Different Cars as a Predictable Proportion of All Cars in Traffic

WILBUR S. SMITH AND F. HOUSTON WYNN
Wilbur Smith and Associates, New Haven, Conn.

• AMERICANS are the most mobile people in the world: almost everyone is on the move every day and most of this travel is performed by car. Even in large urban areas such as Detroit, Washington, and Philadelphia, two-thirds or more of the trips by metropolitan residents are made by automobile. In small communities, virtually every trip is made by car.

The automobile, therefore, has become an accepted form of travel in nearly everybody's life and, as such, serves an important part in the actions of individuals as they relate to the various fields of commerce and public service. Because most Americans are motorists, the identification of their cars serves to identify them.

For many years, the quantity of traffic which passes specific locations has been the principal measure of the effectiveness of outdoor advertising. It is of interest to many others. This is not an adequate measure of the markets which are reached, and research to improve the measurement of these markets has been carried on for quite some time. Extensive research studies in Fort Wayne, Ind. (*1*), Cedar Rapids, Iowa (*2*), and London, Ontario (*3*), reported by the Traffic Audit Bureau (TAB), pointed the way for a more intensive investigation of the composition and character of traffic on city streets which would develop a measurement of traffic quality.

In 1956 the Outdoor Advertising Association of America authorized research studies on the quality of urban traffic by Wilbur Smith and Associates. The studies reported here, representing only a part of the total research, were based on the premise that increasing proportions of urban residents today perform most of their necessary travel by car and that the measurement of automobiles can be effectively substituted for the direct measurement of people.

Traffic information for the studies was collected in 13 different cities with participation by the operators of outdoor advertising plants in those cities and under the joint technical supervision of the consultant. From these studies, pertinent facts relating to urban traffic behavior have been derived.

It is the purpose of this paper to describe some of the studies and findings which should be of interest to persons working with traffic measurement and evaluation. Additional marketing information was obtained but is not included because it is beyond the scope of this presentation.

Principal Findings

Among the most significant results of the study are the following:

1. Local traffic is a constant proportion of the combined vehicular movement which passes any representative series of locations in an urbanized area. The proportions of local and non-local traffic which are characteristic of a particular city may be determined by classifying the combined daily volume of vehicles at a few carefully selected locations. Local traffic was found to dominate the over-all traffic in all the test cities.

Local traffic is composed of vehicles that are owned (or registered) within an urbanized area. Non-local traffic is composed of vehicles that are owned (or registered) outside the urbanized area. In these studies, the urbanized area identified with each city was the "home" county (or counties) in which the city was located.

2. When the average proportion of local cars to all traffic is known, the number of different local cars in any volume of representative traffic (combined movement at more than a specified minimum number of locations) bears a consistent relationship to the number of cars owned (registered) in the local area.

3. A daily index of exposure has been prepared which may be used to compute the number of different cars in any one-day volume of local traffic when the local car ownership (number of cars registered) is known.

4. The number of different cars in the accumulated 7-day volume of local cars at a representative series of locations also bears a consistent and predictable relationship to the number of cars registered locally. Different cars are a much smaller proportion of weekly volumes than of daily volumes. There will be more different cars in a given volume for one day than there will be for the same volume accumulated over a week.

5. Preliminary studies show that the number of different cars in an accumulated monthly (four weeks) volume of local cars at any representative series of locations may also be a predictable proportion of locally owned cars. Different cars are a smaller proportion of monthly traffic volumes than of weekly and daily traffic volumes.

6. Preliminary investigation of multiple exposures in the accumulated daily volume of local cars at any representative series of locations suggests that the numbers of vehicles which are encountered at least two times, three times, four times . . . *N* times, may bear a predictable relationship to the number of cars which are encountered at least once (the number of different cars in traffic).

General Description of Studies

Traffic data were collected during the summer of 1956 in 13 cities that varied widely in terms of geographic location, population, and economy. Because the data collection technique was based on field tabulation of car license numbers, consideration was given to states which issue license plates according to place of registration, generally denoting the owner's residence. The cost of identifying car origins (address where registered) in states which do not issue license plates coded to the county of residence is much greater than the cost for sorting coded license numbers for county of registration.

The studies were conducted in the following cities: San Francisco-Oakland, Calif.; Minneapolis-St. Paul, Minn.; Houston, Tex.; Norfolk-Portsmouth, Va.; Spokane, Wash.; Greenville, S.C.; Waterloo, Iowa; Lima, Ohio; Reno, Nevada; Pocatello, Idaho; Gulfport, Miss.; Austin, Minn.; and North Platte, Neb. Geographical location of the survey cities is shown in Figure 1.

Population of the counties in which the cities are located ranged from 20,000 to 1,500,000. Included were coastal and river cities as well as inland communities. The diverse economic structure of the several cities ranged from recreation and agriculture to industry and shipping.

Detailed field investigations of traffic volume characteristics and patterns were conducted in each city. Information was collected on (a) total traffic volumes, (b) traffic composition and origins (state passenger cars by county of origin, out-of-state passenger cars, and trucks), and (c) daily and hourly variations. The methods used for counting traffic and recording license numbers were in accord with accepted traffic and marketing survey procedures.

The number and location of traffic recording stations in each community were determined after thorough study of the area. Stations were selected to provide a representative cross-section of the total traffic moving in each city; they were situated along major highways, radial arterials, and secondary streets; they included locations in the downtown, in the intermediate sections, and on the fringes of each city surveyed. Combined, the data collected at the stations in each urban area provided a broad sample of

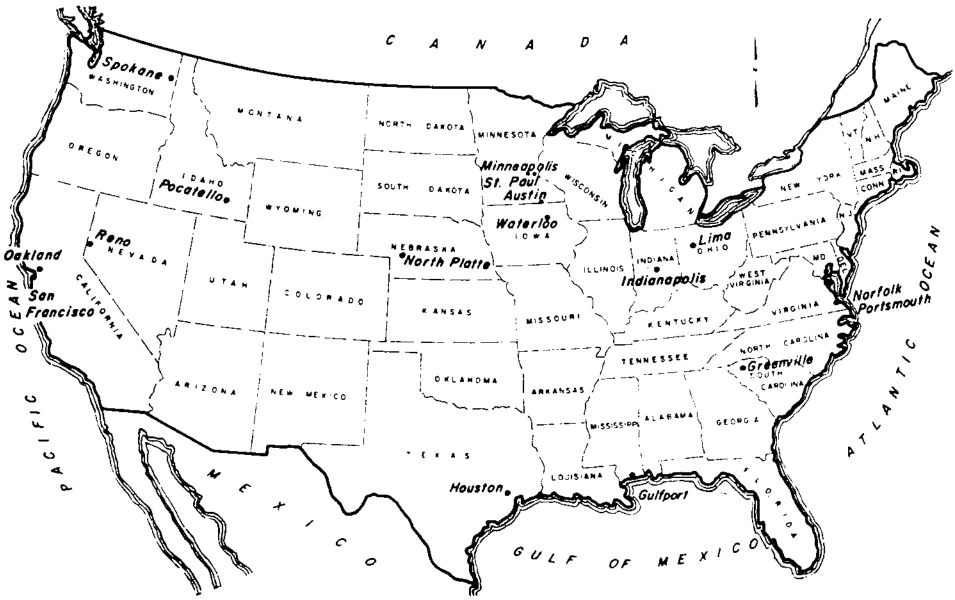

Figure 1. Location of surveyed cities.

the total traffic movement within that area.

In each city, all survey stations were operated during the same week and a full week of license number recording was scheduled for most stations. One or more "control" stations were designated at which license numbers were recorded continuously, 18 hours a day (6 A.M. to 12 midnight), for seven consecutive days. At other locations, volumes were recorded continuously for 18 hours for only one day in seven. At some locations no other data were collected, but at most stations license numbers were "sampled" for 10 minutes during each hour of the other six days of the week. The recording crews assigned to sample stations rotated once each hour through three different locations. All continuous records of license numbers were kept by 10-min time intervals for comparison with sample records.

Recording stations were operated by two-man crews who observed traffic moving in only one direction past the station. The crew kept a complete count of all traffic passing the station in the chosen direction. License numbers were recorded for all in-state cars, and the state of origin for out-of-state cars (passenger cars only); the type of vehicle was listed for all other traffic.

After traffic counts and license plate recordings were edited, the data were punched in machine cards identified by (a) the city in which data were collected, (b) station number, (c) day of week, (d) direction of travel, (e) time interval, and (f) complete license number. Cards were not prepared for incomplete license numbers, which were listed among the "misses."

ADEQUACY OF DATA

The recorded license plate numbers were obtained from a large volume of traffic—more than 2.25 million vehicles—passing 176 different counting stations. More than 1.5 million license numbers were recorded for in-state passenger cars in the gross traffic stream, as shown in Table 1.

Some in-state license numbers in the passing traffic were not recorded for a

TABLE 1

TRAFFIC OBSERVED AT COUNTING STATIONS IN THIRTEEN CITIES[1]

City	Number of Stations	Total Vehicles	In-State Cars	Recorded Numbers	Percent Missed[2]
San Francisco-Oakland, Calif.	34	345,862	274,201	228,748	16.5
Minneapolis-St. Paul, Minn.	31	431,219	361,957	282,322	21.9
Houston, Tex.	17	206,460	166,628	142,979	14.2
Norfolk-Portsmouth, Va.	17	313,033	233,231	201,226	13.7
Spokane, Wash.	14	147,461	105,033	98,409	6.3
Greenville, S. C.	13	191,452	152,847	136,189	10.8
Waterloo, Iowa	10	118,742	105,247	102,913	2.2
Lima, Ohio	8	89,649	71,278	68,688	3.6
Reno, Nev.	9	117,857	65,305	61,078	6.5
Pocatello, Idaho	6	129,381	103,613	100,449	3.0
Gulfport, Miss.	5	83,028	57,477	52,747	8.2
Austin, Minn.	7	29,436	22,788	22,135	2.9
North Platte, Neb.	5	57,569	40,544	39,836	1.8
Total	176	2,261,149	1,760,149	1,537,719	12.7

[1] One-way traffic volumes actually counted and recorded during the 7-day survey in each city. The 10-min-per-hr samples obtained at many of the stations have not been expanded for this listing.

[2] The percent of in-state license numbers missed varies from city to city for many reasons. Very heavy traffic on multi-lane streets, inclement weather, poor nighttime illumination, and illegible license numbers were the principal factors.

number of reasons. Of those recorded, as many as 10 percent were not recorded correctly according to comparative tests of 12 of the recording crews. Thus, the license plate numbers represent a known sampling of the passing traffic, with an unknown but substantial amount of recording error, such as wrong numbers and letters, and inverted sequences.

Examination of the license plate data, considering the uses to which they have been put in the following analyses, shows that deficiencies in the data are largely compensated for, in a statistical sense, when large volumes of data are combined and conclusions are based on the combined data.

In the smaller cities, the volume of in-state license numbers collected in 1-day continuous recording at all stations sometimes equaled the number of cars registered in the home county. A high proportion of the recorded numbers represented local (home county) cars. In the course of the 7-day study, the volume of home county license numbers listed at the counting stations amounted to as much as three times the number of registered vehicles in the same communities.

A typical license number consists of two alphabetic and four numeric characters with the alphabetic data coded to the county in which the vehicle is registered (Nevada, Ohio, Texas). License numbers are issued in blocks of 10,000 (0,000-9,999) with a common alphabetic prefix (AA, AB, AC, etc.). If an error is made in recording alphabetic data, the number may be incorrectly identified with, (type 1) another block of numbers in the same county, (type 2) a block of numbers in some other county, or (type 3) a block of numbers which has not been issued. In the type 3 situation, editing will eliminate the number from further consideration and the vehicle passage will be classed as one of the in-state cars missed by the recorder. If the error results in the designation of a local car as a car from another county (type 2), the number of passages by local cars will be understated. If local cars dominate traffic, the number of local passages lost in this way may exceed the number gained from incorrect reporting of non-local cars as local cars. However, these errors will offset one another to some degree.

In the case of incorrectly recorded numbers which attribute a car passage to another car registered in the same county (type 1), and where neither car has been previously recorded, the number of different cars recorded is correct, despite the error. If the recording error involves a repeat passage by a vehicle but is recorded as a vehicle which has not passed before, the number of different cars reported is greater than the number actually passing. However, as the volume of passages increases to a point where the number of passages by local vehicles exceeds the number of cars registered in the local county, most passages represent cars that have already been exposed. Whether a recording error is made or not, a local license number is more likely to represent a repeat passage than to identify an initial passage (new exposure) by a local car. As the number of passages mounts to several times the local car registration, practically all are repeats; type 1 recording errors thus lose virtually all significance in the evaluation of exposure in the combined total volume of passages which take place at a number of different locations over an extended period of time (a week or more).

The studies described in this paper are principally concerned with local cars. Most of the recording errors in this traffic are of type 1, which are of little significance in the large volumes of data to which daily, weekly and monthly exposure are related.

The statistics which relate to the analysis of the traffic volume data are of a specialized variety which are concerned with "large" numbers. The license plate data represent samplings from a finite population with replacements (home county registration, for instance). Each time a sample is drawn (a license number recorded), the sample is returned to the "pool" and may be drawn again. There are a number of restraints which affect the likelihood of a license number being sampled during any specific interval of time. These include the following:

1. Some registered vehicles are out of service. At any given moment, most vehicles are not in motion. As the observation time lengthens, more and more of the registered vehicles are put in motion about the community. In the course of a day, perhaps 85 to 90 percent are in use. During successive days, some of the remaining vehicles appear. Some will never appear, however, because they have been removed for servicing, have been sold and moved to another community, or have been destroyed.

2. Non-random pattern of movement. Very few vehicle trips are made without plan, while most of them follow specific routes between places of trip origin and destination. The same or very similar routings are repeated many times by some drivers during the course of a week or a month (for example, travel between home and work). If the path of these routine trips chances to pass one or more counting stations, the particular vehicle may appear more than once in a relatively small sampling at the station. If the path of the routine trips does not pass a station, frequency of appearance is likely to be lower than average.

3. Frequency and length of trips. Some vehicles make more trips and travel more miles than others. The more a vehicle travels in the city, the more likely it is to pass a counting station.

4. Location and number of counting stations. The larger the number of counting stations, and the greater their dispersion, the more nearly random are opportunities for any vehicle in traffic to be observed in any specified interval of time.

LOCAL CARS AS A PROPORTION OF URBAN TRAFFIC

Nearly all of the counting stations in each survey city were located on heavily traveled streets radiating from the central business district. In each city, one or two stations were also located on heavily traveled streets within the central business district. Heavily traveled locations were sought to obtain many data with the limited number of field personnel used in each city. Many counting stations were situated on the principal U. S. highways serving each community, but care was taken to see that some stations were located to intercept travel on important access streets that were tributary to purely local areas. Only one counting station was located on each street unless the street passed through the central business district. In a few instances, two stations were placed on such through

TABLE 2

WASHINGTON CARS AS A PERCENTAGE OF ALL VEHICLES[1] AT LOCATIONS IN SPOKANE

Sta.	Percentage								Avg. Daily Vol.
	Mon.	Tues.	Wed.	Thurs.	Fri.	Sat.	Sun.	Week	
1[2]	69	67	68	70	70	72	73	69	5,205
2[3]	58	60	59	61	65	62	66	62	5,066
3[4]	86	86	81	80	80	81	92	83	5,485
4[4]	82	78	78	81	82	85	84	81	7,112
6[2]	70	67	68	72	64	70	69	70	5,091
10[4]	74	70	68	72	74	72	79	73	8,582
11[3]	72	61	66	65	65	74	81	69	5,285
12[3]	60	62	65	59	62	69	72	64	7,849
All[5]	71	69	69	69	71	74	77	71	63,233

[1] 18-hr (6:00 A.M.–Midnight) one-way traffic.
[2] In central business district.
[3] Near periphery of urban development.
[4] Well away from central business district in heavily urbanized areas.
[5] Average for all 14 stations in Spokane.

streets, one on either side of the central business district.

The first significant investigation of the traffic count data was undertaken to determine the average composition of travel in each study area—the proportion of in-state cars to all other cars and trucks; and, within the volume of state cars, those from the local area.

The proportion of in-state passenger cars to all other traffic at each station followed a consistent pattern with regard to other stations during successive days of the week, as shown in Table 2 for traffic in Spokane. However, each counting station in Spokane was found to have individual characteristics with regard to the average proportion of Washington

TABLE 3

LOCAL (HOME COUNTY) CARS AS PERCENTAGE OF TOTAL STATE CARS (18 HOURS)

Sta.	City	Class.	Mon.	Tues.	Wed.	Thur.	Fri.	Sat.	Sun.	Total
1	Oakland[1]	State	5,350	4,890	4,740	4,840	5,470	5,310	3,670	34,270
		Local	4,200	3,540	3,490	3,550	4,090	4,310	2,770	25,950
		% Local	78.5	72.4	73.6	73.3	74.8	81.2	75.5	75.7
2	San Francisco[2]	State	4,000	3,890	4,130	3,250	4,040	3,680	3,890	26,880
		Local	2,270	2,120	2,420	1,720	2,320	2,100	2,570	15,530
		% Local	56.8	54.5	58.6	52.9	57.7	57.1	66.1	57.8
2	Norfolk[2]	State	5,289	5,255	5,231	4,920	5,550	4,761	3,725	34,731
		Local	4,613	4,482	4,569	4,194	4,493	4,159	3,215	29,725
		% Local	87.2	85.3	87.3	85.2	81.0	87.4	86.3	85.6
1	Greenville[2]	State	3,600	2,770	3,380	3,570	4,030	4,130	3,390	25,870
		Local	2,700	2,730	2,570	2,610	2,970	3,000	2,360	18,940
		% Local	75.0	72.4	76.0	73.1	73.7	72.6	69.3	73.2
8	Waterloo[2]	State	3,907	3,689	3,618	3,633	4,289	3,755	2,421	25,312
		Local	3,551	3,304	3,278	3,316	3,896	3,470	2,191	23,006
		% Local	90.0	89.6	90.6	91.3	90.8	92.4	90.5	90.9
1	Lima[2]	State	3,723	3,486	3,604	3,457	3,771	3,735	3,740	25,510
		Local	2,637	2,398	2,548	2,375	2,598	2,545	2,525	17,626
		% Local	70.8	68.8	70.7	68.9	93.87	68.1	67.5	69.0
1	Pocatello[1]	State	5,645	5,711	5,503	5,599	6,350	6,208	4,497	39,513
		Local	4,821	4,808	4,742	4,619	5,320	5,195	3,652	33,157
		% Local	85.4	84.2	86.2	82.5	83.8	83.7	81.2	83.9
1	North Platte[1]	State	2,307	2,193	2,396	2,546	2,425	2,443	2,218	16,528
		Local	1,913	1,856	1,980	2,051	1,951	1,979	1,628	13,358
		% Local	82.9	84.6	82.6	80.6	80.5	81.0	73.4	80.8

[1] Central business district station.
[2] Intermediate station.

TABLE 4

LOCAL (HOME COUNTY) CARS AS A PROPORTION OF ALL IN-STATE CARS AT COMBINED STATIONS (18 HOURS)

City	Group	Class.	Cumulative Volume at Station							
			1	1–2	1–3	1–4	1–5	1–6	1–7	1–8
Norfolk	A[1]	State	3,374	7,756	12,208	19,038	24,540	30,203	32,316	37,242
		Local	2,759	6,642	10,497	15,837	20,046	24,923	26,808	30,879
		% Local	81.1	85.7	86.0	83.2	81.7	82.5	83.0	82.9
	B[2]	State	5,409	8,853	15,088	20,115	25,675	29,445	34,523	37,634
		Local	3,793	6,813	12,215	16,286	20,869	23,934	88,076	30,645
		% Local	70.1	77.0	81.0	81.0	81.3	81.3	81.3	81.4
Spokane	A[3]	State	3,309	5,076	9,026	11,963	12,286	14,800	16,510	19,778
		Local	2,771	4,091	7,618	10,184	10,403	12,553	14,024	16,897
		% Local	83.7	80.6	84.4	85.2	84.7	84.8	84.9	85.4
	B[4]	State	3,266	8,810	11,761	16,449	18,024	18,537		
		Local	2,813	7,419	9,989	14,010	15,415	15,831		
		% Local	86.1	84.2	84.9	85.2	85.5	85.4		

[1] Station 1 plus Stations 3 to 9.
[2] Stations 10 through 17.
[4] Stations 1 through 8.
[3] Stations 9 through 14.

cars to other vehicles. The traffic counts for Spokane are typical of the counts obtained in all of the study areas. Although the ratio of Washington cars to all other vehicles is relatively stable throughout the week at each station, there is considerable difference in the average proportion of Washington cars to others from one location to the next.

Of the in-state cars, the proportion of local (in-county) cars showed a very similar pattern. The seven-day continuous counts at eight of the central stations in various cities (Table 3) show the stability of the proportion of local cars as related to that of state cars in the different study areas.

When data from several counting stations in a study area are combined, the variabilities typical of individual stations (Table 2) quickly become submerged. After data from a few well-dispersed stations have been combined, an "average composition" develops which is typical of the community. The proportions of in-state vehicles to other vehicles, and of non-local state cars to local cars in the gross volume will change very little as additional counts are combined at random. These average proportions will develop as different series of widely-scattered stations are combined. Table 4 indicates that the average composition of traffic in a community can be developed by assembling data from surprisingly few locations. The relationship of in-state cars to all other vehicles exhibits stabilities similar to those shown for local cars as related to non-local state cars. The combined stations must have wide geographic distribution in the community, however, to develop a true cross-section from a minimum number of counts. In very small cities, traffic at a single central business district location may be nearly representative of the over-all average, but the proper location of such a station is such a critical matter that it is doubtful if efforts to measure average composition should ever be based on a single location.

TRAFFIC EXPOSURE

The car license numbers have been explored and analyzed in many ways. The most enlightening studies were the comparative analyses of data from several cities which related different local cars in traffic to the combined local passages recorded at a number of different counting stations in each city.

A clear distinction should be made between the total passages recorded at the traffic counting stations and the number of different cars which made the passages. "Total passages" represent the total number of times that passenger cars passed the survey stations in the one-directional traffic recorded. They include repeated passages at one or more stations. "Different cars" are the number of separate cars which passed at least one location in a group of stations. "Different cars" exclude repeated passages. For example, a passenger car may have passed one station more than once, and it may have passed several stations. The record of license numbers would show several passages by the same car. Passages after the first represent repetition or repeated exposure.

Analysis for a Typical Day

As previously noted, "exposure" in this study was evaluated in terms of passenger cars rather than people. The base was the number of passenger cars registered in the home county ("local" cars) rather than the population. Thus, exposure was expressed as the number of different local cars passing a given point or series of points out of the total cars registered. The county was used as the base area because it is the smallest political subdivision for which automobile registration information was directly available from the state motor vehicle departments. In most of the study cities, the urbanized area was approximately co-extensive with county limits.

To illustrate how total traffic volume, through the groupings of stations, affects exposure, a detailed analysis was made of exposure in a typical city—Spokane. In general, it is applicable to all of the survey cities. Exposure in Spokane during a typical 18-hr weekday is shown in Figure 2, which shows how total passages and different cars in traffic relate to each other as movements through a series of stations in Spokane are combined. In Figure 2A total passages are plotted against different cars for two separate groupings of stations totaled cumulatively. The two curves below the 45-degree diagonal represent the number of different cars in the volume of total passages at combinations of stations in each of the two groups. The 45-degree diagonal indicates only the total passages. It is significant that a given volume of total passages represents about the same number of different cars in each station group.

In Figure 2, the basic exposure factors are shown. Total passages and different cars are both expressed as percentages of local registrations. The curves for each of the station groupings are virtually coincident. This means that the total passages and the different cars at these groups of stations are closely related proportions of local car registration. Table 5 gives the cumulative volume and repetition at both groups of stations for Spokane County cars.

TABLE 5

CUMULATIVE VOLUME AND REPETITION AT GROUPS OF STATIONS LOCAL CARS, SPOKANE COUNTY, WASHINGTON

Group	Sta.	18-Hr Traffic: Total Passages	Different Cars	Repetition (%)
A	2	1,320	1,233	7.1
	2–3	4,847	4,342	11.6
	2–4	7,413	6,586	12.6
	2–5	7,632	6,770	12.7
	2–6	9,482	8,480	11.8
	2–7	11,253	9,635	16.8
	2–8	14,126	12,024	17.5
B	9	2,812	2,490	13.0
	9–10	7,418	6,576	12.8
	9–11	10,027	8,842	13.4
	9–12	14,006	12,221	14.6
	9–13	15,409	13,139	17.3
	9–14	15,825	13,456	17.6

The degree of exposure at the survey stations in each of the surveyed cities was determined by relating total local passages and different local cars at groups of stations to county registration. Total passages were plotted against different cars for 18, 12-, and 6-hr periods; all values were expressed as percent of county registrations. A summary of the 18-hr total local passages and different cars as related to local registrations is given in Table 6. It was evident from curves fitted to the plotted data (Fig. 3) that the degree of exposure increases as traffic volumes increase. In every city, the

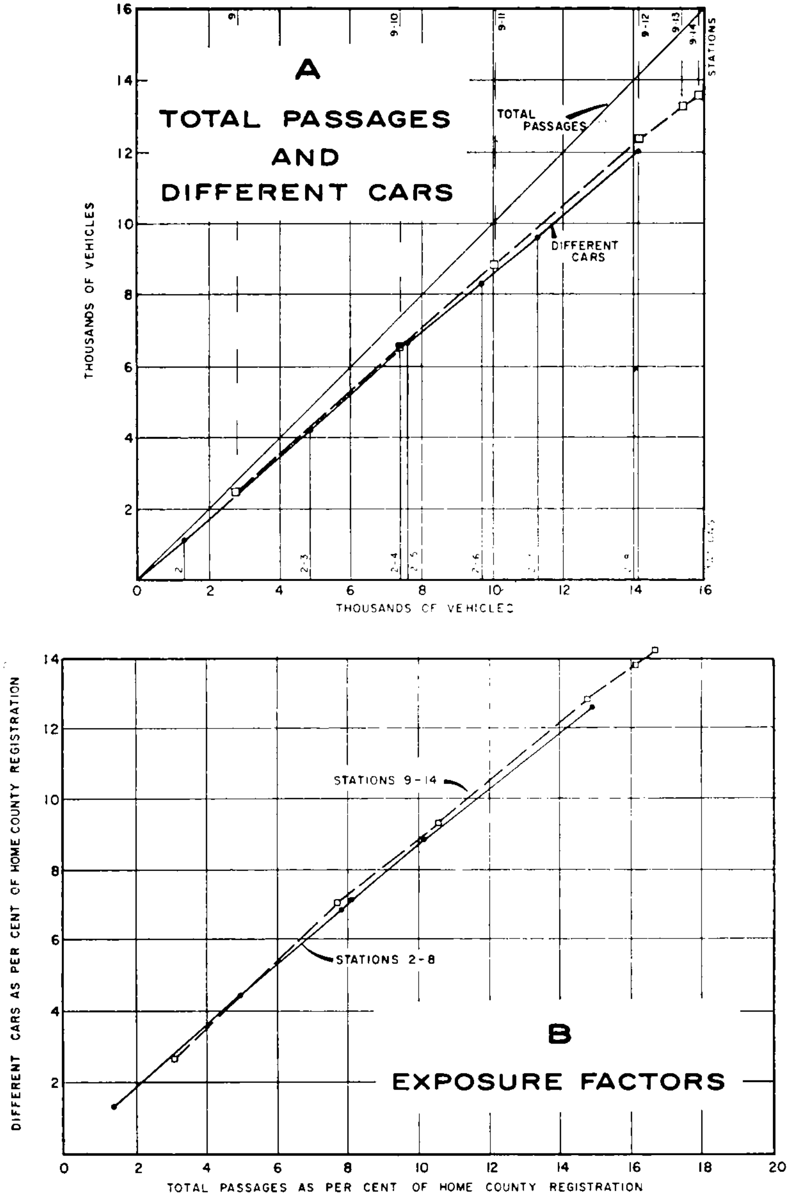

Figure 2. Exposure of local cars, Spokane, Wash.

curves follow a reasonably consistent pattern; different cars increase at a gradually diminishing rate as total passages increase. In almost every city, the proportion of different cars to total passages at groups of stations within the same community was similar when comparable volumes were observed, regardless of the counting period (6, 12, or 18 hr).

When data from all of the study areas were plotted together with the total num-

TABLE 6

SUMMARY: 18-HR HOME COUNTY TOTAL PASSAGES AND DIFFERENT CARS AS RELATED TO HOME COUNTY REGISTRATION

City	Home Co. Pass. Car Reg.	No. of Stations	Total Passages Number	Total Passages % of Co. Reg.	Different Cars Number	Different Cars % of Co. Reg.	As % of Total Passages	Repetition Rate
San Francisco	238,339	16	29,730	12.47	25,330	10.63	85.18	1.174
Oakland[1]	314,336	5	14,480	4.61	12,680	4,03	88.06	1.142
		5	16,410	5.21	15,090	4.80	92.00	1.087
		5	17,090	5.44	15,780	5.02	92.33	1.083
Minneapolis	308,239	18	47,254	15.33	38,094	12.36	80.62	1.240
St. Paul	148,465	13	26,418	17.79	21,455	14.45	81.21	1.231
Houston	394,390	17	51,820	13.14	43,571	11.05	84.10	1.189
Norfolk	127,877	17	63,903	49.97	42,056	32.89	65.83	1.519
Spokane	95,122	7	14,126	14.85	12,024	12.64	85.10	1.175
Spokane		6	15,825	16.64	13,456	14.15	85.03	1.176
Greenville		6	9,350	14.45	7,050	10.89	75.41	1.326
Greenville	64,719	6	10,810	16.70	7,890	12.19	72.99	1.370
Waterloo	38,961	7	17,860	45.84	12,054	30.94	67.48	1.482
Lima	33,918	7	16,194	47.74	10,781	31.79	66.67	1.500
Reno	29,459	8	19,753	67.05	11,582	39.32	58.65	1.705
Pocatello	16,492	6	17,021	103.21	10,321	52.68	51.05	1.959
Gulfport	24,283	4	7,827	32.33	5,143	21.18	65.70	1.522
Austin	15,980	6	9,725	60.86	5,520	34.54	56.76	1.762
North Platte	11,472	4	7,520	65.55	4,070	35.48	54.11	1.848
Fort Wayne	36,720	20	45,350	123.50	21,160	57.62	46.66	2.143
London	41,722	12	32,362	77.56	17,240	41.30	53.28	1.877
Max.	394,390	20	63,903	123.50	43,571	57.62	92.33	1.083
Min.	11,472	4	7,520	12.47	4,070	10.63	46.66	2.143

[1] These three groups of data remain to be combined in one series.

ber of passages and the number of different cars, both stated as proportions of local cars owned (registered), the several sets of data were found to be related to each other in a remarkably consistent pattern. A composite picture of this relationship is depicted in Figure 4, which includes data from two earlier surveys (Ft. Wayne, Ind., and London, Ont.)

A composite "exposure curve" was fitted to the available exposure information from each of the surveyed cities. This curve (Fig. 5) showed that exposure increases at a decreasing rate as the total traffic increases. For example, when total passages represent 50 percent of the local registration, the degree of exposure is about 31 percent; when the total passages represent 100 percent of the local registration, the degree of exposure is about 52 percent.

The composite curve comes close to nearly all the individual curves for each of the surveyed cities. Most of the observed exposure values fall within a few percent of the exposure curve (that is, within the 95 percent confidence interval, 1.96 standard errors).

The consistent relationship, based on data for the surveyed cities, may be called an "index of exposure." The index of exposure shows a regular increase in the number of different cars in traffic as total passages accumulate. Thus, the number of different local cars can be estimated once the total of local passages has been determined. The exposure curve was by far the most significant finding of this research. Until this relationship was demonstrated, the number of different cars in a given volume of traffic could only be determined through costly and time-consuming procedures.

The exposure curve has been fitted mathematically to the field data from the various study areas. In relating the exposure curve to the values plotted for individual cities, predicted exposure values are slightly less than average in its middle and upper ranges, and slightly more than average in its lowest ranges. Thus, exposure is slightly understated in the middle range of the curve. It appears that the exposure curve is considerably influenced by observed values in the lower reaches. These values frequently

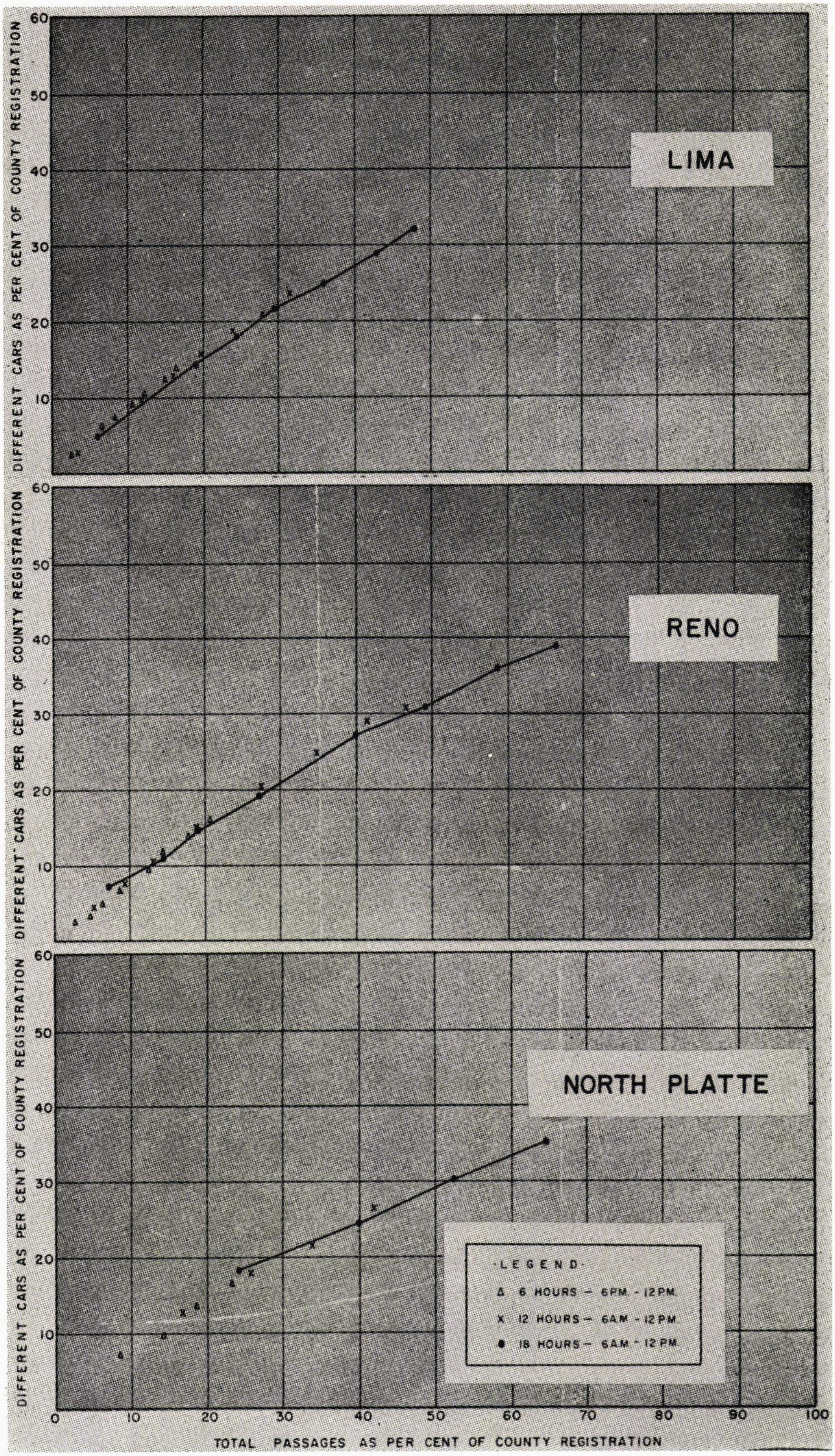

Figure 3. Comparison of observed exposure for 6, 12 and 18 hours.

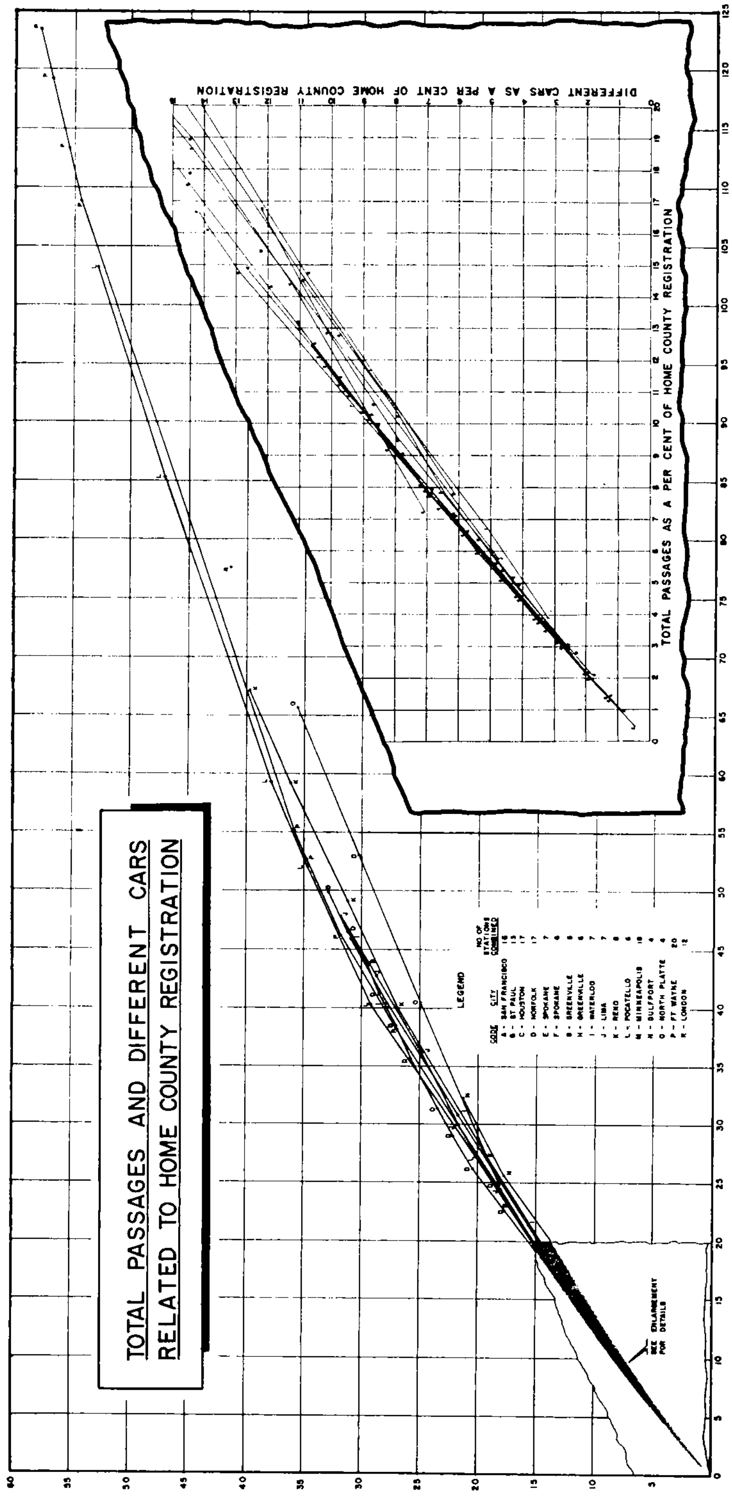

Figure 4. Total passages and different cars related to home county registration.

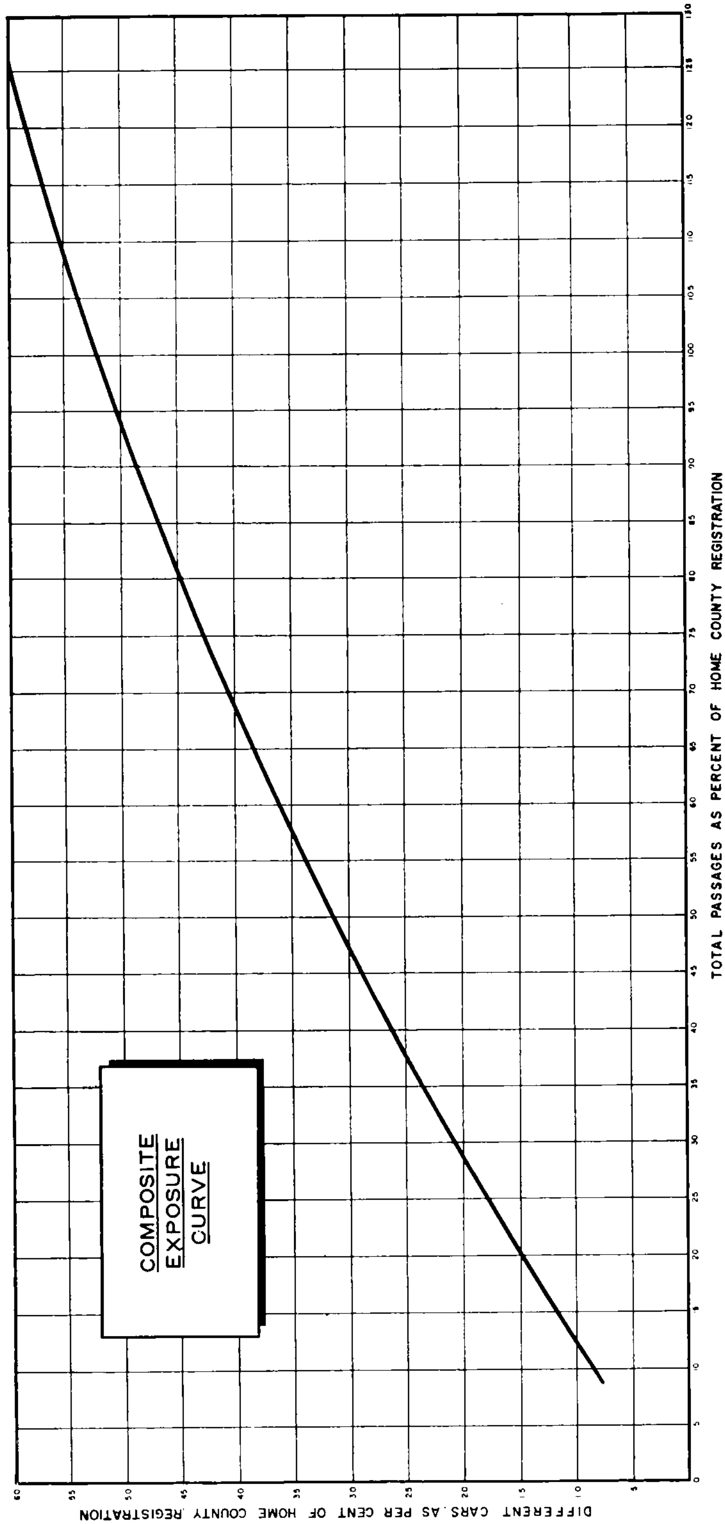

Figure 5. Composite exposure curve.

represent exposure at single stations, or at groups of low-volume stations. Examination of the basic data has shown that traffic from several different stations must be combined to develop a stable estimate of the proportions of local cars in traffic. Stable relationships within the local traffic may also depend on such a representative cross-section of traffic.

The values of the exposure curve were derived mathematically and may be used for estimated exposure in local traffic. In developing the index of exposure, an "exponential" prototype was used. This mathematical model, which represents a decreasing rate of increase in Y (degree of exposure) as x (total passages) increases, was expressed as

$$Y = 100 - A\,R^{-x} = 100 - A\,(R^{-1})^{x} \quad (1)$$

Simplifying,

$$Y = 100 - A\,B^{x} \quad (2)$$

In logarithmic form, Eq. 2 can be expressed as a straight line,

$$\log(100 - Y) = A' + x\,B' \quad (3)$$

in which

$A' = \log$ A; $B' = \log B$; and A, B, R constants.

The curve was calculated to be:

$$\log(100 - y) = 1.99207 - 0.00311\,x \quad (4)$$

where $-x$ is the number of total passages as percent of local car registration and y is the number of different cars as percent of local registration.

This curve correlates highly (about 0.99). The function log (100—y) has a standard error of 0.00743.

Analysis of Exposure for Extended Periods

The number of different local (home county) cars in daily traffic volumes has been shown to be a regular and predictable proportion of the daily volume when the following basic conditions are met:

1. Daily volume is composed of the combined travel at several widely dispersed locations in a city.
2. The proportion of local (home county) cars to all vehicles in traffic is known.
3. The number of local automobile registrations is known.

Additional exploratory analyses have been made concerning the number of different automobiles exposed to a series of counting stations in the course of a week. Here, too, a regular pattern has been found. The relationship of exposure to passages in daily traffic volumes does not apply, however, to data which are accumulated over a period longer than a day. During the course of a week or a month, the repetitive pattern of the work trips and other travel which is performed regularly at short time intervals produces a bias in the frequency with which certain cars are observed. The cars which are detected while they are engaged in this routine type of travel are likely to make repeated passages at greater frequency than are cars engaged in unique or infrequent errands. Therefore, although exposure increases as the volumes of traffic accumulate over a period of 2, 3, 7, or N days, the amount of exposure generated in a given volume of traffic becomes a smaller proportion of the volume as the accumulation period is lengthened.

Approximate exposure curves have been computed for several of these conditions, including weekly and monthly (four weeks) time intervals. These studies indicate, for example, that a daily volume of local cars sufficient to achieve exposure to 90 percent of the different local vehicles (passages equal to approximately 260 percent of local registration) would, if developed over a period of 7 days, expose only 70 percent of the local vehicles. If the accumulation of the same volume of passages represented a counting period of a month (four weeks), the exposure achieved would amount to only 60 percent of the local cars. (In all cases, it is assumed that the number and location of observation stations would meet minimum requirements for distribution

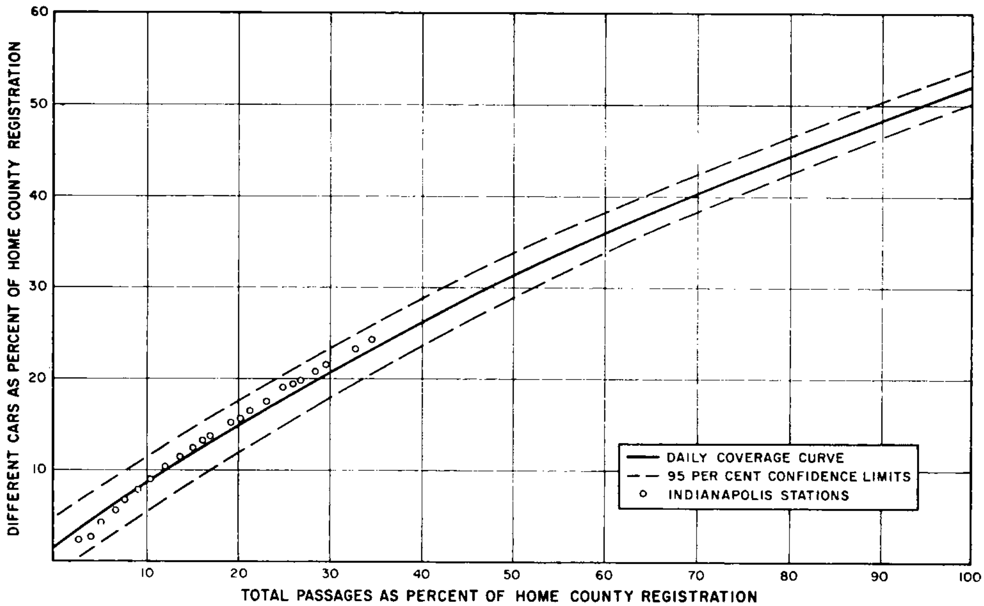

Figure 6. Comparison of daily coverage curve and observed Indianapolis data.

throughout the study area to develop a representative cross-section of traffic.)

Verification of Exposure Index

The studies which led to the development of a daily index of exposure were based on data accumulated in the 13 areas in the summer of 1956 and earlier studies in Fort Wayne, Ind., and London, Ont. To further verify the exposure curve, a new and independent survey was conducted in Indianapolis, Ind., during the summer of 1959. Some 860,000 Indiana license numbers were recorded at 23 counting stations during a 1-week study in July. Traffic was counted and classified and license numbers recorded continuously, 18 hr per day, for the full 7-day period at all locations. Figure 6 shows the Indianapolis data superimposed upon the daily exposure curve developed in the earlier studies. The Indianapolis data agreed almost exactly with the information collected in earlier studies, and confirmed the basic characteristics described by the exposure index. Similar confirmation was obtained for exposure over longer periods of time, to the full seven days of the study.

FREQUENCY OF LOCAL CARS IN TRAFFIC

Small volumes of license numbers, whether collected at a single location or at a number of different counting stations, consist almost entirely of different vehicles, especially if the counting period is only a few hours. For instance, in the cities surveyed a daily volume of local cars equal to 5 percent of local registration was found to consist of different vehicles in proportion ranging from 78 to 90 percent (see Fig. 4), and daily passages equal to 20 percent of local registration were found to contain from 68 to 79 percent different vehicles; but daily passages of local vehicles equal in number to local registrations contained only 52 to 54 percent different cars in the two cities in which this comparison could be made.

In most instances, the duplicated license numbers in small volumes of traffic represent one additional passage by a number of different cars. Repetition by a specific vehicle may occur in the form of another passage at the station where the vehicle was first identified (such as would occur if the driver drove around the block seeking a place to park), or it may take place when the vehicle passes another counting station in the course of its travels.

In large volumes of local passages—volumes which approach or exceed the number of cars registered—a great many vehicles are detected two or more times. Exploratory studies indicate that the number of cars exposed two times, three times or N times will constitute a predictable proportion of the combined volumes of traffic recorded at counting stations in the several cities. Because the analysis of exposure frequency requires larger volumes of data than were needed for the analysis of initial exposure, the work that has been done up to now is related only to weekly (7-day) accumulations of license data in the surveyed cities.

These studies are still in the preliminary stage and firm statistical relationships have not yet been developed. The frequency of exposure in volumes of local passages equal to 100 and 200 percent of local registration appears to be as given in Table 7.

TABLE 7

DIFFERENT CARS AS PERCENT OF LOCAL REGISTRATION

Frequency of Exposure (No. Times)	Volume of Local Passages Equal to	
	Local Registration	Twice Local Registration
One or more	44	62
Two or more	23	41
Three or more	13	28
Four or more	8	20
Five or more	5	14

It appears likely that the daily, weekly and monthly frequency of exposure in local traffic volumes ultimately will be formalized in a series of equations similar to the daily coverage curve shown in Figure 5. It then will be possible to predict the number of different vehicles likely to be exposed at least 2, 3, or N times in any volume of local traffic, as long as that volume has been compiled according to the basic criteria described earlier.

CONTINUING STUDIES

The studies reported herein represent findings to date which may interest traffic engineers. Data collected in the 1956 studies, plus information from studies in Fort Wayne, Cedar Rapids, London, and Indianapolis, also contain many useful facts concerning the exposure and frequency of repetition of non-local vehicles in traffic. Present plans envision the completion of the exposure and frequency studies of local traffic and the extension of similar investigations to (a) non-local vehicles which represent families oriented toward the urban communities as centers of trade and commerce and (b) other non-local vehicles. As these studies continue, it is probable that new field data in a variety of forms will be added to the information already available.

ACKNOWLEDGMENTS

This paper is based on data contained in copyrighted reports delivered to the Outdoor Advertising Association of America in November, 1958, and April, 1959. The paper has been prepared with permission of the copyright holder. Further details on the studies may be obtained from the Market Research and Development Committee, Outdoor Advertising Association of America, Chicago, Ill.

The authors wish to acknowledge the assistance of Herbert S. Levinson and others who contributed to the planning and interpretation of the studies.

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