by auto and by common carriers, where the latter are in fact available in the respective zones.

He also suggests that "the number of employees in places of shopping, recreation, etc., is the only valid measure of attraction of such centers," instead of floor-space data as proposed by the author. It would seem that, for purposes of long-term projections, it would be much more convenient to measure areas on a map and then to establish factors of floor space per 100 workers for various non-residential uses. For any future year, areas of non-residential uses would first be forecast and then translated into person-trips on the basis of the future intensity of use of floor space by workers and occupants. For example, future office space in CBD's would first be forecast. Then, in the light of the increasing use of office equipment for data processing, requiring greater areas of office space, estimates of office employees for the future would call for higher factors of floor space per 100 office workers.

In a paper by Harper and Edwards (HRB Bull. 253) of which the author was not aware when he wrote his own paper), they state: "Some workers in the field of city planning have been saying that the traffic which flows in and out of a city every day is generated by the buildings, or rather by the businesses which occupy and use the buildings in the center. So far as could be ascertained, such statements have not been checked... To investigate, the Ontario Joint Highway Research Program sponsored research at Queen's University to see if a relationship between amount of floor space in use in various classifications and travel to the CBD could be demonstrated." Of some 120 cities where O-D studies

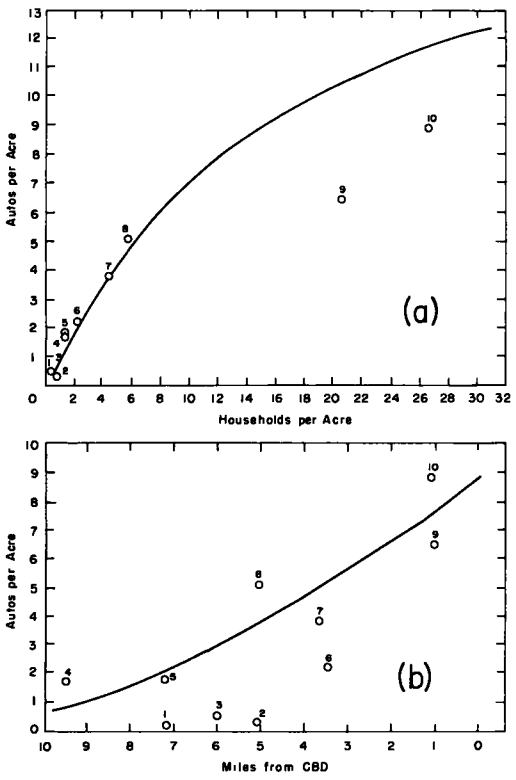


Figure 3. Auto distribution vs (a) household distribution and (b) distance from the CBD for 10 locations in Cincinnati, Ohio.

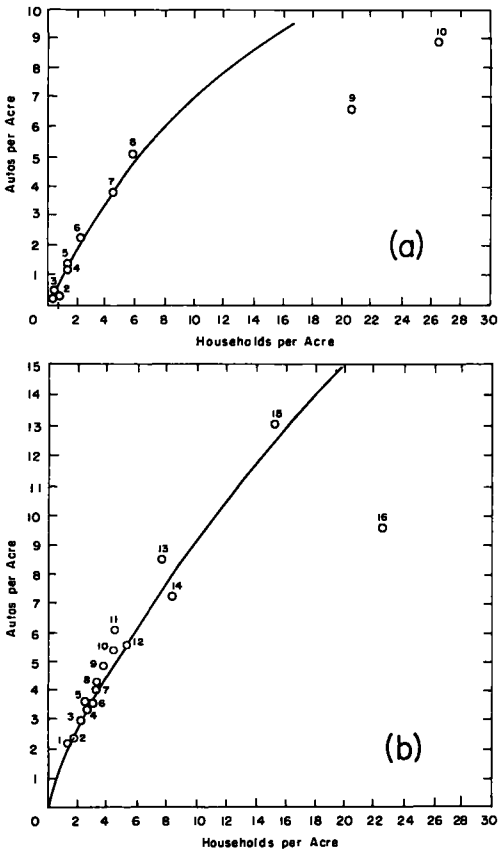


Figure 4. Comparison of auto vs household concentration for (a) 10 locations in Cincinnati, Ohio, and (b) 18 New York and New Jersey counties.

had been made, they could find only Philadelphia, Detroit, Baltimore, Seattle, Vancouver and Tacoma where they could estimate floor areas in CBD's. They conclude: "The results are such that it is possible to say that the number of people attracted to an area in a city center appears to be closely related to the amount of floor space being used for various purposes in the section of the CBD considered. It seems that, for highway planning, it would be valid to use sound, economic forecasts of future floor-space use in a central area as an index of the area's future attraction."

Not only has some support been received from Harper and Edwards in the matter of using floor space as an indicator of trips to and from non-residence areas, but there is a painful awareness of the general paucity of data on employment in small areas of employment. Consequently, the author is herein pleading for some types of data not now available, as indicators of the daytime population in non-residence areas of economic activities. Data are needed to give meaning and quantitative expression to relationships between person-trips and land use, which are assumed to be generally available but which do not now, in fact, exist.

Again, when Professor Howe says that censuses of business, and various state employment publications, combined with information from a city directory, can give a comprehensive picture of the actual distribution of jobs in an area, the author takes that statement with an oversized grain of salt. In this area, he can only comment that Professor Howe needs to get his hands dirty with statistical data on economic activities and social behavior in order to temper his optimism with humility.

Planners talk freely and qualitatively about land use and its traffic generating characteristics; so much so that many students of planning take it for granted that quantitative land-use data are generally and readily available in usable form for correlating with person-trip data; that a number of such relationships had been generally established.

# ERRATA

## BULLETIN 253

In Bulletin 253, pages 187 and 188, the following corrections should be made to the equations:

Eq. 3 $$A_j = k\,1\,P_i e^{R(d-x)}$$

Eq. 4 $$e^{R(d-x)} = E$$

Eq. 5 $$E = e^{R(d-x)}$$

Eq. 6 $$\log_e E = \log_e \left( e^{R(d-x)} \right) = R(d-x)$$

Eq. 8 $$\log_e E = (d-x) \log_e (1+r)$$

Eq. 9 $$E = (1+r)^{(d-x)}$$

Eq. 10 $$A_j = k\,1\,P_i (1+r)^{(d-x)}$$

This just is not so. Statistical data on areas devoted to residence and non-residence uses are not generally and readily available in such form that they could be used as factors of trip generation, either now or in the future.

The exponential-type mathematical function, as an expression of the inverse relationship between trips and impedances like distance, does not seem to appeal to Professor Howe and so he dismisses it quite abruptly; he prefers the "gravity model"— a power function. It is the privilege of any researcher to choose the mathematical function which, in his judgment, best expresses the law he is trying to state mathematically. Unfortunately, economic and social data never precisely define the mathematical function. The researcher must select from a family of curves the one which in his judgment is best suited to express the law he is seeking. It is the author's judgment that the exponential-type function does this best for the inverse relationship quoted previously. The soundness of the author's judgment may be demonstrated with Professor Howe's own Eq. 1 and his own nomenclature.

For use in a practical problem, Eq. 1 may at first be rewritten as

$$A_j = k\, P_i e^{-x} \tag{2}$$

Then several constants are introduced which, however, do not change the form of the equation as an exponential-type.

$$A_j = k\, 1\, P_i\, e^{-R(d-x)} \tag{3}$$

Now it is assumed that the total number of employees that work in non-residence zone j, and that are drawn from all residence zones in the study area, may be obtained from Census data. From these data, k may then be obtained by dividing the total employees who work in non-residence zone j by the employed labor force (ELF) in the study area. The constant k would thus be expressed as "employees in zone j per 10,000 employed labor force in the study area."

$P_i$ is the population in residence zone i. In the equations, it is merely an indicator of the ELF residing in zone i. If ELF of zone i happens to be available, wonderful! But that is a rarity. By applying the constant 1 or "ELF per 1,000 population," obtainable from the last available decennial Census data, a guesstimate may be made of the ELF in residence zone i.

The product $k1P_i$ then is equal to employees in non-residence zone j per 10,000 ELF in study area multiplied by the ELF in residence zone i. This product thus yields "probable employees in non-residence zone j drawn from residence zone i," if travel distance, time, cost, etc., were not real travel impedances. This computed number of employees drawn from zone i consequently reflects only the size of $P_i$ in zone i, but not its travel impedance from zone j.

For the function

$$e^{-R(d-x)} = E \tag{4}$$

which reflects the effects of travel impedances, the average "employees per 10,000 ELF for the study area," or k, lies on a circle at a mean travel distance d from the non-residence zone j to all residence zones in the study area from which employees were drawn. This distance d (or time) is obtainable as part of the employee data that the author has recommended be assembled. When x is equal to the mean distance d, in Eq. 4, e becomes equal to one. $A_j$ for trips from centers of residence zones lying on the circle of mean distance, d, then becomes equal to $k1P_i$, or equal to the probable number of employee trips. When x is smaller than d and d-x is positive, the entire exponent is negative. Thus, where the center of a residence zone is closer than the mean distance, d, the number of trips drawn therefrom is larger than average; when x is larger than d, and d-x is negative, or where a residence zone is farther away than the mean distance, d, the number of trips drawn therefrom is fewer.

By not probing his own mathematical equation too deeply, Professor Howe has come to an apparently erroneous conclusion that the exponential-type function "assigns the total population to the co-terminus non-residence center and this is scarcely a defensible assignment."

Incidentally, R in Eq. 4 has a special significance. It expresses neatly how the differential percentage rates of trips per 10,000 ELF vary with numerical differences in travel impedances. The closer or farther away a residence zone is from the area of employment, the greater or fewer the "trips per 10,000 ELF" it furnishes this area of employment. It is these differential rates of attraction which it is desired to establish for various types of areas of employment and for other areas of attraction.

A mathematical transformation of Eq. 4 will bring this out sharply.

SEE ERRATA SLIP, PRECEDING PAGE

$$E = e^{-R(d-x)} \tag{5}$$

$$\log_e E = \log_e\left(e^{-R(d-x)}\right) = -R(d-x) \tag{6}$$

$$\text{Then let } R = \log_e\left(1-r\right) \tag{7}$$

$$\log_e E = -(d-x)\log_e(1+r) \tag{8}$$

$$E = (1+r)^{-(d-x)} \tag{9}$$

then

$$A_j = k\,1\,P_i\,(1+r)^{-(d-x)} \tag{10}$$

The constant r in Eqs. 9 and 10 represents the increased (percentage) differential rate, compounded, of trips per 10,000 ELF, with each numerical unit of reduction in travel distance x, from the average travel distance, to reach non-residence zone j or, in general, with each numerical unit of reduction in travel impedance like time, cost, and other impedances, expressed in cents, which would be substituted for d and x in Eq. 9 or Eq. 10.

In the future, given new areas of employment, the employee reservoir, and the corresponding spatial distribution of employees in the various residence zones from which these areas of employment would draw employees, can thus be computed from Eqs. 9 and 10.