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Simulated Home Interview By Television

WILLIAM R. McGRATH and CHARLES GUINN, respectively, Director and Transportation Planning Assistant, Dept. of Traffic & Parking, New Haven, Conn.

•DURING 1962 the New Haven Department of Traffic and Parking undertook an origin and destination survey specially designed to meet their technical needs within a severely limited budget. What is believed to be the first attempt to combine the low cost of postal surveys with the inherent advantages of personal interview was employed. Mass interview by television was substituted for the standard door-to-door technique. It was hoped by this means to obtain the accuracy and control of the home-interview method at a fraction of usual costs. This report discusses the factors establishing this interviewing technique, the actual technique employed, and the results of the survey.

The city of New Haven needed an areawide transportation study as a sound base for traffic planning by the traffic department. It was evident that the study must develop detailed information of traffic generation and travel patterns in the greater New Haven area to fulfill the purpose. These also had to be used for all other aspects of the work; therefore, a low-cost field survey technique was mandatory.

An essential phase of the transportation study was a complete O-D survey, because no field survey of this magnitude had ever been conducted for the metropolitan area.

The scope of the planning program to be based on the survey included expansion of the travel pattern, trip distribution by mode, and trip assignment to the street network. The goal was to generate present and future travel patterns on any proposed street network. This would be accomplished by simulating a street network and assigning the O and D movements by computer. In this manner any proposed street change could be checked for its effect on the entire system.

Inasmuch as the survey had to be adaptable to expansion to a target year based on future land use, population, and socio-economic changes, a detailed analysis of traffic generation and travel pattern for the entire metropolitan area was required. Trip characteristics such as mode, purpose and time had to be determined. Also, related factors such as auto ownership, income and persons per dwelling unit were needed. Land use at the trip end was required for analysis of transportation-land use relationships important in determining future travel patterns. A complete land-use survey of New Haven was included in the CRP program, therefore, the necessary land-use data were available for the transportation study.

The need for detailed information to study the effect of changes in the street system required the use of small traffic zones. The use of large traffic zones would not permit adequate simulation of traffic flows on the street network, because any large zone would contain too large a portion of the street system. The number of zones needed for the greater New Haven area was determined to be over 500. A large sample was desired to insure a representative sample for each zone.

The need for a low-cost, large-sample interviewing technique eliminated the standard home-interview technique from consideration; yet, the detail and accuracy obtainable from this interview technique were desired. Therefore, an interview technique that would combine the detail and accuracy of the home-interview approach with the low cost of a postal survey was developed.

By using census tracts as traffic zones and enumeration districts as subzones vast amounts of data concerning land use, population, and transportation characteristics

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became available to the survey. These data included population, age distribution, number of dwelling units, housing standards, family income, and actual dwelling unit characteristics. In a similar manner, these data could be used to "debias" the sample by determining the degree of variation and correcting for it.

Census information made possible the use of a postal survey; however, a high degree of accuracy still had to be obtained from this detailed postal questionnaire. To achieve accuracy, the personal contact so important to the home survey had to be injected into the postal survey. The best low-cost method of achieving personal contact with the public seemed to be by television. It was decided that a properly developed television program could provide the necessary contact to generate accurate answers to detailed questions.

The traffic department developed a postal questionnaire which could be coordinated with a television explanation. The questionnaire was adapted from the standard home-interview form; however, some changes were made to accommodate a postal form. The form consisted of two 6- by 9- in. attached cards. One card (Fig. 1) contained the instructions for completing the questionnaire and a plea for public support. The other card (Fig. 2) contained the survey questions. The postal questionnaire itself encouraged the public to watch the television program for a clear explanation in completing the form.

The distribution of the survey questionnaire was similar to most postal surveys. A questionnaire was addressed to each dwelling unit in the fourteen town metropolitan area; this required 100,000 questionnaires. They were mailed under a bulk rate which cost 2.5 cents per questionnaire. They were bundled according to town to facilitate mail handling. The returned questionnaires were received under a business reply permit which cost 6 cents per return. The mailing of the questionaires was scheduled to have them arrive on the day before the television progam.

GREATER NEW HAVEN TRAFFIC STUDY

Do YOU wonder why THEY don't do something about traffic?

YOU are THEY!

YOU can do something about the TRAFFIC PROBLEM

PLEASE COMPLETE AND RETURN THIS QUESTIONNAIRE

Information is needed concerning travel habits of people throughout the entire area to be able to plan further transportation improvements for **YOU.** Answers from all persons in the Greater New Haven Area are needed for a complete survey.

WATCH TV CHANNEL 8 — TUESDAY — JUNE 5, 8:00 P.M.
Half hour program on Traffic and Transit — aid in completing this form

Please include ALL TRIPS made, during one entire week-day (4 a.m.-4 a.m.) by EACH person, living at your address, over 5 years of age.

Record, separately, each BUS, TAXI, AUTO-DRIVER, and PASSENGER trip, regardless of who owns the car.

A trip (for the purpose of this survey) starts at one point (for example: 113 Campbell Ave., West Haven) and ends at a different point (for example: 2100 Dixwell Ave., Hamden). When you finish there and go to another place (or return to 113 Campbell Ave., West Haven) that would be another trip.

Trips made together, by more than one member of the family, would be recorded as separate trips by each person. Thus a shopping trip, by husband and wife, in the same car, would be entered as two separate trips (one auto-driver and one passenger) to the store, and two separate trips returning from the store.

DROP IN ANY MAIL BOX - - POSTAGE IS PREPAID

This is an official function of the New Haven City Government — No commercial activity of any sort is involved.

Dept. of Traffic & Parking
William R. McGrath, Director

R-52

Figure 1.

GREATER NEW HAVEN TRAFFIC STUDY

Please complete, detach, and mail this questionnaire. All answers will be strictly confidential. Postage is PREPAID — just drop into any mail box.

1. Number of persons in family, living at home, over 5 years old
2. Number of passenger cars owned by persons living at this address
3. Type of parking for passenger cars at home: 1-Garage ☐ 2-Driveway ☐ 3-Lot ☐ 4-Street ☐
4. Did you fill this out during the special TV program? Yes No

Date form completed

Please list all trips made, from 4 a.m. yesterday until 4 a.m. today, made by each person, living at your home, over 5 years old. Give complete address or nearest intersection.

	Where did this trip begin Address	Town	Where did this trip end Address	Town	Method of Travel	Time	Purpose of Trip
	113 Campbell Ave.	West Haven	2100 Dixwell Ave.	Hamden	Bus ☐ Taxi ☐ Auto-Driver ☑ Auto-Pass. ☐	7 A.M. P.M.	Work ☑ Shop ☐ Social & Recreational ☐ School ☐ Eat Meal ☐ Business ☐ Medical ☐ Home ☐
1					Bus ☐ Taxi ☐ Auto-Driver ☐ Auto-Pass. ☐	A.M. P.M.	Work ☐ Shop ☐ Social & Recreational ☐ School ☐ Eat Meal ☐ Business ☐ Medical ☐ Home ☐
2					Bus ☐ Taxi ☐ Auto-Driver ☐ Auto-Pass. ☐	A.M. P.M.	Work ☐ Shop ☐ Social & Recreational ☐ School ☐ Eat Meal ☐ Business ☐ Medical ☐ Home ☐
3					Bus ☐ Taxi ☐ Auto-Driver ☐ Auto-Pass. ☐	A.M. P.M.	Work ☐ Shop ☐ Social & Recreational ☐ School ☐ Eat Meal ☐ Business ☐ Medical ☐ Home ☐
4					Bus ☐ Taxi ☐ Auto-Driver ☐ Auto-Pass. ☐	A.M. P.M.	Work ☐ Shop ☐ Social & Recreational ☐ School ☐ Eat Meal ☐ Business ☐ Medical ☐ Home ☐
5					Bus ☐ Taxi ☐ Auto-Driver ☐ Auto-Pass. ☐	A.M. P.M.	Work ☐ Shop ☐ Social & Recreational ☐ School ☐ Eat Meal ☐ Business ☐ Medical ☐ Home ☐
6					Bus ☐ Taxi ☐ Auto-Driver ☐ Auto-Pass. ☐	A.M. P.M.	Work ☐ Shop ☐ Social & Recreational ☐ School ☐ Eat Meal ☐ Business ☐ Medical ☐ Home ☐
7					Bus ☐ Taxi ☐ Auto-Driver ☐ Auto-Pass. ☐	A.M. P.M.	Work ☐ Shop ☐ Social & Recreational ☐ School ☐ Eat Meal ☐ Business ☐ Medical ☐ Home ☐
8					Bus ☐ Taxi ☐ Auto-Driver ☐ Auto-Pass. ☐	A.M. P.M.	Work ☐ Shop ☐ Social & Recreational ☐ School ☐ Eat Meal ☐ Business ☐ Medical ☐ Home ☐
9					Bus ☐ Taxi ☐ Auto-Driver ☐ Auto-Pass. ☐	A.M. P.M.	Work ☐ Shop ☐ Social & Recreational ☐ School ☐ Eat Meal ☐ Business ☐ Medical ☐ Home ☐
10					Bus ☐ Taxi ☐ Auto-Driver ☐ Auto-Pass. ☐	A.M. P.M.	Work ☐ Shop ☐ Social & Recreational ☐ School ☐ Eat Meal ☐ Business ☐ Medical ☐ Home ☐
11					Bus ☐ Taxi ☐ Auto-Driver ☐ Auto-Pass. ☐	A.M. P.M.	Work ☐ Shop ☐ Social & Recreational ☐ School ☐ Eat Meal ☐ Business ☐ Medical ☐ Home ☐
12					Bus ☐ Taxi ☐ Auto-Driver ☐ Auto-Pass. ☐	A.M. P.M.	Work ☐ Shop ☐ Social & Recreational ☐ School ☐ Eat Meal ☐ Business ☐ Medical ☐ Home ☐
13					Bus ☐ Taxi ☐ Auto-Driver ☐ Auto-Pass. ☐	A.M. P.M.	Work ☐ Shop ☐ Social & Recreational ☐ School ☐ Eat Meal ☐ Business ☐ Medical ☐ Home ☐
14					Bus ☐ Taxi ☐ Auto-Driver ☐ Auto-Pass. ☐	A.M. P.M.	Work ☐ Shop ☐ Social & Recreational ☐ School ☐ Eat Meal ☐ Business ☐ Medical ☐ Home ☐
15					Bus ☐ Taxi ☐ Auto-Driver ☐ Auto-Pass. ☐	A.M. P.M.	Work ☐ Shop ☐ Social & Recreational ☐ School ☐ Eat Meal ☐ Business ☐ Medical ☐ Home ☐

Figure 2.

One half-hour of television time, 8:00 PM to 8:30PM on Tuesday, June 5, was donated by the local station as a public service. A television show was produced by the traffic department and the television studio which would clarify the survey questionnaire and encourage return of an accurately completed questionnaire. The program was made up of film clips and interviews of certain officials designed to associate the viewer with national and local traffic problems so that he might feel something should be done to alleviate the problem and that completion of the questionnaire would contribute substantially to the solution.

A large section of the program was devoted to a detailed explanation of the questionnaire. A large-scale questionnaire was displayed and a step-by-step explanation of the questions was conducted. Various typical travel situations were discussed and clarified. At the close of the program local officials gave a plea for a large return of the completed questionnaires.

An advertising campaign was organized to encourage the public to watch the television program. The major medium employed was the local television station on which the program was to be shown. However, daily and weekly newspapers as well as radio stations were used to get across the "Watch the TV Program and Help Solve the Traffic Problem" message.

The returns were control coded by home zone (zone of residence) and the total number of returns per zone was tabulated. The percentage return was calculated by comparing the total number of dwelling units in each zone with the total returns for that zone. The total number of dwelling units was determined from the census data.

The returns were analyzed for bias by comparing the return percentages by zone with income, auto ownership and distance from the center. For a further check for bias the number of total trips per dwelling unit reported for each zone was correlated with income, auto ownership and distance from the center.

TABLE 1

GENERATION CHARACTERISTICS

City	Year	Population	Trip/Person	Person/ Car	Trip/ DU	Persons/ DU	Car/ DU
Chicago	1956	5,169,663	1.92	3.85	5.96	3.10	0.80
Detroit	1953	2,968,875	1.77	3.51	5.88	3.31	0.94
Washington	1955	1,568,522	1.67	3.75	5.05	3.02	0.81
Pittsburgh	1956	1,472,099	1.61	3.75	5.26	3.26	0.87
St. Louis	1957	1,275,454	1.94	3.48	6.05	3.12	0.90
Houston	1953	878,629	2.22	3.43	7.16	3.22	0.94
Kansas City	1957	857,550	2.18	3.26	6.69	3.07	0.95
Phoenix	1957	397,395	2.29	2.87	6.88	3.01	1.05
Nashville	1959	357,585	2.29	3.35	7.52	3.28	0.98
Fort Lauderdale	1959	210,850	1.69	2.72	3.63	2.15	0.79
Charlotte	1958	202,272	2.36	3.28	8.10	3.43	1.05
Reno	1955	54,933	2.48	2.43	6.87	2.77	1.14
New Haven	1962	408,172	2.31	2.50	7.25	3.12	1.24

As a means of further control large sample (60%) home interviews were taken for selected zones (7 of 500) and the results of these were compared to the TV-postal survey for those zones. The number of trips per dwelling unit by time, mode and purpose were correlated for each survey technique. In this manner the TV-postal survey was checked for time, purpose and mode bias.

The postal survey was debiased by purpose and mode by applying differential expansion factors. Factors were also used to expand the returns to 100 percent for each zone.

RESULTS

The number of usable returns totaled 11,000, which constituted a 10 percent sample. This was considerably below the originally anticipated and desired return of at least 20 percent. Conversely however, the percentage of unusable replies was quite low, less than 0.5 percent of the total. The percentage usable returns by zones was found to vary directly with income. A 30 percent return was common in zones with a mean family income over $10,000 per year, but the return was as low as 1.5 percent in zones with family income below $4,000 per year.

The bias favoring high income groups resulted from the large reply from a higher auto ownership group than the mean. This tended to inflate the survey results since high income, high auto ownership groups exhibited a high trip per dwelling unit rate. The use of many small zones made it possible to dampen this effect since small zones possess more uniform social-economic factors than large zones. The over reporting of trips per dwelling unit was offset by applying reduction factors based on the difference between auto ownership as reported and the actual auto ownership of the zones.

The breakdown of trips per dwelling unit by mode indicated "under reporting" of auto passenger trips. Correction for this bias was achieved by determining auto occupancy as reported and adjusting auto passenger trips to a reasonable auto occupancy rate determined by roadside observation.

The questionnaire asked, "Did you fill this out during the special TV program?" The question was intended to determine the pattern variation between viewer and nonviewer replies. It was hoped that in this manner the effect of the television interview on accuracy could be analyzed. Unfortunately, the format of the TV program as finally developed did not make this possible. The original concept called for an intensive 30-min interview during which the viewer would complete his questionnaire.

There was to be a minimum of extraneous material in the program. The television question was worded with this in mind and the questionnaire form was printed.

The television station officials convinced the traffic officials that a program containing a long interview period would not gain a large audience. As a result, the length of the actual interview time was substantially reduced. The reduction in interview time removed the possibility of the viewer completing the questionnaire during the program; therefore, the wording of the question no longer applied. Many replies were marked that the questionnaire was not completed during the program, but written notes on the cards indicated the person replying had watched the program. The wording problem removed an analysis of the television effect on returns since non-viewer replies could not be compared with viewer replies.

Several problems were encountered in performing the survey. The greatest problem was to gain public attention for the television portion of the survey. Since only one television channel was used in an area which has about four-channel coverage, switchover from the traffic program was possible and very probable. An increased publicity campaign would reduce the number of viewers changing channels, however, a more effective method would be blanket coverage of all channels.

The bias in the sample appears to be no different than a normal postal survey.

The generation factors determined from the New Haven survey are compared with similar generation factors from other transportation studies in Table 1. The New Haven generation seems reasonable especially in view of New Haven's high auto ownership rate of 1.24 autos per dwelling unit which would cause a high trip per dwelling unit rate.

A percentage breakdown of total trips by purpose is given in Table 2 for New Haven and from other transportation studies. The New Haven percentages are close to those of metropolitan areas of similar size. The social-recreational percentage is slightly higher than the other studies, however, this might be due to the later New Haven date, June 5.

The bias encountered in auto ownership was chiefly caused by under reporting for dwelling units from which no trips were made that day. The largest portion of "no trip" dwelling units also were "no auto" dwelling units. Thus, as the percentage of dwelling units without autos decreases and auto ownership increases the bias decreases. An example of this bias is shown by analyzing the lowest income area in the New

TABLE 2

PERCENT BY PURPOSE COMPARISON

City	Survey Date	Home	Work	Business	Shop	Soc.-Rec.
New Haven	1962	39.6	19.0	10.1	9.6	13.1
Chicago	1956	43.5	20.5	12.4	5.5	12.8
Detroit	1953	39.5	23.5	6.9	8.2	12.1
Washington	1955	41.7	23.4	6.6	8.2	7.1
Pittsburgh	1958	43.4	21.0	13.5	8.4	7.9
St. Louis	1957	40.5	20.8	6.0	10.5	12.3
Houston	1953	40.3	18.9	7.1	10.1	10.8
Kansas City	1957	38.4	20.6	6.7	9.9	12.9
Phoenix	1957	37.2	18.2	7.9	11.5	11.2
Nashville	1959	37.6	19.1	6.5	10.5	13.6
Fort Lauderdale	1959	38.6	17.2	11.7	13.8	12.9
Charlotte	1958	36.6	21.9	7.5	9.0	12.8
Reno	1955	38.6	16.9	11.2	10.4	14.3
Average		39.6	20.2	8.7	9.7	11.7

Haven area. The actual auto ownership rate was 0.48 autos per dwelling unit; however, this postal survey showed a 0.94 auto ownership rate. The variation between actual and interviewed auto ownership for the city of New Haven was 1.17 to 0.94. The variation for the entire metropolitan area was 1.33 to 1.24 which demonstrates the decrease in bias as auto ownership increases.

The bias introduced by reporting from higher auto ownership groups was dampened by under reporting of non-work trips. Thus, within the auto driver mode, the two effects tended to cancel each other for all zones except those of very low income.

A check for accuracy of the travel pattern was made by comparing actual trips crossing the New Haven city limits with the number determined from the survey data. An over reporting of trips bound to New Haven from residential suburbs was anticipated since the survey was conducted by the city traffic department which is not a metropolitan organization. The cordon line check indicated the survey crossings were 96 percent of the actual crossings. This would indicate that within the city limits the survey results give good representation of the actual travel pattern.

The use of third class mail created an almost impossible delivery problem. It developed that it was impossible for the post office to maintain delivery date promised on every route. Even though all cards were in the post office on the agreed date, a substantial number were not received by the public for as many as three days after the TV program. The use of first-class mail would have increased the cost but the delivery problem would have been lessened.

In general this type of interview technique appears to be a good method of gathering an accurate large sample within a limited budget. For the several reasons discussed herein, the study did not fully reveal all the potentialities of the TV interview technique. From numerous personal and written comments it was evident that the TV program was seen and that it was thought provoking. The net result, however, was a postal survey neither better nor worse than might normally be expected. One general use in the future for this technique would be to upgrade older O-D surveys. Also, this technique could be used to determine trip generation characteristics for a synthetic survey.

Home Interview Survey and Data Collection Procedures

FREDERICK W. MEMMOTT, III, Survey Supervisor, Upstate New York Transportation Studies

•SUCCESS in travel survey design and implementation rests upon the accurate measurement of the total universe of person and vehicular trips. In the urban area this is more or less accomplished by means of the home interview, truck and taxi, and external or cordon line surveys. Each of the above surveys measures different parts of the internal, internal-external, or the external-external universe of travel. This paper describes quality control procedures related to the measurement of internal-internal or internal-external travel accomplished by means of the home interview survey.

What procedures are used to check that the number of trips reported is indeed a representative sample of all internal travel? The conventional approach is that of the screenline survey which measures the gross travel occurring between two or more portions of the cordon area. The results obtained are usually 5 to 15 percent greater (in terms of gross travel) than that reported by the home interview survey. Various hypotheses have been offered as an explanation of this difference, such as the "under reporting" of non-peak hour trips, the internal travel by persons living outside of the cordon area, and double crossings of the screenline.

Evidence obtained from different travel studies indicates that the home interview survey under reports trips by an average of about 10 percent. This necessitates the factoring of home interview reported travel to that indicated by screenline counts to measure the total universe of travel. Is this factoring necessary or desirable? Could home interview survey procedures be refined so that survey results are within 1 or 2 percent of that reported by the screenline survey?

QUALITY CONTROL

Improvement of home interview survey techniques is best obtained by refinements of existing procedures. This includes improvements of the sample selection process and in obtaining travel data from respondents.

Sample Selection

The first requirement of the sample selection process is that it be drawn from the complete urban universe of dwelling unit and non-dwelling unit quarters. This refers to the selecting of samples from current listings of dwelling places obtained from city directories, utility company meter records, assessor's tax account records, or field listings of dwelling places designed for sample selection or sample selection and land-use classification purposes. Great emphasis is placed on the word "current." Any listing of this type is subject to constant change brought about by new residential construction and urban renewal and slum clearance projects, and must be kept current if it is to be of value. Equally important is the completeness and accuracy of the listing. If dwelling places are omitted or duplicated on documents used as the sample source, the sampling rate will be correspondingly affected.

No matter how good the dwelling place list may appear to be, dwelling places are occasionally omitted. An interval check procedure detects errors of this type by verifying the correctness and accuracy of the dwelling place list. It provides a systematic method of adding newly discovered dwelling places to correct the dwelling place listing.

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Likewise, it permits the removal of erroneously listed buildings or addresses. It permits the proportion of sample to total dwelling units to be systematically adjusted.

Survey Techniques

Assuming that the list of dwelling places selected as a sample is representative of all dwelling places in the urban area, how good is the interview process in obtaining complete household trip information? What improvements can be made to insure the complete reporting of all travel taking the traveler outside of the block origin?

The standard interview procedure involves the following: (1) the mailing of a "Dear Householder" letter to the sample address in advance of the travel day, and (2) a personal interview with at least one responsible adult living at the sample address within three days after the travel day. This procedure has been extensively used in the past. It consistently under reports travel.

To overcome this systematically occurring discrepancy, three modifications to the basic interviewing procedure have been devised. The first of these modifications is simply requiring the interviewer to interview all persons 16 years of age and older at the assigned sample address. This is accomplished by making at least one personal visit to the sample household to obtain detailed information on the travel made by all members of the household. Additional callbacks, either in person or by telephone, are made to those members of the household not originally interviewed in person to verify the completeness and correctness of the information already obtained.

The second modification, not used in the Niagara Frontier home interview survey, is to encourage the voluntary reporting of trips made by the respondents but not remembered until after the completion of the personal interview. This is done by leaving a small card with the respondent at the close of the interview. On the card is a request for any additional travel information and instructions for reporting such travel by telephone.

The third modification is that exemplified by the "pre-interview" technique. Pre-interview identifies an interviewing procedure which features before and after travel date visits to the household by the interviewer. Trip cards on which travel data can be recorded are left for each member of the family on the interviewer's first visit, who at the same time explains their use and arranges for a return visit to the household as soon after the travel date as is mutually convenient. On the second visit, the interviewer reviews the trip cards completed by members of the household and transfers this information plus additional household and person data to the standard interview form or document.

In comparison, the "standard" technique involves one visit to the household by the interviewer, conducted as soon after the travel date as is possible. In this case, the interviewer obtains the data by question and answer either directly from the respondent or from members of the household present and familiar with the travel of those members not present at the time of the interview. No trip cards or other respondent travel logs or diaries are used.

BACKGROUND OF PRE-INTERVIEW TECHNIQUE

How did the pre-interview technique come about? Unfortunately, no complete history is available. It has long been believed that if person contact could be established with the household prior to the travel date, then more complete and accurate travel data could be obtained from that household. The question then was as it is now: Would the improvement in trip reporting more than compensate for the additional interviewer time and cost involved in using this procedure?

The first attempt to determine this came about with an origin and destination survey conducted in New Orleans several years ago. No conclusive results were obtained at that time. Since then this technique has been experimentally utilized in the Pittsburgh and Penn-Jersey Transportation Studies. In the former application, the results were promising, although not conclusive enough to warrant a full-scale adoption of technique for the home interview survey in Buffalo. The results obtained in the latter application indicated no basic improvement over the standard interviewing technique developed during the past several decades.

THE NIAGARA FRONTIER HOME INTERVIEW SURVEY

The Niagara Frontier Transportation Study cordon area encompasses an area of approximately 800 square miles, containing over 400, 000 dwelling places. It includes the cities of Buffalo, Niagara Falls, and Lockport and the suburban towns and villages adjacent to these cities.

In this area, 4 percent of the field-listed dwelling places were selected as sample units. This produced a total of over 16, 000 scheduled interviews, of which 13, 000 interviews were completed. The selected samples were divided into three groups: 80 percent to be interviewed by the study's consultant, 10 percent to be interviewed by NFTS personnel using "regular" interview techniques, and 10 percent to be interviewed by NFTS personnel using pre-interview technique. Personnel employed by the study's consultant were under instructions requiring that the interviewer or the editing staff personally contact each respondent sixteen years of age and older by means of personal visit or a telephone call after the initial interview. The same instructions were in effect for NFTS personnel only during the last five weeks of the interviewing period. Otherwise interviewing instructions, data requirements, personnel supervision and administration were essentially identical between the two organizations.

In brief, interviews have been classified into groups, depending on the organization to which the sample was assigned and the degree of personal contact obtained with the residents of the household. Emphasis is placed on the effectiveness of intensive interviewing and the pre-interview technique, taken singly and in combination with each other, in improving trip reporting in comparison with conventional techniques.

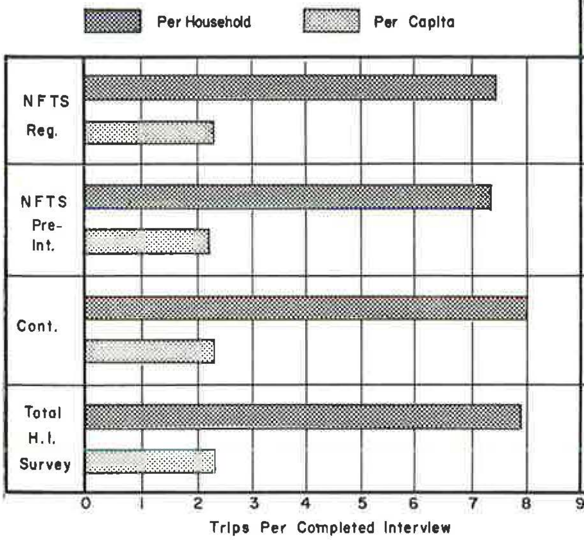
RESULTS

Figure 1 gives the basic Niagara Frontier home interview survey results as a function of the organizations and techniques involved. The completed interviews and trips reported for the NFTS regular, NFTS pre-interview, contractor, and total home interview survey are shown. In this paper, trips reported are raw data, since no trip linking or collapsing of passenger ride-to-ride trips has been done. These data have also been calculated and graphed as reported trips per household and reported trips per capita. There is a difference in the household rates (7. 5 for NFTS versus 8. 0 for the contractor) and a similarity in the per capita rates (each is on or about 2. 3 trips per person).

Is there any appreciable difference in the average household characteristics of the interviews completed by each organization? In addition to trip and interview data, Figure 1 also gives average persons per household, average automobile ownership, and average family income. The numeric values shown for each of the listed family characteristics remained practically identical between organization and technique group. This substantiates the contention that each group is a representative sample of the same universe of dwelling places. It also shows that any differences in interview rate or trip reporting cannot be attributed to differences in family characteristics but are a function of organizational efficiency and the interviewing techniques.

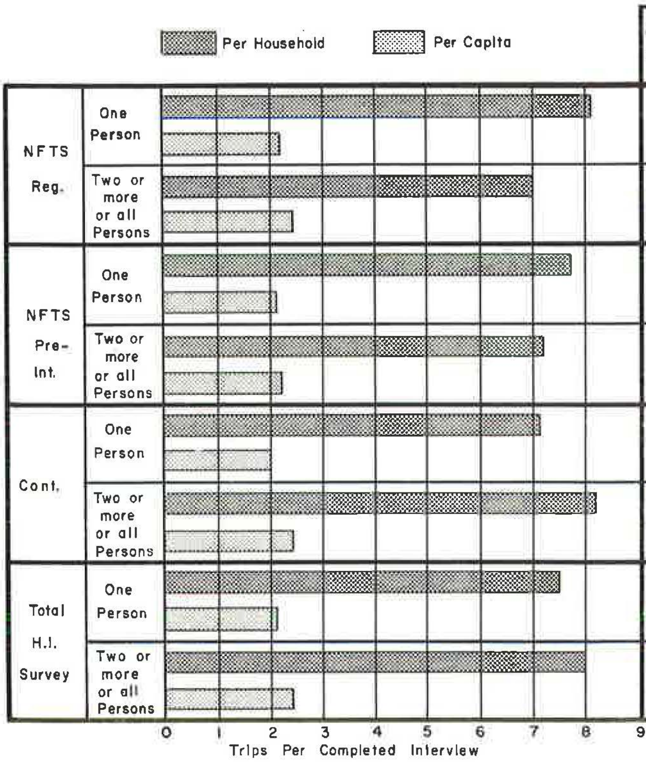
Figure 2 shows the number of completed interviews and trips in households where one person 16 years of age and older was interviewed and in households where two or more persons 16 years of age and older or all persons 16 years of age and older were interviewed for the same organization and technique groupings as before. These data have also been calculated and plotted as reported trips per household and reported trips per capita.

The results are somewhat contradictory. NFTS interviewers show a higher household trip reporting rate in families where only one person 16 years of age or older was interviewed. The opposite of this is indicated by the trip reporting rates of interviews conducted by the contractor. Here the higher trip reporting rate occurs in families where two or more persons or all persons 16 years of age and older were interviewed. The major difference between NFTS and contractor interviews lies in the percent of households where two or more or all persons 16 years of age and older were interviewed. The values are 52, 57, and 87 percent for the NFTS regular, NFTS pre-



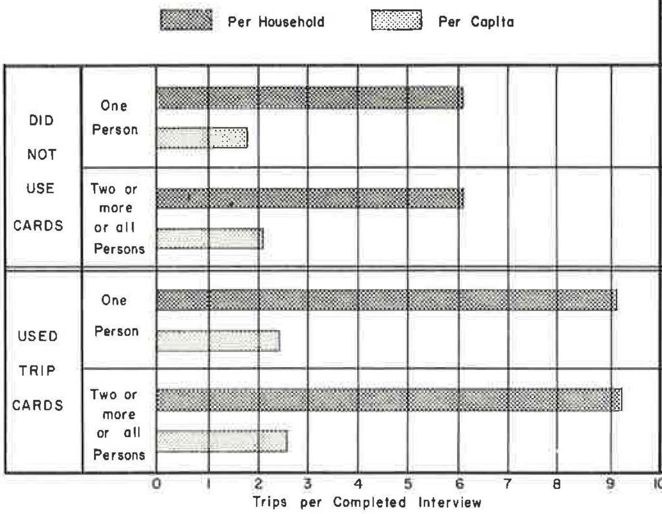
	COMPLETED INTERVIEWS	REPORTED TRIPS	AVERAGE PERSONS PER HOUSEHOLD	AVERAGE AUTO. OWN.	AVERAGE FAMILY INCOME
NFTS Reg.	1,395	10,498	3.32	0.94	4.82
NFTS Pre-Int.	1,354	10,037	3.39	0.97	4.62
Cont.	10,564	84,875	3.42	0.95	4.67
Total H.I. Survey	13,313	105,410	3.40	0.98	4.68

Figure 1. Niagara Frontier home interview survey results.



		COMPLETED INTERVIEWS	REPORTED TRIPS	AVERAGE PERSONS PER HOUSEHOLD	AVERAGE AUTO. OWN.	AVERAGE FAMILY INCOME
NFTS Reg.	One Person	672	5,411	3.73	1.02	5.02
	Two or more or all Persons	723	5,087	2.94	0.86	4.65
NFTS Pre-Int.	One Person	575	4.438	3.62	1.06	4.84
	Two or more or all Persons	779	5,599	3.22	0.91	4.46
Cont.	One Person	1.384	9,889	3.53	1.03	4.88
	Two or more or all Persons	9,180	74986	3.40	0.97	4.64
Total H.I. Survey	One Person	2,631	19,738	3.60	1.04	4.91
	Two or more or all Persons	10,682	85,672	3.36	0.96	4.62

Figure 2. Trip reporting vs number of persons interviewed.



		COMPLETED INTERVIEWS	REPORTED TRIPS	AVERAGE PERSONS PER HOUSEHOLD	AVERAGE AUTO. OWN.	AVERAGE FAMILY INCOME
DID NOT USE CARDS	One Person	269	1,640	3.40	0.93	4.25
	Two or more or all Persons	511	3,124	2.96	0.79	4.00
USED TRIP CARDS	One Person	306	2,798	3.82	1.17	5.32
	Two or more or all Persons	268	2,475	3.60	1.14	5.28

Figure 3. Trip reporting vs use of trip cards.

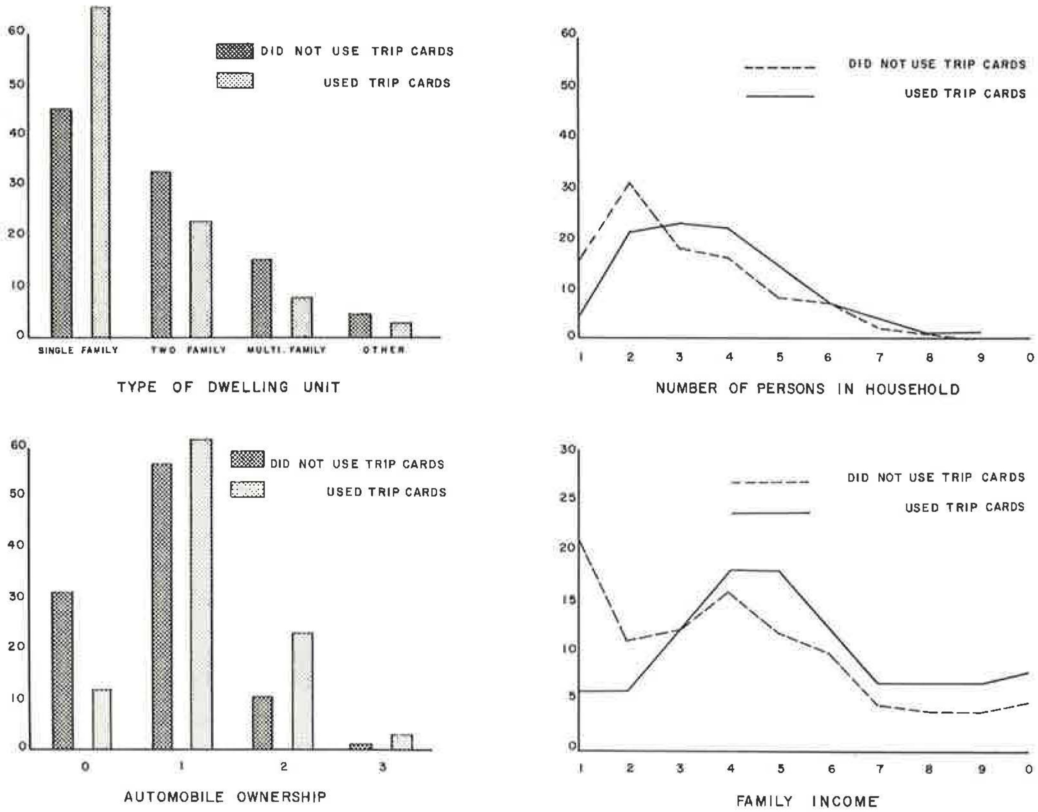


Figure 4. Household characteristics and use of trip cards.

interview, and contractor, respectively. Herein lies one explanation for apparent differences in household trip reporting. In NFTS interviews, households where two or more or all persons 16 years of age or older were interviewed were those which tended to be small in size, own fewer cars, and have a lower family number than the comparable contractor group. In NFTS interviews, the interviewer was usually able to complete interviewing the adult members of this household on a single visit — hence those 16 years of age and older were considerably easier to reach and, as a household, made fewer trips than the comparable contractor group.

Therefore, the 30 to 35 percent difference consists of households having an above average number of trips per household, persons per household, automobile ownership, and family income.

The results for reported trips per capita are as expected. Households where only one person 16 years of age and older was interviewed report approximately 2.1 trips per capita, whereas, households where two or more or all persons 16 years of age or older were interviewed report approximately 2.4 trips per capita. This indicated that interviewing more than one adult member of the household does pay off in terms of increased per capita trip reporting. However, these figures are not inclusive enough to warrant further estimates as to the total effects of intensive interviewing.

Figure 3 analyzes the basic results of the NFTS pre-interviews in terms of those households using or not using trip cards. If in any household one or more members used trip cards, then that household is considered to be one using trip cards.

Households not using trip cards report an average of 6.1 trips per household, while those using trip cards over 9 trips per household. Similar results are indicated for trips per capita. Households not using trip cards report approximately 2.0 trips per capita while those using trip cards report approximately 2.5 trips per capita. This is 3 trips per household and half a trip per person greater per day for those using trip cards. Clearly there must be an explanation for this phenomenon.

Figure 4 shows the differences in household characteristics between those using or not using trip cards. The users as a group are more likely to be residents of single-family dwelling units, to own more automobiles, to have a higher average family income, and to have larger families. The household differences between the two groups are of such a magnitude that they must not be ignored.

CONCLUSIONS

The two basic conclusions obtained are as follows:

1. The pre-interview technique does not increase trip reporting. It facilitates the reporting of trips by those who are willing to complete the trip cards. Those who do use trip cards normally make more trips and have different household characteristics than those who do not use trip cards.
2. Intensive interviewing, where the goal is personally to interview all members of the household 16 years of age and older, does increase trip reporting in proportion to the attainment of this goal.

Both the pre-interview and intensive-interviewing techniques are somewhat more expensive in terms of interviewer man-hours and miles driven than the standard technique. Therefore, increased expenditures on intensive interviewing are justifiable inasmuch as better data can be obtained for the incremental investment. This is not true for the pre-interview technique.

Therefore, use of intensive interviewing procedures is recommended in future home interview surveys.

Inventorying an Arterial Network for Computer Assignment: Methods and Implications

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•HISTORICALLY, the inventory of transportation facilities has accompanied land-use and origin-destination surveys as one of the three major inventories of a transportation study. This inventory provides the base for determining the deficiencies of the existing arterial network and the starting point for planning future improvements. Of prime importance is the use of the inventoried network for traffic assignments, and the requirements of this assignment process dictate many of the criteria for designing the inventory.

The inventory must express the arterial network in a numeric or mathematical form since the traffic assignments are accomplished by use of computers. The inventory must also be designed to accommodate network revisions so that traffic assignments can be made on:

1. The present network.
2. The present network plus committed construction.
3. The present and committed system plus additional facilities planned to meet future traffic demands.

Finally, the methods developed for inventorying the facilities must also make it possible to code the network rapidly so that it can be tested early in the study process by initial traffic assignments in order to calibrate the assignment model for future assignments.

Based on previous experience it has generally taken six months or longer to inventory and code an arterial network for a study area the size of the Niagara Frontier before the first traffic assignment could be made to the network. A six months' inventory would have produced an impossible scheduling problem for the Niagara Frontier Transportation Study. It was, therefore, necessary to develop a method that would meet the requirements

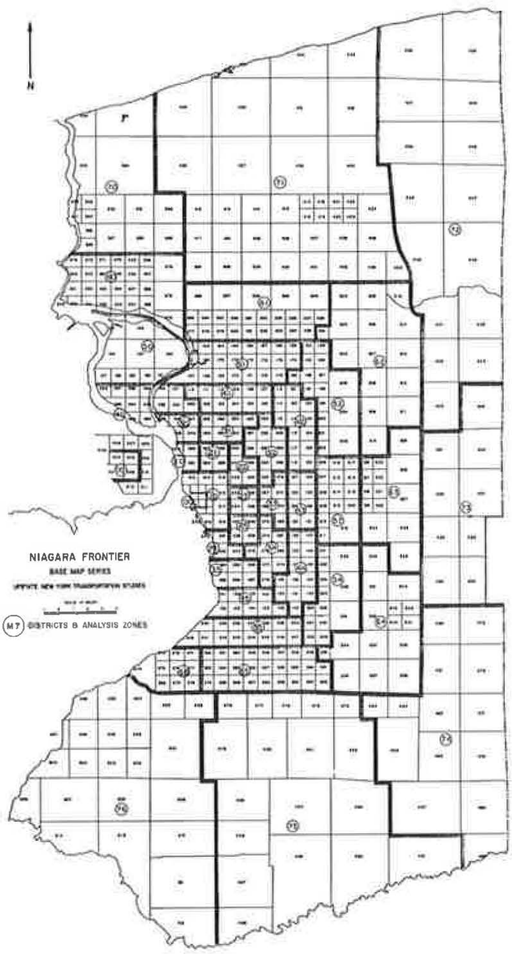

Figure 1.

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above and at the same time produce an inventoried and coded network in a minimum amount of time.

This paper describes the method developed by which the arterial network of Niagara and Erie counties was inventoried within two months. This two-county area has a population of 1,300,000 people, and the network, as finally defined, consisted of 3,900 miles of streets and highways, described by 2,020 nodes and 3,330 links. Essentially a paper survey, the inventory involved a minimum amount of field work to supplement the available data on the highway and street characteristics of the study area.

ORGANIZATION OF STUDY AREA

In addition to the arterial system within Erie and Niagara counties, a skeletal network within adjacent counties was selected and inventoried to simulate trips from these external areas.

As a first step in organizing this total area, a ¼-sq mi grid was laid out over Erie and Niagara counties with the X-Y axis oriented east-west and north-south, respectively. This grid was then used to organize the two counties into 514 traffic zones ranging in size from ¼ sq mi to 16 sq mi, with the size depending on the density of development. The basic grid used was identical to that used in coding the land-use survey. All traffic zones were made multiples of these quarter square mile areas, thus readily permitting the summary of all land-use data by traffic zone. The external area was similarly organized into 31 traffic zones, however, no basic underlying grid was used. Instead, each county was generally divided into four traffic zones of equal size by a pair of north-south and east-west lines.

To provide a basis for the orderly numbering and the grouping of traffic zones into districts, a system of rings and sectors was laid out along zone boundaries. These ring and sector boundaries along with the layout of traffic zones within the study area are shown in Figure 1. The rings are essentially concentric belts with a common origin at Niagara Square in Buffalo. Sectors are wedges of approximately 36 degrees radiating outward from the common origin of the rings. Section boundaries have been oriented generally to bracket outlying communities.

Each district is identified by the 2-digit number enclosed in a circle. These numbers correspond to its ring and sector location. Once the traffic zones were grouped into districts they were then numbered from 001 to 551, using consecutive numbers within each district.

Generally the zones within a district were numbered in a serpentine fashion. However, in districts where a cluster of smaller zones, representing a community, was encountered, the smaller zones were numbered consecutively before proceeding with the orderly numbering of the larger zones. Modifying the numbering system within a district in this way permits the grouping of data for communities in outlying areas.

DEFINING THE ARTERIAL SYSTEM

The arterial highway system of the Niagara Frontier is defined as the network of streets and highways that provides the basic travel paths for the interzonal movement of traffic throughout the study area.

This definition is particularly applicable since present computer assignment techniques require the load node or centroid of each traffic zone to be interconnected by the arterial system so that there is access from each zone to every other zone. In order to provide this continuous interzonal access, it was necessary to include many different types of facilities in the arterial network. These facilities ranged from expressways to narrow 2-lane conventional highways and also included a few "artificial" streets. The latter were introduced as a result of adopting a grid-type layout of traffic zones to facilitate data handling that in some instances produced zones with no presently developed street or highway access.

Within the definition, arterials were classified into five distinct types: (1) major street and (2) secondary street (both surface streets); (3) expressway; (4) surface-to-expressway ramp; and (5) expressway-to-expressway ramp.

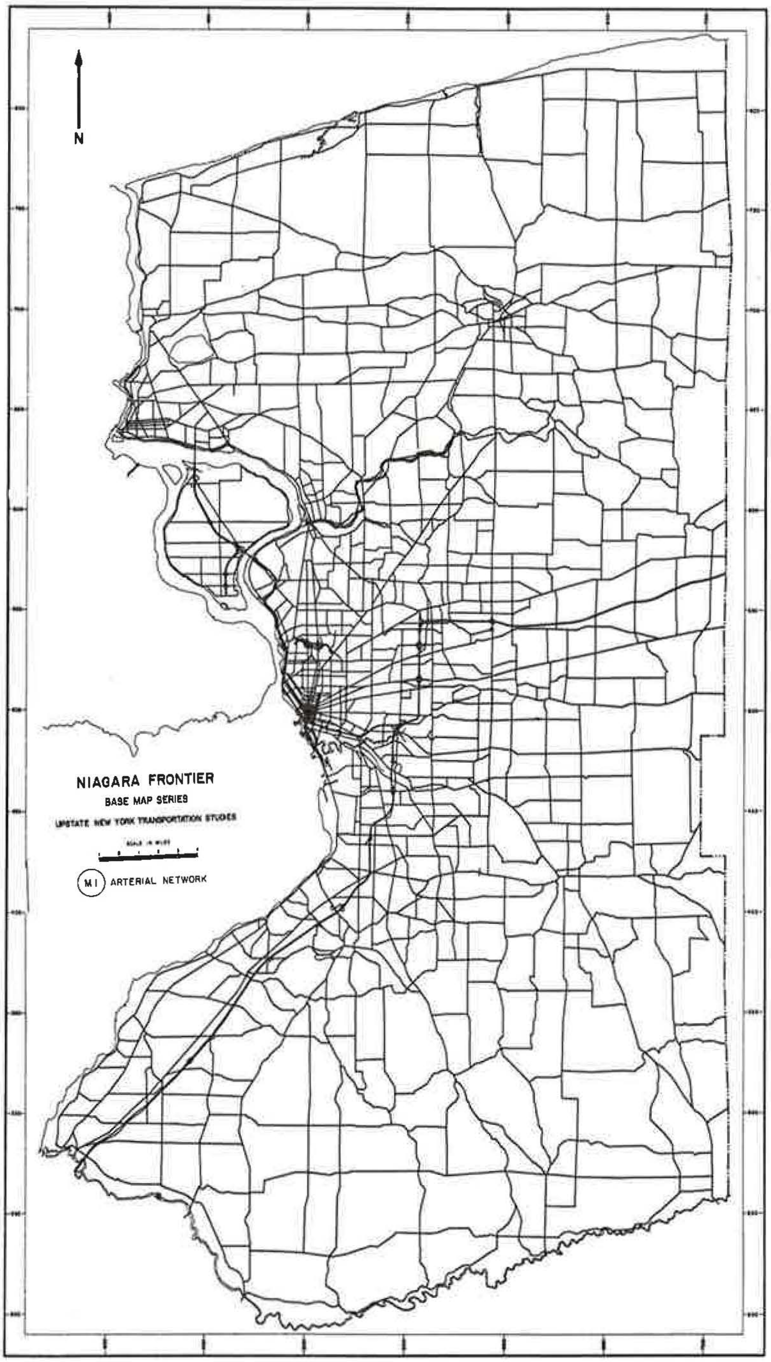


Figure 2.

Expressways and their ramps were easily identified by their geometric features (multi-lane, divided highways), access control, and type of traffic found on them. Surface streets and highways, however, were less easily identified, and it was necessary to establish criteria or characteristics for these streets to maintain consistency and accuracy. Each was considered if it had one or more of the following characteristics:

1. Major Streets
   a. Four or more traffic lanes.
   b. A total paved width of 56 ft or more.
   c. Traffic control devices and signal system that provide for preferential treatment to traffic on the street.
   d. Streets with reversible lanes.
   e. Streets with parking prohibited during peak-hour traffic.
   f. A continuously signed route (numbered or truck route).
   g. A part of a one-way couplet if arterial by other criteria.
2. Secondary Streets
   a. Any street (no matter what the design standard) if it is the only route available to through traffic.
   b. Any street which gives access to a traffic zone and which is likely to be improved within the planning period.
   c. Any artificial street which must be inserted into the system to provide access to a presently undeveloped traffic zone.

Using these definitions and principles, the existing arterial network of the Niagara Frontier was identified and delineated on a set of base maps ranging in scale from 1:4,800 in Buffalo to 1:24,000 in the rural areas.

This phase of the work required very close cooperation with officials in city, county, and state agencies. Their review and comments were essential to the determination of the existing arterial network. Identification of each arterial type was the first step of the inventory. This was accomplished by color coding each selected street or highway by type as it was posted on the base maps. The selected arterial network is shown in Figure 2.

INVENTORY AND CODING

Items Inventoried

In determining which characteristics of the network to inventory, consideration was given to two important factors: the kind of data required for traffic assignment purposes, and additional information needed for evaluating and planning improvements to the existing arterial system.

Since the coding form (Fig. 3) was designed to accommodate all the items to be inventoried, this discussion of the inventoried items is essentially a review of that form. Each item on the form falls into one of two general categories: identification, which includes map number, district, and link identification; and characteristics, which include direction, length, zoned speed, parking restrictions, width, intersection control, one- or two-way streets, area type, volume, and year volume count was made.

The items in the identification category serve as the index for the characteristics and make it possible to locate readily each individual item inventoried in the entire arterial network.

Requirements for Traffic Assignment.—The particular assignment program used by the Niagara Frontier study was based on a minimum time path routing with a capacity restraint that increased link travel time as assigned volume increased. Because the assignment of trips theoretically begins under zero volume conditions, the initial input of travel time on each link had to represent a reasonable travel time for one car to traverse the link, assuming no interference from other traffic. This travel time was defined as the free-flow time, i.e., the travel occurred under extremely low volume conditions, delayed only by fixed traffic control and the inherent features of the street design.

To determine this free-flow travel time, it was assumed that vehicles would drive at the posted speed limit (zoned speed) between intersections and that all delays along a section of arterial street would be a function of the intersections at each end of this section. Inasmuch as the selected arterial network did not include all streets and highways, the average delay time assigned to each coded intersection included also delays due to intermediate controls at uncoded intersections representing local streets not a part of the arterial network.

Field time runs were made under extremely low volume conditions (during early morning hours) over selected sections of the arterial network. From these field tests it was possible to determine the average arterial intersection delay for each link type within three different area types. The link types were those previously defined, and the area type generally corresponded to those defined in the Highway Capacity Manual (1) as downtown, intermediate, and outlying. Free-flow travel time was then calculated for each link as follows:

$$\text{F F travel time} = 3,600\left(\frac{\text{zoned speed (mph)}}{\text{length (mi)}}\right) + \frac{1}{2}\left(\begin{matrix}\text{intersection delay (sec)}\\ \text{at each end of link}\end{matrix}\right) = \text{time (sec)} \tag{1}$$

With a selected sample of travel times to determine average delays, the inventory requirements to determine travel time were length, link type, area type, and zoned speed.

Capacity, the second required input of the assignment program, was based on revised curves (2) which immediately set the requirements for several inventory items: street width, link type, one- or two-way street, parking restrictions, area type, and intersection control. Bus stops were omitted since parking generally controlled capacity on bus routes.

Certain basic assumptions, however, were necessary before the curves could be used. The hourly volumes from the capacity curves had to be converted to average daily traffic in order to make them comparable to the assigned volumes. This was accomplished by setting the tolerable level of service during design hour at 11 percent with a 60-40 directional split. The size of the network required the use of some approximations to simplify the machine calculation of link capacities. Therefore, it was assumed that each coded intersection of surface streets in the arterial network was signalized with a 60-sec cycle and that there was approximately 20 percent turning traffic and 10 percent commercial vehicles at each.

Capacity for each intersection approach in the network could then be determined from the curves. Intersection control governed the amount of green time available; i.e., when a major and secondary link intersected, 60 percent of the green time was allocated to the major road, and 40 percent to the secondary. Controls for each of the intersection types are:

Intersecting Links	Allocation of Cycle Time (%)
Major and secondary	60-40
Major and major	50-50
Secondary and secondary	50-50
Secondary and major	40-60

Using a numeric code for the intersection control at each end of the link, the intersection controlling capacity as well as the link capacity could quickly be determined by machine sorting and processing. This method of determining capacity on surface streets was adopted to give emphasis in the assignment program to the additional capacity available on most primary streets resulting from favorable signal control and signing. This became increasingly important in a traffic assignment where a capacity restraint was used to increase link travel time as more volume was assigned to the link. Column 25 in the coding form was allocated for intermediate control, although it has not yet been used. As more inventory data become available on traffic control

NIAGARA FRONTIER TRANSPORTATION STUDY

ARTERIAL SYSTEM CODING FORM

Cols. 1-25 Coded by __________ Date____ Cols. 26-35 Coded by __________ Date____ Card No. ________ System________

Checked by __________ Date____ Checked by __________ Date____ Approved by __________

MAP NUMBER	DIST. RING	DIST. SECTOR	LINK IDENTIFICATION "A" NODE	LINK IDENTIFICATION "B" NODE	DIRECTION	LINK LENGTH (0.01 MILES)	ZONED SPEED	LINK TYPE	ONE OR TWO WAY	INTERSECTION CONTROL A	INTERSECTION CONTROL B	INTERMEDIATE	HALF WIDTH	PARKING	AREA TYPE	1 OR 2 WAY 24 HOUR ESTIMATED VEHICLE VOLUME	YEAR OF VOLUME COUNT	
1 2	3	4	5 6 7 8 9	10 11 12 13 14	15	16 17 18	19 20	21	22	23	24	25	26 27	28	29	30 31 32 33	34 35	36 37 38 39 40

Figure 3.

devices, this information will be included in the inventory and used in capacity calculations. The capacity of expressways and ramps was handled separately from the surface streets. Here it was assumed that there were no signalized intersections except for off-ramp terminals (handled as surface streets), and capacity was based on the number of lanes available.

Requirements for Planning.—It should not be inferred by the previous heading that the items inventoried to determine capacity and travel time are not important to the planning process, for they are very important. In addition to these items, however, gages must be devised to measure the use of the arterial system and determine its deficiencies. Existing volume is one gage. When used in combination with the items previously inventoried, a volume to capacity ratio can be calculated for each link and the vehicle-miles of travel can be determined for each link type and compared to the available vehicle-miles of capacity.

To determine the current existing volumes on the network all recent volume counts (and dates) taken throughout the study area were obtained from local and state highway organizations. The procedure used was to post all existing counts. These were then posted on the arterial system maps. Based on these counts the volumes were estimated on links where no counts were made and all counts were updated to 1962 by annual expansion factors for each base year. Since the annual expansion factors used for each year were constant for each link type, it was only necessary to inventory the volume and the year the volume count was made. (This resulted in an approximate volume count which is currently being revised by a counting program.)

Organization of Work

To organize the work of inventorying and coding a large arterial network efficiently, the entire operation had to be thought of as a system with inputs and outputs. The input to the system consisted of three basic items: arterial network maps, the physical

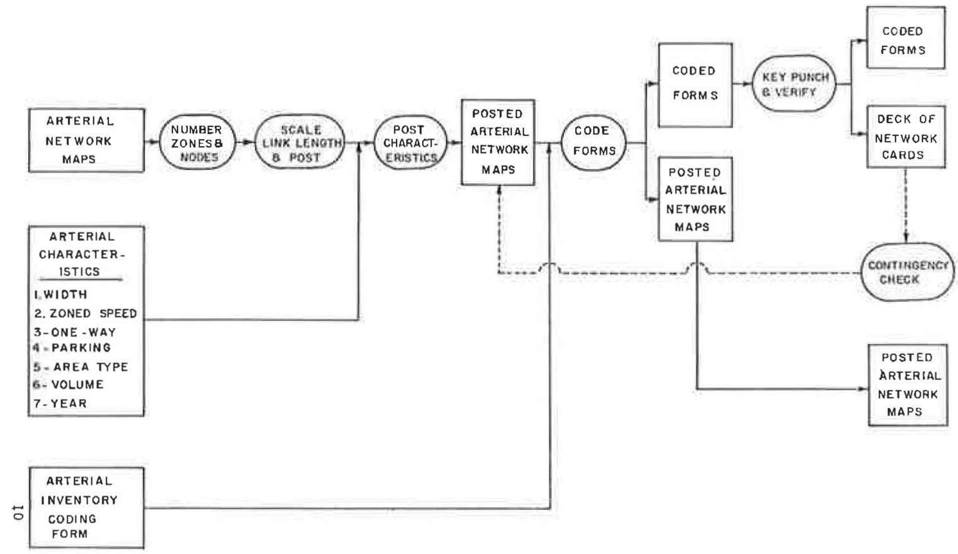
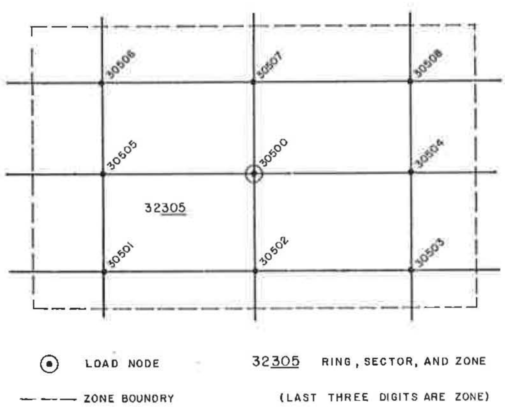


Figure 4. Arterial system coding operation.

and traffic characteristics of the network, and coding forms. The desired output from the system was: a deck of cards which described the network for computer assignment and which could be used also for summarizing all inventory data for planning purposes; and a set of posted arterial network maps which described the coded network. A block diagram (Fig. 4) describes this entire operation from the initial input of data to the final output. All succeeding techniques used to perform the system operations were developed to minimize field work since the survey was designed essentially as a paper inventory.

Coding Techniques

Node Numbering.—Once defined, the arterial network had to be described in a form usable by electronic computers and other high-speed data processing machines. Each intersection in the arterial network, therefore, was assigned a 5-digit identification or node number. For ease in locating specific intersections, the first three digits of each node number corresponded to the traffic zone in which the node was located, and the last two digits represented the number of that node within the zone. To identify the load node or centroid in each zone, the last two digits of this node were always designated 00 and the remaining nodes numbered from 01 to 99. The use of a 5-digit node number greatly speeds coding and, later, plotting work. Five-digit nodes can be mechanically converted to a 4-digit computer numbering system. The overall savings in time are substantial. A typical section of the numbered network is shown in Figure 5. The dashed lines represent zone boundaries, and the large bold numerals the number of the ring, sector and traffic zone.



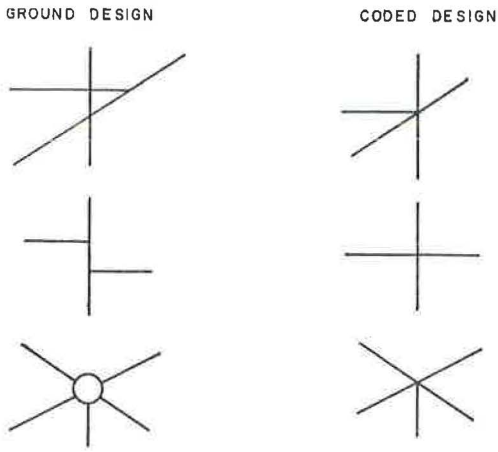


Figure 6.

Usually in any traffic assignment program there is an upper limit to the number of nodes that can be used to describe any one network. Therefore, to conserve on node numbers used in the network, staggered street intersections which fell within 200 ft of each other were considered to be at the same point with all links emanating from one node. Examples of this are shown in Figure 6.

A log of nodes used was kept to insure that the maximum number would not be exceeded and to avoid any duplication of numbers within the network.

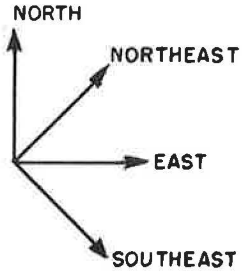
Compared to past procedures where blocks of node numbers were reserved for each map to provide a means of locating nodes. This method of node numbering proved very satisfactory during the inventory. Coders and others not too familiar with the network had no problem in finding specific links or intersections. To add a node to a map was accomplished by looking at the node log to obtain the next unassigned node number in the zone in which node was located. Since there are 100 node numbers available in each zone, it will not be necessary to reuse numbers deleted from a previous network when updating or modifying a network.

Posting.—The inventory items were posted on a set of arterial network maps to provide a common source for the items to be inventoried and to identify quickly the link on which each item was located. Since the map number, ring, sector, and zone boundaries, link identification, and link type were previously delineated on each map, posting involved recording the length, zoned speed, one- or two-way traffic, half pavement width, parking restrictions, area type, 24-hr volume, and year of volume count for each link of the network.

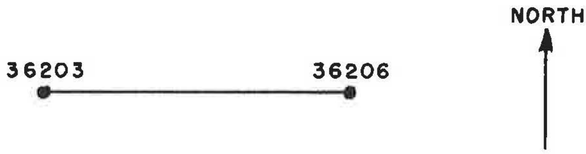
Length was scaled directly from the maps with specially prepared scales which read miles directly to the nearest 0.01 mi. Zoned speeds, obtained from tabulations of legal speed limits prepared by the New York State Traffic Commission, were posted in miles per hour. In instances where a speed changed within the limits of a link, a weighted average was used. One-way streets were indicated by a directional arrow in the direction of traffic flow. No arrows were used for two-way streets. Half street width for each link represented the curb-to-curb pavement width divided by two. In determining this width, any median areas or other permanent barriers which reduced the usable curb-to-curb pavement were subtracted. On links of variable width the least half width was posted since this would be one of the controlling factors in calculating capacity.

Parking regulations were posted in only one of two ways on each link. Either parking was permitted (P) on the entire length of link, or it was prohibited (NP) on the entire link. In cases where parking regulations varied during the course of the day, those regulations which governed during peak periods of traffic and appreciably affected capacity were posted. Area type was posted as either downtown, intermediate, or outlying and was generally on a zone basis. When available, 24-hr vehicle volume counts and the date the count was made were posted on each link. The best possible estimate was then made for the remainder of the links from the known counts on adjacent links. Direction and intersection control were not posted on the maps. Direction was a coding convention, and intersection control was determined from the types of intersecting links at each node.

Directional Conventions.—Certain conventions were adopted to simplify the coding of links and to put the data in a form suitable for the traffic assignment program used. Links were only coded in the specified grid directions, as follows:



The node from which the links to be coded emanate was designated the A node. The nodes at the opposite ends of the links were designated B nodes. All links were then coded from A to B in the specified grid directions, for example:

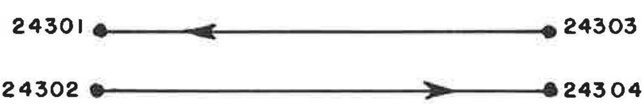


Numbers 36203 and 36206 identify the nodes of a link. This link would be coded in an easterly direction 36203 to 36206, making 36203 the A node and 36206 the B node. This convention provided the coders with a logical procedure to follow in coding the network and provided the inventory with a directional index of the network.

The only exception to these instructions was made in the case of one-way links. These links were always coded with the A to B node convention representing the actual direction of traffic flow on the link. This enabled the computer program to assign traffic in the proper direction on streets coded as one-way. Because no direction code was designated for south, southwest, west, and northwest grid directions, these directions used the respective code for their 180 degree complement.

Link Location.—As previously stated, the first three digits of each node number represent the zone in which the node is located. Therefore, for purposes of summarizing link data and keeping track of the links coded in each zone, a link was assumed to fall within the zone in which the A node was located. Although there were many instances where links were located within two or more zones, the above convention was adhered to and proved very satisfactory for the summarization of inventory data by traffic zone.

Expressways.—Unlike surface arterials (major and secondary streets) which were generally coded as two-way streets, all expressways were coded with one-way links. In the following example, 24301, 24302, 24303, and 24304 are nodes.



The first link was coded according to the direction from node 24303 to 24301 and the second from node 24302 to 24304. Although they are in opposite directions, each link received the same direction code. Street width on expressways was considered as 12 times the number of lanes, assuming that for practical purposes all the expressways inventoried had 12-ft lanes.

Interchange Ramp Coding Design.—Each connector between a surface street and an expressway was designated as a ramp, either one-way or two-way. One-way ramps were delineated with directional arrows in the same manner as surface streets and expressways. Ramps were coded in either of two ways: as they actually existed on the ground or by an abbreviated coding design. Generally all ramps were coded as they existed if maps of sufficient scale were available so that link lengths could be determined. If, however, adequate maps were not available, then an abbreviated coding design was used.

As constructed on the ground, the interchange in Figure 7 is a conventional cloverleaf. The simplified coding design provides for each of the eight individual turning movements of the interchange and requires much less coding. To determine the link length for each ramp, assume that a direct movement is made on a short ramp and an indirect movement on a long ramp of the interchange. The length of a short ramp was then considered equal to the distance from the street node to which the ramp was connected to a point midway on the bridge of the cross-street. For example on the sketch of the coding design, AB and DC are short ramps representing direct movements, B and D the street nodes, and E a point midway on the bridge of the cross-street. Therefore, the short ramps were coded so that AB = BE and DC = DE in lengths.

The length of a long ramp was considered equal to the distance between the street node to which the ramp was connected to a point midway on the bridge of the cross-street plus 0.1 mi for the indirectness of the movement. Using the same example as above, AD and BC are long ramps. Therefore, the lengths of the long ramps were coded as AD = DE + 0.1 mi and BC = BE + 0.1 mi.

Coding Overlays.--To insure that no links were omitted or duplicated during the coding of the arterial network, each posted map was covered with a vellum paper overlay. As each link was coded on the arterial coding form it was recorded on the overlay by tracing over that particular link with a pencil. The overlay then became a graphic index of the coded links and provided the coders with a visual means of checking which links had been coded. These overlays became significantly more important as the number of coders increased and the work of each overlapped.

Coding Operation

Coding.—Using the techniques previously described, each item on the coding form was coded for every link in the arterial network. In a network as large as that of the Niagara Frontier it was essential to set up simple bookkeeping procedures (in addition to coding overlays) to prevent duplication and omissions in the network coding. The method devised was to record the number of each zone to be coded on a coding form and to file this set of forms by district groupings. Once the coding operation was under

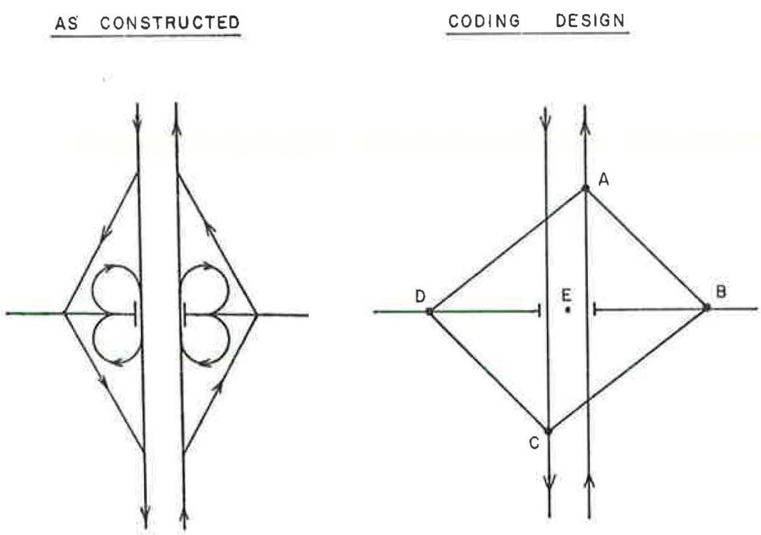


Figure 7.

way, each coder would go to this file and obtain the form(s) for the zone(s) he was assigned to code. If additional forms were required for a particular zone, the zone number was entered on each subsequent form and it was numbered 2 of 3, etc.

On completion of coding in a zone, the coder then placed the completed form in a separate file maintained for completed but unchecked forms and proceeded with the coding of links within another zone. Each of the coded forms was subsequently checked by a different coder and placed in a "completed" file to await keypunching. A separate log (by traffic zone) was then maintained for all forms sent to the data processing section for keypunching so that the exact location of all coded information was known at all times.

Coding Corrections.—Coding corrections were basically of two types: those found during the coding and keypunching operations and those found after the contingency checks were performed on the coded data. In each case a few simple rules sufficed to insure that corrections were properly carried out.

1. General.—Under no circumstances were additional links placed on a coding form once it was logged out for keypunching.

2. Corrections to Previously Coded or Keypunched Links.—The corrected link was entered on a new coding form with the zone number and the word "Corrections" written in the upper left corner. The original coding form with the incorrectly coded link was then located and crossed out. If the link had already been keypunched, the incorrect card was located and destroyed.

3. Corrections Subsequent to Contingency Checks.—These corrections were handled in much the same manner. The errors were listed as the contingency checks were run and the necessary corrections coded on new forms. The link cards in error were then located and destroyed and replaced with the cards keypunched from the coded corrections.

Network Revisions.—The network coding had to be flexible so that revisions or modifications could be made for subsequent traffic assignments. This revision or updating of one network to another can be handled in much the same manner as corrections and additions to the existing arterial network were accomplished. These techniques must, however, be supplemented so that a positive record is kept for each network tested and so that there will be no confusion in going from one network to another. This can be easily accomplished by filing a duplicate deck of network cards and a set of posting maps.

Once the geometrics of a proposed network have been developed, they must be incorporated into the previous system. This can be accomplished by first delineating the proposed changes on an overlay of the existing network, which immediately points out the links in the present network that must be deleted. These deletions, including link identification and location, should be coded on the coding form in columns 1-14. From this record a set of revised arterial network maps can be prepared, deleting the portions of the previous network no longer required and including the proposed modifications. All nodes that are required to describe the revised geometrics are then located and numbered. The node numbers used in each zone in updating a network should begin with the next highest number that was used in the previous network.

After posting all required data on the revised arterial maps the changes in the network should be coded using the same procedures previously developed. To complete the updating operation the coding forms containing the deletions and additions to the network should be sent to the data processing section where the deleted link cards will be removed from the network deck and the new links keypunched and added. All work should be fully documented and the bookkeeping methods used in coding the original system should be used.

Contingency Checks

Contingency checks were performed on all coded and calculated items in the arterial inventory. To insure the accuracy of the coding, single-field and multiple-field checks were set up for all coded data. These checks included comparison for impossible codes, values above or below allowable limits, or multiple-field combinations that were not allowable.

NIAGARA FRONTIER TRANSPORTATION STUDY

NODAL LINK SUMMARY
CODING FORM

System _____

Card No. _____

Zone __________ Checked By __________ Date __________

Coded By __________ Date __________ Approved By __________

NODE					No. of One-Way Links		No. of Two-Way Links		Total No. of Links		NODE					No. of One-Way Links		No. of Two-Way Links		Total No. of Links	
5	6	7	8	9	41	42	43	44	45	46	5	6	7	8	9	41	42	43	44	45	46

Figure 8.

Other contingency checks were set up for all calculated inventory items. These checks were not made to check the accuracy of machine calculations, but to find incompatible combinations that slipped through the coding operation. For example, the assignment program used had a maximum allowable value for travel time on a link and even though safeguards were built into the coding instructions to prevent exceeding this value, it was still possible for a coder to code inadvertently a link length and zoned speed combination which would pass the contingency checks for coding but give a value exceeding the allowable maximum. Contingency checks for each of the calculated values were, therefore, established to eliminate these errors.

In addition, a "zero balance" check was performed to insure the completeness of the coded network since this is the most essential requirement of the traffic assignment program. To perform this check the deck of network inventory cards was reproduced with the A and B nodes reversed. This deck was then merged with the original deck and the cards sorted in sequence on the A node. This permitted a machine summary to be made of the number of links emanating from each node. This nodal link summary was then mechanically compared to a manual count of the number of links at each node (coded on Form 130.2, nodal link summary, Fig. 8) punched into a separate deck. If the difference in the number of links at each node from both sources did not equal zero, the coded network was checked to determine if the network coding was incorrect or the manual count was incorrect. Using this procedure all missing or duplicate links in the arterial system were found, thus eliminating program stops during traffic assignments.

MANPOWER REQUIREMENTS

The Niagara Frontier arterial network inventory and coding operation required approximately two months to complete and was accomplished with six coders and one coding supervisor. At the end of this period some 3,900 miles of arterial streets and highways had been inventoried and described in numeric form by 2,020 nodes and 3,330 links. To provide a basis for estimating manpower and time requirements for future inventories of this type, a record was kept for each significant phase of the operation. Excluding the time required to determine the arterial system (which was done by professional personnel), the inventory and coding required a total of 1,546 man-hours. This total time can be broken down into three phases: zone and node numbering, posting inventory data, and coding. The actual time required for each of these phases was as follows:

Operation Phase	Man-Hours
Zone and node numbering	105
Posting inventory data	625
Coding	816
Total	1,546

For estimating purposes the man-hours must be related to the size of the network inventoried. Because the number of nodes used to describe a network bears a direct relationship to network size, the node has been adopted as a standard unit and all time reduced to the man-hour requirements per node. The man-hour requirements for each node in the network are as follows:

Operation Phase	Man-Hours per Node
Zone and node numbering	0.052
Posting inventory data	0.309
Coding	0.404
Total operation	0.765

Applying these man-hour rates to the number of nodes in a future network to be inventoried should provide a good basis for estimating the time and manpower required to complete the survey.

IMPLICATIONS

There are many benefits to be gained from the symbolic representation of a detailed inventory of a regional transportation network. This is especially true where the network representation can be assembled in the memory of a high-speed computer which provides, in effect, a simulation or operating model of the actual network itself. Some of the remarkable possibilities are presented in the following:

1. Performance characteristics of the actual network can be assembled and summarized at high speeds. With current link volumes included in the inventory, vehicle-miles of travel can be summarized by link type and by geographic location. Analyses of the spatial characteristics of overloads and excess capacity by type of facility can be programmed. Other characteristics such as the pattern of parking restrictions, intersection controls, and speed regulations, can be assembled, cross-tabulated, and analyzed in minutes instead of the days required to make a field inspection.

2. A better understanding and testing of network performance is possible. Relationships between characteristics of the network can be analyzed and tested to obtain a

better idea of how networks perform. The impact of intersection control on free speed, the relationship of speed to congestion, and the impact of turning movements on both speed and capacity are typical areas where additional research is needed.

3. More realistic assignments are possible. The inclusion of all arterial streets in the network to which traffic is assigned was a significant improvement over previous assignment routines. With better understanding of network performance with respect to capacity, speed, turns, etc., better assignment techniques can be devised. Studies of route choice, optimum zone size, highly detailed assignment requirements for special cases such as redevelopment areas and central business districts will provide a better basis for designing assignment programs.

4. Better testing and evaluation of plans are possible with improved assignment techniques. With faster and more accurate and detailed assignment techniques, better evaluation of proposed plans is possible. The cost of travel over a network, based on operating costs, accident costs, and personal time costs, is a powerful tool in measuring relative performance of different network plans. Additional refinement of these cost factors will improve the ability to discriminate between plans. With improved assignment techniques and especially with the high speed-low cost aspect of computer assignment, the question of scheduling of planned improvements seems ripe for analysis and programming.

In addition to the advantages gained in traffic assignment and the summary and review of network data, many implications can be drawn from the use of this numeric form of inventory for the arterial network. Through the use of simple coding procedures the arterial network can be related to the land-use survey, provide a means of sampling the vehicle-miles of travel over the network, serve as a base for mass transit (bus and rail) studies, and be used to inventory all data related to streets and highways. The use of similar coding techniques may also have application in the study and assignment of rail travel and the movement of goods.

Relating the Arterial System to Land Use

The land use along each arterial street can be related to the coded network by simply cross indexing the two surveys. Land use in a study area can be coded by block face to each street by giving each street and each block a numeric code. By using a block numbering system based on an X-Y grid coordinate system and by adopting a directional coding convention for the network so that the X-Y coordinates always increase in the direction the link is coded, the land use for each block face fronting on the arterials can easily be summarized for each link in the network. This is accomplished by matching the network card deck and the land-use deck on block number within street code.

A wealth of information may be obtained from the land-use and arterial relationship.

1. The land fronting on each type of arterial can be summarized to determine if certain arterial types generate predominant land uses.

2. The sphere of influence of an expressway on the land use in an area may be determined through the study of successive land-use band widths on either side of the expressway.

3. Intersection types can be reviewed to ascertain if particular land uses are peculiar to intersections of the same type.

In the study of alternate locations for a route, a detailed study can be made quickly of the type and amount of land that will be displaced by each alternate route. In fact, if the appraised evaluation of each land-use parcel can be obtained from assessor's records, these values can be coded and the loss in the tax base determined for each route. In addition, within the assumption that the assessed evaluation is a function of market value, an estimated right-of-way cost could be calculated from the land-use information for alternate route locations. Moreover, couple this knowledge with the use of high-speed computers, and a means is available to determine what savings, if any, could be attained by shifting the alignment of a proposed alternate within specified locational restrictions through a corridor.

Sampling Vehicle-Miles of Travel

Using the street code and link identification, it is also possible to separate all arterial streets from local streets by machine processing. This technique is very useful in establishing sampling procedures for vehicle volume counts to determine vehicle-miles of travel over the local and arterial streets. For local streets, the sample can be selected on the basis of the coded block faces used in the land-use survey. The address of each sample location can be readily found from the block coordinates and street code.

To sample arterial street travel the sample may be selected either by link or node. For example, if it is decided to take intersection counts at every fifth intersection, the sample would be machine selected from the total number of nodes. The street address of each intersection could then be determined from the street code of the links emanating from the node. If it is decided to sample links and count at midblock locations, the sample can be selected in the same manner and the link identified by street name and the names of the intersecting streets at both ends. This sampling procedure for travel on local and arterial streets not only makes it possible to take a better statistical sample through machine processing but also saves much time in determining the street addresses required to locate the count stations in the field.

The method is particularly useful in scheduling a short-count program to determine travel volumes. A sample of intersection locations could be determined and short counts made at each station. If the approach volumes at each intersection are counted for each turning movement, the volume on each link emanating from the intersection node can be summarized by machine through use of adjacent node numbers to identify individual movements. The short counts can then be expanded to 24-hr or average annual daily traffic through machine processing by relating the short counts to control station counts. Since the ultimate goal of a counting program is to determine the volume of traffic on each link of the network, the selected sample can be analyzed for turning movements by intersection type and relationships developed to extrapolate the sample counts to the remainder of the network.

Mass Transit and Railroad Studies

Although primarily developed for the inventory and coding of a highway network, the same techniques may be applied to mass transit lines and urban freight railroads. At the time the arterial network is coded the links which are utilized as bus routes (including local streets) can be given an identifying code and subsequently separated from the highway network for transit assignments. A transit network derived by this method would have to be modified slightly to meet its own special needs, such as additional load nodes along the system to account for pickup and discharge of passengers, the insertion of transfer points to permit changing from one bus route to another, and the use of turn prohibitors to eliminate impossible trips which might occur (not part of regular scheduled bus route) due to favorable time on transfer links. The rail system would require development of similar coding techniques such as transfer points and turn prohibitors but the same numeric coding system to identify links could be used throughout.

Of course, the real research problem is to determine how much the choice of mode of travel is a function of the alternative networks and how much is a function of factors such as car ownership, demographic characteristics, and other factors. If it is possible to segregate the auto-using only population from the transit-using only population, then it would be possible to allow the network performance itself to determine the mode split for the remaining population. To the extent that this is a large proportion, this would not only greatly facilitate the process of assigning travel but would also represent a significant improvement on present assignment techniques as related to mode of travel. With present techniques, each mode is generally segregated and assigned separately to its own particular network.

Inventorying Data Related to Streets and Highways

The numeric coding system for describing the arterial network also provides an excellent base for inventorying all data related to streets and highways. Although this paper has primarily stressed the use of the system to inventory and code for traffic assignment purposes, it should be pointed out that items such as lighting, parking meters, traffic control signs, traffic signals, and other related information can readily be inventoried and stored for future reference using this inventory and coding technique. With few modifications it would be possible (by using street name codes and number addresses) accurately to locate by street address the items previously listed. Moreover, if a street and highway system is inventoried and coded in sufficient detail, i.e., both local and arterial streets for the entire study area, it would be possible to select an arterial system based on a given set of criteria by machine processing. This would perhaps eliminate much of the subjectivity that has been experienced in the past when defining an arterial network for a study area.

SUMMARY

The implications of numeric coding for an arterial network are just now beginning to be investigated. From the foregoing it can easily be seen how many of the surveys made during the course of a transportation study can be integrated through numeric coding which also provides a basis for storage of information in a data bank. The availability of high-speed data processing machines provides a relatively low-cost method of directly comparing the data of one survey to another and permits ready access to individual items stored in the data bank.

While this paper has stressed the use of numeric coding primarily for traffic assignment, the implications drawn from the technique point out many areas for further research: the determination of vehicle volumes on each link in a network based on a selected sample of short counts, the integration of several modes of travel into one overall assignment, and the simulation of actual operating conditions on a network based on the characteristics inventoried.

The Upstate New York Transportation Studies (UNYTS), as a continuing study, will refine or develop and use many of the methods briefly discussed. Many other additional uses will undoubtedly be found as new and different approaches are developed to study the urban transportation problem.

ACKNOWLEDGMENTS

In developing the method discussed in this paper, the author was assisted by the work of other transportation studies, especially the Chicago Area Transportation Study and the Pittsburgh Area Transportation Study. Special acknowledgment is also made to Roger L. Creighton and John R. Hamburg.

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Trucks at Rest

LOUIS E. KEEFER, Director, Pittsburgh Area Transportation Study

•THE purpose of this paper is to report a variety of preliminary findings about trucks at rest, that is, when they are not in movement on the streets. Such findings are limited to the data collected in a typical truck-taxi survey conducted by a typical areawide transportation study. Thus, they are not as exhaustive as might be developed from more intensive, in-depth interviews or observations. They are, however, useful in suggesting that, although highway improvements will materially aid the trucking industry, careful attention must be given also to developing modern and efficient facilities for loading and unloading, parking and maintenance, and other at-rest activities.

The Pittsburgh Area Transportation Study (PATS) made its truck-taxi survey during the fall and early winter of 1958. The survey, scheduled concurrently with the home interview survey, recorded trips by trucks and taxis registered at addresses in the study area. These were sampled at the rate of one in ten from official registration lists in Harrisburg (1). The interview was made with the driver of each vehicle or with his dispatcher. The data recorded included the type of vehicle, the garaging address, the business of the owner, and trip information similar to that obtained in the home interview survey.

During the survey 45 percent of the sample vehicles did not report any trips on the designated travel date. At first, this would appear to reflect only the relatively depressed economic condition of the Pittsburgh area during the survey period. Subsequent appraisals by various interviewers would indicate, however, that very few fleet operators or reputable businessmen reported no trips. Most non-tripmaking trucks appeared to be owned by individuals who did not want to be bothered; these persons seemed to find it simpler to say the truck was not used than to describe the trips that may have been made. The various accuracy checks indicated that many trips were, in fact, unreported. A correction factor of 20 percent was applied for planning purposes (2).

However, the proportion of sampled vehicles that did report tripmaking was fairly consistent by truck type and by day of week (Table 1). (For purposes of this paper, a "light truck" is defined as having 4 wheels; a "medium truck" is defined as six wheels or more and a straight body; and a "heavy truck" is defined as any combination vehicle, that is, truck-trailer, truck-semitrailer, etc.) Moreover, the average number of trips per vehicle per day was entirely consistent (Table 2). These findings are shown to demonstrate that the data for tripmaking trucks only seem relatively unbiased (although also subject to some underreporting). Thus, within limits, the conclusions drawn regarding the at-rest characteristics of the 23,000 tripmaking trucks should be generally representative of the 19,000 non-tripmaking trucks as well.

PROPORTION OF TIME AT REST

Various analyses have demonstrated that not all motor vehicles registered in the study area are likely to be used during a typical weekday. This includes both cars and trucks. On the average, only 81 percent of the 393,000 registered cars will leave the garage, and only 55 percent of the 42,000 trucks garaged and operating in the study area (3). Even the motor vehicles that are used are not used very continuously — at least, not in continuous motion on the streets. On the average, both tripmaking cars and trucks are being driven less than an hour a day; they are at rest 95 percent of the time!

Paper sponsored by Committee on Origin and Destination.

TABLE 1

PERCENTAGE OF TRIPMAKING VEHICLES IN THE TRUCK-TAXI SURVEY

Day	Vehicle Type				Avg. All Vehicles
	Taxis	Light Trucks	Medium Trucks	Heavy Trucks	
Monday	90	56	52	65	55
Tuesday	96	57	46	65	57
Wednesday	100	55	53	71	55
Thursday	82	58	53	83	57
Friday	—	53	54	43	53
Avg. weekday	91	56	52	67	55

TABLE 2

TRIPS PER DAY PER TRIPMAKING VEHICLE

Day	Trips (no.)				Avg. All Vehicles
	Taxis	Light Trucks	Medium Trucks	Heavy Trucks	
Monday	46	11.2	8.4	3.8	10.7
Tuesday	46	8.2	8.6	2.5	11.0
Wednesday	33	8.7	9.4	3.7	9.2
Thursday	40	10.8	8.9	3.5	11.1
Friday	—	13.1	8.7	2.9	11.2
Avg. weekday	42	10.5	8.8	3.4	10.6

TABLE 3

TRUCK-TAXI TRIPS INVOLVED IN THE DURATION-OF-STOP ANALYSIS

Type of Trip	Trips (no.)				Total
	Taxis	Light Trucks	Medium Trucks	Heavy Trucks	
No stop	11,763	24,175	4,477	10	40,425
Stop calculated	16,740	112,733	54,435	2,192	186,100
Stop unknown	661	14,943	7,882	892	24,378
Total	29,164	151,851	66,794	3,094	250,903

The immobility of the automobile (an incongruous phrase) is easily understood. When a driver takes his automobile somewhere (to work, for example) there it will normally stay until he takes it elsewhere. It cannot readily be shared by another driver (even in the same family) because it cannot be returned automatically to some common base of operations, such as home. The immobility of the truck is more difficult to picture. The typical image is that of many trucks constantly in motion: picking up laundry and dry cleaning, delivering department store purchases, making calls to service television sets, and generally circulating among a diversity of urban activities. Stops are viewed as momentary and travel as continuing throughout the workday. Actually, this impression is misleading; many stops are much more than momentary.

The duration of stop was not directly reported in the PATS truck-taxi survey. Rather, it was calculated from the start and arrival times reported for each trip. All trips by each truck were sorted into trip sequence. Then, the arrival time of the first trip was subtracted from the start time of the second trip; the arrival time of the second trip was subtracted from the start time of the third trip; and so on, to derive the duration of stop for the first, second, and following trips, respectively. The duration of stop for the last trip, of course, could not be calculated.

All told, the duration of stop remained unknown for 24,378 trips (Table 3), with the proportion highest for the truck types reporting the fewest total trips per truck (mediums and heavys). On average, as the last trip of the day, the vast majority are to base of operations (89 percent); the next most frequent purpose is personal business (9 percent). The remainder are varied throughout the four other trip purposes (to pick up goods, to deliver goods, to pick up and deliver goods, and to service). This breakdown holds generally for each vehicle type; to base of operations, for example, accounts for 84, 87, 92, and 78 percent of the last trips by taxis and by light, medium, and heavy trucks. Unfortunately, there is no way of knowing how many of these last trips also involve overnight loading, unloading, or other activities.

It is known, however, that the last trip usually occurs late in the afternoon, a common sense observation substantiated by Figure 1. For example, at midafternoon (3:00 PM) about 68 percent of the light trucks have yet to make their final trip of the day, about 59 percent of the medium trucks, and about 51 percent of the heavy trucks; after dinner (7:00 PM) only about 5 to 6 percent of the light and medium trucks are still on the road and about 20 percent of the heavy trucks. By comparison, it is evident that many taxis are on the streets until the last party breaks up.

Table 3 shows that 40,425 trips reported no duration of stop, with the proportion highest for taxis and light trucks. This is partly a function of the time coding technique;

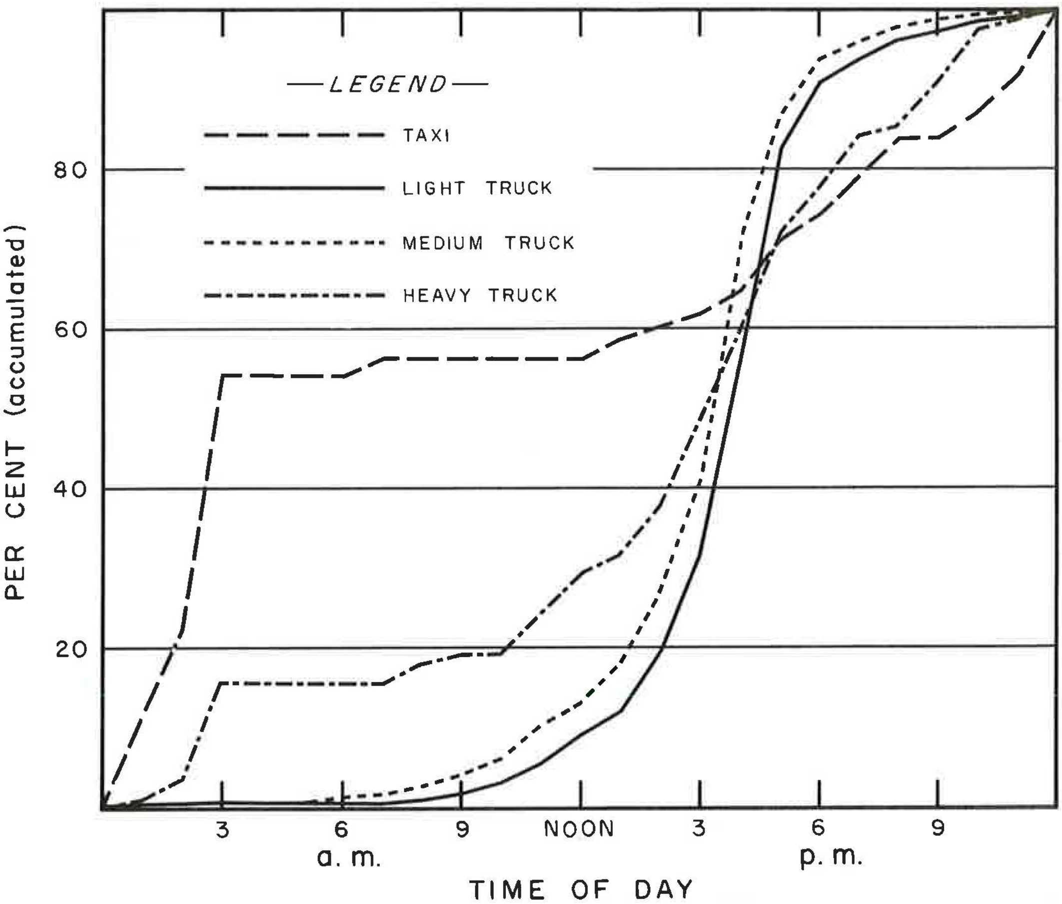

Figure 1. Percentage accumulation of last daily truck-taxi trips.

although start and arrival times were reported to the nearest minute, they were coded to the nearest tenth of an hour. Thus, a 5-min stop could be coded as no stop or a 2-min stop as a 6-min stop, depending on rounding. This is not a serious problem, however, and will not affect the analysis so much as erroneous time reporting itself. Despite the use of truck trip logs (4) distributed in advance of actual interviewing to truck fleet dispatchers and, subsequently, to their truck drivers to maintain a running record of the day's tripmaking, there are likely to be errors in the reported travel times. Except for a tendency to round off times to the nearest quarter hour, however, there should be no obvious bias; rounding errors should be largely self-canceling. Tripping, or making multiple stops within the same block, is not considered in the analysis; for certain kinds of delivery trucks, this omission would tend slightly to overstate the average duration of stop.

With these cautions asserted, the general analysis findings follow; they are organized largely to compare duration of trip stops by trip purpose, destination ring and destination land use, business-occupation, time of day, and truck type. The trips with unknown lengths of stops are specifically excluded; the findings are for the 226,525 trips whose duration of stops could be calculated.

Duration of Stop by Trip Purpose

Six trip purposes were used in the truck-taxi survey. A given trip could be to pick up goods, deliver goods, or for the combination purpose of picking up and delivering goods. These three trip purposes accounted for 71 percent of all truck trips. Trips to the base of operations (for example, a dump truck garaged overnight at the driver's home and taken to a construction site in the morning) were 15 percent of all truck trips. Service calls were 11 percent. About 3 percent of all truck trips were for work-connected personal business. Where pickup or panel trucks were used as a family car, the trips were not recorded in the truck-taxi survey but in the home interview survey. Taxi trips consisted entirely of service (96 %) and to base of operations (4 %) purposes.

TABLE 4

AVERAGE DURATION OF VEHICLE STOP BY TRIP PURPOSE

Purpose	Average Duration of Stop (min)				Avg.
	Taxi	Light	Medium	Heavy	
Pick up goods	—	29	51	110	36
Deliver goods	—	15	27	127	19
Pick up and deliver	—	14	25	50	17
Service	6	122	91	—	58
To base of operations	63	79	55	131	73
Personal business	—	90	47	—	82
Avg.	7	37	38	113	34

Table 4 gives the average duration of vehicle stop by trip purpose by vehicle type. The larger and heavier trucks made the longest stops, almost two hours on the average whether loading or unloading or simply waiting for an assignment. Obviously, they are seldom used for making service calls or for personal business. The smaller trucks

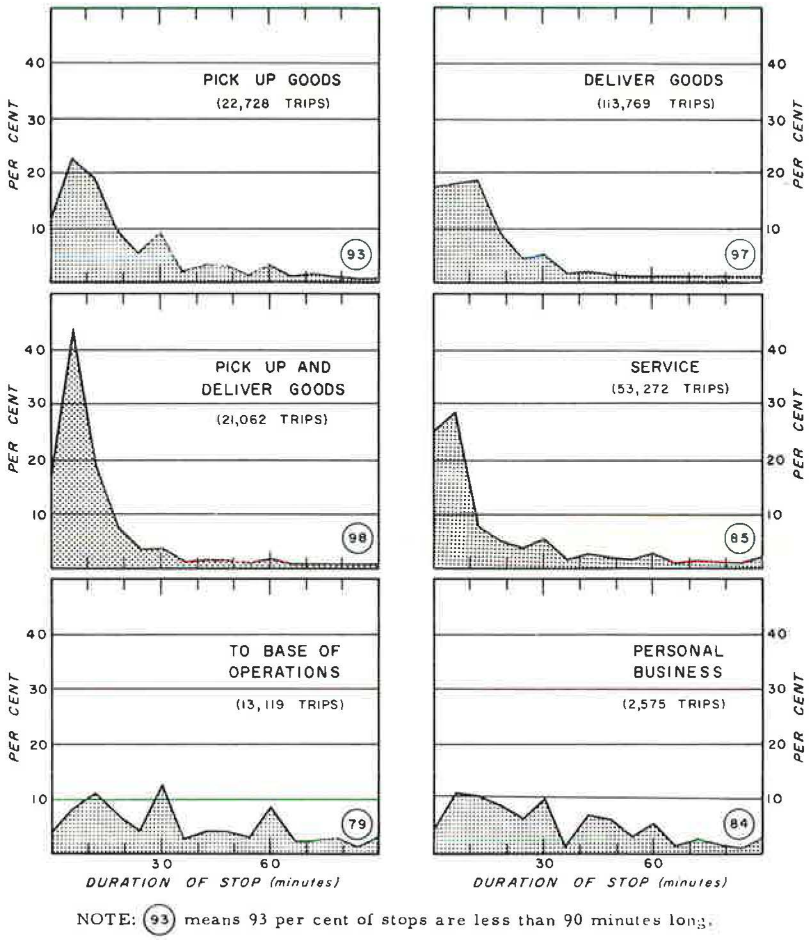

Figure 2. Percent of truck-taxi trips by duration of stop by trip purpose.

(lights and mediums) averaged just over one-half hour per stop. Service stops ranged from 1½ to 2 hours. Goods-handling stops ranged from 14 to 51 minutes. Taxis made the shortest service stops (6 min) but stopped as long as trucks at their base of operations.

Without respect to vehicle type, the personal business trip required the longest period of vehicle inactivity (82 min), somewhat longer than the 73-min wait at the base of operations. Service calls averaged 58 minutes. Picking up goods required 36 minutes, or nearly twice as long as delivering goods. Where goods were both picked up and delivered, only 17 minutes were required; apparently such trips can involve only small parcels easily handled by the driver alone.

Figure 2 shows the percentage of truck trips by duration of stop by trip purpose. The circled numbers at the lower, right-hand corner of each graph show the proportion of trips with stops less than 90 minutes; the total number of trips in each trip purpose category is shown in parentheses. For example, there were 2,575 personal business trips, of which 16 percent require a stop exceeding 90 minutes. Except for personal business and to base-of-operations trip purposes, the distributions are marked by the high proportion of trips that make short stops and by the rapidly decreasing proportion that make longer stops. The bumps at ½- and 1-hr intervals reveal the slight biases in time reporting.

The foregoing evidence suggests that the goods-handling stops (except for the largest trucks) may account less for the average truck's daily at-rest time than do the stops at its base of operations and at the driver's personal business destinations. Actually, it would seem that stops for all purposes might be shortened in the future. Better vehicle design and improved loading-unloading facilities should reduce the average time at rest for goods-handling purposes; better management should reduce the waiting for assignment at a base of operation; substitution of an alternate travel mode, or a management ruling, might eliminate the inactivity during some of the personal business calls (most of these trips, however, are to eat lunch and so could not be eliminated). Similarly, the service call may never be shortened.

Duration of Stop by Truck Owner's Business

The truck-taxi survey recorded the truck owner's or operator's business as one of 10 categories. Three (primary metal manufacturing, outdoor public services, and mining-agriculture) reported only 1,535 trips combined, or 0.7 percent of all reported truck trips, and hardly warrant discussion. (It is significant to note, however, that the dominant employer in the Pittsburgh area, primary metals, accounted for only 7 percent of the total trucks garaged in the area and for an even smaller proportion of the total tripmaking.) Manufacturing other than primary metals, however, was the most active trip-producing business, reporting 27 percent of all trips. Transportation, utilities, and communications, as a group, reported 24 percent; wholesaling, 21 percent; services, 13 percent; retailing, 12 percent; governmental, institutional, and religious, as a group, 8 percent.

Table 5 shows the duration of vehicle stop according to the owner's business by vehicle type. Again, heavy trucks, regardless of the business in which they are used, made the longest stops; light and medium trucks, the shortest stops. As among the different businesses, there was remarkably little variation as to duration of stop. All except wholesaling averaged around one-half hour; wholesaling, however, averaged twice that. No clear reason can be determined for this variation. Possibly, it is because wholesaling activities tend to cluster in particular areas and create their own crowding and congestion. Certainly, this is true around the produce markets lining Penn Avenue in Pittsburgh's Strip district.

Figure 3 shows that 17 percent of the stops by trucks in the wholesale businesses were longer than 1½ hours, a noticeably higher proportion than for trucks in the other businesses. Generally, however, the distributions are more uniform than those by trip purpose shown in Figure 2. This is not very surprising — the nature of the goods to be moved, which can be inferred from the truck owner's business, is perhaps less important than their quantity and gross weight. It would normally take longer to load a large truck than a small truck, no matter what the cargo.

Duration of Stop by Destination Land Use

Clearly, there should be some relationship between the trucker's business-occupation and the type of land use to which most of his truck trips are destined. But a truck owned by a wholesale firm would obviously make trips to other kinds of activity sites, for example, to retail establishments. This is why there cannot be an exact correspondence between the duration of truck stop by business-occupation (Table 5) and by destination land use (Table 6).

TABLE 5
AVERAGE DURATION OF VEHICLE STOP ACCORDING TO OWNER'S BUSINESS

Business	Average Duration of Stop (min)				Avg.
	Taxi	Light	Medium	Heavy	
Retail	—	33	39	115	35
Services	—	25	29	171	26
Wholesale	—	81	48	80	70
Manufacturing (other than primary metals)	—	16	24	146	18
Transportation, utilities, and communications	7	52	42	142	26
Governmental, institutional, and religious	—	18	35	28	25
Avg.	7	37	38	113	34

Although heavy trucks average a 5-hr stop at residential land, this seems appropriate for loading or unloading a moving van — about the only kind of heavy truck likely to make residential stops (Table 6). The 14-min taxi stops at "transportation" represent reporting-in at the taxi company headquarters; the 8-min stops at "streets" represent waiting at taxi stands.

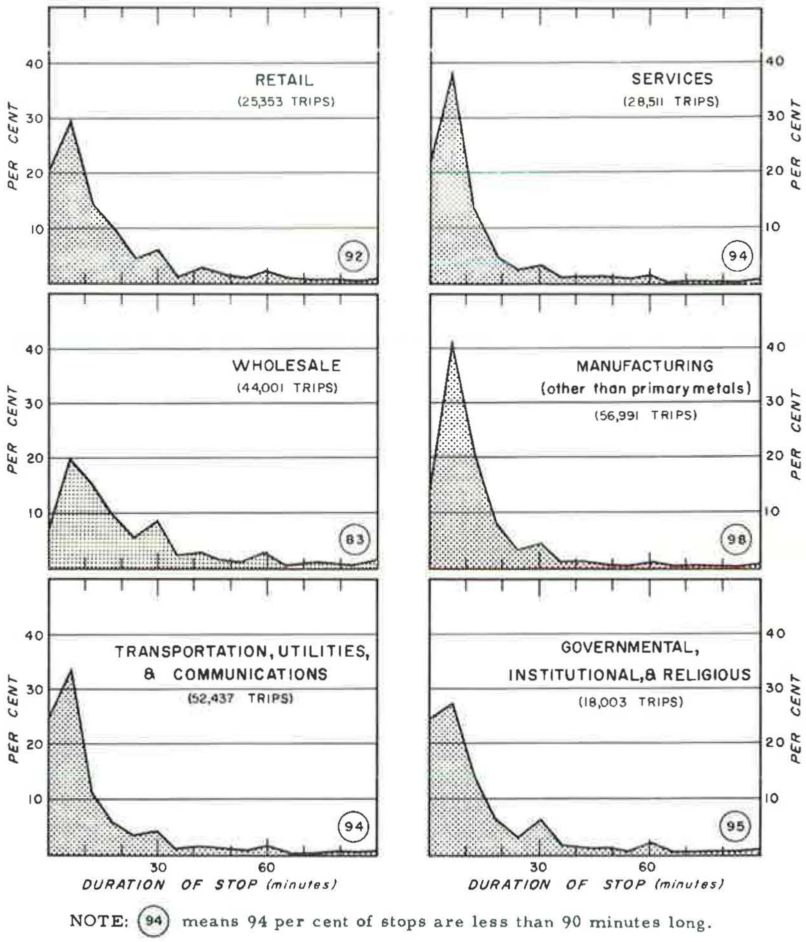

Figure 3. Percent of truck-taxi trips by duration of stop by owners business.

TABLE 6

AVERAGE DURATION OF VEHICLE STOP BY DESTINATION LAND USE

Destination Land Use	Average Duration of Stop (min)				Avg.
	Taxi	Light Truck	Medium Truck	Heavy Truck	
Residential	6	30	33	306	27
Retail establishments	6	33	25	136	30
Services	6	46	35	33	37
Wholesale	5	59	48	69	53
Manufacturing	4	83	53	130	67
Transportation, utilities, and communications	14	76	56	104	58
Public buildings	4	63	30	30	39
Public open space	2	68	50	—	51
Airports, streets, and railroad land	8	27	51	24	26
Avg.	7	37	38	113	34

TABLE 7

AVERAGE DURATION OF VEHICLE STOP BY DESTINATION RING

Destination Land Use	Average Duration of Stop (min)				Avg.
	Taxi	Light Truck	Medium Truck	Heavy Truck	
Ring 0	6	29	24	132	19
Ring 1	7	37	29	57	28
Ring 2	7	31	29	78	27
Ring 3	8	30	31	129	27
Ring 4	6	32	31	118	29
Ring 5	8	33	34	104	31
Ring 6	7	39	39	65	38
Ring 7	22	39	30	42	36
Avg.[a]	7	33	32	89	30

[a]Averages do not correspond with other tables because trips to ring 8 (outside the cordon line) are excluded.

Duration of Stop by Destination Ring

It might be supposed because of congestion and crowding that truck stops would tend to be longest in the more highly built-up central portions of the study area (the inner rings). This does not seem to be true. The average duration of stop (Table 7) generally increases with increasing distance from the Golden Triangle (ring 0). In the Triangle itself, light and medium truck stops are shortest (29 and 24 min, respectively). Taxi stops are also shortest there (6 min) but heavy truck stops are longest; however, they are also the least frequent (only 1 percent of all Golden Triangle truck trips). The overall brevity of stops in the Triangle suggests several possibilities: greater mechanical efficiency of goods handling equipment; greater manual efficiency because working under time pressure; greater enforcement of loading zone time limits; greater frequency of illegal parking (and, hence, increased desire to limit the length of stop); or simply better overall business management by downtown firms. This, of course, is just guesswork; it is impossible to discover the reasons from transportation study data.

Omitting trips beyond the cordon line, Table 7 shows, by inference, that such trips have longer stops on the average than trips with destinations inside the cordon line (the overall duration of stop time drops for each truck category). For example, heavy truck trips to ring 0 through 7 averaged an 89-minute stop; trips to ring 0 through 8 averaged 113 minutes. There were lesser differences for light and medium truck trip stops. There is no readily apparent reason for this; perhaps it is simply part of the transition between predominately urban and predominately rural activity.

Duration of Stop by Time of Day

As shown by Figure 4, the longest stops of the day for any truck tended to be during the morning hours (5:00 to 9:00 AM). From 8:00 to 4:00 PM, the average duration of stop decreased steadily. Possibly, this reflected a tendency for trucking activities to pick up momentum as the business progresses — starting slowly while there is still much time and accelerating as there is increasingly less time to get the job done. Such at-rest trucking activity as continues after normal closing hours (5:00 to 6:00 PM) again resumed a slower pace. There were, of course, slightly longer stops during the lunch and dinner hours.

It is not possible to demonstrate psychological motivation by transportation study data; however, it is possible to show that the average duration of stop for all trucks varies by time of day by trip purpose (Table 8). There is a discernible trend for nearly all kinds of trips to involve progressively shorter stops between 6:00 AM and 6:00 PM. This seems particularly so for trips to pick up goods — decreasing from 74 minutes to 20 minutes. Evidently, the heaviest and most complete load is taken on early in the

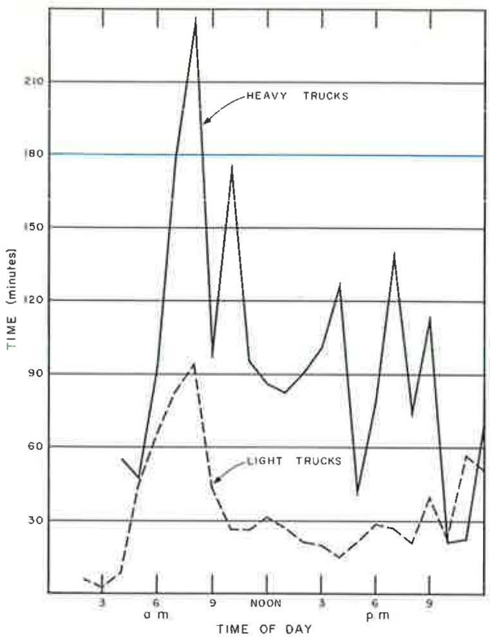

Figure 4. Average duration of truck stops by time of day.

TABLE 8

AVERAGE DURATION OF STOP FOR ALL TRUCK TRIPS BY ARRIVAL HOUR BY TRIP PURPOSE

Arrival Hour (beginning)	Trip Purpose: Pick-up	Deliver	Pick-up and Deliver	Service	Op. Base	Pers. Bus.
6 AM	74	18	12	194	107	6
7	51	19	19	244	157	273
8	46	24	22	235	92	116
9	38	16	10	121	92	99
10	34	16	12	68	82	31
11	27	17	14	66	82	57
12 Noon	33	17	17	88	73	47
1 PM	25	14	15	81	56	39
2	23	14	12	45	56	61
3	26	12	13	40	49	117
4	14	11	7	30	39	31
5	20	12	8	67	51	60

TABLE 9

COMPARISON OF AVERAGE TRIP TIME AND AVERAGE STOP TIME

Vehicle Type	Average Trip Time (min)	Average Stop Time (min)
Light truck	13	37
Medium truck	16	38
Heavy truck	34	113
Taxi	14	7
Avg.	14	34

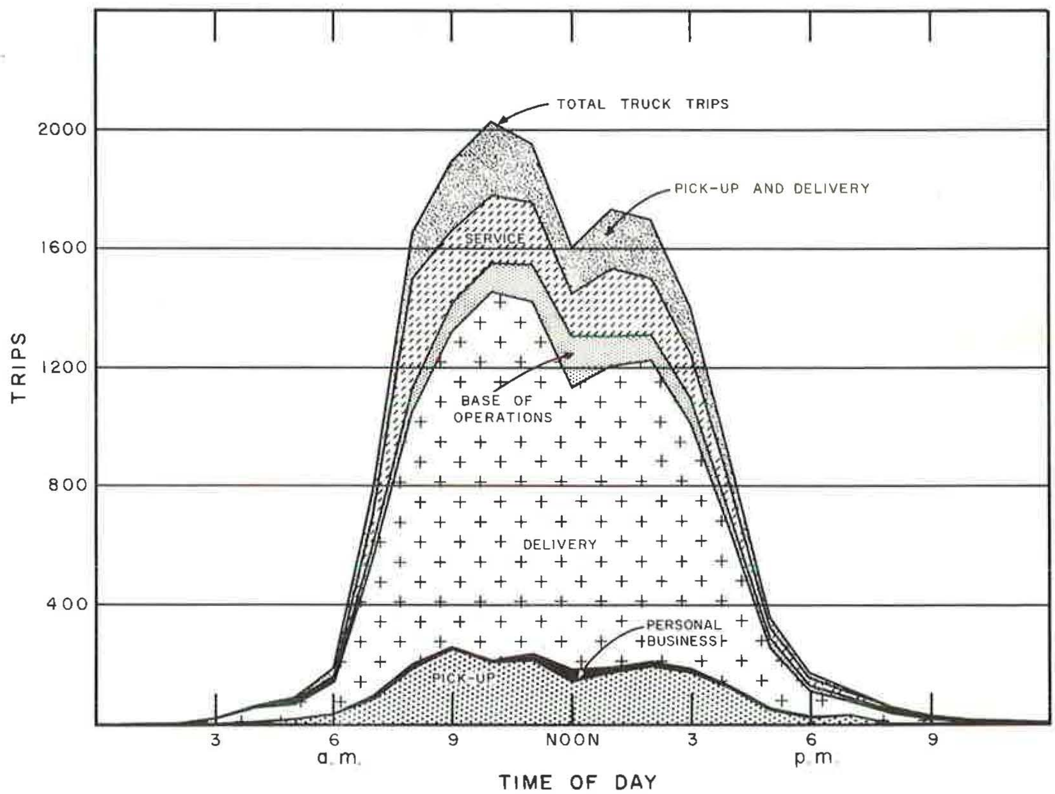

Figure 5. Truck trips by time of day by trip purpose.

morning; loads taken on later in the day must be lighter and less complete (unless it is assumed that the goods handlers work faster in the afternoon). Strangely enough, there was less variation in the average duration of stop to deliver goods or to pick up and deliver goods. Since the proportions of truck trips by trip purpose do not vary significantly by hour of day (Fig. 5), it is clearly the trend toward shorter stops that produce the pattern in Figure 4.

COMPARISON OF TRIP TIME AND STOP TIME

If the typical truck is at rest 95 percent of the day, the average stopped time must greatly exceed the average time in motion, or trip time. Strictly speaking, it is impossible to make a direct comparison because the duration of stop after the last trip of the day could not be calculated. This, of course, is the longest stop of all, representing, in most cases, overnight parking or storage. Although there is some truck activity after dark, the bulk of all truck trips occur during the day; in fact, nine out of ten truck trips are made between 7:00 AM and 6:00 PM (Fig. 5).

Excluding the time at rest after the close of the work-day, however, the average truck stop during the day took about twice as long as the average truck trip itself (Table 9). The average trip time for a light truck was 13 minutes, while its average stop time after the trip was 37 minutes; medium trucks averaged 16 minutes per trip, 38 minutes per stop; and heavy trucks, 34 minutes per trip, almost 2 hours per stop. Taxis, on the other hand, took longer to complete their journeys than to complete their stops, 14 minutes vs only 7 minutes.

Some concept of a typical truck's activity during the day can be reconstructed from what has been presented (except that a representative mixture of trip purposes will have to be assumed; there is a wide variation by individual vehicles). A typical trip-making medium truck, for example, makes nine trips a day. Without respect for the owner's business, assume that one trip is to the base of operations, one is to pick up goods, and seven are to deliver goods. The 9 trips themselves would total 144 minutes (16 min × 9); the trip stop at the base of operations, 55 minutes (Table 4); the trip stop to pick up goods, 51 minutes; and the 7 stops to deliver goods, 27 minutes each. This totals 439 minutes, or just over 7 hours. In this hypothetical example, the truck is in motion about $2\frac{1}{2}$ hours a day or roughly 10 percent of the time, somewhat more than the average total travel time.

Clearly, the shortening-up of truck stops could have important implications. The productivity per truck would be enhanced. Perhaps two trucks could do the work of three. This would not mean less truck travel; the same mileage would result. But it would mean that truck registration would be reduced as could be the consequent demand for terminal and parking facilities in particular areas of concentrated truck activity. No doubt truck owners and operators are well aware of this. Their efforts toward improved truck utilization, together with the trend toward higher-capacity trucks, may be the reason why truck registrations are increasing less rapidly than auto registrations in many urban areas.

The most obvious way to improve truck utilization, of course, is to operate around the clock with successive drivers. With the exception of long-haul carriers and certain special kinds of off-hour trucking (as by newspapers, dairies, shift-work plants, etc.), very little truck activity occurs after normal working hours. Despite the potential cost savings involved, business affairs evidently cannot easily be rearranged to take advantage of the less crowded driving and parking conditions after hours.

SUMMARY

Despite relative brevity of a majority of truck stops, they are, on the average, longer than casual observation would suggest. Counting overnight storage, the average truck is at rest 95 percent of the time; counting only the stops made during the day, the average truck is at rest more than twice as long as it is in motion. This suggests that, although highway improvements will materially aid the trucking industry, careful attention must be given also to developing modern and efficient facilities for loading and unloading, parking and maintenance, and other at-rest activities.

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2. "The Accuracy Checks." Vol. 1: Study Findings, p. 11, PATS (1961).
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Variations in Personal Travel Habits by Day of Week

SHELDON W. SULLIVAN, Pittsburgh Area Transportation Study

• ORIGIN-DESTINATION studies have demonstrated that travel in an urban area is remarkably regular in nature. It is, indeed, this particular phenomenon that permits a confident prediction of future tripmaking. This does not mean, however, that tripmaking is exactly orderly day by day but, rather, that travel is highly repetitive and, being so, forms a consistent—hence, predictable—pattern over a period of several weeks or months.

Certain trip types, such as trips from home to work or to school and return, are very regular on a daily basis through the week. These types of trips are a strong influence in stabilizing the total number of trips occurring day to day. Other types, however, such as trips for shopping, social-recreation, and personal business reasons, are apt to be more widely and unevenly spaced through the week, and therefore, are chiefly responsible for the day-to-day fluctuations that occur in tripmaking volumes.

This paper explores some of the weekday tripmaking variations that were revealed in the Pittsburgh Area Transportation Study's 1958 home interview survey. Chiefly, attention is given to the day-to-day variations in tripmaking for the whole study area, with a separate examination of daily variations in travel to the Golden Triangle, Pittsburgh's central business district.

SAMPLE ADJUSTMENT

Evenness in Sampling a Factor

Before measuring daily tripmaking variations, it was necessary to adjust for the differences by day of the week in the number of interview schedules used in deriving the original trip factors. These factors were based on 16,247 completed interviews plus 1,683 schedules in which trips were possible but, for various reasons, interviews were not consummated. The method of correction was to find each day's percentage variation from the daily average number of interviews and to apply that percentage to all trip tabulations for each day. For example, with the 5-day average number of interviews equal to 100.0, Monday total interviews amounted to 107.19465 times that average, that is, slightly over 7 percent higher. Applying this factor to Monday's total travel of 2,268,080 person trips adjusts the number of trips to 2,115,852 person trips.

Perhaps a superior method of adjustment could have been achieved by using more complex factors based on some of the unexpanded household characteristics, such as auto ownership, persons per dwelling place, or licensed drivers per dwelling place (Table 1). Inasmuch as this information was not uniformly available for the noninterviews, no attempt was made to include these variables in the correction method. It is noteworthy, nevertheless, that households interviewed on Tuesday have somewhat lower ratios of persons, autos owned, and licensed drivers per dwelling place and have the highest percentage of no autos per dwelling place (Table 1). This probably had some effect on the low trip volumes reported for Tuesday.

Sampling Variability

Given an equalized number of interviews per day, the effect of sampling variability should be relatively slight in this examination since it deals with two large universes.

Paper sponsored by Committee on Origin and Destination.

TABLE 1

COMPARISON OF SELECTED HOUSEHOLD CHARACTERISTICS BY TRAVEL DAY OF WEEK

Day	Completed Interviews	Per Dwelling Place					
		Persons	Autos	Licensed Drivers	Autos Owned		
					0 (%)	1 (%)	2 or More (%)
Monday	3,473	3.33	0.89	1.3	26.7	59.1	14.2
Tuesday	2,958	3.23	0.84	1.2	29.3	57.9	12.7
Wednesday	3,296	3.28	0.87	1.3	28.4	57.9	13.7
Thursday	3,284	3.22	0.85	1.2	28.9	58.3	12.8
Friday	3,236	3.22	0.89	1.3	26.6	59.4	14.0

In the first case, this report deals with data for the entire study area based on 17,930 samples (an average of 3,586 samples per day of week); and in the second, it deals with the most concentrated single trip generation area (about 1,065 samples per day).

AGGREGATE INTERNAL TRIP VOLUMES

Daily Variations by Mode of Travel

After equalization, total tripmaking is characterized by one comparatively light day of travel, one very heavy day, and three remaining days of the week with fairly equal amounts of travel.

Figure 1 shows that Tuesday travel (by all modes) falls 7 percent short of the 5-day average of about 2,200,000 person trips in the study area; Friday tripmaking soars to nearly 12 percent above average. Monday, Wednesday, and Thursday trip volumes are about 3 percent, 1 percent, and 0.5 percent below average, respectively.

The pattern of auto driver trips closely resembles that of total travel—not unnaturally since auto driver trips constitute a little more than half of all trips each day. Driver volumes are fairly steady Monday through Thursday but rise very sharply on Friday. The drop shown for all modes on Tuesday is less pronounced in driver trips than for other modes.

Passenger tripmaking forms a pattern similar to that of auto driver tripmaking but with an accentuated profile. (This includes auto passengers, 97.4 percent; taxi passengers, 2.3 percent; and truck passengers, 0.3 percent.) Passenger travel is well below average on Monday, falls off further on Tuesday to nearly 13 percent below average, approaches the average on Wednesday and on Thursday, then climbs on Friday to about 23 percent above the daily average of passengers.

Mass transit ridership is the most regular of all modes. Monday is high for the week at 3.5 percent above average; the low day, Tuesday, is 6 percent below average. Unlike driver and passenger travel, transit trips drop below average on Friday.

To summarize briefly, Monday is an above average day for mass transit travel but is below average for both driver and passenger tripmaking. The low total trip volume on Tuesday is the result of decreases in travel in all modes. Wednesday and Thursday appear to be average days because tripmaking on those days approximately equals the daily average within each mode of travel. The very substantial gain in total trips on Friday represents large increases in driver and in passenger volumes only, since mass transit trips fall below average on that day.

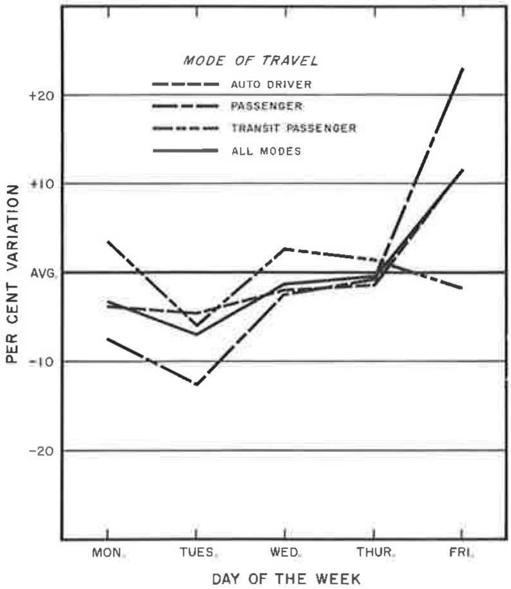

Figure 1. Daily variation of total internal person trips by mode of travel.

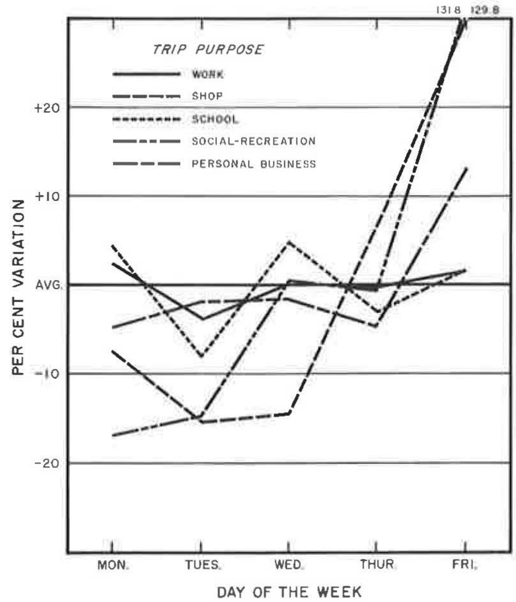

Figure 2. Daily variation of total internal person trips by trip purpose.

Daily Variation by Trip Purpose

Figure 2 shows that work trips remain within 4 percent of the average by day of week and are the most regular of all trip types. School trips are the second most steady, varying less than 8 percent from average. Tripmaking for personal business reasons stays within 5 percent of average until Friday when they rise to 13 percent above average. Shopping trips are well below average until Thursday and Friday when extremely large gains are made. Social-recreation trip volumes are very low until Wednesday when they reach their 5-day average, remain average on Thursday, and rise steeply on Friday.

When the effect of variations in trip purposes on total daily volumes is considered, the above average number of trips to work and to school on Monday are more than balanced by below average trips for shopping, social-recreation, and personal business. The low total volumes for Tuesday are the result of a decrease in activity in each trip category except personal business. While below average amounts of shopping and social-recreational trips on Tuesday are not unexpected, the substantial decreases in work trips and in trips to school are difficult to rationalize. Wednesday tripmaking is about average in each trip purpose category except trips for shopping and school. Light shopping offsets moderate gains in school trips on Wednesday; above average shopping volumes on Thursday approximately equal the decreases in school and personal business trips so that Thursday total travel about equals the 5-day average. Very large increases in trips for shopping, social-recreation, and personal business are responsible for nearly all of the gain in total trips shown for Friday.

Reviewing briefly, the major differences in total trip volumes by day of the week are caused by an uneven trip distribution during the week within shopping, social-recreational, and personal business categories. Heavier shopping on Thursday and Friday probably is a combination of the need for groceries and sundries for the weekend and the fact that these days are traditional paydays. The influence of paydays on Friday trips for personal business may be even greater because there are checks to cash and bills to pay. Many of these trips are probably parts of combinations of shopping and personal business trips. The larger volumes of social-recreational trips on Friday are expected.

GOLDEN TRIANGLE TRIPMAKING

Daily Variation by Mode of Travel

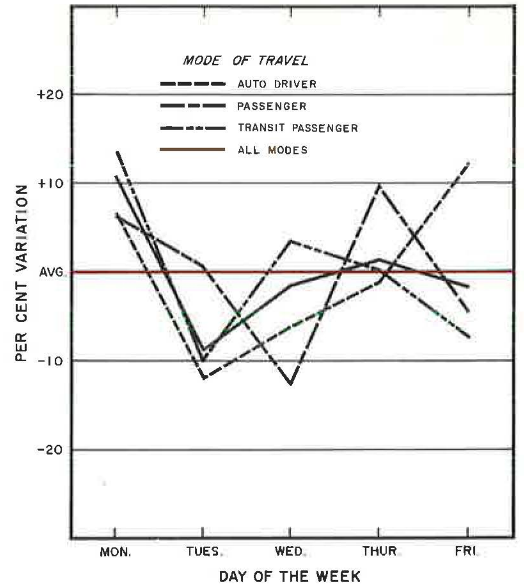

Figure 3. Daily variation of Golden Triangle person trips by mode of travel.

Just as there is a high and a low day of travel for the entire study area, so it is with Golden Triangle (GT) tripmaking (Fig. 3). Unlike the total study area, however, the GT tripmaking peak occurs on Monday when volumes are nearly 11 percent above the 5-day average of about 133,000 person trips. Like the total study area, Tuesday is the lightest travel day since volumes are almost 9 percent below average. Also, like the total study area, Wednesday and Thursday travel approximates the 5-day average. Reversing the condition found on Monday when total study travel is below average and GT trip volumes reach a peak, Friday travel to the GT falls slightly short of average, whereas total study tripmaking soars far above average.

Driver trips average a little more than one-fourth of all GT trips. They are most numerous on Monday and Friday when they are above average by 7 percent and 12 percent, respectively. Tuesday trips drop to 12 percent below average (low for the week); Wednesday shows a gain toward average by about 6 percent; Thursday driver trips are about 1 percent below average.

Passenger trips represent, on the average, about 15 percent of total GT trips. They are well above average on Monday (about 6.5 %) and on Thursday (about 10 %). Tuesday volumes are about average. Wednesday passenger trips fall nearly 13 percent below average, while Friday is about 4.5 percent under average.

About 57 percent of all internal person trips to the GT are made by mass transit, including trips made by railroad. The peak for this mode occurs on Monday when mass transit trips are nearly 14 percent higher than the daily average. The high Monday volumes are due largely to the impact of evening openings in the majority of GT retail stores. Tuesday and Friday mass transit volumes both are well below average (10 % and 7.5 %, respectively). Wednesday travel is 3.5 percent above average and Thursday mass transit trips equal the daily average.

From the standpoint of traffic congestion, it is probably fortunate that peaks for driver trips and mass transit ridership to the GT do not occur on the same day of the week. However, both driver and transit volumes are very heavy on Monday (Fig. 3). The full effect of this condition is reduced, however, because tripmaking is spread out more evenly throughout the day. This distribution is also a result of evening openings of retail stores, the effect of which is indicated further by examination of trip purposes.

Daily Variations by Trip Purpose

High tripmaking volumes to the GT on Monday are caused largely by far above average shopping activity, induced by most retail stores remaining open in the evening; but substantially above average trips for work add considerable weight to total trips, as do, to a lesser degree, trips for personal business (Fig. 4). The significant drop in shopping and work trips is, conversely, the principal reason for the deep decline in total GT trips on Tuesday. Wednesday travel shows small to moderate increases in all trip categories. Shopping trips show a large gain on Thursday because the stores remain open in the evening again. Social-recreational trips also start to increase, but most of this gain is offset by a sizable loss in personal business trips. The spec-

TABLE 2

PERCENTAGE DISTRIBUTION OF GOLDEN TRIANGLE TRIPS BY DESTINATION LAND USE FOR EACH TRAVEL DAY

Day	Land Use									Total
	Retail			Services				Public Buildings	All Other	
	Department Stores	Other	Total	Central Offices	Personal Services	Other	Total			
Monday	30.6	10.7	41.3	20.4	13.7	10.1	44.2	6.5	8.0	100.0
Tuesday	24.6	10.5	35.1	25.3	12.1	8.5	45.9	8.1	10.9	100.0
Wednesday	23.6	8.8	32.4	23.5	16.4	9.7	49.6	8.3	9.7	100.0
Thursday	27.9	10.5	38.4	22.4	14.2	9.5	46.1	7.8	7.7	100.0
Friday	19.5	11.2	30.7	22.7	14.3	12.2	49.2	7.8	12.3	100.0

tacular increase in trips on Friday in the lightly weighted social-recreational category is balanced by very deep losses in shopping trips and below average volumes of personal business trips. Work trips remain steady on Friday.

Daily Variation by Land Use at Destination

Establishments that deal in retail goods and services attract about four-fifths, or more, of all person trips to the GT each day (Table 2). Public buildings are the only other major trip generators, drawing an average of about 8 percent. Trip percentages to all other land uses, such as wholesalers, manufacturers, utilities, residences, and parks are inconsequential individually.

As could be expected, retail stores attract their largest percentages on Monday and Thursday. This is due mostly to the influence of department store trips since the trip percentages for other retail outlets remain fairly steady throughout the week. The percentage of trips to department stores drops sharply on Friday.

Service establishments draw their highest percentages on Wednesday and Friday. Actually, the trip volumes to these places are very steady, and the variations are the result of lighter or heavier trip weighting in other land uses. This is particularly true of trip percentages to central offices, which are mostly work trips and very regular in volumes. A greater proportion of trips to personal service establishments consisting of financial, legal, and medical offices occurs in the latter part of the week. The somewhat higher percentage on Friday for trips to other service places is understandable since these include theatres, nightclubs, and other indoor recreational places. Day-to-day percentages of trips to public buildings are quite regular except on Monday. The lower percentage for Monday is largely the result of heavier weighting by other land uses.

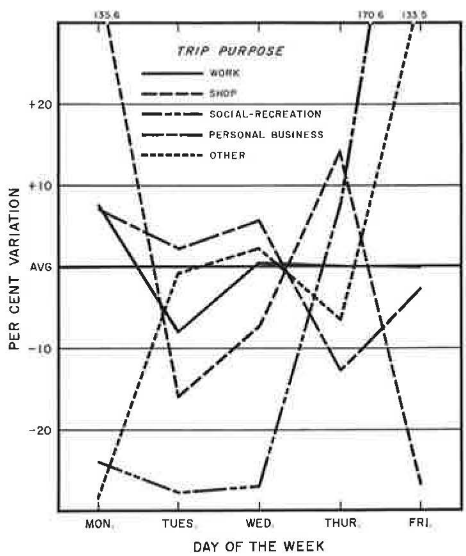

Figure 4. Daily variation of Golden Triangle internal person trips by trip purpose.

TABLE 3

PERCENTAGE ACCUMULATION OF GOLDEN TRIANGLE TRIPS BY HOUR OF ARRIVAL FOR EACH DAY OF THE WEEK

Day	Accumulation (hour ending)												
	AM			PM									
	9	10	11	12	1	2	3	4	5	6	7	8	9
Monday	39.9	52.2	60.4	66.7	71.3	75.6	79.5	82.4	85.4	89.0	93.4	97.2	98.7
Tuesday	41.9	56.6	66.6	73.6	77.3	82.9	86.9	89.5	92.0	94.0	95.9	97.6	98.6
Wednesday	45.4	59.7	69.3	74.4	77.6	84.2	87.6	91.3	93.4	95.3	96.7	97.7	98.9
Thursday	40.2	53.7	62.1	68.7	72.0	76.9	81.0	85.8	88.6	90.9	93.7	97.3	98.8
Friday	30.9	57.3	65.1	70.7	73.9	77.5	81.5	84.2	86.1	89.8	91.5	94.1	96.8

Daily Variations by Hour of Arrival

Table 3 shows the percentage distribution of trips to the GT by day of the week. The hourly accumulation of trips to the GT by day of the week is generally fairly regular because about 60 percent of these trips each weekday are trips to work. These trips are reflected in the morning peak-hour accumulation.

The effect of evening shopping can be observed in the higher percentages that occur in the late afternoon and early evening hours on Monday and Thursday. Similarly, increased social-recreation on Friday appears in the higher percentages in late evening hours on that day. Curiously, Friday morning accumulation is considerably slower than on other days at 9:00 AM but catches up by 10:00 AM. Inasmuch as nearly all tripmakers who arrive in the GT before 9:00 AM are going to work, many of them must have later starting times on Friday or are just plain late. If the latter is the case, the need for timeclocks, tougher supervisors, or increased personnel turnover may be indicated.

CONCLUSIONS

It appears desirable in future O-D studies to plan more carefully to obtain an equal number of samples by day of the week.

The presence of holidays within the interviewing period can result in wide differences in the number of samples scheduled by day of the week. The number of interviews pertinent to the expansion factor may vary significantly by day of the week. If no attempt were made to equalize the number of interviews per day or, at least, to factor for any inequality, serious distortions could result if large differences were present in both tripmaking volumes and number of interviews by day of the week. These differences probably can be reduced by finding, near the end of the interviewing period, the number of completed interviews by day and by adjusting the travel dates of the remaining schedules with an eye toward equalization.

In the Pittsburgh study, rather large differences in trip volumes were found between the peak day and the average day of travel. In the whole study the difference amounted to about 250,000 person trips, or about 12 percent, whereas in the Golden Triangle the difference was about 13,000 trips, or 11 percent. Awareness of the extent of these differences is vital, of course, in transportation planning.

Evaluation of Some Elements of Auto-Driver Trip Productions

F. E. COLEMAN, Connecticut Highway Department

• THERE are many characteristics that influence the number of trips made daily by motor vehicles. An attempt to determine the most predominant and influential elements of auto-driver trips was conducted by the Connecticut Highway Department in conjunction with Alan M. Voorhees.

The basic data were obtained in the Southeast Area Traffic Study (SEATS). The study area consists of 23 towns in southeastern Connecticut, covers a 750-sq mi area, and has a population in excess of 190,000.

A 2 percent sample of the dwelling units in the area was selected and a home-interview O-D survey was then conducted. The trip breakdown used in the survey categorized trips into twelve trip purposes. For the analysis of trip production rates, these twelve purposes were grouped into four trip types, work, long, short and non-home based. The long and short classifications were based on trip length characteristics, with the non-home based trips being defined as those trips made with neither origin nor destination at the home. A final consolidation of the four trip purposes was made into work and non-work trips in order to facilitate a comparison of the results to those obtained in the Hartford Area Traffic Study (HATS). Table 1 gives the trip purpose breakdown.

It has been pointed out in other studies (1), that family size and car ownership have a great bearing on the number of trips made by a motor vehicle. From the SEATS home-interview survey, the relationship between the number of persons per family, the number of cars per family, and the number of auto-driver trips made was found.

As family size increases to 9 persons, the number of auto-driver work trips for 1 and 2 car families increases 40 percent and 30 percent, respectively, while the number of work trips for 3 car families doubles (Fig. 1). The gradual increase in the number of work trips being made by one car families can be explained by the fact that the single car families are limited to the number of extra work trips that can be made. In 2 car families, the second car is commonly used by the housewife for transportation, and these trips fall into the non-work trip group.

Auto-driver non-work trips have patterns different from those of work trips (Fig. 2). These trips increase at a higher rate with an increase in family size and car ownership, and then decline

TABLE 1

AUTO-DRIVER TRIP PURPOSES

Category	Type	Purpose
Work	Work	Work
Non-work	Long	Related to business Medical-dental Shopping-shopping goods Social Recreational Other
	Short	Personal business Eat meal Educational Civic-religious Shopping-convenience goods
	Non-home based	Non-home based

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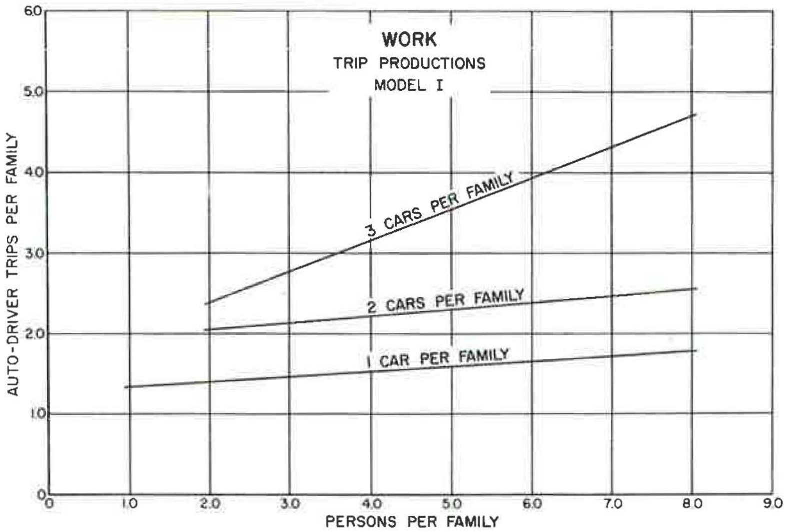

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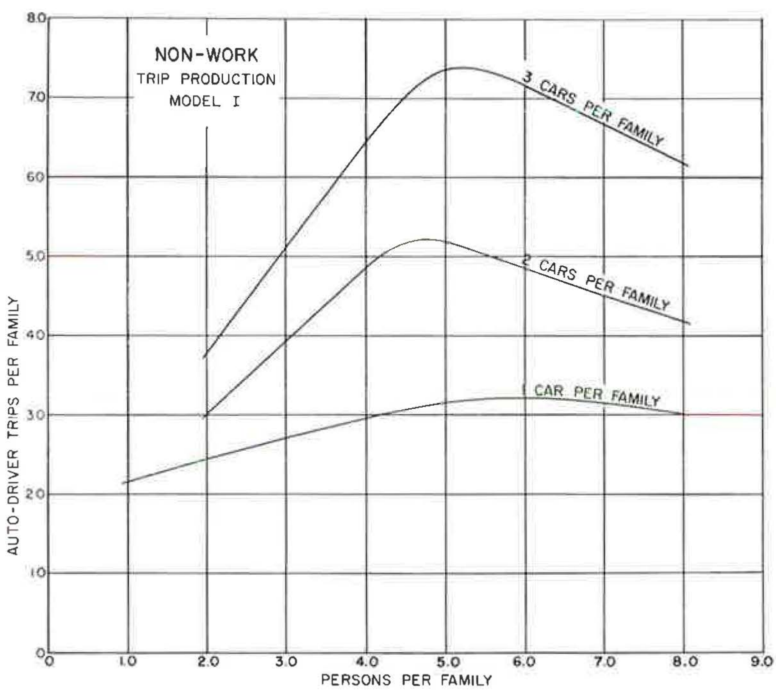

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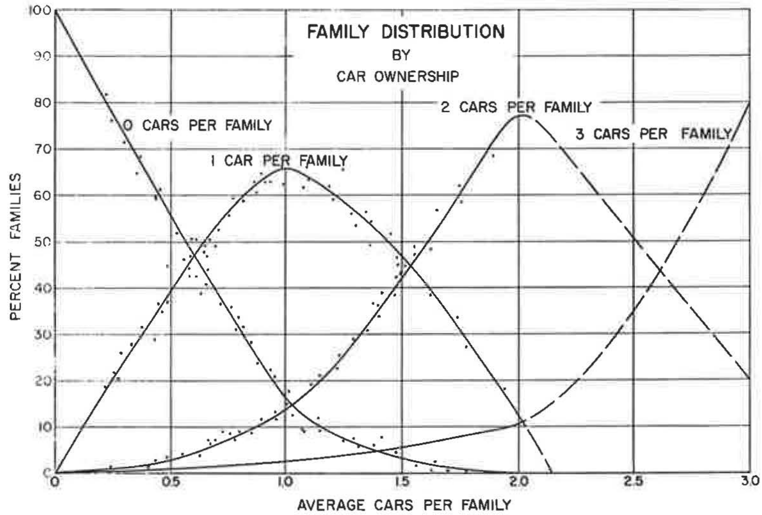

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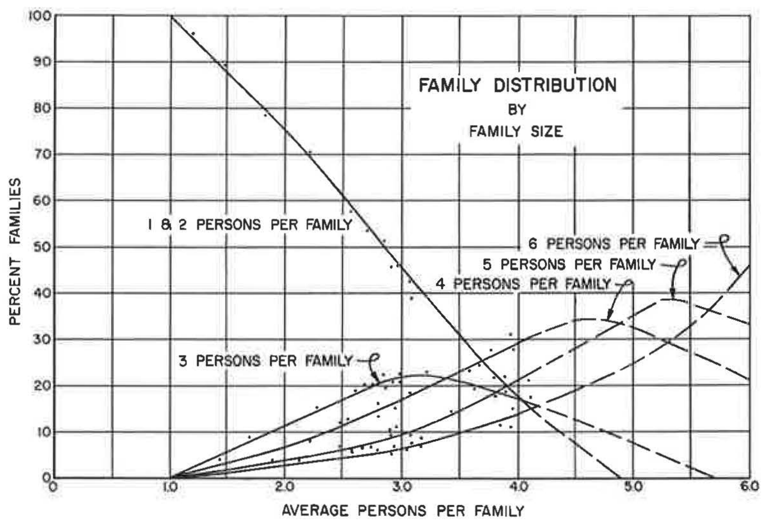


Figure 4.

rather sharply. The break point occurs between 5 and 6 persons per family for 1 car families and between 4 and 5 persons per family for 2 and 3 car families. In 1 car families the rate of increase and decrease is far more gradual than for 2 and 3 car families, indicating that in the former category these types of trips are kept at a minimum. This apparently is a result of a combination of factors. The work trip takes priority and idles the car for at least one-third of the day. Also, single car families are probably lower on the income scale. If this is not the case, and the family is of the type that needs to make extra trips, a second car would be present. A detailed analysis of the trips made by 2 car families seems to indicate this. For example, in families with 4 or more members the number of social trips being made falls off rapidly. Since this type of trip accounts for 20 percent of the total non-work trips, its impact is readily felt. Shopping trips also decline, and these account for 9 percent of the total non-work trips. This seems logical for as family size increases the influence of economic pressure is felt. Income data would have been useful to correlate these observations but were only available as median income by town. Trips made for educational and civic-religious purposes also decreased as family size increased, but it is difficult to deduce a reason for this.

As would be expected, convenience shopping trips increased slightly. This type of trip accounted for 22 percent of the total non-work trips. Related business trips increased sharply in comparison to convenience shopping, but this is understandable since these types of trips are actually supplemental to work trips.

Those trips classified as personal business, eat meal, recreation and medical-dental remained fairly constant as family size increased. It would seem reasonable to assume that as social trips declined with an increase in family size that recreation trips would also. However, the observed data did not corroborate this theory. Possibly visiting other people becomes a chore while family type trips for recreational purposes do not.

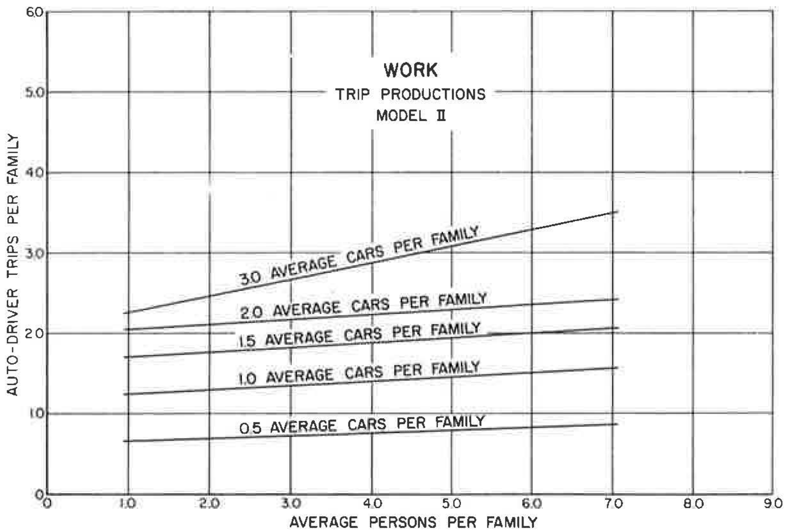
It must be kept in mind that these curves are a direct product of individual observations. In using these relationships to predict auto-driver trips it was apparent that some adjustment should be made to reflect the average conditons of the traffic zones. These zones are the units for which trip production will be considered.

To develop a set of curves that would predict travel on an average basis, family size and car ownership were investigated. From census data of tracted areas in Connecticut (Hartford, Bridgeport, New Haven, Waterbury, Stamford) the relationship between the average number of persons per family and the percent of families having 1, 2, 3, etc., members was established. This relationship proved to be consistent for the various areas that were tracted and the resulting curves had very little scatter (Fig. 3). The dashed portion of the curves were estimated to account for larger family sizes than were actually observed in the SEATS home interview.

The curves in Figure 4 were developed from the same census data to relate the average number of cars per family to the percent of families having 1, 2, 3, etc., cars per family. Again these data were very consistent for each of the tracted areas considered and resulted in very little scatter. The percent of families not owning cars rapidly decreases as family size increases, and it is felt that the predominant characteristic of no car families is retired couples who rely on mass transit for their transportation.

Having established the relationship in Figures 3 and 4, the framework was provided for converting Model I to an average persons per family and average cars per family basis for predicting auto-driver trip production. Trip production rates for various combinations of family size and car ownership were determined from Model I for work and non-work trips. These rates were then adjusted by applying the relationships of the percent of persons for a given average family and average number of cars in the family. The adjusted volumes were then plotted, resulting in Model II (Figs. 5 and 6).

With the new set of curves it was possible to compare the theoretical trip productions to the actual trips obtained from the home interview. This was done for each town in the study area by obtaining the average number of persons per family and the average number of cars per family. The trip production rates were then obtained from the Model II curves and expanded by the number of families. Retired families were not considered for auto-driver work trip productions for obvious reasons.



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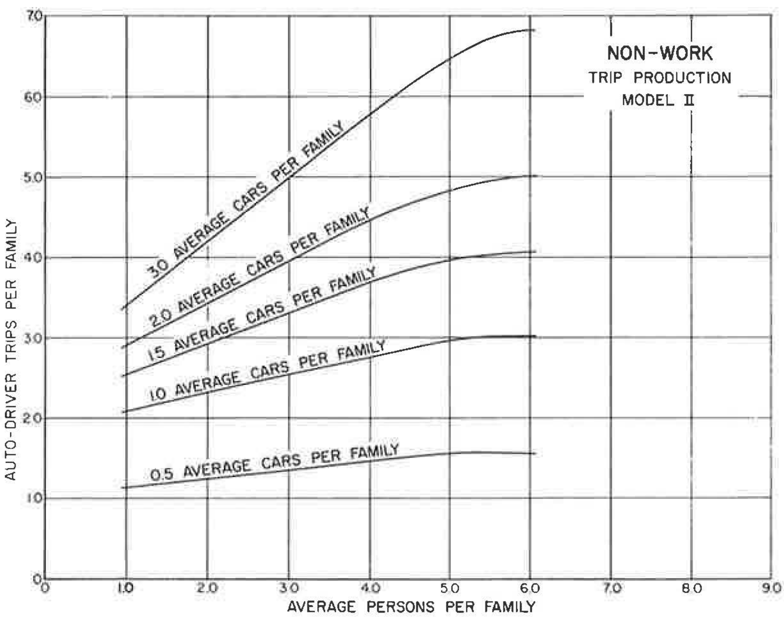

Figure 6.

TABLE 2

COMPARISON OF AUTO DRIVER TRIP PRODUCTIONS

	WORK TRIPS						NON-WORK TRIPS					
	ACTUAL	THEO. * MODEL I	A/T	THEO. * MODEL II	A/T	HATS METHOD	A/T	ACTUAL	THEO. * MODEL I	A/T	THEO. * MODEL II	A/T	HATS METHOD	A/T
REGION 1	246	246	1.00	232	1.06	246	1.00	524	489	1.07	477	1.10	499	1.05
REGION 2	161	138	1.16	129	1.25	134	1.20	215	269	0.80	255	0.85	269	0.80
REGION 3	345	330	1.04	311	1.11	339	1.05	563	707	0.80	667	0.85	684	0.83
REGION 4	221	219	1.01	207	1.06	232	0.96	492	454	1.08	437	1.12	468	1.05
REGION 5	383	401	0.96	374	1.02	400	0.96	923	829	1.11	802	1.15	807	1.14
REGION 6	534	469	1.14	414	1.20	483	1.10	975	961	1.01	918	1.06	974	1.00
REGION 7	177	202	0.87	197	0.90	226	0.79	478	441	1.08	409	1.17	461	1.03
TOTAL	2067	2005	1.03	1894	1.09	2060	1.01	4170	4150	1.01	3965	1.05	4162	1.00

* MODEL I - Curves developed from home interviews
* MODEL II - Home interview curves modified by average family size and average car ownership conditions
* HATS METHOD - Based on car ownership only

The comparison of trip productions from Models I and II, as well as the method used in HATS, which utilizes only SEATS car ownership, is given in Table 2. The results indicate that considering family size as related to average persons per family and average cars per family did not increase the accuracy of the study.

As mentioned previously, income level is a desired variable but was not available for SEATS. More work is planned in areas of the state for which this information is available.

The observed data revealed basic characteristics of travel patterns, namely that the number of trips do change as family size increases, and that this increase is influenced by car ownership. Although these basic elements are important in individual cases, they do not have too much effect on the total volume of trips made in an area.

REFERENCE

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Characteristics of Summer Weekend Recreational Travel

CHARLES C. CREVO, Connecticut State Highway Department

•THE recent trend in the use of mathematical models for the distribution of vehicle trips has resulted in a more detailed examination of trip purpose. This is one of the more important refinements developed, because it is evident that trips made for different purposes vary in characteristics.

In two traffic studies made by the Connecticut Highway Department, the Hartford Area Traffic Study (HATS) and the Hartford Metropolitan Transportation Study (HMTS), recognition was given to various trip types. In the application of the gravity model technique of vehicular trip distribution, as developed by Alan M. Voorhees, Connecticut used a four trip purpose model. These trip purposes were work, social, commercial, and non-home base.

Both studies were conducted in an inland area where there are no great recreational facilities to act as traffic generators; therefore, the four-purpose model was adequate. However, future studies by the highway department will involve areas along the shore line, and it will be necessary to consider the effects of recreational travel to and from the shore.

The basic problem confronted in this study was the determination of the characteristics to be developed. First and foremost, it was decided that travel time is important in the consideration of the distribution of travel patterns, and subsequently for its application in the gravity model technique of vehicle trip distribution. Likewise, vehicle occupancy was considered important because it is a basic element of trip production, and persons per vehicle is the conversion factor for relating population to vehicles. The third characteristic is the relationship of trip production to the population density of the origin. A similar relation selected for the fourth characteristic is the effect of car ownership on trip production. Finally, the distribution by hour of vehicles arriving at recreational areas was felt to be of value in estimating the expected time an increased load imposed on a highway system providing access to a recreational facility.

To obtain the necessary information, it was decided that vehicular trips to recreational areas would have to be detected by some type of personal interview. The two types of interviews chosen were the Home Interview Origin and Destination and the Roadside Interview Origin Surveys.

STUDY AREA

The study was conducted in southeastern Connecticut, referred to as the southeast area. This recreational area (Fig. 1) consists of the following 23 towns: Bozrah, Colchester, East Haddam, East Hampton, East Lyme, Franklin, Griswold, Groton, Lebanon, Ledyard, Lisbon, Lyme, Montville, New London, North Stonington, Norwich, Old Lyme, Preston, Salem, Sprague, Stonington, Voluntown, and Waterford. The area also coincides with the Southeast Area Traffic Study being conducted by the Connecticut Highway Department.

Descriptions of the facilities available at the beaches and parks selected for study are as follows:

Ocean Beach Park

Ocean Beach Park is located at the southernmost point of New London and on Long Island Sound. This salt water public beach, operated by the city, has a boardwalk lined

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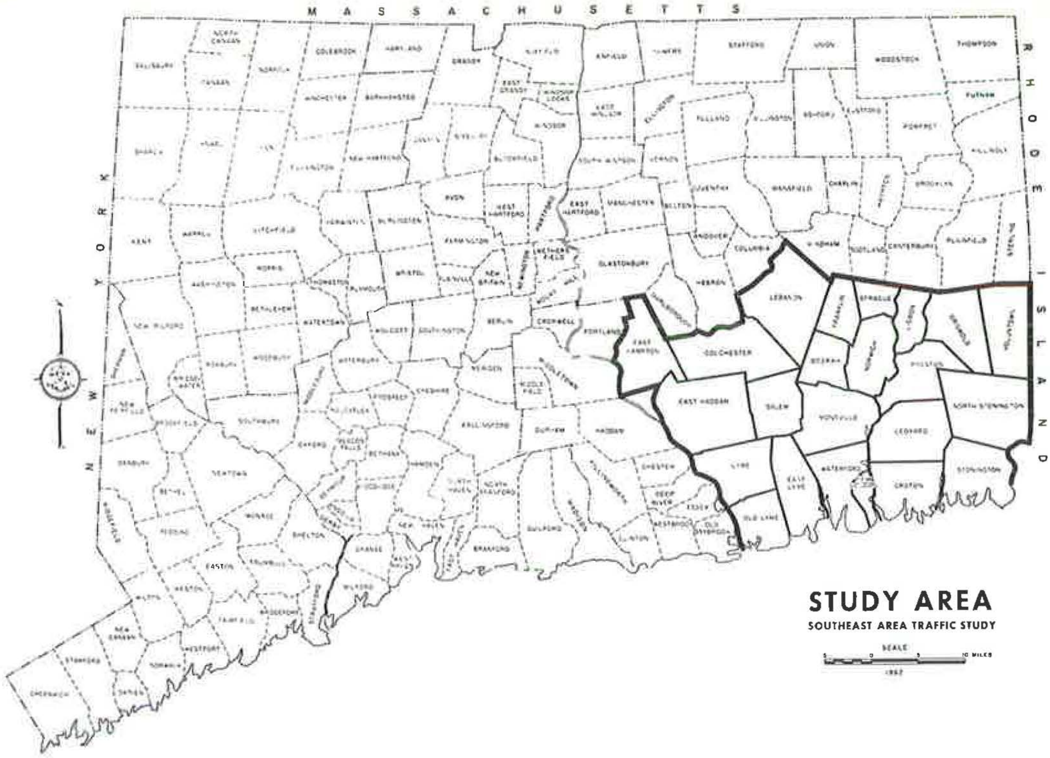


Figure 1.

with commercial amusements and concessions. There is also a dance hall which is open only evenings. A paved parking area for approximately 2,000 vehicles is provided, and a small picnic area is available at a considerable distance from the beach. The main route of access to Ocean Beach is Conn. 213, which connects to US 1A in the center of New London.

Rocky Neck State Park

Rocky Neck State Park is a 561 acre site bordering on Long Island Sound in the southwest corner of East Lyme. Operated by the state, it offers salt water bathing, boating, fishing, hiking, shelter, picnicking, and a food concession. A large part of this tract is devoted to camping, but this area is excluded from the beach and picnic facilities. The area is served by a direct connection from the Connecticut Turnpike.

Devil's Hopyard State Park

Devil's Hopyard State Park is an 860 acre recreational area situated in East Haddam, operated by the state. There are no bathing facilities; however, fishing is provided by the Eight Mile River. Hiking trails and picnic areas are also provided. The area is encircled by state routes, but it has no access by a high type roadway.

Hurd State Park

Hurd State Park is a state-operated 698 acre area located in East Hampton on the east bank of Connecticut River. Recreational facilities at this fresh water location are boating, hiking, picnicking, and shelter. Access is provided by Conn. 151.

Hopeville Pond State Park

Hopeville Pond State Park consists of 316 acres and is located in Griswold. It provides fresh water swimming, boating, and fishing, and facilities for hiking and picnicking. Access is provided by an interchange on the nearby Connecticut Turnpike.

HOME INTERVIEW SURVEY

The weekend recreational trip home interview survey was conducted in conjunction with a survey by the Connecticut Highway Department. The department's survey was for weekday travel in the southeast area and was made Tuesday through Saturday.

The sample to be interviewed was selected randomly by towns, with the number in each town based on the percent population of the study area.

The weekend interviews were taken during the months of July and August, and only on Tuesdays. This was because Monday was not an interview day for the weekday trip inventory. However, it was felt that people would remember their recreational trips after a day or two had lapsed. The weekend form was the same as the weekday except for the basic information on the reverse side. It was deemed unnecessary to duplicate this information on the weekend form.

In addition to recreational trips, as many other trips as the interviewee could recall were recorded. This was for possible future use. All trips made between 4:00 PM Friday and 12:00 PM Sunday were considered as being weekend trips.

Advance notice of the survey was publicized by area newspapers, and the households to be interviewed were notified by a letter which appealed for cooperation as citizens.

ROADSIDE O AND D

A survey was conducted at each of the five selected recreational areas. An attempt was made to choose an average weekend, and it was decided to interview on Saturday and Sunday, August 26 and 27, 1961, between the 9:00 AM and 3:00 PM. In addition to the assumption of detecting average trips, it also provided a steady flow of in traffic so that a 100 percent sample resulted at all five areas.

Each of the facilities has a toll booth or booths and controlled vehicular access. The interviewers were stationed at these points and questioned the drivers as they waited in line to enter. Only the origin and number of people in the car were recorded.

Advance notice of this survey was also publicized in area newspapers. "Survey Ahead" signs, as well as warning and stop signs, were placed prior to the interview stations to inform the motorists.

Probably the most limiting factor in summer weekend recreational travel is the weather. Inclement weather would considerably reduce the amount of recreational travel. The only weather problem during the field study period occurred at Rocky Neck State Park on Saturday, August 26, in the morning. There were rather frequent heavy showers in this area. However, at Ocean Beach, 7.5 miles to the east, the weather was excellent. Heavy clouds could be seen over the Rocky Neck area, but there was no other indication of rain. Therefore, it is doubtful that travelers who started out for Rocky Neck earlier in the morning had any knowledge of the precipitation. For this reason, it is being assumed that there is no variation in the visitation to Rocky Neck at that time.

The limitation placed on the roadside O-D surveys is in the number of interviews, rather than sample size, because at all interview locations a 100 percent sample was taken. However, the number of interviews taken at Hopeville Pond, Devil's Hopyard, and Hurd State Park are insignificant compared to Ocean Beach and Rocky Neck and were not included in the travel time factor analysis. Also, car occupancy at these areas was not recorded. Arrival time alone is significant. For the travel time analysis of the trips to the two remaining areas, the entire State was considered, with trips external to the study area being grouped according to an average of travel times.

The home interview survey is limited in its sample size. Even though a 2 percent sample was randomly selected by towns, the number of weekend trips could vary greatly by town. This is because the weekend trips were detected on the following Tuesday.

If a great number of the interviewees were not at home on Tuesday, a call-back was necessary on another day, and then the weekend trips were not recorded. Thus, the sample size is smaller than was originally planned. In this study, only the recreational trips that had a destination listed as playground, beach, or park were used. Commercial recreation was omitted. The home interviews were taken within the study area, but trips external to this area were considered accordingly.

ANALYSIS OF DATA

The data from both the home interview and the roadside survey were coded and put on punch cards for tabulation on a Remington Rand file computer No. 1. The coding was based on the Connecticut 3-digit town number with a 2-digit appendage for zone designation. Thus, each trip has two 5-digit code designations, one for origin and one for destination. Other information was also coded and punched, thereby providing a complete record of all the trip data. With this arrangement the data could be sorted into any order for ease of analyzing.

Upon completing the above phase, it was necessary to develop a system of travel times between zone centroids. This was accomplished by a tree building process based on the Moore minimum path algorithm (1) which determines the shortest path between two centroids, given any number of alternate routes.

The mechanics of tree building is in coding a network of street and highway segments, called links, between intersections and centroids, called nodes. Each link is assigned a distance and speed. This information is stored into the computer memory, and the tree building program then determines the shortest path from each centroid to all others. The centroid to which the shortest paths are determined is called the home node. The final product is a computer tabulation composed of the shortest travel time from the home node to each other node as well as the path or route which must be traced to make the trip in this minimum time. A separate tree is required for each centroid, a total of 110 trees for the study area, including external stations. The externals are centroids located on major routes on the periphery.

Having tabulated the O and D's of the trips and the travel times, the next step in considering trip production based on destination was to develop travel time factors by considering the ratio of actual and theoretical trips. It is assumed that trip production for recreational travel is based on population. For this reason the population of each zone was taken as a percent of the state population. The statewide population was used, because it is reasonable to assume that trips can originate anywhere within the state or beyond.

From this point on, each recreational facility was considered individually. The total number of vehicle trips and person trips were recorded for each zone.

On the assumption that the population generates the trips, the theoretical number of trips from any zone would be a proportional number of the total trips based on the zonal percentage of the population. In general terms this can be expressed as

$$\text{Theoretical trips}_{ir} = \sum_{n}^{r} T \times \frac{P_i}{P_s}$$

in which

i = any zone or group;
r = a recreational facility;
$\sum_{n}^{r} T$ = the total number of trips to a recreational area from all zones;
P_i = population of the zone; and
P_s = total population of the state.

The actual number of trips to a recreational area is known from the survey conducted there. The ratio of the actual person trips to the theoretical person trips is then plotted against the travel time in minutes from each zone (2). When the curve of best fit is plotted to the scatter of points, the result will be a travel time factor curve.

This curve is of the form $R = kT^b$, in which R is the ratio of actual and probable trips, k is a constant, and T^b is the travel time to some power. This is the form of the travel time factor in its application to the gravity model.

This method was applied to both Ocean Beach and Rocky Neck so that the resulting curves could be compared and analyzed.

For the characteristics of the relationships between trips per family vs population density and car ownership, it was necessary to determine the population density in families per residential acre, and the car ownership for each zone. Once density and car ownership were established, the number of person trips and the number of vehicle trips per family were plotted.

The determination of car occupancy provided no great problem and was found by dividing the total number of persons entering the facility in the given time by the total number of vehicles entering during the same period, as recorded in the field survey.

The analysis of arrival patterns merely entailed the grouping of arrivals by hour, and plotting the percent of the vehicles arriving at hourly intervals, and also the cumulative percent arrival by comparable hourly intervals.

RESULTS

The data collected in the roadside survey at Ocean Beach and Rocky Neck are to be used in developing travel time factors, car occupancy, and time of arrival.

The 2-day survey at Ocean Beach interviewed 1,257 vehicles. The number of occupants in each car ranged from 1 to 9 persons, and the time of travel varied from a low of 1.0 min, for trips originating within the zone, to 2 hr 10 min for more distant origins. The total number of person trips was 3,329.

For the same survey period at Rocky Neck, 592 vehicles were interviewed. Car occupancy ranged from 1 to 9 persons also, and travel time ranged from a low of 6.0 min to a high of 2 hr 5 min. The high value for the low end of the range is because the zone in which Rocky Neck is located has a population of only 12 people. There is no dense population closer than 6.0 min traveling time. The total number of person trips to this facility during the 2-day weekend was 2,220.

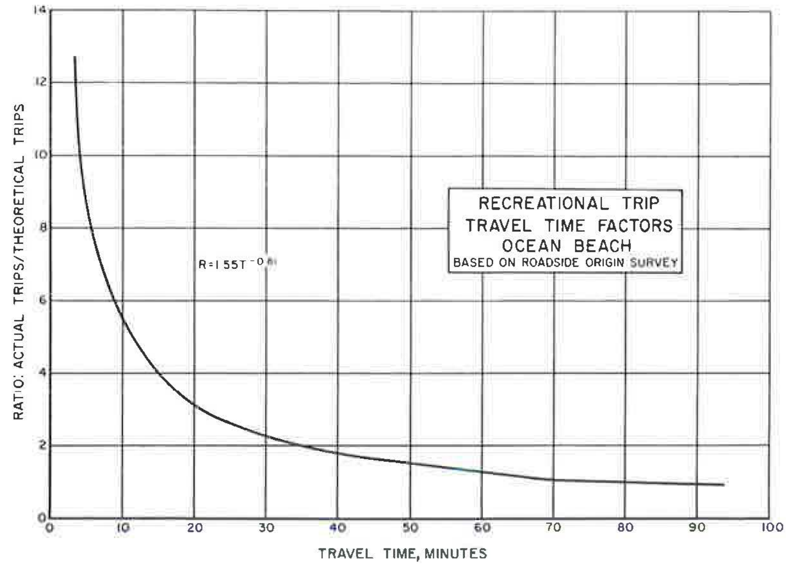
Trips originating outside Connecticut were not included in the analysis. At Rocky Neck there were 70 vehicle trips from the Springfield, Mass., area, and 5 vehicle trips from Rhode Island. At Ocean Beach there were 150 trips from Massachusetts and 176 from Rhode Island. However, 154 of the Rhode Island trips were interviewed Saturday when an industrial firm from Westerly sponsored an outing for its employees.

Trips originating outside the study area but within the state were grouped according to an average travel time. This was necessary because the tree building process was limited to the southeast area. For groups in the area contained by HATS, the time to an external station from the HATS trees was added to that of the southeast area. Times to population groups in the remaining area were estimated to the external station on the route serving the area.

The home interview survey provides the data to be used in developing the characteristics of trips as related to density and car ownership. The interviews conducted during the months of July and August resulted in 1,319 trips, of which 286 were vehicle trips for recreational purposes of the playground, beach, and park variety. This accounted for 670 person trips. Additional recreation trips of the commercial variety, bowling or golf, for example, were omitted from the analysis.

TRAVEL TIME FACTORS

The ratio of actual and theoretical trips was developed as discussed previously. This was done for both recreational facilities and then plotted against a corresponding travel time. A scatter diagram resulted indicating that a curve of the exponential form would probably be the best fit. The ratios were grouped in 5-min travel time intervals and a regression analysis was performed. To obtain results in the form of an exponential curve, a least squares linear regression in terms of the logarithms of the variables was computed (Figs. 2 and 3).



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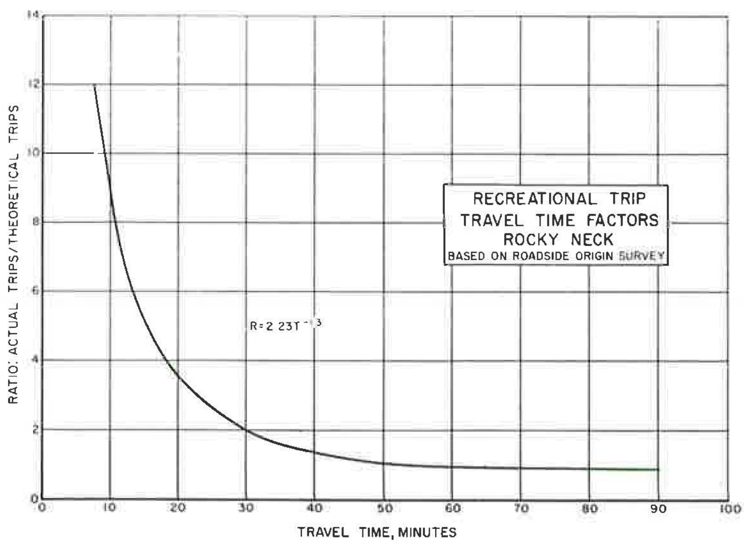

Figure 3.

The equations relating the ratio of actual to theoretical trips and travel time to Ocean Beach and Rocky Neck, respectively, were computed to be $R = 1.55T^{-0.81}$ and $R = 2.23T^{-1.3}$, in which R = actual number of person trips per probable number of person trips, and T = travel time in minutes.

The curves are very close in value except in the range of travel times from 3 to 20 min. This is due mainly to the inherent population distribution of the zones in which the study sites are located. Rocky Neck is situated in a zone that has a 1960 population of 12 people; therefore, there are no travel times less than 6.0 min. This tends to force the curve to the right, thereby increasing the slope. Ocean Beach zone, with a population of 284 people, is much smaller in area, resulting in shorter travel times for the more densely populated surrounding zones.

CAR OCCUPANCY

For the 2-day 12-hr survey period a total of 1,257 vehicles entered Ocean Beach. These vehicles contained 3,329 people. The average car occupancy was 3,329 persons per 1,257 vehicles, 2.7 persons per vehicle.

For the same period, there were 592 vehicles entering Rocky Neck with a total of 2,220 persons. Average car occupancy was 2,220 persons per 592 vehicles, 3.8 persons per vehicle.

Comparison shows a significant difference in car occupancy due to the facilities available at the recreational areas. Rocky Neck is a state park with no commercial amusements and only one food concession. Bathing and picnicking are its biggest attractions and it tends to attract the family type trip, which usually includes children.

Ocean Beach is a city-operated public facility with a boardwalk type layout with commercial amusements as well as bathing facilities and a small picnic area. Observation on the beach and of the vehicles entering showed a high number of the younger set patronizing this area, resulting in a lower average car occupancy.

TRIPS PER FAMILY VS CAR OWNERSHIP

The relationship between the number of trips made per family and car ownership is based on the home interview survey data. Car ownership for the zones was determined by random sampling of the local motor vehicle tax assessment cards for each town, and then locating the selected sample on a zone map. The sample was then expanded to the town car ownership.

The trips per family in each zone were grouped by similar car ownership and an average value taken. The least squares regression equations relating car ownership to vehicle trips per family and person trips per family, respectively, are $T_V = 2.5 + 1.4C$ and $T_P = 3.5 + 4.2C$, in which T_V = vehicle trips per family, T_P = person trips per family, and C = car ownership by zone (Fig. 4). As car ownership increases, the number of vehicle trips increases, but at a rate less than that of person trips. This shows that larger families have a higher car ownership rate.

TRIPS PER FAMILY VS DENSITY

Again using the data from the home interview survey, the relationship between trips per family and density was developed. As density increases, the number of vehicle trips per family decreases slightly (Fig. 5). Similarly, the number of person trips per family decreases, but at a faster rate.

It is evident that the low density areas generate more person trips per family than the high density areas. However, this is justified when it is considered that the lower density areas have a higher car ownership.

The equations of the regression lines computed for vehicle trips per family and person trips per family, respectively, are $T_V = 4.4 - 0.10D$ and $T = 11.8 - 0.71D$, in which T_V = family vehicle trips, T_P = average family person trips, and D = density in families per residential acre.

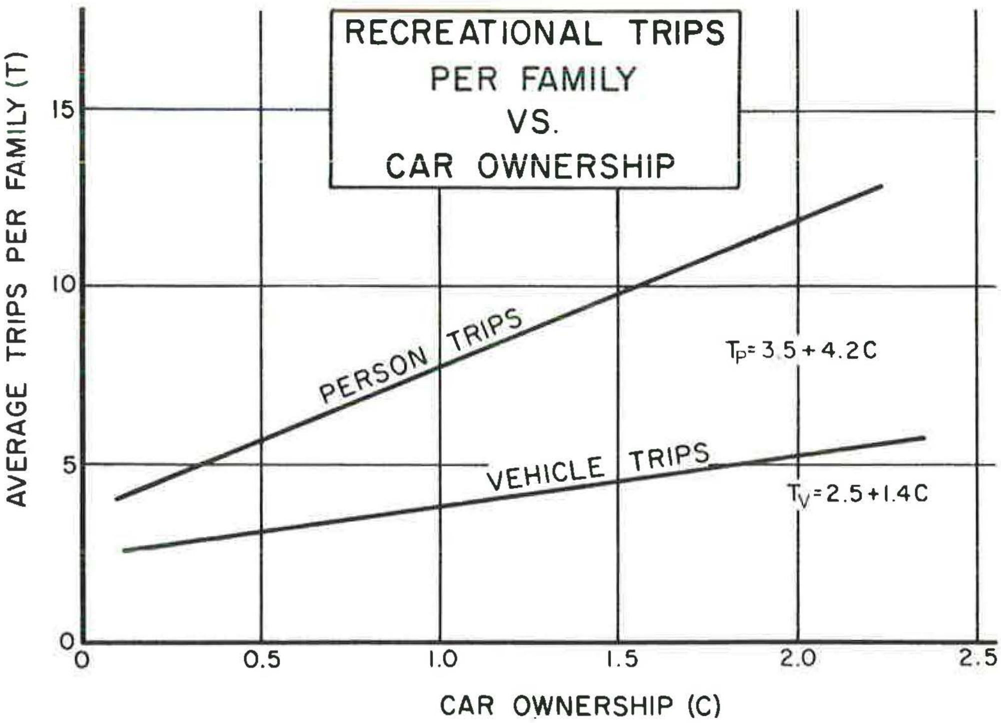

Figure 4.

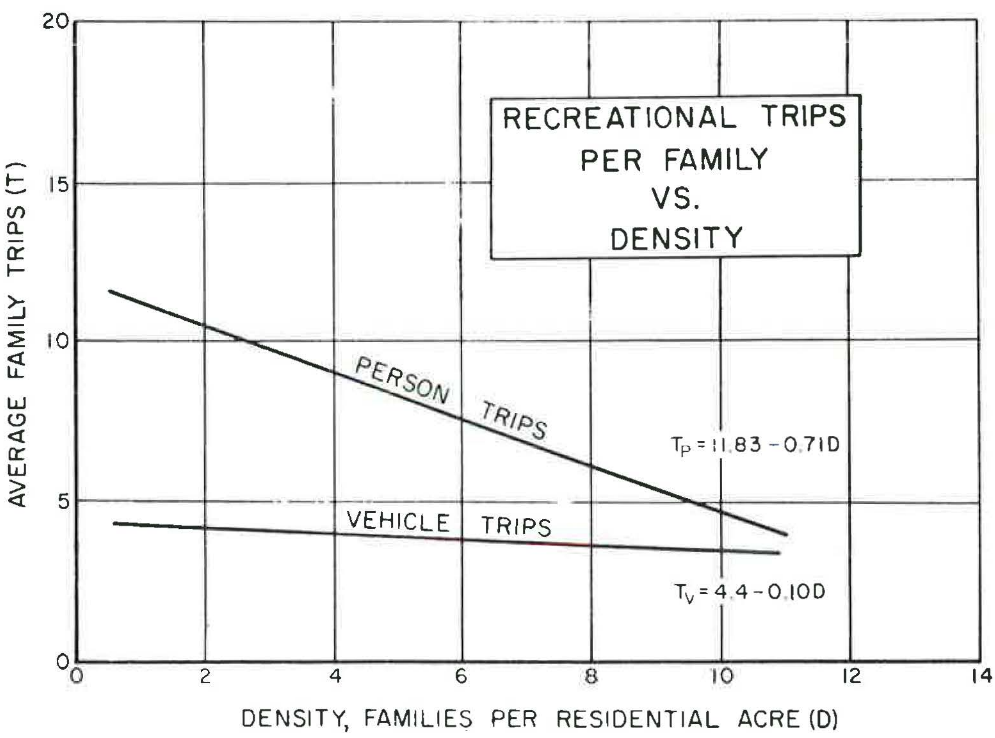

Figure 5.

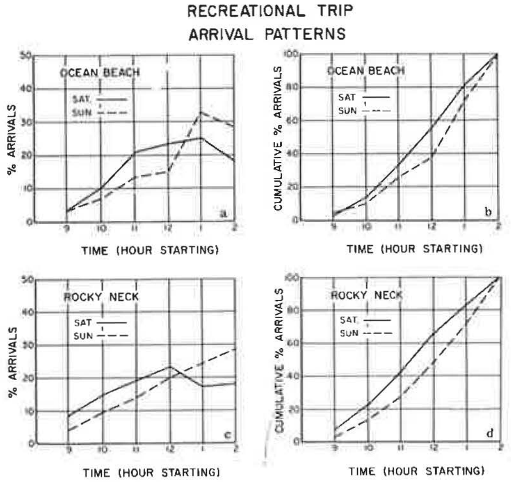

Figure 6.

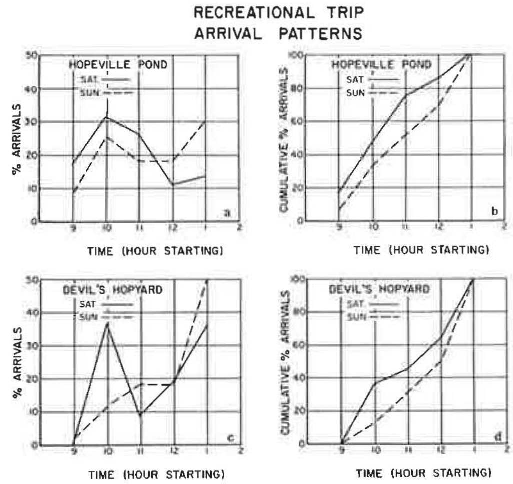

Figure 7.

TIME OF ARRIVAL

In the analysis of the arrival characteristics of recreational trips, Hopeville Pond State Park and Devil's Hopyard State Park were considered in addition to Rocky Neck and Ocean Beach. Figures 6 and 7 show the arrivals at each recreational area by percent arrivals and percent cumulative arrivals vs tıme.

Figure 6a shows the difference between Saturday and Sunday at Ocean Beach. The Saturday peak occurs between 1:00 and 2:00 PM, and declining thereafter. On Sunday, the peak is again from 1:00 to 2:00 PM, however, the increase is much higher, going from 15 percent to 33 percent from 12:00 Noon to 1:00 PM. The low morning volume is most likely due to the church attendance before the recreational trip.

Figure 6c shows a similar relationship at Rocky Neck. The difference is that on Saturday the peak is at the 12:00 Noon to 1:00 PM hour and then drops off, followed by a slight rise. This may be due to the late afternoon picnic or cookout. For Sunday there is a steady increase in volume which indicates the family groups possibly starting out early for an all day affair.

Figure 7a, showing the arrivals at Hopeville Pond, indicates the strong attraction for the picnic type recreation trip, even though fishing, bathing and boating are available. The Saturday curve shows the early morning arrival, thereafter declining and picking up again slightly for the afternoon. The Sunday curve shows the definite noon and evening feast outdoors.

Figure 7c portrays the arrival curves for Devil's Hopyard. There were no arrivals from 9:00 to 10:00 AM; however, there is a strong resemblance to the Saturday curve of Figure 7a. Sunday shows an increase in the early hours and then levels off at noon. There follows a rapid increase to the peak hour between 1:00 and 2:00 PM.

The survey period ended at 2:00 PM, therefore, the hour beginning at 1:00 PM was the last at which a count was taken.

CONCLUSION

The travel time factor curves developed for Ocean Beach and Rocky Neck illustrate that the facilities available at recreation areas do not strongly influence travel considerations. This is especially true of the trips greater than 25 min in length. Any travel less than this time could very well be influenced by the proximity of two recreational areas competing for visitation. It is logical to assume that people living within minutes of a beach hesitate to travel a much longer time to visit another recreational area.

Based on the similarity of the travel time curves, it is concluded that the grouping of data collected at both survey sites would result in a curve capable of providing time factors for use in the mathematical model. Applied to the model, the factors would adequately assist in the distribution of vehicular traffic to recreational areas.

The values derived for car occupancy do differ according to the facilities available at a recreational area. This varying characteristic can be utilized in estimating vehicle trips which are usually based on population. Car occupancy is the factor by which person trips are converted to vehicle trips and vice versa.

The characteristics of family trips as related to density and car ownership follow the trend of other trip types. That is, as density increases car ownership decreases and less trips are made. However, for purposes of this study, only weekend trips were considered, and for this reason the frequency would be less than weekday trips of other types.

As illustrated in the arrival curves, the time depends somewhat on the facility visited. Areas offering family activity show a definite trend of arriving in time to eat lunch or for a late afternoon cookout.

On Sundays the religious trip influences the arrivals and causes a peak near noon.

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A Method of Estimating Traffic Behavior on All Routes in a Metropolitan County

THOMAS C. MURANYI, Chicago Area Transportation Study

• WITH the constantly increasing demands for traffic information needed in the every day work of traffic and highway-engineering, thousands of road stations have been established for traffic counting. However, it is believed that in various Western European countries and the United States, there is essentially more valuable information hidden in these counts than is evaluated and placed at the disposal of traffic experts. This statement refers particularly to studies where the detailed geometric design of single road sections or junctions is not the problem to be solved, but rather development of an entire road network.

It seems to be obvious that the source of information about traffic behavior should be the traffic inventory regardless of the purpose of the study—estimating the present traffic demands or forecasting future traffic.

Despite the significant progress in synthetically simulating traffic on extended networks of large study areas, better knowledge of prevailing traffic conditions still remains part of the framework for long-range transportation studies. Evidence from comprehensive assignment analyses proves, furthermore, that a theoretical trip distribution on the network can match the requirements of the planner only when the real traffic behavior is taken into consideration.

It is well known that the main source of knowledge concerning the very variable traffic pattern within one year is the permanent counts and the repeated monthly sample counts at the so-called "key" stations. Moreover, these counts contain all the elements characterizing the traffic behavior. The problem is that by means of factors obtained from a relatively low number of stations, it is impossible to characterize all the important traffic fluctuations present in a large network. Perhaps these adjustment factors are good enough to convert one-day counts into annual average traffic volume (ADT). However, an average sometimes is far from being sufficient. The ADT of two routes can be absolutely identical. But some of the main problems, especially for traffic and highway engineers, originate in the fact that the traffic pattern of these routes, described with the ADT, can be completely different within twelve months. If the traffic character of one of these routes is a typical working day traffic, the traffic volume can be expected to be steady throughout the whole year. Meanwhile, heavy weekend traffic or important recreational traffic of the summer months can produce peak daily volumes, which are two to five times higher than the ADT.

It is most desirable for planners and engineers to know the locations of routes, within the study areas, with unusual traffic patterns. In other words, to know the traffic character of the different roads of the network. This paper gives criteria for classifying routes by traffic characters into types. The allocating of road sections to these different types is an objective grouping based on a few machine counts. A counting and evaluating procedure with built-in statistical control was developed. The method develops factors for each of these route types. The factors, with statistically estimated accuracy, reproduce synthetically all-important details of the traffic and their peak for the entire network.

The method shown is that used in the Lake County Transportation Study (Illinois). Estimating traffic behavior on Lake County roads was accomplished in a manner similar to that used in a comprehensive traffic research conducted by the author in Hungary, Austria, The Netherlands, Switzerland and Western Germany. The characteristics of

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traffic observed in Europe, when compared with the results of analysis of traffic on Illinois highways, demonstrate a large area of agreement between human behavior in Europe and in this country. This also proves, indirectly, the objective criteria used by the classification of the network to produce factors which characterize the traffic behavior of roads with sufficient accuracy in the large field of traffic engineering and planning activity.

METHOD OF CLASSIFYING ROUTE TYPES

It is generally known that route by route, the pattern of daily traffic volume during the twelve months of the year is essentially different. Figures 1 and 2 show four characteristic relative volume trends from Lake County. Without knowing the traffic character of a route, it is impossible to convert sample counts accurately to ADT, or to determine other traffic characteristics. A classification of route types by traffic character is necessary. Results of comprehensive traffic analyses show that a usable parameter for classification can be the ratio of recreational traffic to the total traffic. The recreational traffic has two important ingredients, and they are: the vacational traffic of the average weekday and the weekend traffic. This kind of information can be obtained by simple machine counts instead of roadside interview. The vacational traffic on an average weekday of the summer months can be expressed by the ratio of the average weekday traffic in August to the average weekday traffic in May and June; that is,

$$\psi = \frac{V_8}{\frac{1}{2}(V_5 + V_6)} \tag{1}$$

in which

V_8 = the daily average weekday traffic in August;
V_5 = the daily average weekday traffic in May; and
V_6 = the daily average weekday traffic in June.

The classification of routes by the various values of the factor means that sample counts of each route segment within the same route type can be converted with a single adjustment factor to ADT. This adjustment factor by route type is the arithmetic mean of ψ factors derived from counts on control stations by the same route type. The standard error of this arithmetic mean is the systematic error of this factor, which influences the accuracy of ADT estimates.

The practical consideration regarding the accuracy in ADT estimates led to the establishment of three characteristic categories of vacational traffic:

1. Routes with a high percentage of vacational traffic, $\psi > 1.2$;
2. Routes with a medium percentage of vacational traffic, $1.1 \leq \psi \leq 1.2$; and
3. Routes with a low percentage of vacational traffic, $\psi < 1.1$.

The weekend traffic can be characterized simply with the ratio of the average traffic of the week V_i to the average Sunday traffic of the summer half year v_7:

$$\frac{V_i}{v_7} = b_7 \tag{2}$$

in which

$V_i = \frac{1}{7}(5\,v_W + v_6 + v_7)$;
v_7 = traffic volume on Sunday;
v_6 = traffic volume on Saturday;
v_W = traffic volume on average weekday; and
b_7 = daily factor for Sunday.

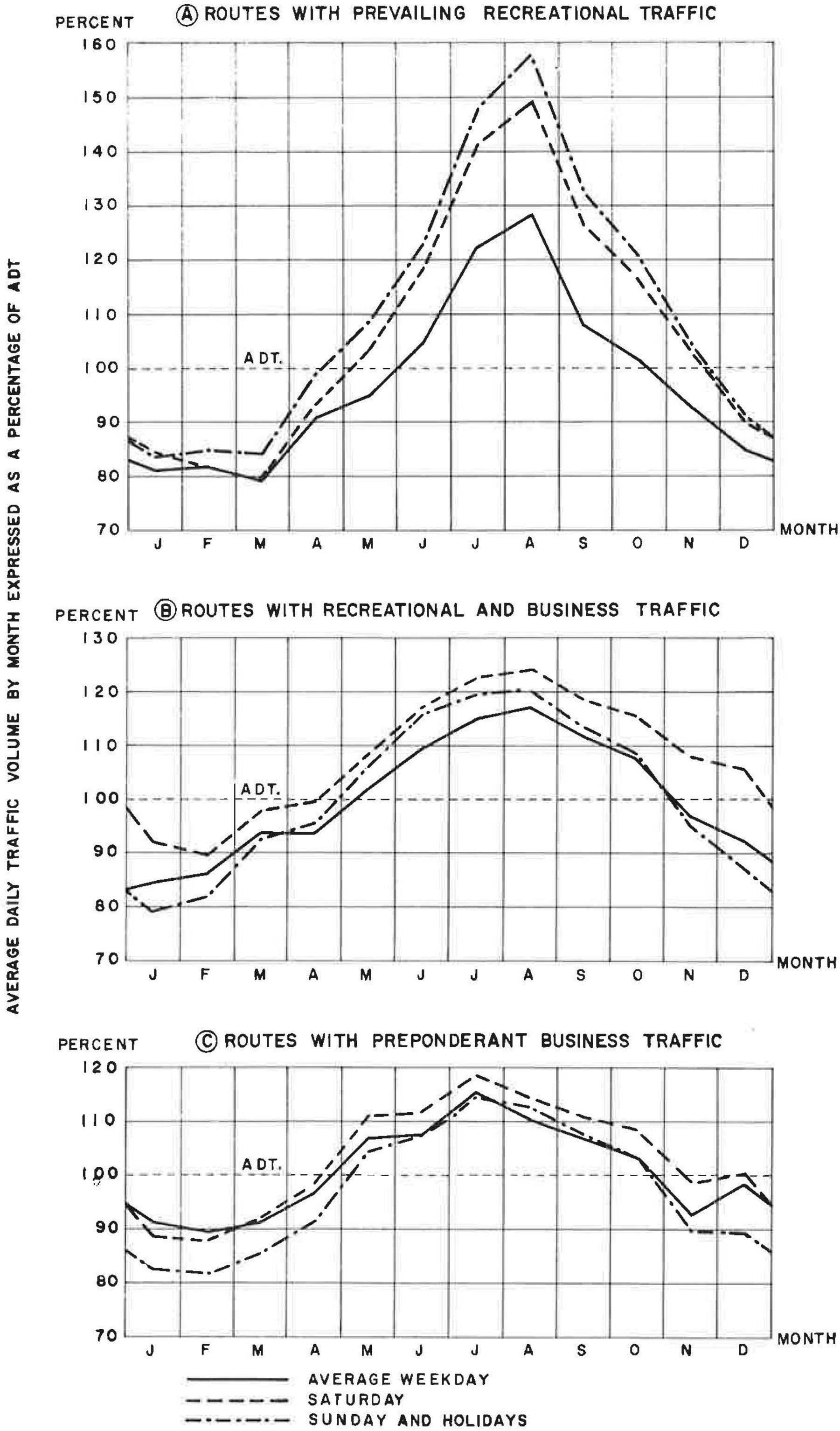

Figure 1. Relative traffic volume trends by route type on rural roads in Lake County (key stations, 1960, 1961).

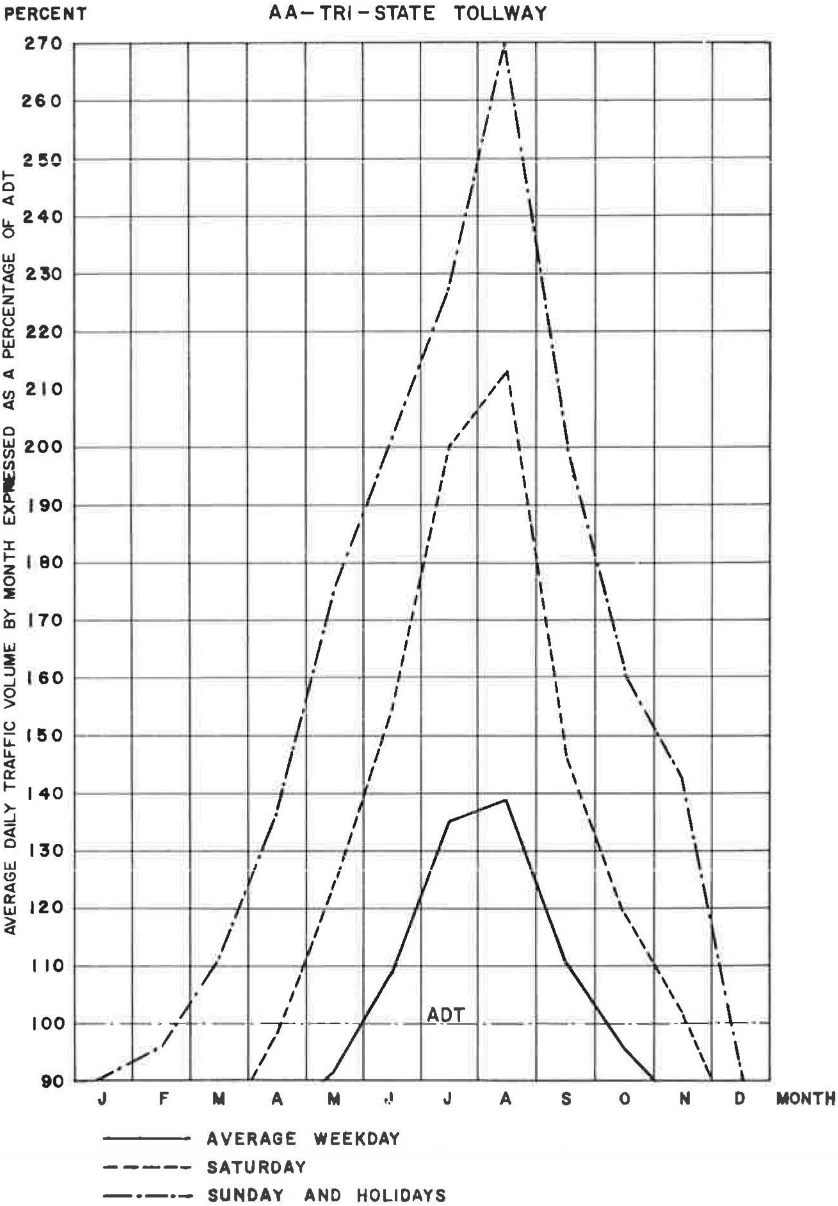

Figure 2. Relative traffic volume trend on Tri-State Tollway (Interstate 94) in Lake County (toll plazas no. 31 and 32, 1960-1961).

To characterize the different intensities of Sunday traffic, the routes can be grouped also in three categories.

1. Routes with relative high Sunday traffic are routes on which the traffic volume of an average Sunday of the summer half year is more than 10 percent higher than the traffic volume of the average weekday: $b_7 < 0.9$.

2. Routes with relative medium Sunday traffic are routes on which the average Sunday traffic of the summer half year is within 10 percent of the traffic on the average weekday: $0.9 \leq b_7 \leq 1.1$.

3. Routes with relative low Sunday traffic are routes on which the average Sunday traffic of the summer half year is more than 10 percent less than the traffic on an average weekday: $b_7 > 1.1$.

Grouping the routes by the combination of 3 types of vacational traffic and 3 types of Sunday traffic would result in 9 route types. Handling of 9 route types in practice is difficult, and also not necessary; therefore, only 4 route types were established where the different intensities of vacational and Sunday traffic were referred to as recreational traffic.

The final classification of the network is as follows:

1. Routes with prevailing recreational traffic (Route Type A) are routes with a high percentage of vacational traffic on an average weekday, regardless of the intensity of Sunday traffic: $\psi > 1.2$; b_7, any value.

2. Routes with recreational and business traffic (Route Type B) are either routes with a medium percentage of vacational traffic on an average weekday regardless of the intensity of Sunday traffic: $1.1 \leq \psi \leq 1.2$; b_7, any value—or with a low percentage of vacational traffic on an average weekday, but with high Sunday traffic; $\psi < 1.1$; $b_7 < 0.9$.

3. Routes with preponderant business traffic (Route Type C) are those with a low percentage of vacational traffic on an average weekday and with low Sunday traffic: $\psi < 1.1$; $b_7 > 1.1$.

4. The Tri-State Tollway represents a separate route type where a very high percentage of vacational trips ($\psi \sim 1.4$) on the average weekday of the summer half year combines with extra heavy and steady Sunday traffic throughout the whole year. Traffic on Sundays during the entire year is heavier than traffic on the average weekday (Table 1). The average Sunday traffic during the summer months is 55 percent higher than the traffic on the average weekday. The tollway (Route Type AA) is a recreational route.

Figure 3 shows the four different route types in the Lake County area. The factors necessary for these classifications were determined from counts of key stations (Table 2) and from counts taken on each of the crossing points of the cordon and screenline. Thirteen additional key stations were established to complete the counts necessary to classify the network by route type and to determine the traffic patterns on these route types.

ADT ESTIMATES BY ROUTE TYPES

After grouping the routes of the network into route types, the factors which characterize the changes of daily, weekly, and monthly traffic patterns can be determined.

Dealing with the ADT estimate problem, the various traffic flows during the weekend by route type is the first important factor which must be considered.

Table 1 shows the traffic on Sundays and Table 3 the traffic on Saturdays, by route type throughout the year. Traffic volume is expressed as a percentage of average weekly traffic. In the weekend traffic of recreational routes (Types AA and A) the

TABLE 1

TRAFFIC ON SUNDAYS BY MONTH AND BY ROUTE TYPE AS PERCENTAGE OF AVERAGE DAY OF WEEK[a]

Route Type	Month											
	J	F	M	A	M	J	J	A	S	O	N	D
AA	137	139	145	149	162	169	143	162	154	147	149	114
A	102	103	105	107	111	112	114	115	115	112	109	104
B	93	94	98	101	103	104	103	102	101	99	97	93
C	92	93	95	97	91	101	102	103	102	101	99	93

[a]Derived from Table 2.

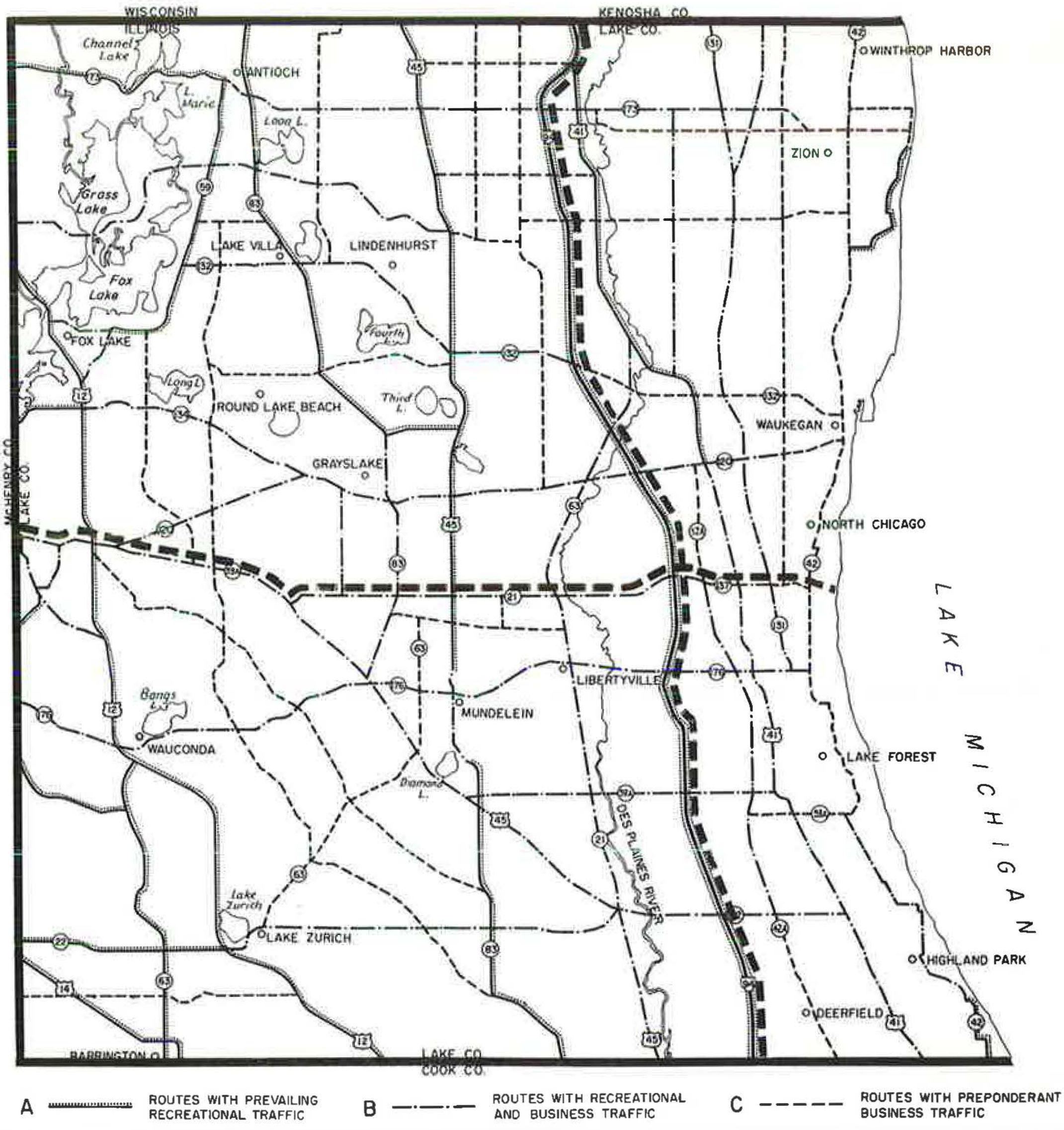

Figure 3. Spatial distribution of recreation routes in Lake County.

traffic of Sundays is dominant. For the importance of the weekend traffic on routes with recreational and business traffic (Type B) and on routes with preponderant business traffic (Type C), the traffic on Saturdays is characteristic. The characteristics of the weekend traffic, by route type, can be expressed as daily factors for Sundays (b_7), daily factors for Saturdays (b_6), and daily factors for average weekdays (b_W). Figure 4 shows the average values of these factors by route type for each month. Another characteristic for the changes in traffic patterns by route type is described as the monthly factor (c_i) given in Table 4. This factor yields as a product with the average day of the month the ADT. From a single sample count taken on an average weekday for any month of the year v_i, the traffic volume of the average day of the month is $b_W v_i$; and the annual average of the daily traffic ADT (V_o) is

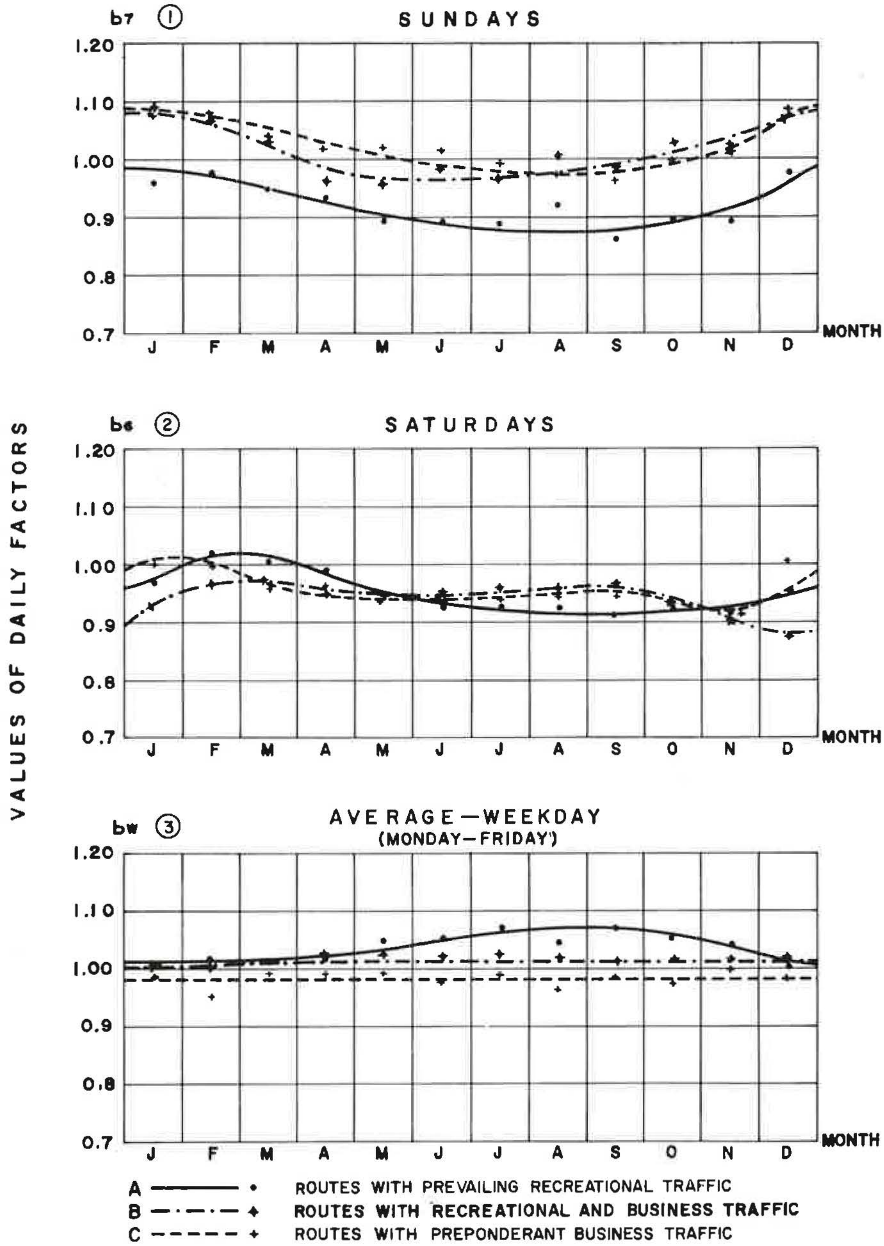

Figure 4. Seasonal fluctuation of daily factors by route type.

$$V_o = (b_w \, c_i) \, v_i \tag{3}$$

Further simplification can be made in practice by computing the product $\varkappa_i$ of the two factors shown above in advance. The values of these $\varkappa$-factors are given in Figure 5 for each route type. These factors give the relations between the traffic volume of an arbitrarily chosen average v_i and V_o.

$$V_o = \varkappa_i \, v_i \tag{4}$$

TABLE 2

ANALYZED KEY STATIONS

(Counts Taken by Illinois Division of Highways, 1960 and 1961)

Station	County	On Route	Location	ψ	Sunday's Traffic as % of avg. Day of the Week	Route Type by Traffic Character
Plaza 31	Lake	Tri-State Tollway[a]	State line	1.43	155	Route Type AA
Plaza 32	Lake	Tri-State Tollway[a]	Lake-Cook line	1.37	155	
2	Lake	Ill. 59 + US 12	S of Ill. 134	1.36	178	
6Z	Lake	US 41	NW of Ill. 63	1.24	122	Route Type A
6BZ	Lake	US 45	S of Ill. 173	1.29	118	
75	Cook	US 12	NW of Ill. 83	1.23	139	
75BX	Cook	US 14	SE of Ill. 53	1.41	102	
75C	Cook	Ill. 62	SE of Ill. 53	1.30	94	
3	McHenry	US 14	SE of Ill. 47	1.32	88	
3BZ	Cook	Ill. 59	N of Ill. 72	1.21	128	
1	Lake	Ill. 176	W of Ill. 42A	1.12	87	Route Type B
1A	Lake	Ill. 42A	N of Ill. 176	1.14	102	
1CX	Lake	US 45	Deerfield Rd.	1.14	118	
2A	Lake	Ill. 134	E of Ill. 59 and US 12	1.11	118	
2B	Lake	Ill. 59A	SE of Ill. 120	1.12	119	
6AZ	Lake	US 41	NW of Ill. 63	1.08	111	
6CZ	Lake	Ill. 120	E of Ill. 131	1.14	82	
1BM	Lake	Edens Expwy.	Cook-Lane	1.10	118	
74	Cook	Ill. 21	SE of Ill. 58	1.09	110	
74B	Cook	Green Bay Rd.	NW of Church St.	1.12	77	
4C	Kane	Ill. 25	SE of S. Elgin	1.07	114	
3R	McHenry	Ch. 25	S of Ill. 120	1.19	123	
3CZ	McHenry	Ill. 31	N of Ill. 176	0.92	122	
1B	Lake	Ill. 42	S of Zion	1.08	93	Route Type C
1R	Lake	Ch. 27	S of Zion	1.05	100	
2C	Lake	Ill. 63	NE of Fairfield	1.08	108	
2R	Lake	Ch. 32	SE of US 12	1.06	108	
73A	Cook	Touhy Ave.	E of US 41	1.01	90	
74C	Cook	Ill. 68	W of Ill. 42A	1.10	106	
75A	Cook	Ill. 83	N of US 42	0.92	104	

[a]Counts taken by Illinois State Toll Highway Commission.

TABLE 3

TRAFFIC ON SATURDAYS BY MONTH AND BY ROUTE TYPE AS PERCENT OF AVERAGE DAY OF WEEK[a]

Route Type	Month											
	J	F	M	A	M	J	J	A	S	O	N	D
AA	104	103	106	106	115	118	125	125	113	108	106	98
A	103	99	99	102	105	108	108	109	110	109	108	105
B	108	103	103	105	105	105	105	105	105	106	110	114
C	99	100	103	104	105	105	105	105	105	106	109	104

[a]Derived from Table 2.

The accuracy of ADT's obtained by means of these $\varkappa$-factors was checked empirically. The accuracy of the ADT's also differ on the route types from which the sample counts were taken (Table 5). This shows that more counts are necessary on routes with prevailing recreational traffic than on routes with preponderant business traffic, if the same level of accuracy in ADT estimates is required.

Table 6 shows the accuracy of converted ADT's by month. June proves to be the best month for sample counts, not only in Lake County, but also in west European countries.

The average errors of ADT estimates are not sufficient information if higher accuracy is wanted. Figure 6 shows the frequency distribution of errors in ADT estimates, by route type. Single machine counts taken on routes with prevailing recreational traffic cannot always be converted to a reliable ADT, because the traffic of recreational routes is not as steady as the traffic on business routes. Increasing the number of machine counts by station eliminates the maximum errors (Fig. 7).

The assignment analysis requires very accurate ADT data on cordon and screenline stations. The total number of vehicles crossing these lines may be compared with the assignment results; therefore, the ADT on routes with heavy traffic must be reliable. Figure 8 shows the accuracy of the converted ADT's values is essentially higher on routes with traffic greater than 500 vehicles per 24 hours than on routes with less than 500 vehicles. In the Lake County study, the ADT value of vehicles that cross the cordon and screenline (Fig. 3) is 269,258 vehicles per 24 hours. The ADT estimates obtained with these $\varkappa$-factors from a single sample count were

TABLE 4

MONTHLY FACTORS (c_1) BY ROUTE TYPE[a]

Month	Route Type			
	AA	A	B	C
Jan.	1.50	1.22	1.17	1.12
Feb.	1.45	1.22	1.15	1.14
Mar.	1.32	1.25	1.06	1.12
Apr.	1.09	1.09	1.06	1.06
May	0.92	1.02	0.97	0.95
June	0.76	0.91	0.90	0.94
July	0.63	0.77	0.86	0.89
Aug.	0.59	0.73	0.85	0.92
Sept.	0.77	0.87	0.89	0.95
Oct.	0.91	0.93	0.92	0.98
Nov.	1.04	1.04	1.02	1.10
Dec.	1.24	1.15	1.07	1.04

[a]Derived from Table 2.

TABLE 5

ACCURACY OF ADT ESTIMATES BY ROUTE TYPE[a]

Route Type	Deviations from Actual ADT as Percent of ADT		
	$n^b = 1$	$n = 2$	$n = 3$
A	± 10.0	± 8.5	± 8.3
B	± 7.5	± 6.6	± 6.8
C	± 4.8	± 3.2	± 2.7
All Routes	± 7.5	± 6.2	± 6.1

[a]ADT obtained by $\varkappa$-factors in Figure 4.
[b]n = number of machine counts taken on an average weekday during the summer half year.

ADT obtained from single machine counts in May = 267,218 vehicles per 24-hour; June = 273,087; July = 266,375; and August = 270,140.

The average value of these deviations from the actual ADT is less than ± 1 percent.

An interesting comparison was made between ADT's obtained from these factors by route type and ADT's derived from a constant factor (ρ) which can be applied for all route types of the area. This so-called ρ-factor was derived by the author in western Europe and was previously presented (1). The value of this factor in Europe was $\rho = 0.31$ (see Table 9) and in the Lake County network it was found to be the same. With this single factor, counts of all kinds of route types can be converted to ADT using

$$V_O = \rho\ (V_5 + V_6 + V_7) = 0.31\ (V_5 + V_6 + V_7) \qquad (5)$$

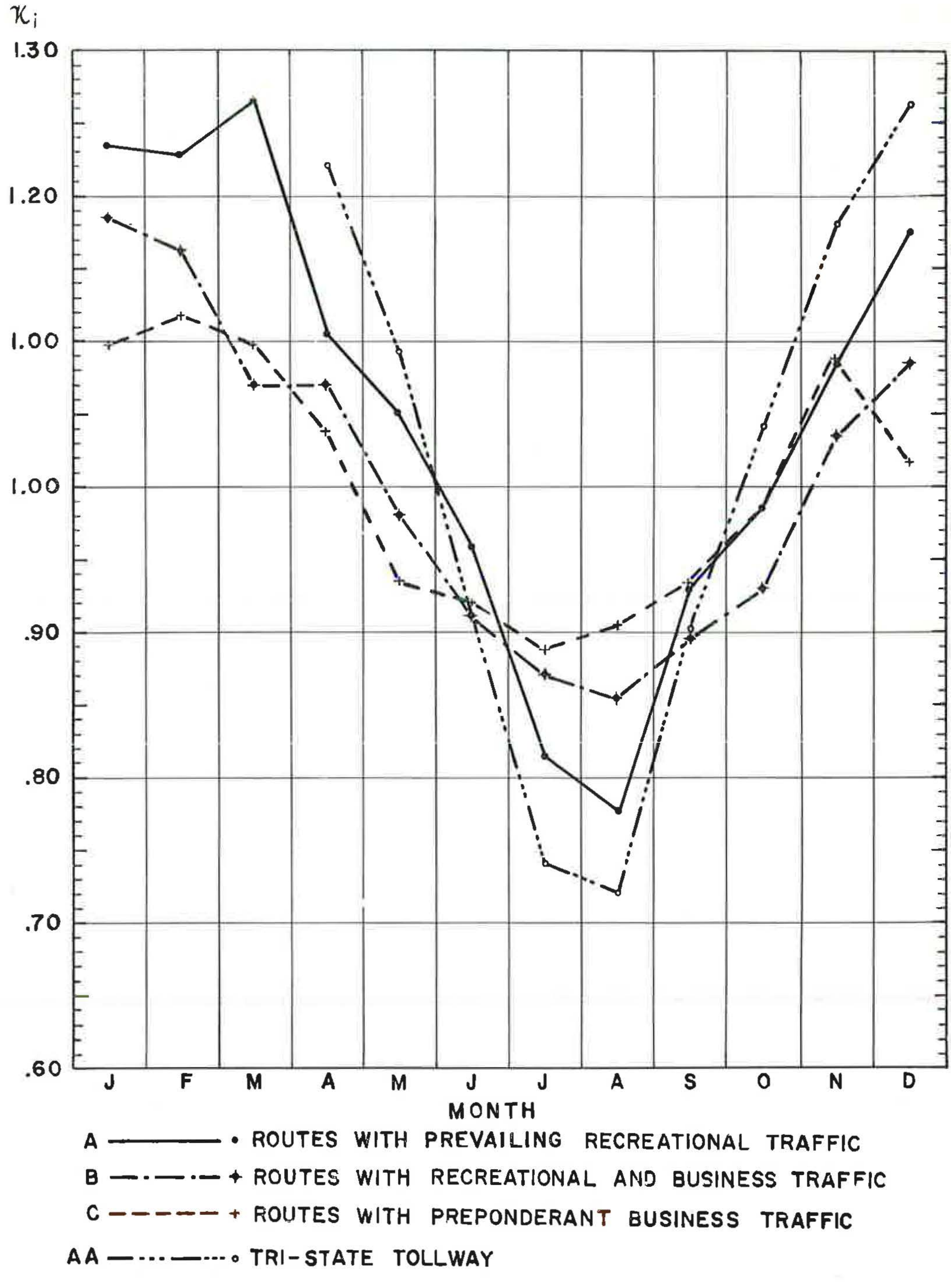

Figure 5. κ_i-factors by route type.

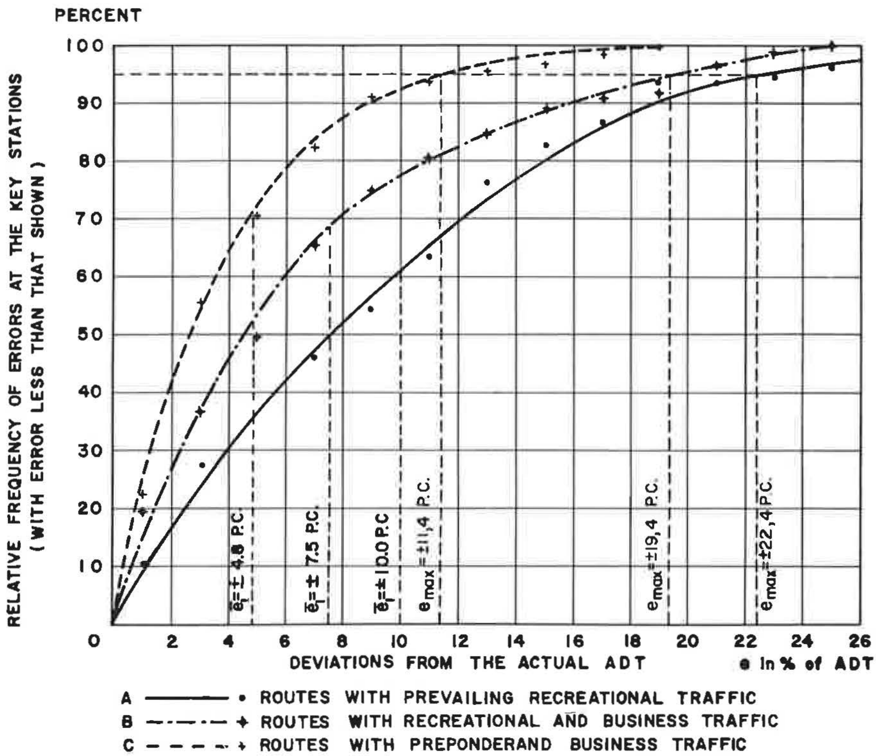

Figure 6. Accuracy of ADT estimates on Lake County's rural highway system (ADT obtained by means of κ_i-factors, n = 1).

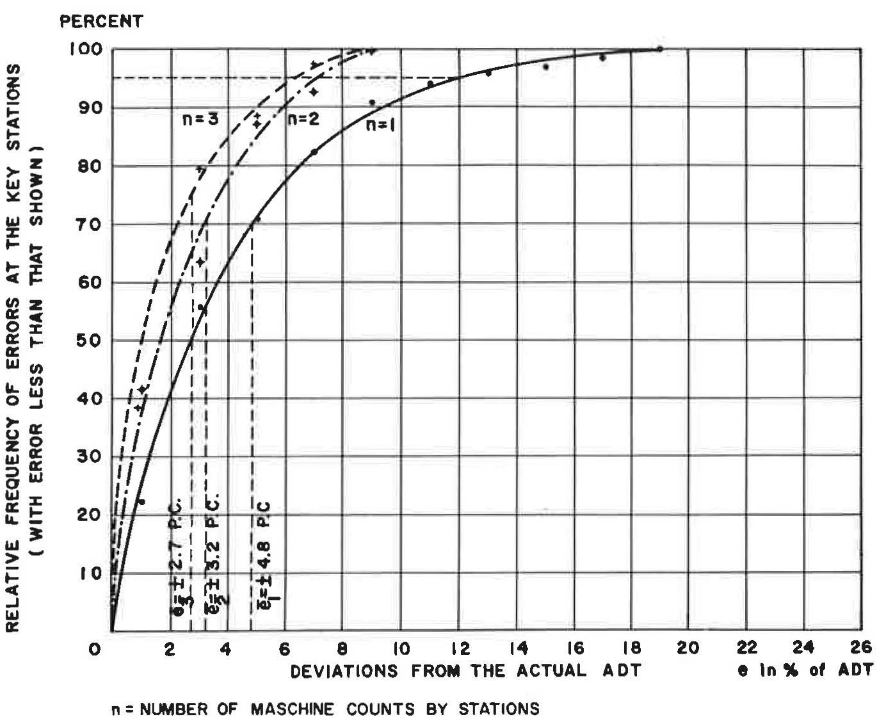

Figure 7. Frequency distributions of errors in ADT estimates, Route Type C.

in which V_5 = the traffic volume on an average weekday in May; V_6 = that in June; and V_7 that in July. Using this 0.31 factor to estimate ADT's on cordon and screen-lines, the result was 270,708 vehicles per 24 hour, which was only ½ percent different from the 269,258 for actual ADT. Figure 9 shows the frequency distribution of ADT values as derived.

The classification of the network, by route type, has three advantages compared to the other procedures:

1. It enables a simple ADT estimate on all route types of an area; and also gives the number of sample counts, by route type, which is necessary to match the different accuracy needs of the assignment procedure.
2. For transportation planning purposes, this method gives the necessary information about peaks and frequency of these peaks, which are quite different by route type.
3. The result of the assignment procedure in the traffic forecast is the allocated ADT value of all trips by links. Knowing the actual traffic character on all routes in a metropolitan area, it is easier to estimate the relative traffic volume of design hours by different routes, for the future. Having the land-use data for the planning and horizon years, it is easier to find relations between traffic characteristics of the present and future network than to estimate the value of an adjustment factor on a master control station for the future.

TABLE 6

ACCURACY[a] OF ADT ESTIMATES BY MONTH[b]

n = 1 Machine Count	Route Type A	Route Type B	Route Type C	All Route Types
May	± 9.4	± 7.9	± 5.0	± 7.6
June	± 7.4	± 5.0	± 4.2	± 5.5
July	± 10.0	± 8.2	± 4.1	± 7.6
Aug.	± 8.0	± 7.1	± 5.1	± 6.8
Sept.	± 12.8	± 9.8	± 5.6	± 9.6
Oct.	± 12.3	± 7.4	± 4.8	± 8.2
Avg. summer half year	± 10.0	± 7.5	± 4.8	± 7.5

[a]Deviation from the actual ADT given as a percentage of ADT.
[b]ADT obtained by κ-factors in Figure 4.

ESTIMATE OF TRAFFIC FOR PEAK HOURS OF THE YEAR

Table 7 gives the relative traffic volume by hours of the day by route type. The relative traffic of Sundays is the highest on the Tollway, but the relative traffic of Saturdays and average weekdays is the highest on routes with preponderant business traffic.

Figure 10 shows the different characteristics in the daily pattern of the peaks between the tollways and 2-lane routes with prevailing recreational traffic. Having the previously described daily and monthly factors by route type and the peak values given in Table 7, the characteristic peak-hour pattern for each route type for the entire year can be computed.

The daily traffic values expressed as a percent of ADT shown in Figures 1 and 2 were computed from the following:

Traffic on Sundays:

$$i_7 = \frac{100}{b_7 c_i} \qquad (6)$$

Traffic on Saturdays:

$$i_6 = \frac{100}{b_6 c_i} \qquad (7)$$

Traffic on average weekday:

$$i_w = \frac{100}{\kappa_i} \qquad (8)$$

In the second column of Table 8, the daily traffic volumes as a percent of ADT are computed for the Tri-State Tollway (shown also in Fig. 2).

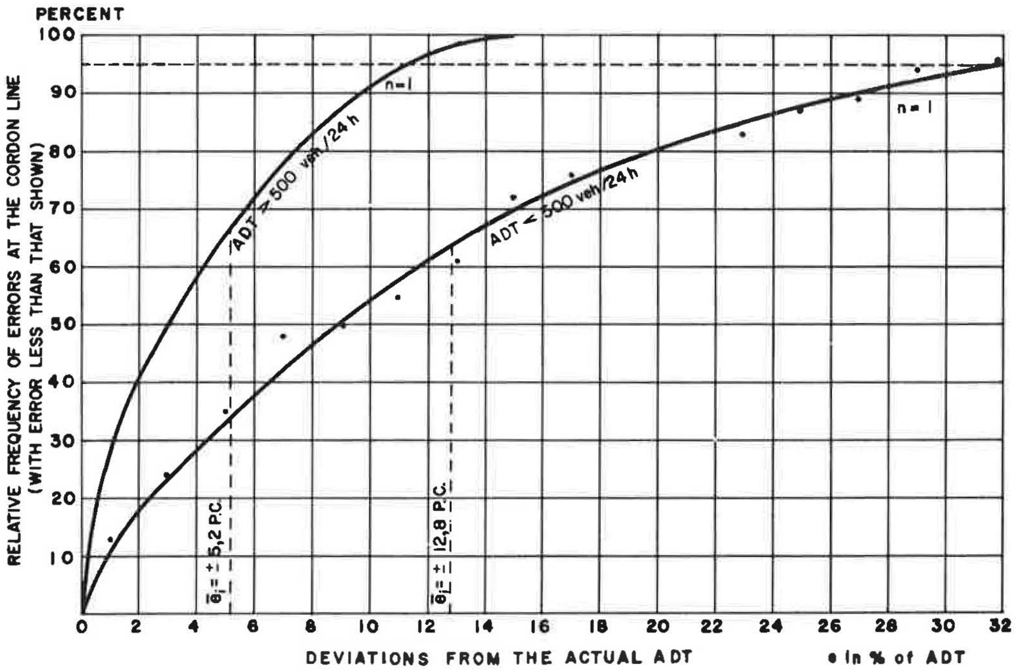

Figure 8. Accuracy of ADT estimates of arterial and local roads.

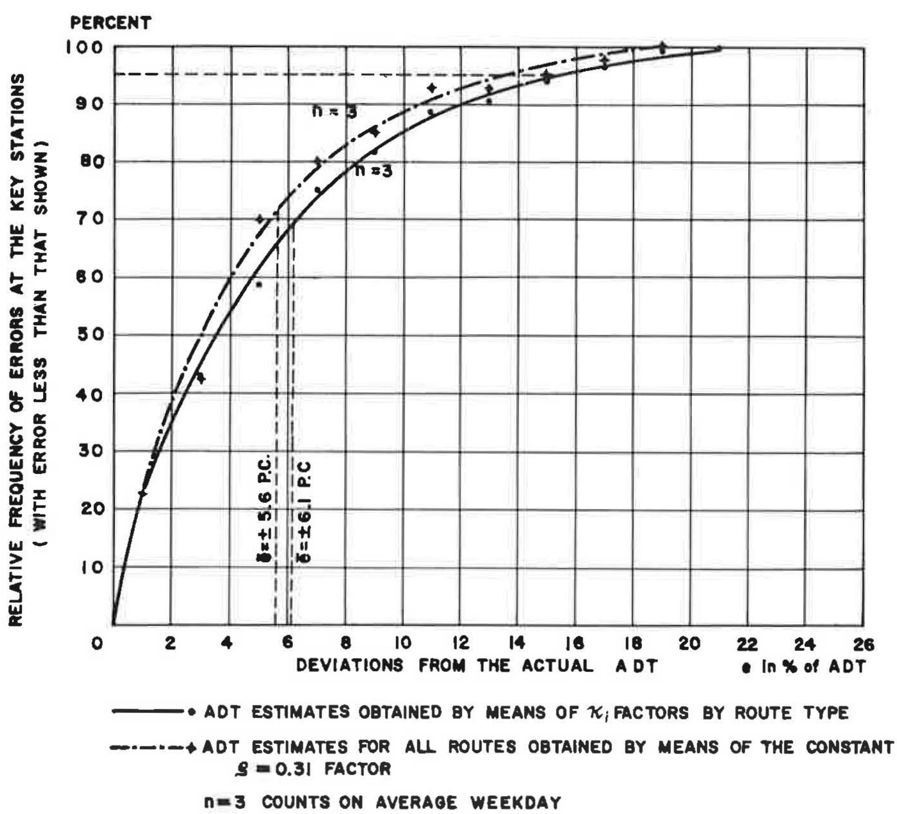

Figure 9. Comparison of accuracy of ADT estimates, all route types in Lake County.

TABLE 7

AVERAGE RELATIVE HOURLY TRAFFIC VOLUME[a] OF THE DAY BY ROUTE TYPE

Route Type	Highest Traffic Volume of Day as Percent of Daily Total							
	1st	2nd	3rd	4th	5th	6th	7th	8th
(a) Sundays and Holidays								
AA	11.5	9.8	8.9	8.2	7.6	6.6	6.0	5.4
A	9.1	8.8	8.4	8.2	7.6	7.2	6.8	6.4
B	9.1	8.6	8.1	7.8	7.6	7.1	6.7	6.5
C	9.1	8.5	8.2	7.9	7.7	7.3	7.0	6.7
(b) Saturdays								
AA	7.4	7.0	6.6	6.3	6.1	5.8	5.6	5.5
A	7.1	6.5	6.2	6.0	5.8	5.7	5.5	5.3
B	7.6	7.3	7.0	6.8	6.6	6.4	6.2	5.9
C	8.1	7.5	7.2	6.9	6.7	6.5	6.2	5.9
(c) Average Weekdays								
AA	9.7	8.7	7.8	6.9	6.4	5.9	5.6	5.3
A	9.6	8.6	7.9	7.8	7.2	7.1	6.8	6.7
B	9.6	8.7	7.9	7.2	6.5	6.2	6.0	5.8
C	10.6	9.5	8.6	7.6	6.8	6.3	5.9	5.5

[a]Counts taken during the summer half year of 1960 and 1961.

TABLE 8

TRAFFIC VOLUME OF THE PEAK HOURS AS PERCENT OF ADT TRI-STATE TOLLWAY

Month	Daily Traffic (% of ADT)	1st	2nd	3rd	4th	5th	6th	7th	8th	Frequency of Peak Hours by Year
		Highest Peak-Hour of Day								
		Average Relative Hourly Traffic Volume								
		0.115	0.098	0.089	0.082	0.076	0.066	0.060	0.054	
(a) Sundays and Holidays										
April	137	15.7	13.4	12.2	11.2	10.4	9.0	8.2	7.4	5
May	176	20.3	17.2	15.7	14.4	13.4	11.6	10.6	9.7	5
June	222	25.4	21.8	19.7	18.2	16.8	14.6	13.3	12.0	4
July	227	26.0	22.2	20.2	18.6	17.2	15.0	13.6	12.2	5
Aug.	270	31.0	26.5	24.1	22.2	20.5	17.8	16.2	14.6	5
Sept.	200	23.0	19.6	17.8	16.4	15.2	13.2	12.0	10.8	6
Oct.	161	18.4	15.7	14.3	13.2	12.2	10.6	9.6	8.7	4
Nov.	143	16.4	14.0	12.7	11.7	10.8	9.4	8.6	7.7	5
(b) Saturdays										
		0.074	0.070	0.066	0.063	0.061	0.058	0.056	0.055	f
May	125	9.2	8.8	8.2	7.9	7.6	7.2	7.0	6.9	4
June	154	11.4	10.8	10.2	9.7	9.4	8.9	8.6	8.5	5
July	200	14.8	14.0	13.2	12.6	12.2	11.6	11.2	11.0	4
Aug.	213	15.9	15.0	14.2	13.6	13.1	12.5	12.0	11.8	4
Sept.	147	10.9	10.3	9.7	9.2	8.9	8.5	8.2	8.1	5
(c) Average Weekdays										
July	135	0.097	0.087	0.078	0.069	0.064	0.059	0.056	0.053	f
July	135	13.1	11.8	10.5	9.3	8.7	8.0	7.6	7.2	22
Aug.	139	13.5	12.1	10.8	9.6	8.9	8.2	7.8	7.4	22

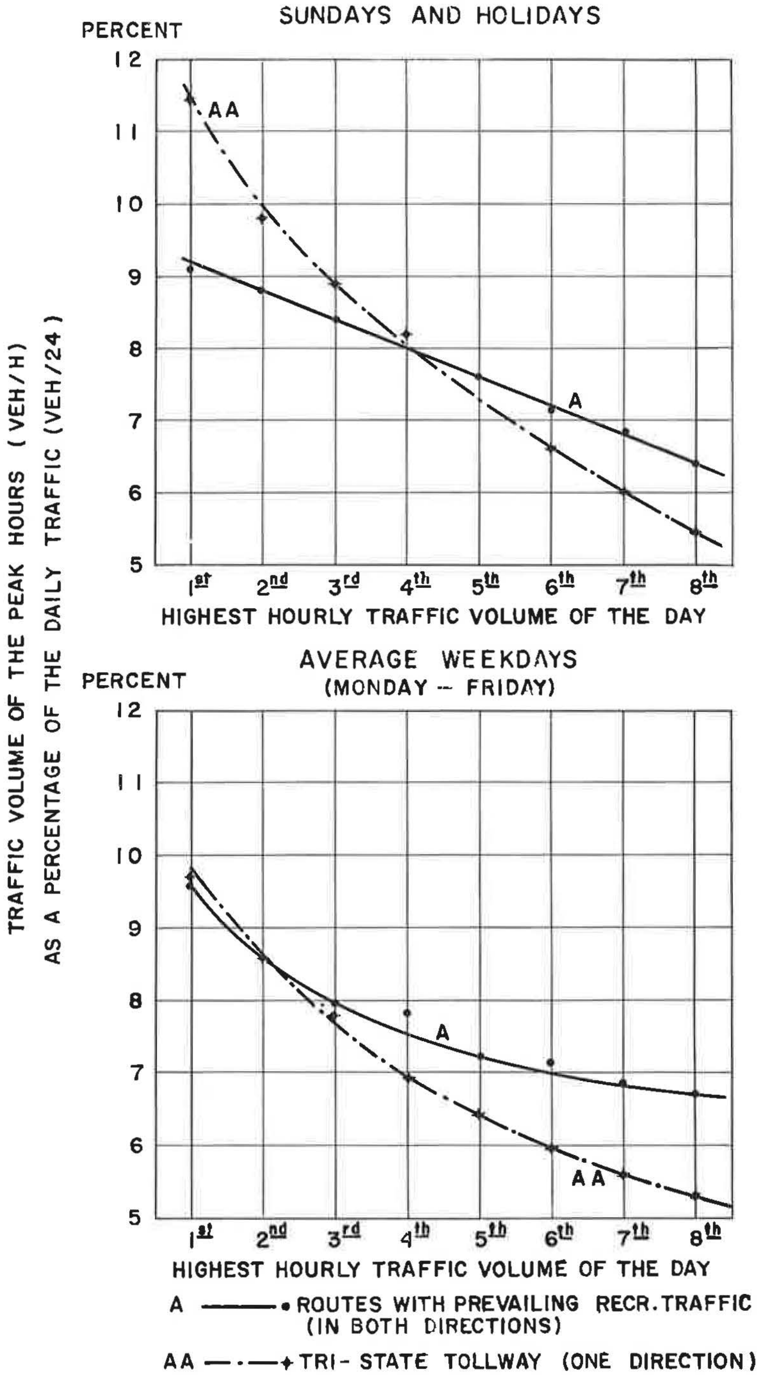

Figure 10. Average relative hourly traffic volumes of the day.

From the average relative hourly traffic volume of the day (δ_i) and the i_7, i_6 and i_W values, the relation between traffic volume of the peak hours and the ADT (ω_i) can be computed for any day as a percentage of ADT.

Sunday peak hours:

$$\omega_7 = \delta_7 \, i_7 \tag{9}$$

Saturday peak hours:

$$\omega_6 = \delta_6 \, i_6 \tag{10}$$

Average weekday peak hours:

$$\omega_W = \delta_W \, i_W \tag{11}$$

Knowing the volume of ADT V_0 and the route type, the peak hour V_{max} for any day of the year can be computed:

$$V_{max} = \omega_i \, V_0 \tag{12}$$

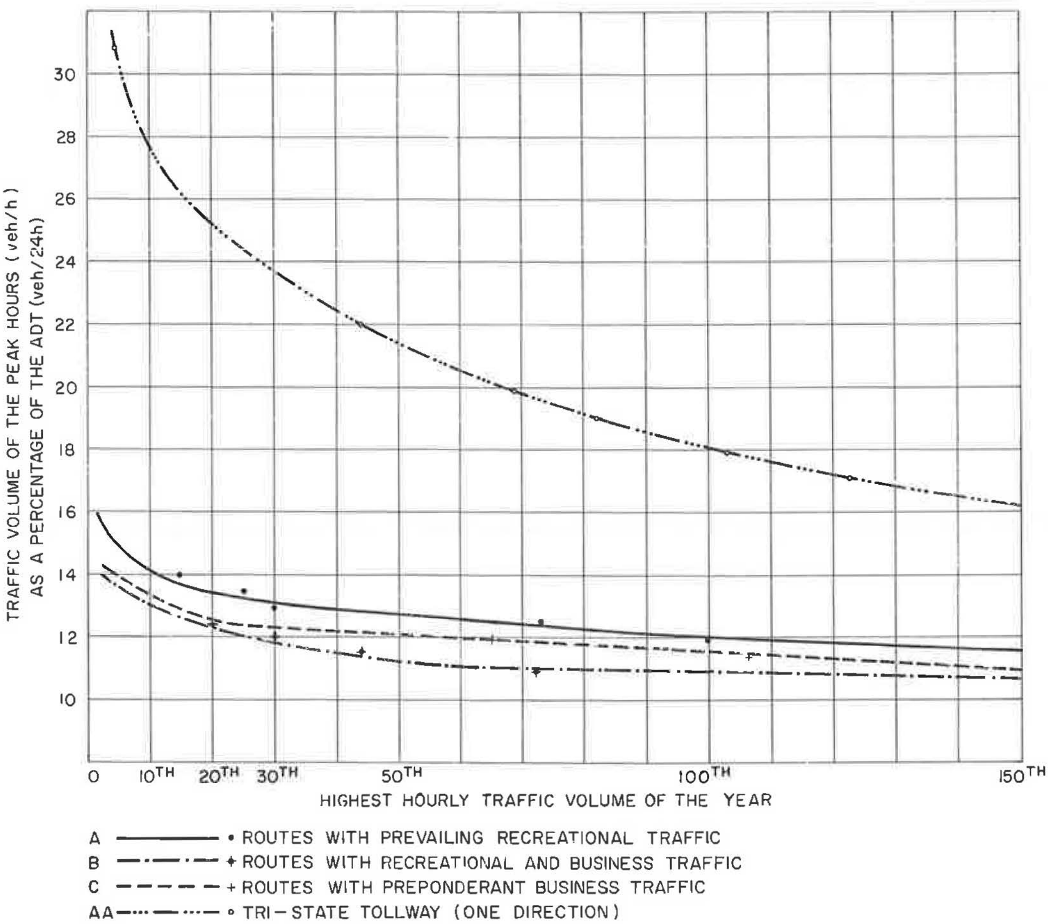

Figure 11. Relation between traffic flow of peak hours and annual average daily traffic.

Computations for Figure 11 were similar to those in Table 8. These diagrams are the basis for selecting the relative traffic volumes of design hours by route types for a given metropolitan area.

COMPARISON BETWEEN TRAFFIC PATTERNS BY ROUTE TYPE IN LAKE COUNTY AND IN EUROPE

Table 9 gives characteristics in traffic patterns by route type in five European countries and in Lake County. These similarities demonstrate, not only the large area of agreement between human behavior in Europe and in this country, but also prove indirectly the objective criteria used by classification of the network to be correct. The factors which characterize the traffic behavior of these routes can be used with sufficient accuracy in the large field of traffic engineering.

SUMMARY

Classifying Route Types by Traffic Character

A usable parameter for classification is the ratio of recreational traffic to the total traffic of summer months. The recreational traffic can be estimated from (a) the vacational traffic of the average weekday; and (b) from the average weekend traffic. The parameter can be obtained for each road section of the network by simple machine counts in May, June and August.

Route Types by Traffic Character in a Metropolitan County

There are four route types by traffic character on the rural roads in Lake County, Illinois: (a) recreational (Route Type AA); (b) prevailing recreational traffic (Route Type A); (c) recreational and business traffic (Route Type B); (d) preponderant business traffic (Route Type C).

The traffic behavior on these routes in Illinois is very similar to the traffic behavior of equivalent types in Europe. A fifth route type found in certain parts of Europe—the mountain roads in the Alps—is, of course, not represented. Within these types, classification of all rural roads in Europe or Illinois could be made satisfactorily.

No conclusions concerning urban route classification were drawn, because traffic counts in the urban part of Lake County have not yet been completed. A brief analysis of preliminary data from Lake County and treatment of Chicago counts suggest that the overwhelming proportions of urban roads can be classified as Route Type C. Only a few exceptions, such as Lake Shore Drive or Edens Expressway in Chicago, could be found, where, despite the heavy weekday use, Sunday traffic exceeded weekday traffic.

TABLE 9

COMPARISON OF TRAFFIC BEHAVIOR BY ROUTE TYPE AND LOCATION

Location	Route Type A					Route Type B					Route Type C				
	κ_5	κ_6	κ_7	κ_8	δ	κ_5	κ_6	κ_7	κ_8	δ	κ_5	κ_6	κ_7	κ_8	δ
Austria	1.00	0.95	0.84	0.71	0.31	0.96	0.93	0.86	0.88	0.31	0.96	0.93	0.88	0.94	0.31
Hungary	0.99	0.92	0.79	0.74	0.30	—	—	—	—*	—	—*	—	—	—	—
Netherlands	1.00	0.93	0.83	0.73	0.30	0.98	0.92	0.88	0.83	0.31	0.92	0.89	0.88	0.89	0.30
Switzerland	1.11	1.02	0.87	0.74	0.33	0.93	0.98	0.92	0.86	0.31	—*	—	—	—	—
W. Germany	0.97	0.85	0.78	0.72	0.29	0.92	0.88	0.83	0.79	0.29	0.94	0.89	0.89	0.88	0.30
European avg.	1.02	0.93	0.82	0.73	0.30	0.95	0.93	0.87	0.84	0.31	0.94	0.90	0.89	0.90	0.30
Lake County	1.05	0.96	0.82	0.78	0.31	0.98	0.91	0.81	0.86	0.31	0.94	0.92	0.87	0.91	0.30

*No information.

Determining Factors to Characterize Traffic Behavior

After grouping the permanent counting stations and key stations into route types, the following factors of these groups can be determined:

1. $\varkappa$-factors by route type and by month (Fig. 5). These factors yield, as products with the daily traffic volume of an average weekday, the ADT.

2. Daily factors by route type and by month (Fig. 4). These factors (b_7, b_6 and b_ω) yield (as products with the daily traffic volume on Sundays, or as products with the daily traffic volume on Saturdays, or as products with the daily traffic volume of the weekdays) the traffic of average day of the week.

3. δ_i-factors by route type (Fig. 10). These factors show the relative traffic volume by hours of the day. The factors should be computed for Sundays, for Saturdays, and for the traffic on the average weekday of the summer months (Table 7).

After grouping all routes of the network into route types (Fig. 3), the $\varkappa_i$-factors of these route types can convert one day counts to ADT.

For all routes in a metropolitan county, characterized with their ADT volume, by means of $\varkappa_i$-factors and b_ω, b_6, or b_7 factors the daily traffic volumes can be computed for any day of the year (Figs. 1 and 2).

The average relative hourly traffic volumes of the day—δ_i factor (Table 7)—yields as a product with the daily traffic volumes (expressed as a percent of ADT and called i_ω, i_6 and i_7 factors) all the peaks throughout the whole year. Not only the peaks of the weekdays, but also the Saturday and Sunday traffic peaks can be computed (Table 8 and Fig. 11).

Having as results of the assignment procedure the traffic forecast (the ADT values on all routes in a metropolitan area), and knowing the route types of the network, it is easier to estimate the relative traffic volume of design hours for the future.

Accuracy of ADT Estimates Differs by Route Types

A single machine count taken on an average weekday during the summer half year, after converting with $\varkappa_i$-factors to ADT shows ± 5 percent deviations from the actual ADT, if the counts were taken on a route with preponderant business traffic. The probable error of ADT estimates is ± 10 percent if the count was taken on a route with prevailing recreational traffic.

The accuracy of the converted ADT value is considerably higher on routes with traffic greater than 500 vehicles per 24 hours than on routes with less than 500 vehicles per 24 hours (Fig. 7).

As the accuracy of ADT has an effect on the accuracy of the derived peak hours and other traffic characteristics, the number of sample counts should be adjusted by route type to any required accuracy.

CONCLUSION

The research briefly outlined in this paper is a pilot study as a part of the Lake County Area Transportation Study. Lake County, which is part of the Chicago Metropolitan Area, has an area of 468 sq mi and contains nearly 250,000 people. The objectives of the study are to develop a comprehensive and detailed highway plan for the county down to and including the roads at the county level. Lake County, especially its northwestern part with its many lakes, is a typical recreational area attracting, during the summer months, a very heavy weekend traffic from nearby Chicago. The study area lies between Chicago, Wisconsin and other states with significant vacational opportunities, which results in a heavy vacational traffic, not only on the weekends, but also on the average weekday of the peak season.

It is important for planners to know the recreational routes of the area. It is well known that the presence of weekend and vacational traffic results in heavy peaks (Fig. 2). Therefore, the knowledge of traffic behavior on all routes in a metropolitan county is important for traffic engineers, too, for it helps them to estimate the appropriate relative traffic volume of design hours by different routes.

REFERENCE

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A Critical Analysis of an Origin-Destination Survey

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•CAN a standard home interview O-D survey yield a pattern of movement which appears to be illogical? Can an abstract theory produce a pattern of movement which is more logical than that reported by an O-D survey? This paper examines the work-trip and shopping-trip patterns found in the 1957 O-D survey of the Cedar Rapids-Marion area of Iowa, and compares movements predicted by the author's field theory of movement with those found in the O-D survey and those simulated by application of a gravity model. The results of the study cast some doubts upon the validity of this particular O-D survey, and may raise further questions about all such surveys.

CEDAR RAPIDS-MARION O-D SURVEY

The Iowa State Highway Commission conducted a home interview O-D survey of Cedar Rapids and adjacent Marion during 1957. Figure 1 shows the area and the O-D zones. Every seventh household was interviewed, and the external cordon was established essentially at the combined corporation lines of these contiguous cities. The results of this study, combined with land-use and travel-time data, were used to create a gravity model of the area. This model, in turn, was used as the basis for predicting future movements in seven Iowa cities (6).

Wiant (6) reports that the gravity model was created in the following way:

> Work trip production was related to the labor force residing in each zone. In calculating the number of auto-driver work trips originating in any zone, adjustments were made for transit riders and auto passengers. Zonal employment data were the basic attraction factor for work trips. Other home base trip production was directly related to car ownership and the zonal attraction factor used for this trip purpose was population plus 25 times retail employment. ... Factors were also derived from the Cedar Rapids data to describe the relation of travel time and trip frequency.
>
> * * *
>
> After "weighting" the model to reflect the true interchange of Cedar Rapids-Marion trips, the traffic model desire line volumes were compared to their home-interview counterparts.

Data on places of residence, employment, and retail trade were supplied to the Iowa State Highway Commission and to the author by the City Planning Commission of Cedar Rapids. Table 3 (Appendix) gives this information, together with coordinates of the centers of activity as selected by the author.

The Field Theory of Movement

The field theory of land use and the movement of people relating to work trips has been presented (3), and may be expressed

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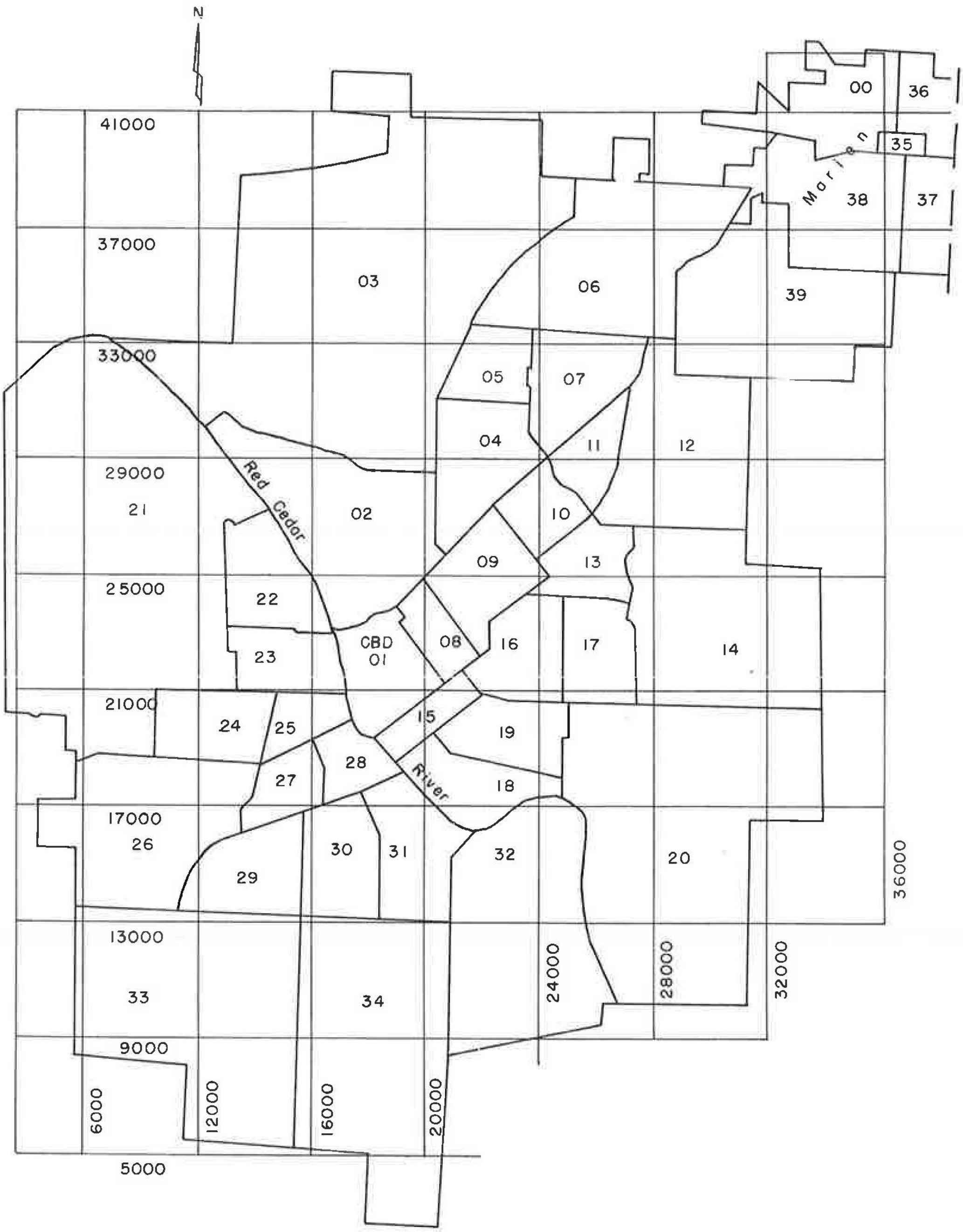

Figure 1. O-D zone map of Cedar Rapids, Iowa.

$$V_{P_iQ_j} = \frac{\frac{Q_j}{R_{ij}} P_i}{\sum_{j=1}^{m} \frac{Q_j}{R_{ij}}} \quad (i = 1, 2, \ldots n) \tag{1}$$

in which

$V_{P_iQ_j}$ = number of one-way work trips from i to j;
P_i = number of workers living in zone i;
Q_j = number of jobs available in zone j; and
R_{ij} = straight-line distance between centers i and j, assuming that there are no physical barriers.

After applying certain balancing iterations, the (n x m) solutions of Eq. 1 will draw the correct total number of workers from each zone of residence and will assign the correct total number of workers to each job site.

A thus-far unreported aspect of the field theory relates to the prediction of shopping trips. Based on the following assumptions:

1. Every household makes a certain average number of shopping trips each day (in particular, one such trip each day will be used for present purposes);
2. The number of retail employees at each shopping center provides a measure of the relative attractiveness of each center; and
3. The straight-line distance between a center of residence and a center of shopping is the proper measure of separation.

The field theory for shopping trips may be expressed

$$M_{H_iS_j} = \frac{\frac{E_j}{R_{ij}} H_i}{\sum_{j=1}^{m} \frac{E_j}{R_{ij}}} \quad (i = 1, 2, \ldots n) \tag{2}$$

in which

$M_{H_iS_j}$ = number of one-way shopping trips from i to j;
H_i = number of households in zone i;
E_j = number of retail employees in zone j; and
R_{ij} = straight-line distance from i to j.

Successive applications of Eq. 2 for i = 1, 2, etc., will assign each household to move to one center of shopping, but will not control, in any way, the total number of shopping trips destined for any center. Since it is a common phenomenon to find certain shopping centers more crowded than others, and since such centers do expand and contract to meet long-term trends in business, it appears obvious that the shopping trip pattern lacks the balancing restraints imposed on work-trip patterns. The number of retail employees in a center seems to be the only logical measure of relative attraction since this quantity is most easily varied to meet short-term changes in demand. Further discussion of these points will be found elsewhere (2).

PHILOSOPHIES BEHIND O-D SURVEYS, GRAVITY MODELS, AND FIELD THEORY

Caution is the order of the day when one is tempted to say that a new theory gives more reliable results than an established empirical solution to a problem. In previous applications of the field theory, reasonable comparisons to O-D findings were obtained, but in the present study several major discrepancies were found. Before proceeding, therefore, it may be well to reconsider briefly the philosophy behind each of the three methods of determining trip patterns.

Home interview O-D surveys determine the trips made by a sample of households on a particular day. Normally only vehicular trips are recorded, i.e., auto driver, auto passenger, and mass transit, as was the case in Cedar Rapids. The sample findings are then multiplied by a factor (in Cedar Rapids, 7) to get a representation of the total pattern of movement with a certain expected probability of error. For example, if the expanded volume for a certain movement is 100 trips, two-thirds of the time one must expect that the actual number of trips making this movement is between 70 and 130, while the remainder of the time the error must be expected to be larger (7). Since walking trips are ignored the possibility exists that many intrazonal trips, and perhaps trips between adjacent zones, are not reported. A person who drives to work and stops at a store to shop on his way home will be considered to have made one of the following two sequences of trips: (a) home to work; work to shopping; shopping to home, or (b) work trip; non-home based trip; shopping trip, depending on the nomenclature being used. Finally, the results of an O-D survey are supposed to represent movements on a "typical day," even though the data may have been gathered over a period of six months or more.

Since 1955, several attempts have been made to fit gravity models to the results of O-D surveys in the hope that such models might be used to extrapolate the findings of the corresponding surveys to future land-use patterns in the study areas (1, 5, 6). The only theoretical justification offered for such action has been that some combination of coefficients, exponents, and adjustments applied to a particular formula permits the calculation of simulated movements which one is willing to say approximates the findings of a corresponding O-D survey. In the Cedar Rapids study, home to work, other home based, and non-home based trips were simulated by such models.

In contrast to the above empirical approaches, the field theory assumes that, for some unknown reason, people move between centers of activity in accord with "laws" similar to those which govern the movement of various types of particles in physical "fields of force." Eqs. 1 and 2 make no attempt to say which persons will make which trips. Based on such assumptions as outlined, these equations yield the relative probabilities of their respective types of movement without regard for mode of transportation. In three previous studies, in which only work trips have been simulated, the theory has yielded results which have been at least consistent with the results of corresponding O-D surveys (2, 3, 4). One limitation on the theory is that it can deal only with a closed field, and cannot simulate trips across an external cordon.

This paper grew out of an attempt to simulate the work-trip pattern found by the O-D survey of Cedar Rapids by means of the field theory. When it was found that the results of the theory did not, in general, compare favorably with the results of the survey, both sets of data were examined in considerable detail in an effort to find the cause or location of the major discrepancies. The balance of this paper presents evidence on which the following question may be answered: Can something as abstract as the field theory create patterns of movement which are more reliable than those found by an origin and destination survey?

WORK TRIP PATTERN IN CEDAR RAPIDS-MARION

Eq. 1 was applied, together with three iterations, to simulate a pattern of work trips. Every worker was assigned to a job site within the external cordon, and every job was filled by a worker living within the cordon. Minor adjustment had to be made in the total number of workers and total number of jobs as given in Table 3 (Appendix). Table 4 (Appendix) gives both the total number of workers drawn from each zone of residence and the total number of work trips assigned to each job site by the theory, by the O-D survey, and by the gravity model. (Detailed movements found by the O-D survey and by the gravity model were supplied by the Iowa State Highway Commission.)

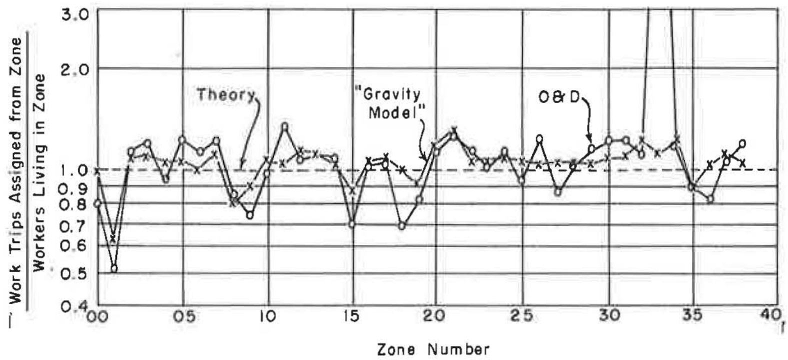

Figure 2. Ratio of work trips by zone of origin.

Figure 2 is based on the data of Table 4 and shows the average number of work trips per worker originating in each zone of residence as found by the three methods of determining movement. Figure 3, also based on Table 4, shows the average number of workers assigned to each job in each zone of employment. In both figures, the average number of workers is plotted logarithmically to indicate that the assignment of 2 workers to a job is an error equivalent in magnitude to assigning ½ worker to a job.

In all of the analyses which follow, gravity model results will be shown in figures, but no comments will be made concerning them.

Where Figure 2 shows ratios greater than unity it would seem that some workers make more than one trip from home to work each day. Such a situation would actually occur if various numbers of workers go home for lunch. Where less than one work trip per worker is made, the zone may have (a) a high rate of unemployment (although it is assumed that Table 3 contains the number of workers actually employed), or (b) a high rate of absenteeism (although the O-D survey is supposed to represent a "typical day"), or (c) a large number of workers who walk to work and are, therefore, of no interest in an O-D survey.

Figure 3 indicates that certain zones were found by the O-D survey to attract more work trips than there are jobs available in those zones, but again trips to eat lunch at home may account for this. Unusually high absenteeism on a "typical day," or workers walking to their jobs would seem to be the only explanations for those zones which appear to attract less than one work trip per available job.

While the field theory, as applied in Figures 2 and 3, creates one work trip for each worker and for each job, if the trips to home for lunch are an important factor in the traffic pattern, the theory can handle them easily. The number of workers living in each zone who go home for lunch can be added to the number of workers living in the

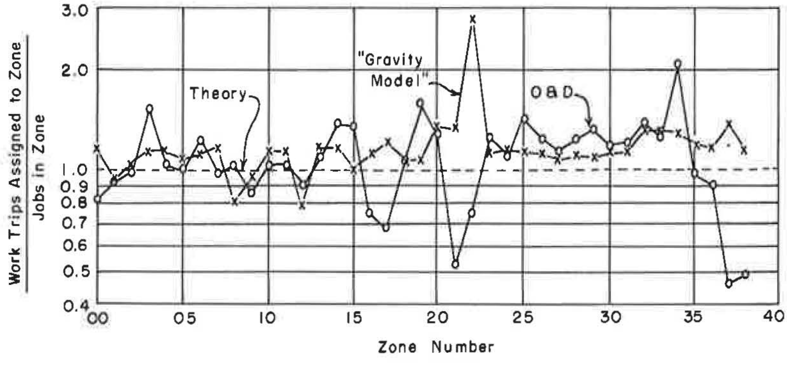

Figure 3. Ratio of work trips by zone of destination.

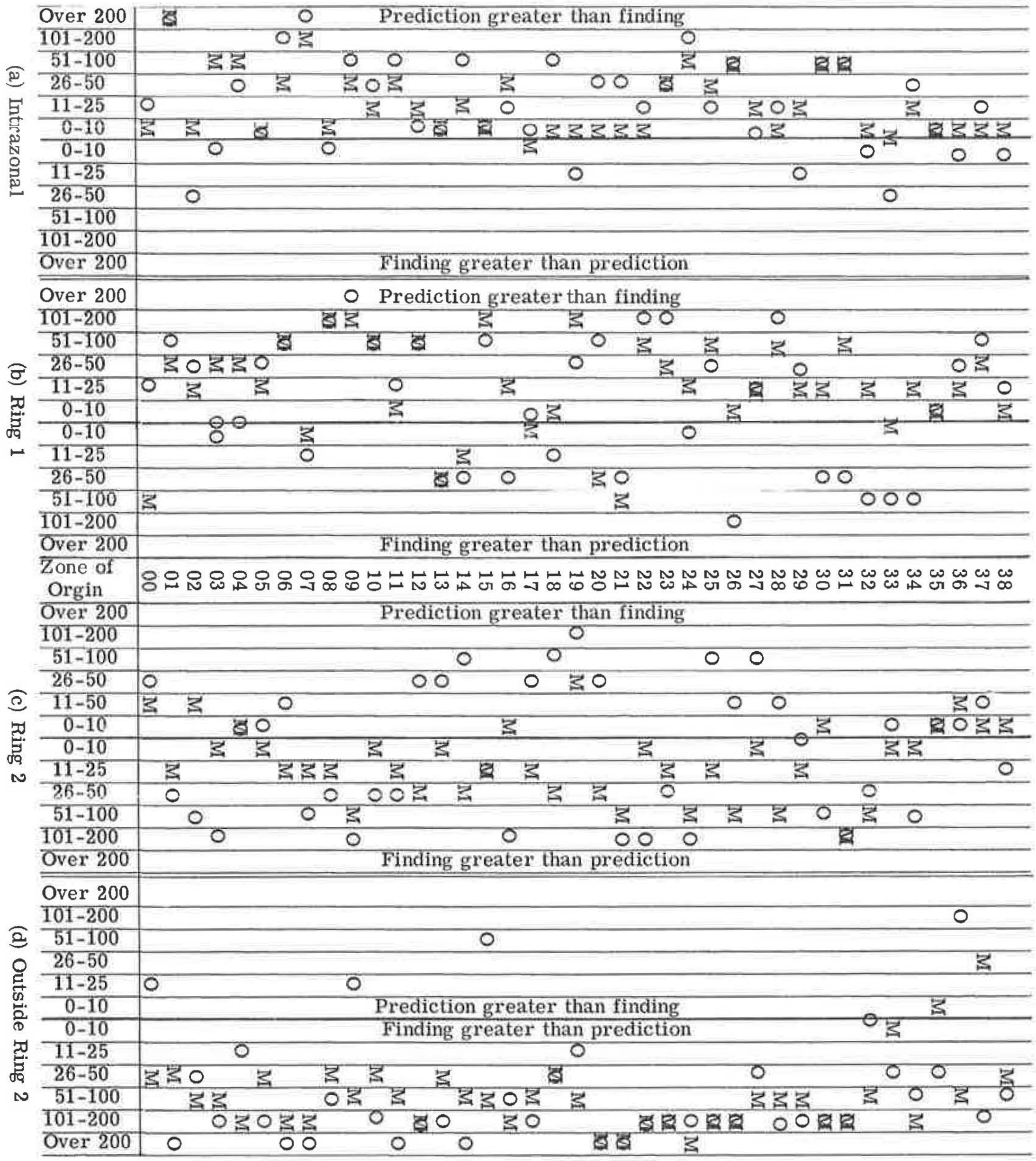

Figure 4. Discrepancies between work trips assigned by theory and found by O-D survey (O) and gravity model (M).

zone, and the number of workers leaving each job site to go home for lunch can be added to the number of jobs at the site to get modified values for P and Q in Eq. 1.

Figures 2 and 3 deal only with the total work trip pattern and do not take into account the possible effects of variations in lengths of work trips. Figure 4, by contrast, is a form of frequency diagram for the distribution of discrepancies between theory assignments and O-D findings of work trips from each zone of residence to four regions of employment. These regions are (a) the zone of origin, i.e., intrazonal; (b) those zones which abut the zone of origin, Ring 1; (c) those zones which are adjacent to Ring 1, called Ring 2; and (d) all other zones, called Outside

Ring 2. For example, Figure 1 shows that zones 03, 04, 06, and 07 form Ring 1 for zone 05, and that zones 00, 02, 09, 10, 11, 12, and 38 make up Ring 2, therefore, all other zones, except 05 itself, are Outside Ring 2. Each part of Figure 4 shows the approximate magnitude of any discrepancies which may exist, and whether the theory or O-D survey gives the larger total movement. Figure 4 (a) shows that in 32 of the 39 zones the theory predicted more intrazonal trips than were found by the survey. Figure 4 (b) shows that in 23 cases the theory assigns more workers to Ring 1 zones of employment than does the survey. Figure 4 (c) indicates that the theory and O-D survey each assigns more than the other in 19 cases, or what one might expect if the theory and survey gave reasonably comparable results. Finally, Figure 4 (d) indicates that the O-D survey, in general, assigns far more workers to job sites Outside Ring 2 than does the theory. In summary, Figure 4 shows that the O-D survey found many more long work trips and many fewer short work trips than were predicted by the theory.

In an effort to determine whether the O-D survey or theory results, as shown in Figure 4, are more logical, the intrazonal work trip pattern was analyzed further. It would seem reasonable to hypothesize that greater opportunities for work close to home, as measured by the product of jobs times workers in a zone, will induce larger numbers of workers to work within their zone of residence. Of course it is possible to have (a) a very large number of jobs available in a zone that houses very few workers, or (b) a very large number of workers living in a zone that includes very few jobs, and either of these cases is likely to distort the hypothesis. Nevertheless, each zone was ranked in ascending order, from 0 to 38, on the product of jobs in the zone times workers living in the zone. Each zone was similarly ranked on the number of intrazonal work trips predicted for that zone by the theory, and found for that zone by the O-D survey. (For purposes of Table 5 and Figure 5, the total number of O-D work trips originating in each zone was multipled by a factor to yield one work trip per worker living in the zone.) Table 5, Appendix, gives these three rankings for each zone, and is arranged by ascending order of product magnitude. This shows, for example, that zone 32 ranks (a) 5 on product magnitude, (b) 4 on intrazonal work trips by theory, and (c) 17 on intrazonal work trips by O-D survey. Figure 5 plots the rankings of Table 5, with the diagonal line of slope 1, and intercept at the origin, representing the hypothesis. With perhaps five exceptional points, the theory fits the hypothesis fairly well, in fact with a coefficient of correlation of 0.936. The O-D results depart rather widely from the hypothesis and have a coefficient of correlation of only 0.378.

CONCLUSIONS REGARDING WORK TRIP PATTERNS

If the hypothesis underlying Figure 5 can be accepted, i.e., if it is logical to expect that, in general, the greater the opportunity for intrazonal work trips, as measured by the product of jobs times workers in the zone, the greater will be the number of

TABLE 1

DATA ON WORK TRIPS ORIGINATING IN ZONE 30

Characteristic	By Theory	By O-D Survey
Workers living in zone	787	787
No. of work trips originated	787	997
Ratio of trips to workers	1.00	1.253
Jobs in zone	1061	1061
Intrazonal work trips	109	55(44[a])
Work trips to Ring 1	202	231
Work trips to Ring 2	409	503
Work trips to Outside Ring 2	67	208

[a]Adjusted value used in Table 5 and Figure 5.

such trips, it may be concluded that the theory gives a much more logical pattern of intrazonal work trips than does the O-D survey. But what impact does the intrazonal pattern have on the longer work trips that may be considered to be of greater importance in transportation planning?

Table 1 pertains to work trips originating in Zone 30. This, plus similar data for all other zones as summarized in Figures 2, 3, and 4, would seem to indicate that the O-D survey found progressively more work trips than predicted by the theory as the length of the trips increased. Furthermore, since the O-D survey indicates that many workers make more than one work trip per day it may be concluded that the O-D survey indicates that the longer the work trip the more likely the worker is to go home to lunch.

Even though one cannot say, in the present state of knowledge, that the theory gives the correct pattern of movement, it seems possible to conclude that the work trip pattern presented by the O-D survey is not completely logical.

SHOPPING TRIP PATTERN IN CEDAR RAPIDS-MARION

The O-D survey determined a pattern of one-way, home-based, vehicular shopping trips. The field theory was applied on the assumption that each household makes one shopping trip per day that originates or ends in the home. The gravity model cannot be considered in this section because it combined shopping trips with all other homebased non-work trips.

For purposes of the theory, a shopping trip is any movement between a home and any place of retail business from a gasoline station or small local grocery store to a major integrated shopping center. With such a comprehensive definition it might be desirable to assume that every household makes an average of two, or even more, shopping trips per day, but for present purposes the assumption of one trip per day will suffice. Solutions of Eq. 2, therefore, insure that every household makes exactly one shopping trip per day, but place no restraints on the total number of shoppers assigned to any single zone of shopping.

Table 6, Appendix, gives the total number of shopping trips originating in each zone and destined for each zone as determined by the theory and by the O-D survey. Figure 6 is based on Table 6 and shows the average number of shopping trips per household originating in each zone. Although it cannot be said that the O-D survey findings are wrong, it seems most unlikely that, on the average, all households in Cedar Rapids-Marion make only one shopping trip every three days (27,365 households and 9,206 internal shopping trips). Figure 6 further indicates that households in zones 15, 32, 33, 34, and 35 average less than one shopping trip every ten days.

Figure 7, also based on Table 6, shows the average number of shopping trips attracted by every retail employee in each zone. Zones 00 and 13 do not have any retail employees, but were assigned one each for study purposes. The theory actually assigns two shoppers to each of these zones while the O-D survey assigns 55 shoppers to zone 00. On the average, the theory assigns 3.58 shoppers to each retail employee with a range in assignments from 2.00 to 4.48 per employee. By contrast, the O-D survey assigns an average of 1.44 shoppers per employee with a range in assignments from 0.24 to 11.20 per employee, omitting consideration of the 55 assigned to zone 00.

Figure 8 corresponds to Figure 4 and shows the discrepancies between theory predictions and O-D findings for shopping trips of varying length, namely from each zone of residence to Intrazonal, Ring 1, Ring 2, and Outside Ring 2, as these terms have been previously defined for work trips. Consistent with Figures 6 and 7, the theory predicts more shopping trips of all lengths than were found by the O-D survey, with few exceptions. The few zones of origin for which the survey found more intrazonal than predicted by the theory, and the 12 zones for which it found no intrazonal trips, are rather difficult to explain. Table 2 shows comparisons between the intrazonal shopping trips of zones 00, 06, 12, 14, 21, 26, and 37, which zones show erratic behavior in Figure 8, and the intrazonal shopping trips of nearby zones of comparable size which appear to show more nearly normal behavior. In each erratic case where the O-D survey actually found intrazonal trips, it found appreciably more than one shopper per retail

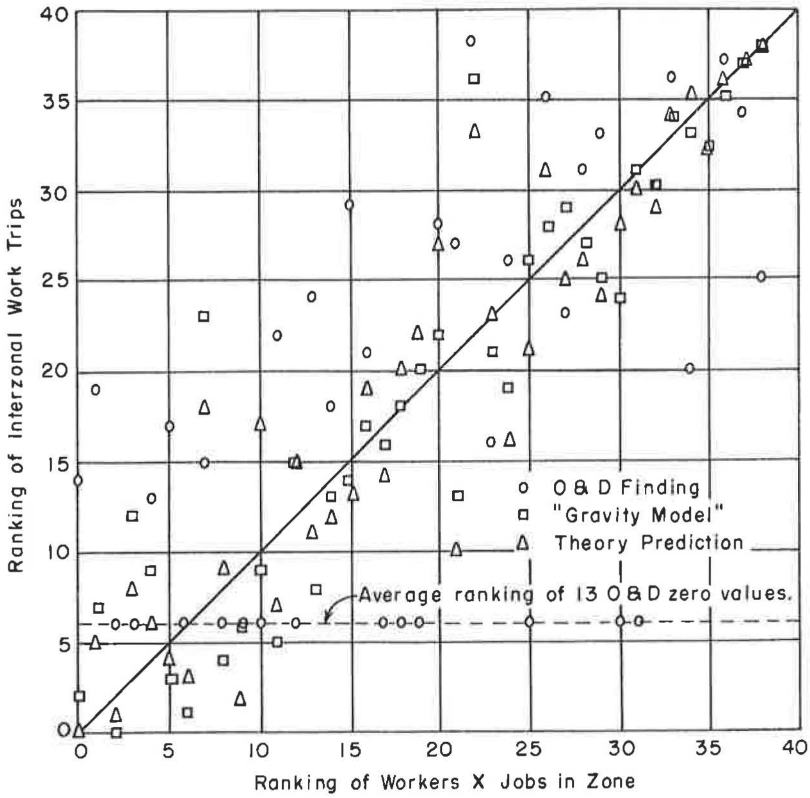

Figure 5. Rankings of intrazonal work trips vs rankings of products of workers times jobs in zone.

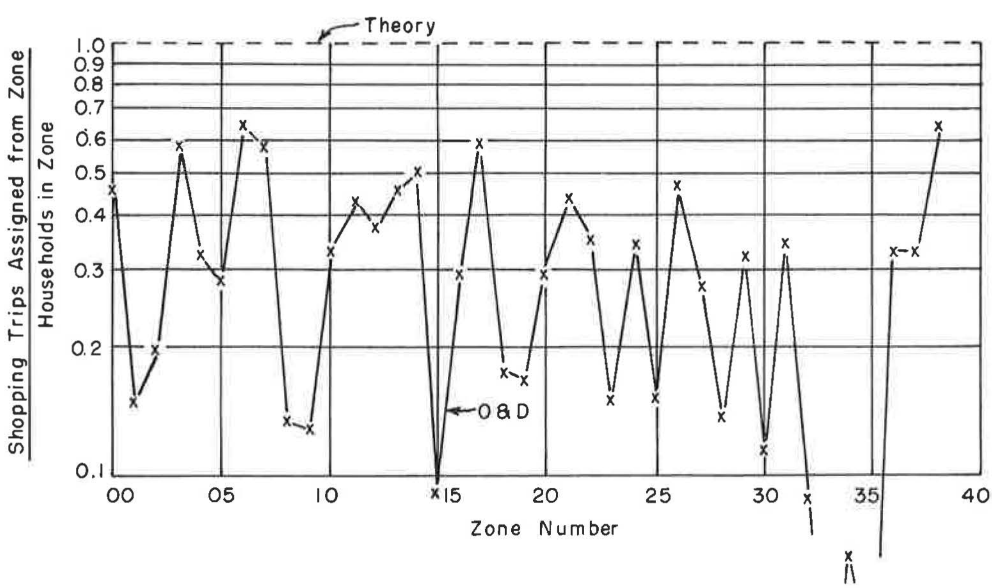

Figure 6. Ratio of shopping trips by zone of origin.

employee in the zone, whereas in the normal case it found considerably less than one intrazonal shopper per retail employee.

If it is reasonable to hypothesize that, in general, the greater the opportunity to make intrazonal shopping trips, as measured by the products of households times retail employees in a zone, the greater will be the number of such trips, Figure 9 can be plotted in a manner similar to that used for Figure 5. Table 7, Appendix, gives the zones ranked in ascending order of magnitude of the product of households times retail employees in the zone, with corresponding rankings by theory predicted and O-D found intrazonal shopping trips, and forms the basis of plotting Figure 9. Again the line of slope 1 passing through the origin represents the hypothesis while the plotted points compare the rankings by theory and O-D survey. As in the case of intrazonal work

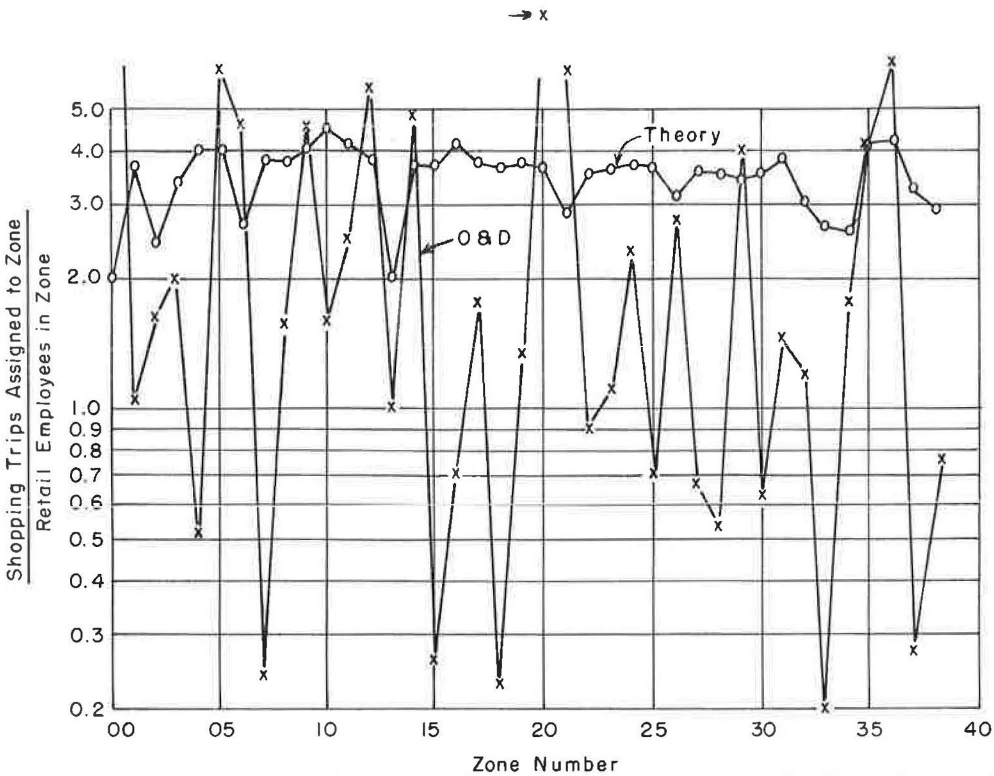

Figure 7. Ratio of shopping trips by zone of destination.

Zone No.	Behavior in Fig. 8	Households in Zone	Retail Employees in Zone	Intrazonal Trips by Theory	Intrazonal Trips by O-D Survey
00	Erratic	532	1	1	13
37	Erratic	400	15	9	0
38	Normal	348	21	10	14
06	Erratic	960	205	96	228
07	Normal	718	262	146	31
12	Erratic	563	52	24	61
11	Normal	553	90	41	15
14	Erratic	1,435	88	57	152
16	Normal	1,373	83	61	14
21	Erratic	1,606	78	48	267
24	Normal	1,071	188	128	59
26	Erratic	917	49	56	0
22	Normal	616	50	19	13

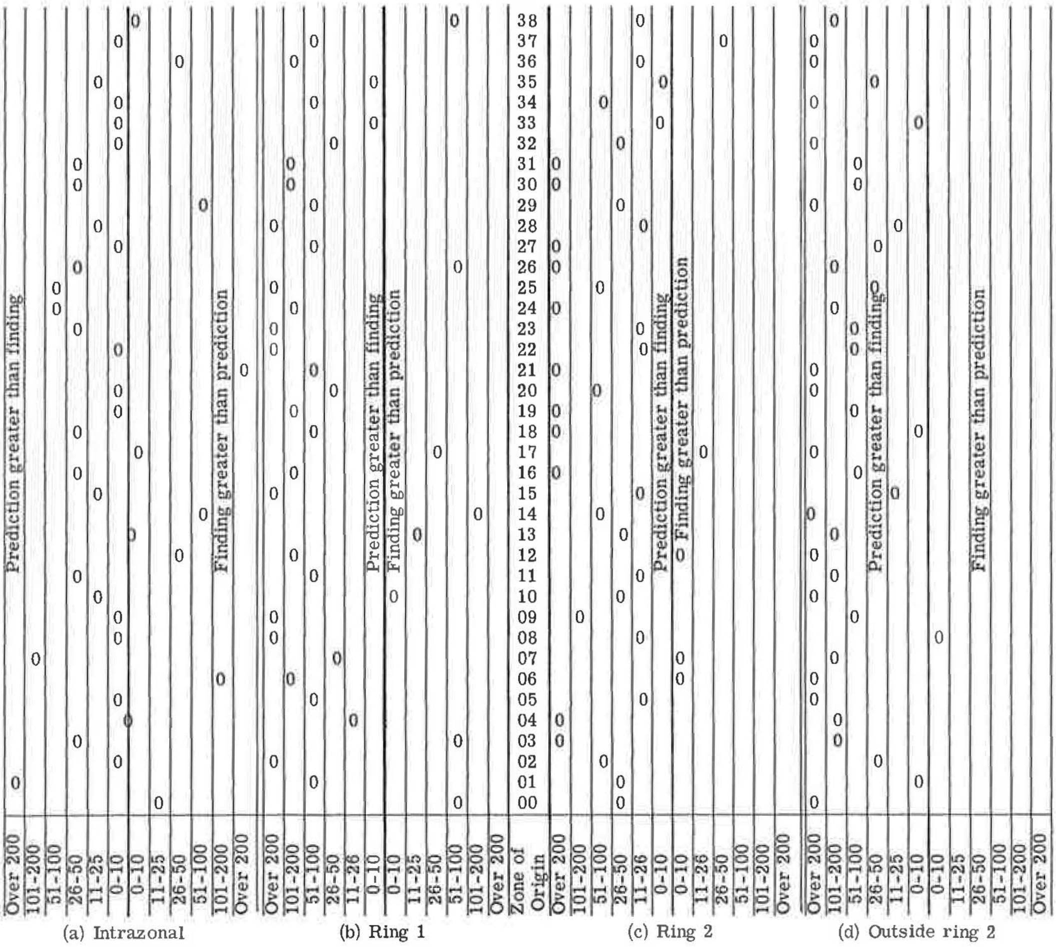

Figure 8. Discrepancies between shopping trips predicted by theory and found by O-D survey.

trips, that the theory gives more consistent results (coefficient of correlation, 0.961) than does the O-D survey (coefficient of correlation, 0.575).

CONCLUSIONS REGARDING SHOPPING TRIPS

Inasmuch as the theory considers a child walking to a neighborhood store to purchase a loaf of bread to be creating a shopping trip, and the O-D survey reports only movements using vehicles, one might expect that the theory would (a) in general predict a larger total number of shopping trips for each zone than found by the survey, (b) consistently predict more intrazonal shopping trips than found by the survey, and (c) possibly predict a smaller number of long trips than found by the survey. In the Cedar Rapids area the theory actually (a) predicts a larger number of shopping trips originating from every zone, but a smaller number destined for nine zones than found by the O-D survey, (b) predicts more intrazonal shopping trips in only 28 of the 39 zones, and in one zone predicts 200 fewer such trips than found by the survey, and (c) with the exception of one zone, predicts more trips to the region Outside Ring 2 than found by the survey.

Judging from Figures 6, 7, and 8, and associated tables, it seems safe to say that the O-D survey found a pattern of shopping trips that is much more erratic than that predicted by the theory.

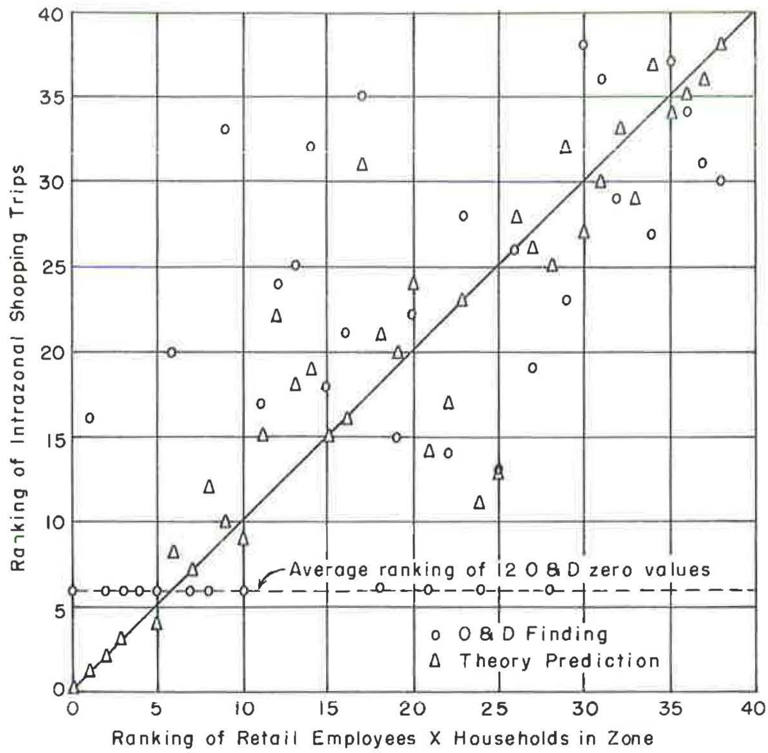

Figure 9. Rankings of intrazonal shopping trips vs rankings of products of retail employees times households in zone.

TRIPS TO THE CENTRAL BUSINESS DISTRICT

Thus far the CBD has been treated as any other zone, but this area, zone 01, should be considered in some detail because it is the most important generator of work trips (containing over one-third of all the jobs in the study area) and of shopping trips (containing over one-half of all retail employees).

Of the 562 workers living in zone 01, the theory assigns 351 to work in the CBD, while the O-D survey found 23 intrazonal work trips out of a total of 292 work trips originating in the zone. The gravity model created 138 intrazonal work trips out of a total of 357 work trips generated in the zone. The theory assigns 604 of the 768 households in the CBD to shop in that area, while the O-D survey found 53 out of a total of 133 originating shopping trips to be intrazonal. Despite the obvious diversity of these numbers, both the theory and survey may be correct since the former deals with all forms of transportation and the latter covers only movements by vehicle. But what of work and shopping from other zones to the CBD?

The theory assigns a total of 10,008 workers to the 10,260 jobs in the CBD (to limit the number of worker and job digits to 4, the theory assigned 9,999 jobs to zone 01); the O-D survey found 9,635 work trips destined for zone 01; the gravity model assigned 9,522 such trips. The theory assigns 14,127 shoppers to deal with the 3,962 retail employees in the CBD, while the O-D survey found 4,084 shopping destinations in the area. Table 8 lists the work and shopping trips destined for the CBD by zones of origin, and Figure 10 shows the values in graphical form.

The zones are grouped as Intrazonal, Ring 1, Ring 2, and Outside Ring 2, as these terms have been previously defined.

1. For the first ring of zones around the CBD, the theory consistently predicts up to 200 more work trips per zone than found by the O-D survey. This difference might

S-Shopping Trip — W-Work Trip

	Zone of Origin	Theory Prediction Exceeds O-D Finding by: Over 200	101-200	51-100	26-50	11-25	0-10	O-D Finding Exceeds Theory Prediction by: 0-10	11-25	26-50	51-100	101-200	Over 200
Intrazonal	01	SW											
From Ring 1	02	S						W					
	08	S	W										
	09	S	W										
	15	S	W										
	22	S		W									
	23	S	W										
	25	S				W							
	28	S	W										
From Ring 2	03	S							W				
	04	S			W								
	16	S				W							
	18		S		W								
	19	S		W									
	21	S									W		
	24	S		W									
	26	S			W								
	27	S	W	W									
	30	S			W								
	31	S									W		
From Outside Ring 2	05		S								W		
	06	S										W	
	07		S									W	
	10	S									W		
	11		S									W	
	12		S								W		
	13		S								W		
	14	S										W	
	17	S									W		
	20	S									W		
	29	S				W							
	32	S							W				
	33						SW						
	34	S				W							
	35					SW							
	36	S	W										
	37		S					W					
	38		S						W				
	00		S					W					

Figure 10. Discrepancies between work trips and shopping trips to CBD predicted by theory and found by O-D survey.

be explained by a combination of circumstances that makes it easy for workers to walk to work but difficult for them to find parking spaces near their work.

2. With two exceptions, the theory predicts considerably more work trips originating in each zone of Ring 2 than were found by the survey. The explanation for this discrepancy is more difficult to find since the minimum walk from this ring is in the order of 10 blocks.

3. Outside of Ring 2, except in Marion and the most remote parts of Cedar Rapids (zones 33 to 38 and 00), the theory predicts many fewer work trips destined for the CBD than were found by the survey. Inasmuch as the theory and survey both assign

roughly the same total number of work trips to the CBD, perhaps the great excess of O-D trips indicates that many people who work in the CBD go to their suburban homes for lunch.

4. The work trips from zones 33 to 38 and 00 present the type of error distribution one might expect if the theory and O-D survey gave reasonably comparable results.

5. When the distribution of shopping trips is considered, without exception the theory predicts more trips, and frequently many more, than were found by the survey. This, however, may be quite reasonable since many people who work in the CBD also shop there, and, because the theory predicts homebased work trips and homebased shopping trips, there is no reason why a person should not go from home to work, from work to shop, and back to home in a single round trip.

On the whole, it seems safe to say that the Cedar Rapids CBD could not survive on the number of work and shopping trips destined for it according to the O-D survey.

SUMMARY AND CONCLUSIONS

In order to predict future patterns of movement within urban areas, it seems necessary that some logical relationships be found between existing patterns of movement and existing land uses. Future patterns of movement may then possibly be extrapolated from anticipated patterns of land use by applying currently observed interrelationships.

An O-D survey, in itself, can only determine existing patterns of movement to some order of accuracy. A land-use study coupled with an O-D survey provides information for relating the movements to the land uses. Gravity models have been set up on several occasions in an effort to provide the required mathematical relationships for extrapolation.

The field theory of movement merely assumes that the pattern of movement between areas of varying land use develops naturally in accord with certain unexplained physical laws. If the theory can simulate existing patterns of movement with sufficient accuracy, variations in the land-use factors in the equations should produce reasonable approximations of related patterns of movement.

In the case of Cedar Rapids-Marion, one is forced to conclude that the theory does not simulate the patterns of movement found in the 1957 home interview O-D survey with a reasonable degree of accuracy. Careful examination of the movements found by the survey, however, leads to the conclusion that the theory actually predicts a more logical pattern of movement than was reported by the survey. It must be left to the reader to decide whether the O-D findings are correct in spite of appearing to be illogical, or that the survey has yielded an invalid picture of the travel situation in the area of study.

ACKNOWLEDGMENTS

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Appendix

TABLE 3

BASIC DATA ON CEDAR RAPIDS-MARION, IOWA

O-D Zone	No. of Households	No. of Workers	Coord. of Housing		Total No. of Jobs	Retail Employment	Coord. of Job Sites	
			N_i	E_i			N_j	E_j
00	532	652(627)*	41**	34**	61	0(1)*	40**	35**
01	768	584(561)	21	18	10260(9999)′	3962	22	19
02	463	419(403)	27	20	445	68	28	19
03	1125	1452(1396)	33	20	381	42	34	19
04	724	834(802)	29	22	1294	79	28	21
05	492	546(525)	33	22	54	9	32	21
06	960	1125(1081)	35	26	766	205	36	29
07	718	822(790)	31	26	2709	262	32	27
08	314	349(335)	23	20	908(1169)	227	22	21
09	1093	1301(1251)	25	22	616	121	24	21
10	746	813(781)	27	24	381	61	26	23
11	553	561(539)	29	26	630	90	30	27
12	563	674(648)	31	28	257	52	32	27
13	400	535(514)	25	26	99	0(1)	26	25
14	1435	1578(1517)	23	30	318	88	20	29
15	308	472(454)	21	20	1028	208	20	19
16	1373	2041(1962)	23	24	330	83	22	23
17	712	749(720)	23	26	129	37	20	27
18	399	492(473)	19	22	2694	273	18	21
19	679	891(856)	19	22	123	36	20	23
20	963	1324(1273)	19	28	103	30	20	29
21	1606	2037(1958)	23	10	292	78	20	09
22	616	893(858)	25	14	105	50	24	15
23	628	720(692)	23	14	633	150	22	15
24	1071	1475(1418)	19	12	749	188	20	13
25	610	710(682)	21	16	948	268	20	15
26	917	1127(1083)	17	12	352	49	16	11
27	560	732(704)	19	16	399	94	18	15
28	472	815(783)	19	18	360	109	18	17
29	749	962(925)	15	14	160	22	16	15
30	665	817(785)	15	18	1061	130	16	17
31	1073	1192(1146)	15	20	1170	187	16	19
32	457	530(509)	15	24	81	15	16	23
33	12	18(17)	11	12	1041	94	12	15
34	735	781(751)	11	18	126	13	10	17
35	65	89(86)	39	36	441	148	40	37
36	1061	1300(1250)	41	38	325	35	40	37
37	400	476(458)	39	38	170	15	38	37
38	348	399(386)	39	36	65	21	38	35
Totals	27365	33360(31999)			32064	7599		

*Numbers in parentheses used for theory calculations and comparisons.

**Coordinates in thousands of feet.

′Jobs in Zone 01 reduced to get four digits, difference added to Zone 08.

TABLE 4

TOTAL NUMBER OF WORK TRIPS DRAWN FROM AND ASSIGNED TO EACH ZONE

Zone No.	Workers Living in Zone	Total Work Trips from Zone by			Jobs in Zone	Total Work Trips to Zone by		
		Theory One-Way	O-D One-Way	Gravity Two-Way		Theory One-Way	O-D One-Way	Gravity Two-Way
00	627	625	502	1275	61	59	50	143
01	562	560	292	713	10260	10008*	9635	19044
02	405	403	469	909	445	443	439	936
03	1397	1395	1683	3121	381	378	592	890
04	804	802	755	1722	1294	1295	1352	2992
05	525	523	656	1130	54	52	54	118
06	1083	1081	1224	2168	766	762	949	1720
07	791	789	993	1788	2709	2700	2575	6430
08	337	335	287	549	908	1169*	952	1458
09	1252	1250	920	2268	616	616	537	1186
10	782	780	777	1708	381	380	400	887
11	541	539	749	1148	630	627	654	1454
12	650	648	711	1516	257	254	364	621
13	515	513	583	1159	99	97	109	235
14	1519	1517	1660	3152	318	316	442	751
15	454	452	316	794	1028	1026	1380	2081
16	1962	1960	2038	4196	330	329	246	743
17	720	718	752	1582	129	127	87	311
18	475	473	321	946	2694	2689	2925	5753
19	857	855	700	1569	123	121	195	265
20	1275	1273	1426	3049	103	101	132	280
21	1959	1957	2537	5117	292	289	153	767
22	860	858	966	1827	105	103	80	599
23	693	691	701	1446	633	630	792	1418
24	1420	1418	1604	3114	749	744	827	1737
25	683	681	634	1424	948	944	1345	2150
26	1085	1083	1345	2226	352	347	444	792
27	705	703	603	1485	399	395	458	866
28	785	783	791	1636	360	357	447	797
29	926	924	1050	1902	160	156	211	351
30	787	784	954	1704	1061	1052	1274	2417
31	1147	1145	1404	2517	1170	1162	1417	2710
32	511	509	563	1246	81	78	113	213
33	18	16	140	40	1041	1029	1301	2725
34								
35	87	85	77	152	441	444	428	965
36	1252	1250	1016	2559	325	327	293	759
37	459	457	485	1029	170	169	79	463
38	386	384	460	804	65	63	32	150
Totals	32049	31960	34024	68505	32064	31960	34022	68505

*Based on adjusted numbers of jobs given in Table 3.

TABLE 5

RANKING OF ZONES BY PRODUCT OF JOBS TIMES WORKERS IN ZONE AND CORRESPONDING RANKINGS OF INTRAZONAL WORK TRIPS

Zone No.	Product Workers Times Jobs	Ranking by Product	Intrazonal Work Trips by Theory		Adjusted* Intrazonal Work Trips by O-D	
			No.	Ranking	No.	Ranking
33	18738	0	3	0	4	14
38	25090	1	10	5	14	19
05	28350	2	6	1	0	—
00	38247	3	15	8	0	—
35	38367	4	10	6	0	—
32	41391	5	9	4	10	17
13	50985	6	8	3	0	—
37	78030	7	30	18	6	15
22	90300	8	15	9	0	—
17	92880	9	7	2	0	—
34	94878	10	28	17	0	—
19	105411	11	10	7	29	22
20	129471	12	27	15	0	—
29	148160	13	25	11	32	24
12	167050	14	25	12	13	18
02	180225	15	25	13	43	29
27	281295	16	30	19	26	21
28	282600	17	25	14	0	—
10	297942	18	39	20	0	—
11	340830	19	55	22	0	—
26	381920	20	76	27	38	28
08	393953	21	24	10	36	27
36	406900	22	130	33	163	38
23	438669	23	59	23	10	16
15	466712	24	27	16	33	26
14	483042	25	51	21	0	—
03	532257	26	126	31	111	35
21	572028	27	70	25	48	23
16	647460	28	75	26	51	31
25	647484	29	61	24	55	33
09	771232	30	83	28	0	—
06	829578	31	113	30	0	—
30	835007	32	109	29	44	30
04	1040376	33	150	34	114	36
24	1063580	34	158	35	26	20
18	1279650	35	128	32	55	32
31	1341990	36	178	36	125	37
07	2142819	37	304	37	81	34
01	5619438	38	351	38	33	25

*O-D work trips multiplied by factor to make total number of such trips equal to number of workers living in zone of origin.

TABLE 6

TOTAL NUMBER OF SHOPPING TRIPS DRAWN FROM AND ASSIGNED TO EACH ZONE

Zone No.	Households in Zone	Total Shopping Trips from Zone		Retail Employment in Zone	Total Shopping Trips Assigned to Zone	
		Theory	O-D*		Theory	O-D**
00	532	530	246	1	2	55
01	768	766	113	3962	14127	4084
02	463	461	92	68	232	110
03	1125	1123	666	42	143	84
04	724	722	234	79	317	41
05	492	489	139	9	36	56
06	960	958	627	205	570	955
07	718	716	409	262	1044	64
08	314	312	41	227	837	358
09	1093	1091	140	121	478	546
10	746	744	248	61	269	98
11	553	551	235	90	382	225
12	563	561	210	52	206	294
13	400	398	183	1	2	1
14	1435	1433	711	88	318	424
15	308	306	0	208	747	53
16	1373	1371	409	83	340	59
17	712	710	418	37	139	66
18	399	397	70	273	971	63
19	679	677	113	36	133	48
20	963	961	282	30	107	336
21	1606	1604	701	78	214	476
22	616	614	216	50	173	40
23	628	626	94	150	535	164
24	1071	1069	369	188	687	436
25	610	608	92	268	960	188
26	917	915	434	49	149	136
27	560	558	153	94	325	63
28	472	470	77	109	381	58
29	749	747	244	22	73	88
30	665	663	77	130	443	81
31	1073	1071	369	187	691	275
32	457	455	40	15	46	18
33	12	10	0	94	238	19
34	735	733	46	13	32	23
35	65	63	0	148	663	617
36	1061	1059	350	35	155	227
37	400	398	134	15	50	48
38	348	346	224	21	65	16
Totals	27365	27279	9206*	7601	27279	10949**

*Excludes trips to outside external cordon.
**Includes trips from outside external cordon.

TABLE 7

RANKING OF ZONES BY PRODUCT OF HOUSEHOLDS TIMES RETAIL EMPLOYEES IN ZONE AND CORRESPONDING RANKINGS OF INTRAZONAL SHOPPING TRIPS

Zone No.	Product Households by Retail Employees	Ranking by Product	Intrazonal Shopping Trips by Theory		Intrazonal Shopping Trips by O-D	
			No.	Ranking	No.	Ranking
13	400	0	0	0	0	—
00	532	1	1	1	13	16
33	1128	2	1	2	0	—
05	4428	3	4	3	0	—
37	6000	4	9	6	0	—
32	6855	5	6	4	0	—
38	7308	6	10	8	14	20
34	9555	7	9	7	0	—
35	9620	8	14	12	0	—
29	16478	9	12	10	73	33
19	24444	10	10	9	0	—
17	26344	11	8	5	13	17
11	28756	12	41	22	15	24
20	28890	13	24	18	16	25
12	29276	14	24	19	61	32
22	30800	15	19	15	13	18
02	31484	16	21	16	14	21
36	37135	17	60	31	105	35
26	44933	18	33	21	0	—
10	45506	19	31	20	11	15
03	47250	20	47	24	14	22
28	51448	21	18	14	0	—
27	52640	22	21	17	11	14
04	57196	23	41	23	41	28
15	64064	24	13	11	0	—
08	71278	25	14	13	10	13
30	86450	26	50	28	22	26
23	94200	27	48	26	13	19
18	108927	28	47	25	0	—
16	113959	29	61	32	14	23
21	125268	30	48	27	267	38
14	126280	31	57	30	152	36
09	132253	32	61	33	51	29
33	163480	33	56	29	0	—
07	188116	34	146	37	31	27
06	196800	35	96	34	228	37
31	200651	36	122	35	84	34
24	201348	37	128	36	59	31
01	3042816	38	604	38	53	30

TABLE 8

WORK AND SHOPPING TRIPS DESTINED FOR CENTRAL BUSINESS DISTRICT

Area of Origin	Zone of Origin	Households in Zone of Origin	Work Trips to CBD by		Shopping Trips to CBD by	
			Theory	O-D	Theory	O-D
Intrazonal	01	768	351	23	604	53
Ring 1	02	463	141	143	275	53
	08	314	212	45	249	11
	09	1093	491	291	665	76
	15	308	272	93	238	0
	22	616	344	254	365	64
	23	628	265	164	352	23
	25	610	295	284	371	78
	28	472	315	184	285	35
Ring 2	03	1125	384	406	573	287
	04	724	226	192	385	82
	16	1373	738	715	803	104
	18	399	157	112	225	29
	19	679	282	199	383	74
	21	1606	667	736	859	312
	24	1071	418	516	501	177
	26	917	308	258	441	112
	27	560	244	71	294	82
	30	665	194	164	305	44
	31	1073	304	407	518	141
Outside Ring 2	05	492	140	195	244	56
	06	960	223	374	399	155
	07	718	135	302	274	137
	10	746	243	332	405	106
	11	553	129	308	257	103
	12	563	104	196	204	46
	13	400	168	264	220	71
	14	1435	464	573	740	140
	17	712	248	321	398	111
	20	963	386	456	476	112
	29	749	248	232	361	37
	32	457	157	164	242	0
	33	12	5	0	6	0
	34	735	197	185	364	23
Marion	00	532	138	139	215	25
	35	65	16	0	22	0
	36	1061	245	144	360	27
	37	400	87	97	135	18
	38	348	72	96	116	0