Traffic Characteristics of Massachusetts Route 128

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This paper presents an analysis of the travel patterns of employees of new industrial development adjacent to Massachusetts Route 128, a limited-access circumferential highway located about 10 mi from the central business district of Boston. These travel patterns are compared with those of in-town industrial employees, and the impact of the "generated " traffic is evaluated.

Most of the data presented are separated according to two major classifications: (a) Route 128 user, and non-user; and (b) present employees who worked for a company before it moved to Route 128, and those who joined a company after it moved. Additional separations are made for each of four types of industry and for each of seven industrial locations along the highway. Also, average times, distances, and speeds to work are presented for the employees who live in outlying, intermediate, and in-town residential areas.

Also included is other information concerning the parking facilities of the new industries along the highway, as well as data on employment-vehicle ratios for various types of industry and ranges of employment.

Finally, an evaluation is made of the study and its methodology, together with comments regarding future areas of research.

●THE INFORMATION in this paper is based on an employee travel pattern survey conducted as part of the survey of new industrial development along Route 128, and has been integrated with an origin-and-destination (O-D) survey of the entire route made by the Traffic Division of the Massachusetts Department of Public Works. The purpose of these surveys was to determine the amount and character of traffic generated by industrial development and the impact of this traffic on Route 128 and on the metropolitan area as a whole.

More specifically, answers were sought for such questions as: are employees moving closer to their place of work; are distances to work becoming longer or shorter; are travel times longer or shorter; are modes of travel changing; to what extent are car pools being used; does the availability of Route 128 permit longer distances to work in less time; what parking capacities are needed; and what are the effects of industrial traffic on the operation of Route 128?

The answers to many of these questions will be influenced by the fact that Boston is on the sea coast, and that Route 128, therefore, is only a semi-circumferential highway. The traffic patterns developed in this section will reflect these characteristics.

Description of Route

Route 128 is a circumferential highway describing an arc of 8- to 10-mile radius around metropolitan Boston (Fig. 1). The northeast section continues as a radial route to Gloucester. The present route replaces an earlier route composed of local roads connecting and passing through the business centers of most of the cities and towns surrounding Boston. Most of the route followed heavily traveled 2-lane roads of obsolete design. Although it appeared upon road maps as a bypass of Boston, it actually had little to offer in time savings or congestion relief.

Though portions of Route 128 were built during the 1930's, the section of highway

from Wakefield (west of Route 1) to Route 9 in Wellesley which was completed in August 1951 provided for the first time an effective, high-speed circumferential highway around the most congested districts of the metropolitan Boston area. This 23-mile link was a 4-lane, fully controlled-access highway bypassing the congested business districts of Wakefield, Stoneham, Woburn, Lexington, Waltham, and Newton.

Subsequently, the highway was extended south of Route 9 as a 6-lane limited-access divided highway, mostly on new location, and was opened as far as Route 138 in December 1956. Construction is continuing to a junction with Route 3 in Braintree. This will substantially complete the new Route 128 around Boston. The length of the route from Gloucester to Braintree is about 70 miles, though this study is principally concerned with the portion from Route 1A to Route 138, a distance of about 55 miles.

The Master Highway Plan for the Boston Metropolitan Area issued in 1948, included Route 128, but no traffic assignment was made to it and no priority established for its construction. The following comment was made: "Most of the route is in suburban areas beyond the limits of congested developments. The new location is such that right-of-way takings will be held to a minimum and the highway can be developed prior to further expansion of population outward from the Metropolitan Area. This highway should serve a useful purpose in connecting the various radial expressways and other important arterial highways, as well as a bypass and outer distribution route."

When the middle section from Route 1 (north) to Route 9 opened in 1951, daily traffic volumes of 12,000 to 15,000 were predicted with possibly 20,000 on Sunday. During 1957 daily volumes exceed 30,000 with over 50,000 common on summer Sundays (Fig. 2). At the time the highway was opened little thought was given to the development of commercial or industrial uses along the roadsides. It was generally believed that the limited-access feature would discourage such development. However, much development has occurred, and the traffic characteristics of the route have been greatly influenced by this development.

Methods and Procedures

During the survey of industrial development along Route 128 (1, 2), interviews were held with management officials at each plant. At the conclusion of each management interview, the company was requested to distribute to each of their employees a questionnaire which was designed to yield travel pattern information with the fewest number of questions, the least effort on the part of the employee and the least possibility of ambiguity. Excellent cooperation was obtained. Most industries preferred to circulate the employee questionnaire in their own way and at their own convenience. Some prepared their own directives urging their employees to cooperate, and distributed them with pay checks; others merely placed them in a convenient place, such as near the lunch room door, and left it to the initiative of the employee to fill them out. Some decentralized the responsibility for distribution by routing the forms to department heads and sub-department heads. The latter method proved most effective.

To verify the reliability of the data obtained from the questionnaire regarding vehicles and people at each plant and their use of Route 128, "gate" counts were made at several individual industries and at the New England Industrial Center.

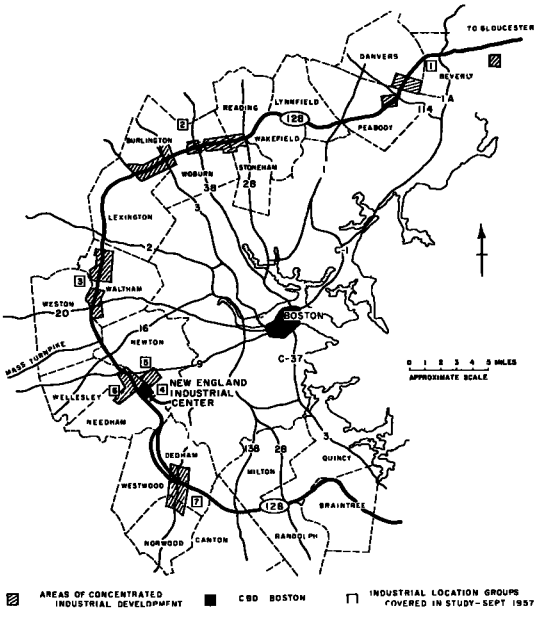
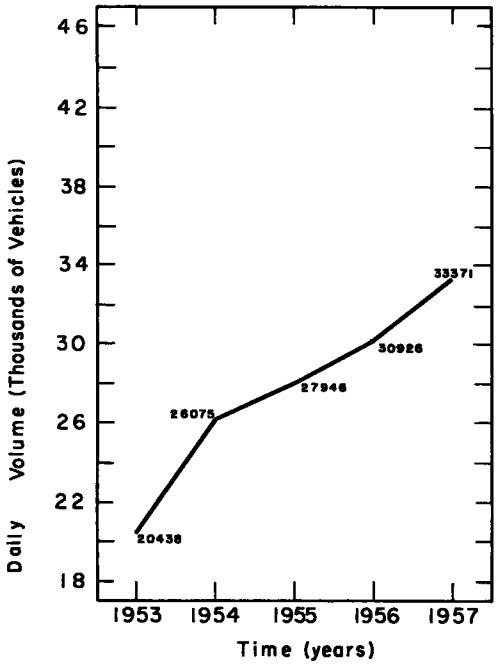
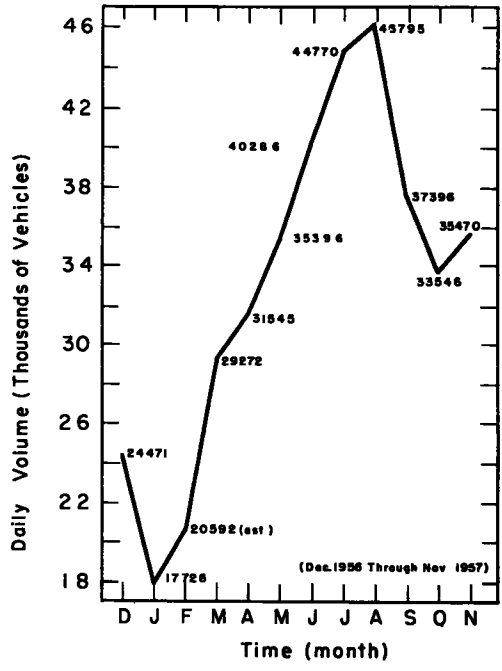
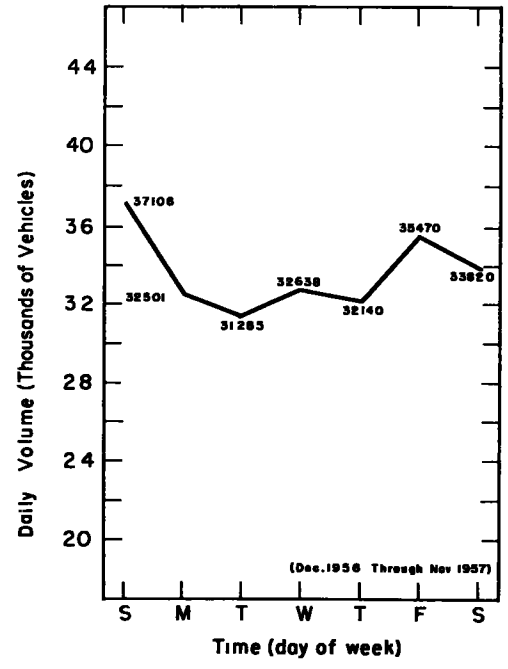


Figure 1. Layout of Route 128 showing areas of industrial development.







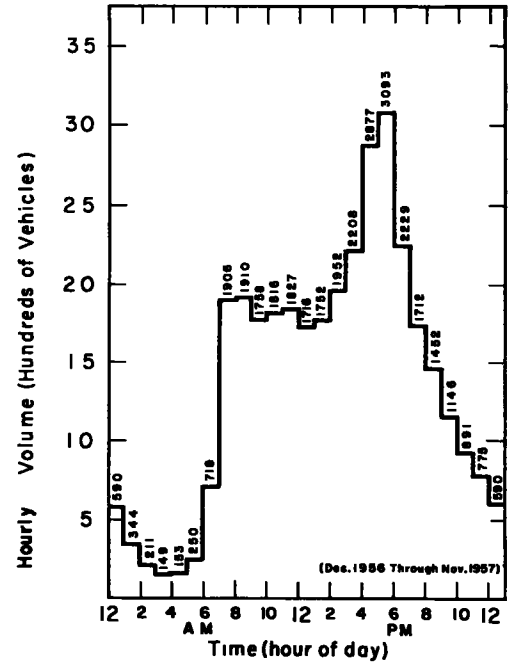


Figure 2. Traffic characteristics on 4-lane divided section of Route 128 at automatic counting station in Burlington, Massachusetts.

The counts were made at the end (or beginning) of the day shift.

The traffic information obtained from the employee questionnaires was supplemented by an O-D survey of all the traffic using Route 128. This was necessary in order to obtain information which would permit an evaluation of the effect of the traffic generated by the industrial development along the highway on over-all highway usage. The O-D survey was conducted by the Traffic and Planning Division of the Massachusetts Department of Public Works during the fall of 1957.

TABLE 1

CHARACTERISTICS OF ROUTE 128 EMPLOYMENT

Type of Industry	Total Employees (%)	Old and New Employees (%) New	Old	Sample Obtained (%)
Distribution	12	46	54	37
Production	72	47	53	45
R and D	13	57	43	43
Service	3	32	68	42
All types	100	48	52	44
Locational Area				
1 North of US 1	14	82	18	45
2 Burlington	18	48	52	57
3. Waltham	26	40	60	55
4. NEIC	13	36	64	31
5. Newton	10	54	46	15
6. Needham	2	45	55	33
7. Dedham	17	36	64	42
All areas	100	48	52	44

Results and Analysis

Description of the Major Separations of Data. The results have been presented in various ways in order to reveal the differences in travel patterns or any correlations which might be useful in future traffic prediction and assignment studies. Data for employees are usually separated into one of the following groups:

1. According to the industrial locational area where the workers are employed;
2. According to the type of industry; and
3. According to the regional zones where employees live.

For most of these three groupings the data are presented separately for:

1. Old Employees—those employed by the company before it moved to Route 128, and
2. New Employees—those who joined a company after it moved to Route 128.

The information is also given separately for Route 128 users who use Route 128 on their trip to work, and non-Route 128 users, who do not use Route 128 in the journey to work.

Characteristics of Route 128 Employment. The distribution of employment along Route 128 has considerable influence on the resulting travel patterns and traffic char-

TABLE 2

DISTRIBUTION OF EMPLOYMENT AND EMPLOYEE QUESTIONNAIRE RETURNS BY YEAR PLANTS STARTED OPERATION ON ROUTE 128

Year Plants Started Operating on Rte. 128	Sept. 1957 Employment (%) At Plants Starting in Each Year	Cumulative	Employee Questionnaires Obtained (%) At Plants Starting in Each Year	Cumulative	Sample Obtained from Plants Starting in Each Year (%)
Before 1951	2	2	2	2	58
During 1951	5	7	7	9	77
During 1952	24	30	19	28	37
During 1953	0[1]	31	1	29	46
During 1954	11	42	10	39	44
During 1955	23	65	18	57	50
During 1956	20	85	27	84	65
To Sept. 1957	15	100	16	100	66
All years	100		100		52

[1]Less than 0.5 percent.

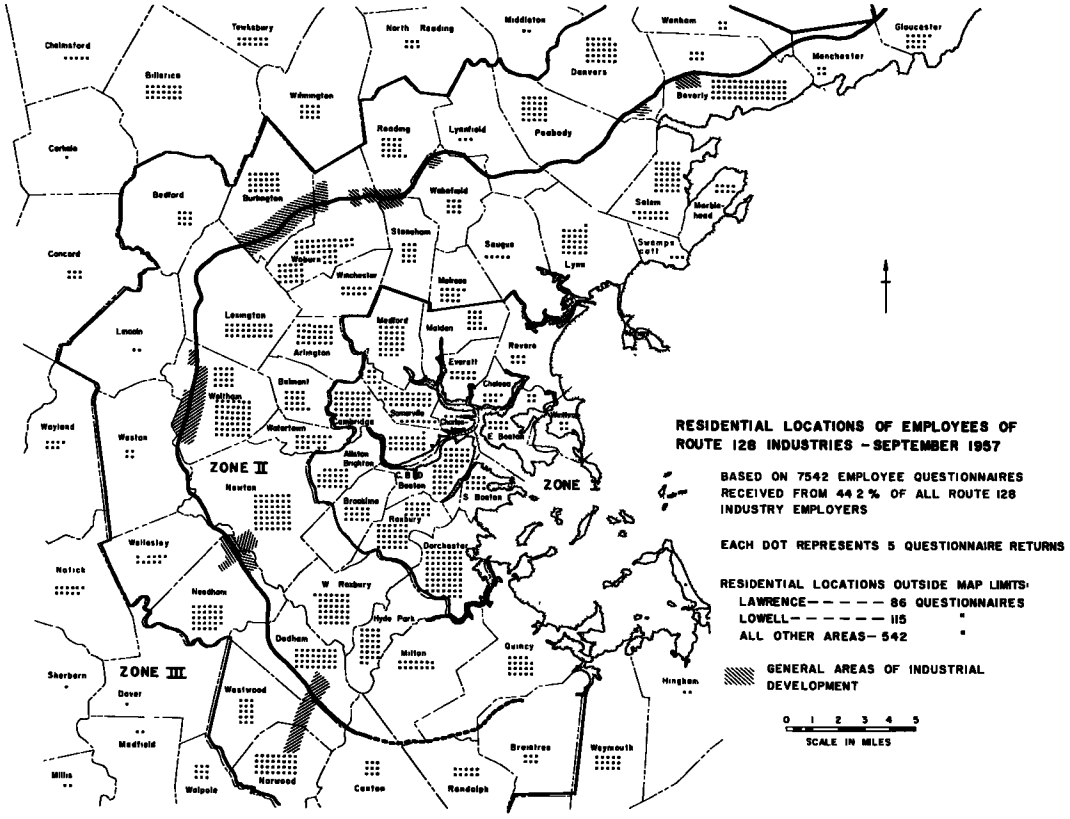


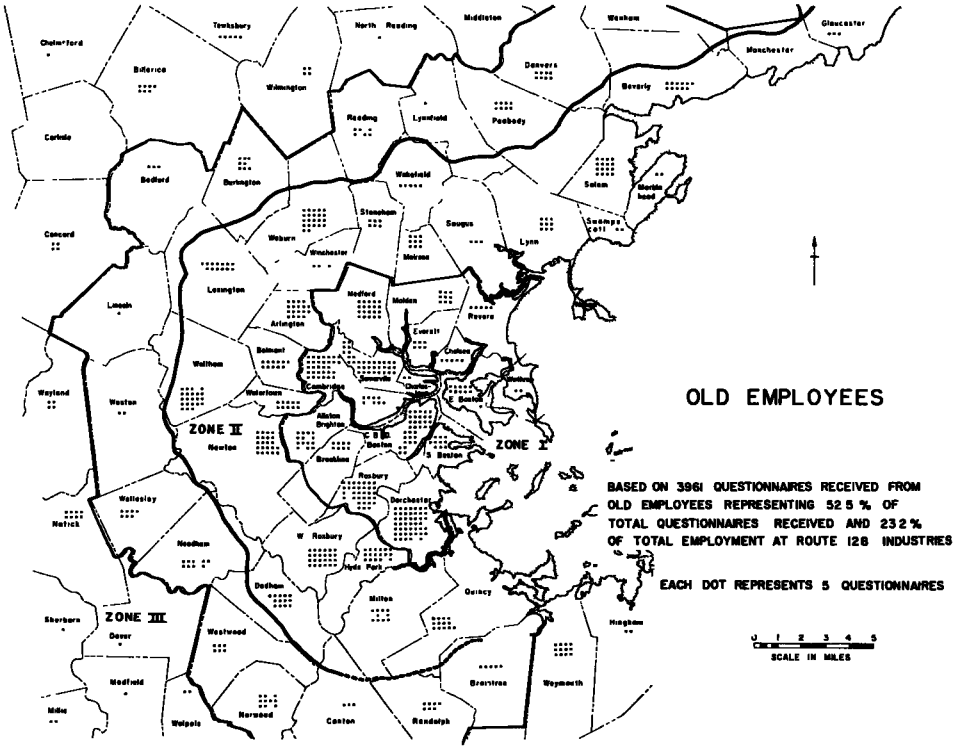
Figure 3.

acteristics. The employment opportunities are distributed among the seven locational areas and the four types of industry as shown in Table 1; this table also includes new and old employee percentages and the size of the questionnaire sample.

The percentages of new and old employees in each locational area or type of industry are influenced by the changes in employment that have occurred after a company moved to Route 128 and by the proportion of "new" and "relocated" plants in each group. New plants represent the start or founding of new enterprises or outlets, while relocated plants indicate those firms which moved to Route 128 from other locations. In the locational area north of Route 1, the relocated industries showed a large increase in employment with 82 percent new employees. Similarly, the research and development companies expanded their staffs more than other types of industry resulting in 57 percent of new employees. On the other hand, the relocated service companies curtailed their employment somewhat on moving to Route 128 and only 32 percent new employees are noted. At the same time, R and D firms had the highest percentage of new companies and service the lowest, further accounting for the high and low percentages of new employees of these two types of industry.

Fifty-two percent of the total employment along the route was concentrated in 4 of the 7 areas, Waltham through Needham; this concentration of employment was spread out over an 11-mile stretch in the central portion of Route 128, or over only 20 percent of the total linear distance between the end locational areas. The high employment density in the central region may be expected to increase even more since a large number of plants have been completed or are under construction particularly in the Waltham area.

A distribution of the percentages of employees working at plants which have started operations on Route 128 since 1951 is shown in Table 2, together with questionnaire


OLD EMPLOYEES
BASED ON 3961 QUESTIONNAIRES RECEIVED FROM OLD EMPLOYEES REPRESENTING 52.5 % OF TOTAL QUESTIONNAIRES RECEIVED AND 23.2 % OF TOTAL EMPLOYMENT AT ROUTE 128 INDUSTRIES
EACH DOT REPRESENTS 5 QUESTIONNAIRES
SCALE IN MILES
ZONE I
ZONE II
ZONE III

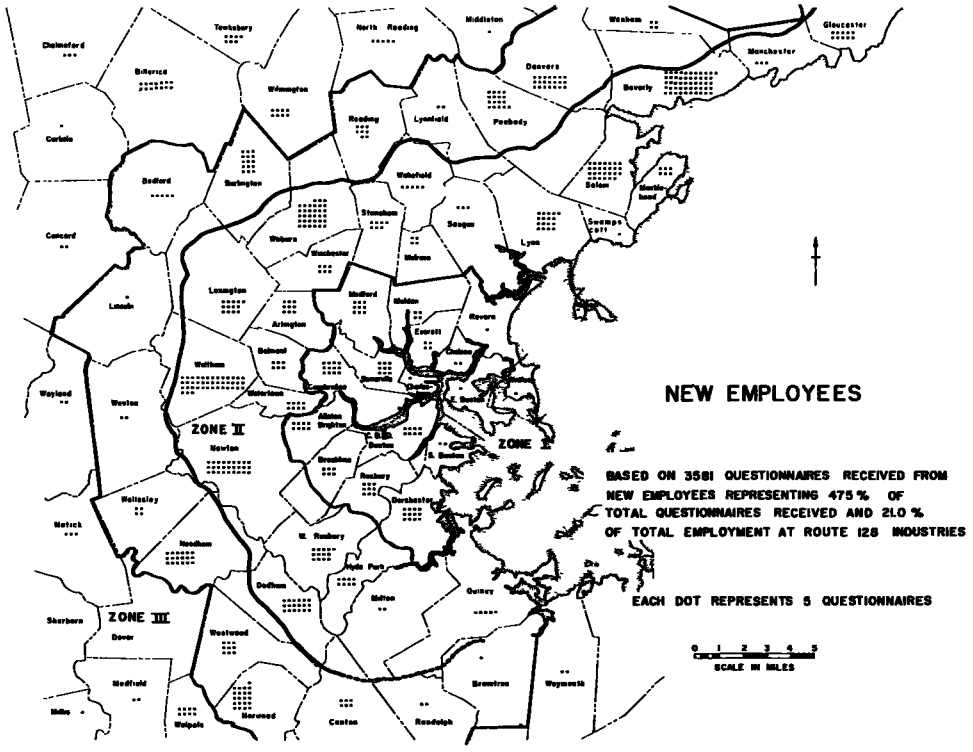

NEW EMPLOYEES
BASED ON 3581 QUESTIONNAIRES RECEIVED FROM NEW EMPLOYEES REPRESENTING 47.5 % OF TOTAL QUESTIONNAIRES RECEIVED AND 21.0 % OF TOTAL EMPLOYMENT AT ROUTE 128 INDUSTRIES
EACH DOT REPRESENTS 5 QUESTIONNAIRES
SCALE IN MILES
ZONE I
ZONE II
ZONE III

Figure 4.

sample size expressed in percent of total employment in each case. The growth of employment on Route 128 is obviously closely related to the amount of traffic generated.

The percentage of employees who returned questionnaire forms in the areas (Table 1) should be quite sufficient to yield reliable results. In order to determine if these returned forms represented a reasonable cross-section of the employment, percentages of the employee questionnaires obtained were summarized by years in Table 2. The cumulative percentages of questionnaire returns and employment are comparable for each year. Therefore, it is concluded that travel pattern trends developed from the employee questionnaire sample can be considered representative.

Living Areas of Route 128 Industrial Employees. The locations of the homes of Route 128 industrial employees is shown in Figure 3. The dot representation allows a visual picture of the relative distribution of homes among the in-town, intermediate, and outlying zones. The zone breakdown is employed to clarify reading of the plot and to allow comparisons between travel pattern data for employees living in the suburbs

TABLE 3

PERCENT OF EMPLOYEES OF EACH TYPE OF INDUSTRY THAT LIVE IN THE IN-TOWN, INTERMEDIATE, OR OUTLYING ZONES

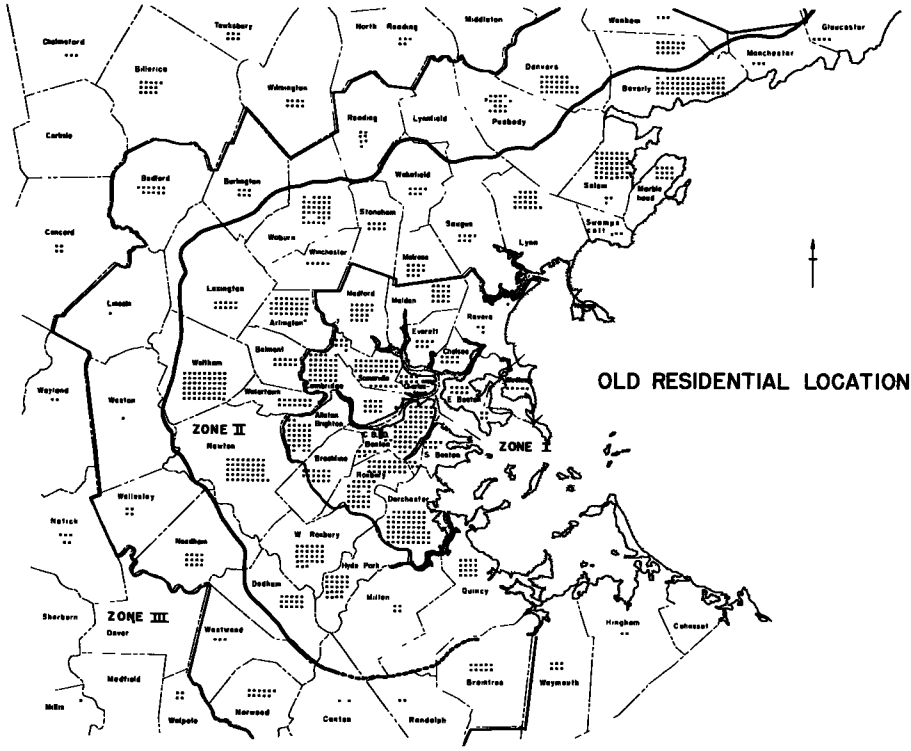
Zone	Type of Industry				All Industries
	Distribution	Production	R and D	Service	
(I) In-Town	31	25	22	17	25
(II) Intermediate	53	56	51	65	55
(III) Outlying	16	19	27	18	20
All areas	100	100	100	100	100

and those living in-town. Additional plots have been made for new and old employees (Fig. 4). Table 3 supplements the plots and gives a summary of the percentages of employees of each type of industry that live in each of the three zones.

Since the communities in the in-town zone are grouped together, the plot gives the impression that most of the employees live in this zone. Actually, more than half (55 percent) of the employees live in the intermediate zone, one-fifth in the outlying zone and only one-quarter in-town. In contrast, of the total metropolitan population living in both zones I and II, 46.5 percent live in the in-town zone (zone I) whereas only 31 percent of the Route 128 employee residences in these two zones are in zone I. A majority of the employees of each type of industry lives in the intermediate zone. More employees of distribution type industries live in the in-town zone than employees of other types of industry. A reason for this might be that these employees are on a lower wage scale than the employees of the other types of industry, and for that reason they cannot afford to live in many of the more desirable and expensive residential areas in zones II and III.

The home locations of new and old employees (Fig. 4) are revealing with respect to changes in labor market of companies after moving to Route 128. Although more than half of either old or new employees live in outer zones II and III, a decidedly lower percentage of new employees lives in the in-town zone. For example, referring to Table 4, only 12 percent of all new employees live in-town as compared to 37 percent of all old employees. A more important difference is found in the intermediate zone where only 46 percent of all old employees live, but 65 percent of new employees. These relationships are significant when assigning traffic to a particular area or route on the basis of land use.

Change in Residence by Route 128 Industry Employees after Starting to Work. The survey sample of old and new home locations of those Route 128 industry employees who moved after starting to work at a Route 128 plant is shown in Figure 5. These employees are definitely shifting their homes to the suburban areas. Table 5 supple-


OLD RESIDENTIAL LOCATIONS
ZONE I
ZONE II
ZONE III
Boston
Cambridge
Somerville
Chelsea
Revere
Everett
Malden
Medford
Melrose
Lynn
Saugus
Wakefield
Stoneham
Woburn
Winchester
Lexington
Arlington
Belmont
Waltham
Watertown
Newton
Brookline
Roxbury
Dorchester
Milton
Quincy
Hyde Park
Dedham
Needham
Wellesley
Weston
Natick
Sherborn
Medfield
Norwood
Canton
Randolph
Braintree
Weymouth
Hingham
Cohasset
Wenham
Manchester
Beverly
Salem
Marblehead
Swampscott
Peabody
Danvers
Middleton
North Reading
Reading
Lynnfield
Wilmington
Burlington
Billerica
Chelmsford
Tewksbury
Carlisle
Bedford
Concord
Lincoln
Gloucester

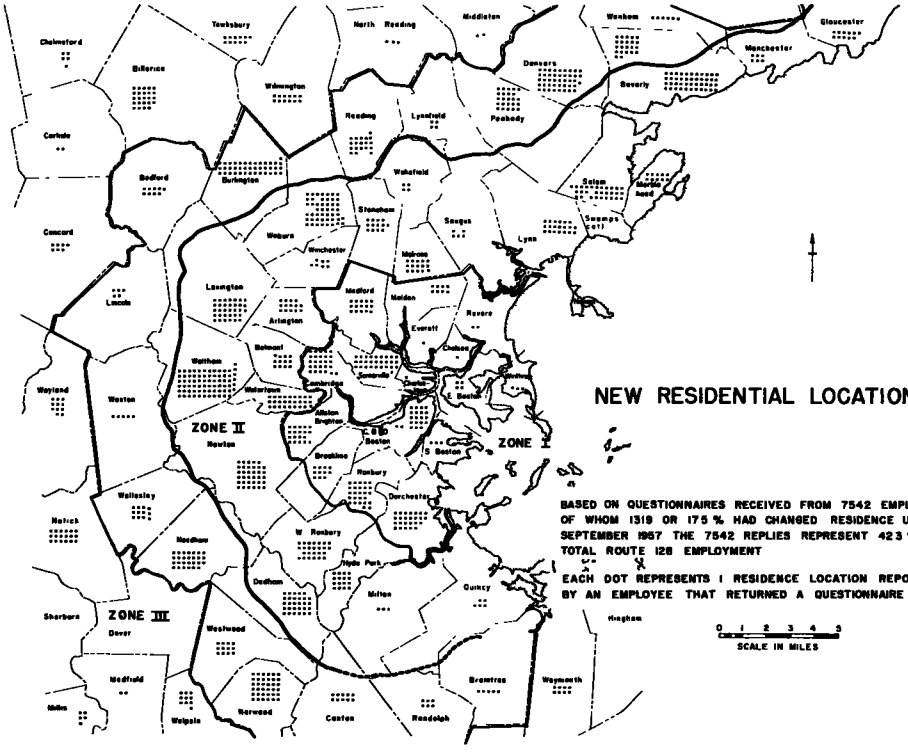

NEW RESIDENTIAL LOCATIONS
ZONE I
ZONE II
ZONE III
BASED ON QUESTIONNAIRES RECEIVED FROM 7542 EMPLOYEES OF WHOM 1319 OR 17.5 % HAD CHANGED RESIDENCE UP TO SEPTEMBER 1967 THE 7542 REPLIES REPRESENT 42.3 % OF TOTAL ROUTE 128 EMPLOYMENT
EACH DOT REPRESENTS 1 RESIDENCE LOCATION REPORTED BY AN EMPLOYEE THAT RETURNED A QUESTIONNAIRE
0 1 2 3 4 5
SCALE IN MILES
Boston
Cambridge
Somerville
Chelsea
Revere
Everett
Malden
Medford
Melrose
Lynn
Saugus
Wakefield
Stoneham
Woburn
Winchester
Lexington
Arlington
Belmont
Waltham
Watertown
Newton
Brookline
Roxbury
Dorchester
Milton
Quincy
Hyde Park
Dedham
Needham
Wellesley
Weston
Natick
Sherborn
Medfield
Norwood
Canton
Randolph
Braintree
Weymouth
Hingham
Wenham
Manchester
Beverly
Salem
Marblehead
Swampscott
Peabody
Danvers
Middleton
North Reading
Reading
Lynnfield
Wilmington
Burlington
Billerica
Chelmsford
Tewksbury
Carlisle
Bedford
Concord
Lincoln
Gloucester

Figure 5.

TABLE 4

PERCENT OF NEW AND OLD EMPLOYEES OF EACH TYPE OF INDUSTRY THAT LIVE IN THE IN-TOWN, INTERMEDIATE AND OUTLYING ZONES

Zone	Type of Industry and Class of Employee									
	Distribution		Production		R and D		Service		All	
	Old	New	Old	New	Old	New	Old	New	Old	New
I In-Town	44	16	39	10	31	21	24	3	37	12
II Intermediate	42	67	46	67	40	54	57	80	46	65
III Outlying	14	17	15	23	29	25	19	17	17	23
Total	100	100	100	100	100	100	100	100	100	100
All zones	54	46	53	47	43	57	68	32	53	47

ments this figure by indicating the percentage of these employees living in the in-town, intermediate, and outlying zones (zones I, II and III, respectively) both before and after changing their home location, and by comparing these data with data on home locations of Route 128 employees who have not moved.

Of the employees who have moved since starting to work at industries on Route 128 over four times as many now live in the intermediate zone as in the in-town zone. Also, considerably more of those who have moved live in suburban areas than those who have not moved.

The distributions of the new employees among zones (Table 4) and of those who have moved (Table 5) are almost identical, even though most of those moving are old employees. This points to the possibility that those employees who are moving are adopting the same living patterns as new employees. As the data in later sections will show, the travel patterns of the new employees and those workers changing residence are almost identical.

Trip-to-Work Travel Times, Distances, and Speeds of Route 128 Industrial Employees. This information has been presented in several ways in order to determine differences in travel patterns between new and old employees, and between Route 128 users and non-users. In addition, the data on Route 128 users were further divided according to the percentage of the trip-to-work distance traveled on Route 128. A general summary of the travel pattern data is given in Table 6.

The Route 128 employment is almost evenly split between new and old employees, and about half of each group uses Route 128 in making its journey to work. There are considerable differences, though, between the travel patterns of the old and new employees, and between those of the Route 128 users and non-users. For example, both the average time and distance to work for old employees are over 30 percent higher than those for new employees, but the average speed is the same for both groups. On the other hand, the distance to work for the Route 128 users is about 75 percent greater than that for non-users, but the time for the trip is only 33 percent greater; consequently,

TABLE 5

PERCENT DISTRIBUTION OF RESIDENCES OF ALL ROUTE 128 EMPLOYEES BEFORE AND AFTER MOVING

Zone	Employees Who Have Moved			Employees Who Have Not Moved	All Employees
	Before	After	% Change		
I In-Town	31	14	-54	27	25
II Intermediate	49	60	23	54	55
III Outlying	20	26	26	19	20
All zones	100	100		100	100

TABLE 6

SUMMARY OF ROUTE 128 EMPLOYEE TRAVEL PATTERN DATA

Trip-to-Work Characteristics	Old Employees	New Employees	All Employees
Class of employee (%):			
Old employees			52
New employees			48
All employees			100
Route 128 Usage (%):			
Route 128 users	49	49	49
Non-users	51	51	51
Average time-to-work (min):			
Route 128 users	31	25	28
Non-users	25	17	21
All employees	28	21	24
Average distance-to-work (miles):			
Route 128 users	16.6	13.4	15.0
Non-users	9.9	6.9	8.5
All employees	13.2	10.1	11.7
Average speed-to-work (mph):			
Route 128 users	32	33	32
Non-users	24	24	24
All employees	28	29	29

the average speed for the users is 33 percent higher than that for non-users.

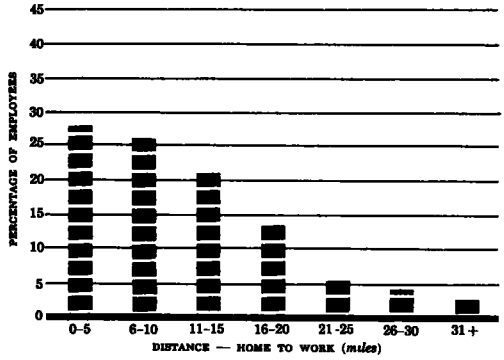
In general, for all four types of industry the time, distance, and speed patterns of old employees are quite similar. These patterns of new employees are nearly the same except for the research and development employees who travel a longer distance to work but still maintain higher trip speeds. In attaining this higher speed, 65 percent of the R and D employees use Route 128 as compared to an average 49 percent usage by employees of all industries along Route 128.

The travel pattern data of the old employees in each of the locational areas, except for area 1 (North of US 1 - N), show almost the same distance to work, although some variance occurs in Route 128 usage and average speeds. Home locations of employees in locational area 1 are closely distributed about that area, resulting in shorter distances to work and shorter distances on Route 128; the homes of employees in other areas are more widely spread out, resulting in longer distances to work.

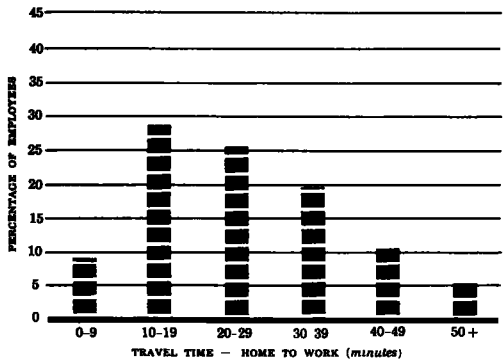
Table 7 gives more detailed information relating percent of home-to-work distance traveled on Route 128, distance-to-work, and average speed of trip. These data indicate that as a greater percent of the trip is made on Route 128, the distance-to-work increases, but the average speed increases at an even greater rate, resulting in nearly the same time to work for all percents of use.

There is little variation in the average speeds and distances of employees in the various locational areas within each percentage range of Route 128 usage. For example, for employees using Route 128 for 1 to 20 percent of their trip, the average distances to work in the central areas, which include over 50 percent of the total Route 128 employment, vary less than 14 percent from the over-all average distance (excluding the end areas) and the speeds for these vary less than 12 percent.

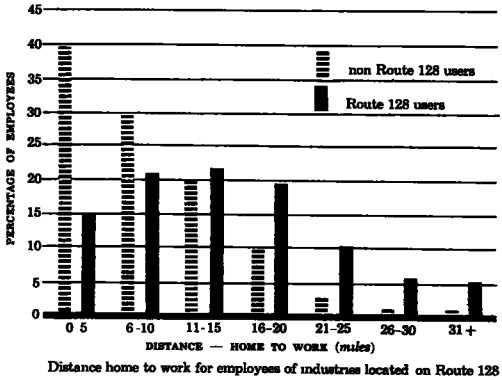
Actually, because of the semi-circular shape of the highway, the travel patterns of the end areas should not be expected to be the same as those in the central portions. For this reason, the planning of a highway such as Route 128 must certainly take into account these differences. It seems reasonable that a full circumferential highway would experience travel patterns more of the nature of those found in the central portions of Route 128 than those at the ends, or than the over-all data given here.



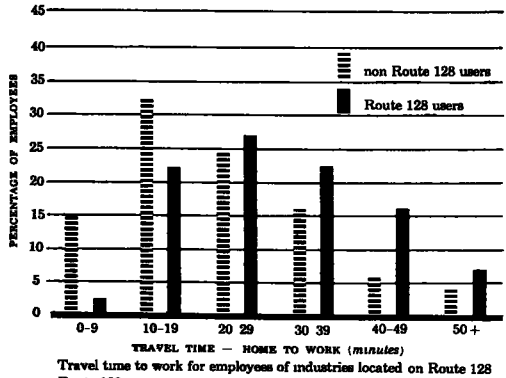
Distance home to work for employees of industries located on ROUTE 128
September 1957



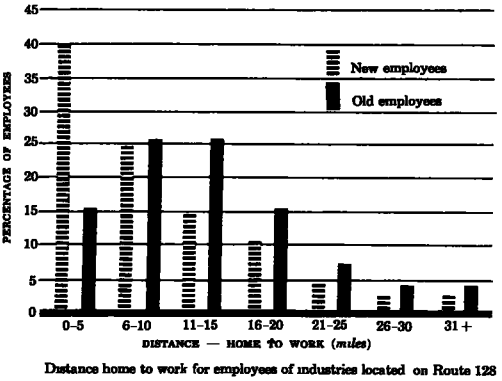
Travel time to work for employees of industries located on Route 128
September 1957



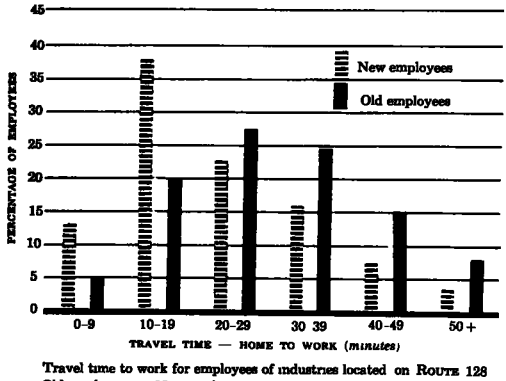
Distance home to work for employees of industries located on Route 128
Route 128 users vs non Route 128 users *September 1957*



Travel time to work for employees of industries located on Route 128
Route 128 users vs non Route 128 users *September 1957*



Distance home to work for employees of industries located on Route 128
Old employees vs New employees *September 1957*



Travel time to work for employees of industries located on ROUTE 128
Old employees vs New employees *September 1957*

Figure 6.

The distribution of the average distances and times-to-work of all Route 128 employees is shown in Figure 6. The differences between the Route 128 users and non-users and between the new and old employees are readily apparent. The range of distances for most of the non-users and new employees is much more limited than that for users and old employees. For example, 90 percent of the non-users travel 15

TABLE 7

PERCENTAGE USE OF ROUTE 128 RELATED TO EMPLOYEE TIME-TO-WORK TRIP, DISTANCE AND AVERAGE SPEED

No.	Locational Area	Percent of Area Employment Using Route 128 in Their Trip-to-Work for the Following Percent of the Trip Distance: None	1-20	21-40	41-60	61-80	81-100	% Total Employment in Area
1	North of US 1 (N)	46.3	9.5	14.4	13 1	9.4	7.3	14.3
2	Burlington	45.1	14.2	10.3	9.6	14.9	5.9	17.5
3	Waltham	44.3	6.8	12.8	15.6	14.2	6.3	26.2
4	NEIC	56.7	5.6	7.8	17.5	8.5	3.8	12.8
5	Newton	69.0	10.0	3.8	6.5	6.5	4.2	10.4
6	Needham	55.9	0.4	11.8	13.4	2.4	7.1	2.2
7	South of Needham	76.3	3.6	14.7	2.2	2.4	0.8	16.6
	All Areas	52.1	8.4	12.0	11.5	10.8	5.2	100.0

No.	Locational Area	Average Distances and Speeds-to-Work of the Employees in Each Area Using Route 128 in Their Trip-to-Work for the Following Percent of the Trip Distance: None a	b	1-20 a	b	21-40 a	b	41-60 a	b	61-80 a	b	81-100 a	b	All Users a	b
1	North of US 1 (N)	6.7	26	9.4	28	7.3	27	6.3	25	9.8	31	11.4	36	8.4	29
2	Burlington	8.0	25	15.4	32	12.3	32	15.3	33	17.8	35	15.9	37	15.6	34
3	Waltham	9.7	24	13.7	28	15.7	31	17.0	33	18.0	34	19.0	38	16.8	33
4	NEIC	8.5	23	14.2	30	14.3	29	17.0	33	13.2	32	17.4	33	15.4	32
5	Newton	7.3	22	12.5	26	19.0	39	18.4	33	16.6	30	19.0	32	16.3	31
6	Needham	7.4	23	13.0	31	16.2	32	22.6	39	13.7	33	16.9	47	17.4	36
7	South of Needham	8.8	23	17.1	30	14.7	28	17.2	34	19.3	35	28.1	39	16.2	30
	All Areas	8.5	24	14.1	30	13.4	30	15.0	33	16.6	34	16.7	37	15.0	32

miles or less to work, while 90 percent of the users travel 20 miles or less to work but 90 percent of the old employees travel 30 miles or less. Thus the radius of the old employee labor market can be extended significantly by re-locating an established company on a highway of this nature. On the other hand, those companies who employ new personnel upon opening a plant will find them drawn from a smaller radius. In locational area 1, however, there is little difference in the distance to work distribution for different groups of employees, mainly because most of the employees live in that immediate area.

In the time and distance-to-work distributions for all employees (Fig. 6) there is a strong similarity between the patterns of Route 128 users and old employees, and between those of non-users and new employees. Since only half of both new and old employees use Route 128, it is obvious that the Route 128 users and old employees are not the same people; the same is true for the non-users and new employees. This seemingly strong correlation was analyzed to determine whether or not any significant relationship really exists. Table 8, which gives trip-to-work data for the employees according to the zone of their residence, may help to clarify this point (Fig. 3 gives boundaries of Zones I, II, and III, that is, in-town, intermediate, and outlying).

Most of the workers in Zone I (in-town) are old employees, and most of these workers do not use Route 128 in their trip to work. In Zone III (outlying), the reverse is true; most of the workers

TABLE 8

SUMMARY OF AVERAGE DISTANCE, TIME AND SPEED-TO-WORK OF ROUTE 128 EMPLOYEES BY REGIONAL ZONES IN WHICH THEY LIVE

Regional Zones Where Employees Live	Zone I In-Town	Zone II Intermediate	Zone III Outlying
Percent of employees living in each zone			
1. Using Route 128	31	52	61
Non-users	69	48	39
2. New employees	23	56	55
Old employees	77	44	45
Distance-to-work (miles)			
Route 128 users	16 4	12.4	20.6
Non-users	12 4	4.6	13.2
All	13.6	8 7	17.7
Time-to-work (min)			
Route 128 users	34.5	22 9	35.0
Non-users	31.5	13.3	25.5
All	32.5	18.3	31.3
Speed-to-work (mph)			
Route 128 users	28.5	32.5	35.3
Non-users	23.6	20.8	31.1
All	25.1	28.5	33.9

are new and use Route 128. Therefore, it would seem that the similarities in distributions that occur in the time and distance-to-work graphs between old employees and users and between new employees and non-users are merely a result of the fact that their trip distances are almost the same rather than any correlation between the groups.

Most of the employees living in-town do not use Route 128, while half of those in the intermediate zone use the Route, and most of those in the outlying zone use Route 128 in their trip-to-work. In some respects this is the expected pattern, since the in-town people are near the center of radial highways and therefore have a number of resonably direct routes to get to work. On the other hand, the people living in the outlying zones have less choice of radial routes leading into Route 128 industrial areas and fewer connecting roads between the widely separated radial routes. Consequently, people in the outlying zone generally must use Route 128 if their work center is not located directly on the nearest radial.

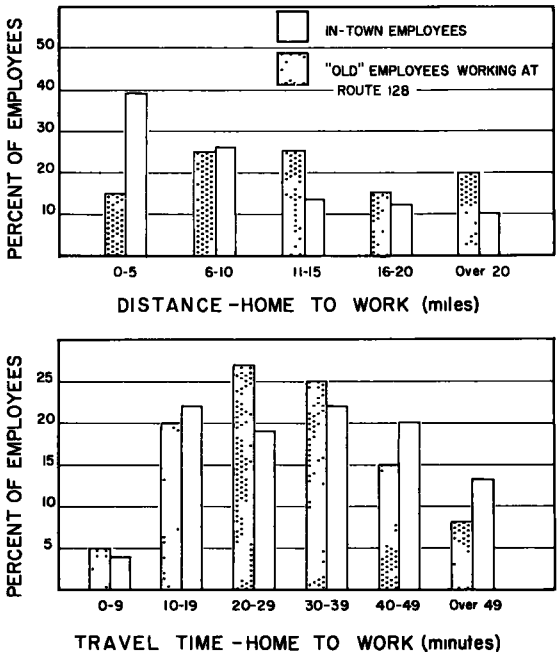


Figure 7. Home to work travel time and distance of old Route 128 and in-town employees.

The effect of Route 128 usage by workers is again apparent when the times, distances, and speeds for the users and non-users are compared for each of the 3 zones. In all 3 zones the Route 128 users travel longer distances and take greater times, but at the same time, are able to maintain greater speeds. It is particularly interesting that the Zone I (in-town) workers who use Route 128 have 30 percent longer trips than non-users but their travel time is little higher than the non-users. One might suspect that this would tend to cause a higher percent of Route 128 usage by these in-town

TABLE 9

SUMMARY OF TRAVEL PATTERN CHARACTERISTICS FOR EMPLOYEES WORKING AT AN IN-TOWN PRODUCTION PLANT AND FOR OLD ROUTE 128 EMPLOYEES AFTER STARTING TO WORK AT A ROUTE 128 PLANT

Employee Group and Mode	Employees in Mode (%)	Average Travel Time Home-to-Work (min)	Average Distance Home-to-Work (miles)	Average Speed of Trip (mph)
In-town workers				
Car	73.9	30	10.5	21
Public transit	16.8	36	5.5	9
Walk	4.1	14	0.9	4
Combinations	5.2	40	7.5	11
All Modes	100.0	30	10.5	21
Old Route 128 workers				
All Modes	100.0	28	13.2	28

TABLE 10

TRAVEL PATTERNS OF EMPLOYEES WHO HAVE MOVED SINCE STARTING TO WORK ON ROUTE 128[1]

No.	Locational Area	Rte. 128 Users (%)	Rte 128 Non-Users (%)	Avg. Dist. to Work (miles)	Avg. Dist. to Work of Rte. 128 Users (miles)	Avg. Travel Time to Work of Rte. 128 Users (min)	Avg. Speed of Rte. 128 Users (mph)	Avg. Dist. to Work of Non-Rte. 128 Users (miles)	Avg. Travel Time to Work of Non-Rte. 128 Users (min)	Avg. Speed of Non-Rte. 128 Users (mph)
1	North of US 1 (N)	55	45	7.5	7.7	17	28	7.1	16	26
2	Burlington	58	42	11.3	14.5	26	33	6.8	17	24
3	Waltham	55	45	12.2	14.9	27	33	8.9	22	25
4	NEIC	59	41	11 7	14.3	26	33	7.9	19	24
5	Newton	48	52	11.6	15.6	29	32	7.9	20	23
6	Needham	50	50	12.9	14.8	28	32	11.1	22	30
7	South of Needham	20	80	10.1	16.0	30	32	8.7	21	25
	All Areas	51	49	10.7	13.4	25	32	8.0	20	25
Type of Industry										
Distribution		58	42	11.9	14.7	27	33	8.1	20	24
Production		48	52	10.1	12.6	24	32	7.8	19	25
R and D		57	43	12.8	16.0	27	35	8.8	20	26
Service		69	31	13.1	13.9	25	33	11.6	29	24
All Types		51	49	10.7	13.4	25	32	8.0	20	25

[1]Based on questionnaires of employees of those who have moved: 1,319 out of 7,542 questionnaires.

people. Also, as the homes become farther removed from the congested center of the metropolitan area, the workers are able to maintain increasingly higher speeds in their journey to work. The only exception to this is for the non-users in Zone II; the reason for this probably lies in the fact that this group of workers has such a small trip-to-work (4.6 miles) that their average trip-to-work speed is considerably reduced by delays at the trip ends.

Comparison of the Travel Patterns of Employees Working at Industries along Route 128 with the Travel Patterns of Employees at an In-Town Location. In September 1958 a special questionnaire was distributed to 580 employees of one production industry located in Cambridge, Massachusetts, and almost 400 forms were returned. The purpose of this separate study was to obtain travel pattern data of employees working at an in-town location for comparison with that of old Route 128 employees, and, therefore, to determine the differences that have taken place since changing from an in-town to suburban place of work.

A comparison between in-town workers and old Route 128 employees to determine travel pattern trends seems reasonable since almost all of the old suburban workers formerly worked at an in-town location.

A summary of travel pattern characteristics of these two groups of workers is shown in Table 9, and distributions of home-to-work travel times and distances are shown in Figure 7. It is apparent that the old Route 128 workers who formerly worked in-town are traveling longer distances from home-to-work than the present in-town workers but are making the trip in slightly less time. Consequently, the old Route 128 employees are making their home-to-work trip at a 30 percent greater speed.

Another trend worth noting is that the distributions of travel times of old Route 128 employees and of in-town employees follow regular patterns even though the distance distributions are quite different and even though one group is working in-town and the other group at Route 128. For example, 26 percent of the in-town employees and 25 percent of the old employees at Route 128 travel to work in less than 20 minutes; similarly, 45 percent and 52 percent travel to work in less than 30 minutes.

On the other hand, 65 percent of the in-town workers but only 40 percent of the old employees at Route 128 travel less than 11 miles from home-to-work. In other words, the differences in each range are much more pronounced with regard to the distance-to-work than with travel time to work.

Travel Patterns of Employees Who Have Moved since Starting to Work on Route 128. Information on employees who have moved since starting to work at a Route 128 plant

was presented previously (Table 5, Fig. 5). It was found that these employees are moving outward from the in-town areas, and tend to be distributed among the three regional zones in the same pattern as new employees. Detailed travel characteristics of these workers who moved are shown in Tables 10 and 11. (In analyzing these tables it will be helpful to make comparisons with data in Tables 1, 6, and 7.)

A slightly higher percentage of the employees who have moved are using Route 128 than all workers. Since the percentage of all employees using Route 128 includes the employees who have moved (about 20 percent of the total), it is evident that employees make more use of Route 128 after moving. In each locational area except south of Needham, about half of those employees moving use Route 128 in their trip-to-work, and most of the travel patterns of the central area employees vary little from the averages. The small usage of Route 128 by employees working in the area south of Needham is caused by the fact that most of these employees live in the southwest quadrant of metropolitan Boston and

TABLE 11

COMPARISON OF TRAVEL PATTERNS OF EMPLOYEES WHO HAVE MOVED WITH THOSE WHO HAVE NOT MOVED SINCE STARTING WORK ON ROUTE 128

Employee Group	Avg. Dist. to Work (miles)	Avg Time to Work (min)	Avg. Speed to Work (mph)
All Route 128 employees	11 7	24	29
1 New employees	10 1	21	28
Old employees	13 2	28	28
2 Those who have not moved	11.9	25	28
Those who have moved	10 7	22	29
Difference	1 2	3	1
Route 128 users[1]	15.0	28	32
Those who have moved	13 4	25	32
Difference	1 6	3	0
Non-Route 128 users[1]	8.5	21	24
Those who have moved	8 0	20	25
Difference	0 5	1	1

[1]Includes the 18 percent of employees who have moved.

TABLE 12

COMPARISON OF BEFORE AND AFTER HOME-TO-WORK DISTANCES OF THOSE EMPLOYEES WHO MOVED AFTER STARTING TO WORK AT A ROUTE 128 PLANT[1]

Employees	Percent of Each Group Who Moved	Average Distance to Work (miles) Before Moving	After Moving
New employees who moved:			
Closer to place of work	37	18.1	8.5
Farther from place of work	44	8.1	16.8
No change in distance to work	19	9.2	9.2
All in group	100	12.1	11.9
Old employees who moved:			
Closer to place of work	39	15.0	7.1
Farther from place of work	43	10.2	17.5
No change in distance to work	18	13.7	13.7
All in group	100	12.7	12.7
All employees who moved:			
Closer to place of work	39	16.3	7.7
Farther from place of work	44	9.3	16.8
No change in distance to work	17	11.8	11.8
All in group	100	12.4	12.4

[1]Based on 2,134 questionnaire returns from 47 industries; one-half these returns were from new employees. Seventeen percent of all the forms indicated a change of residence after starting to work at a Route 128 plant. Of those moving, 42 percent were new employees.

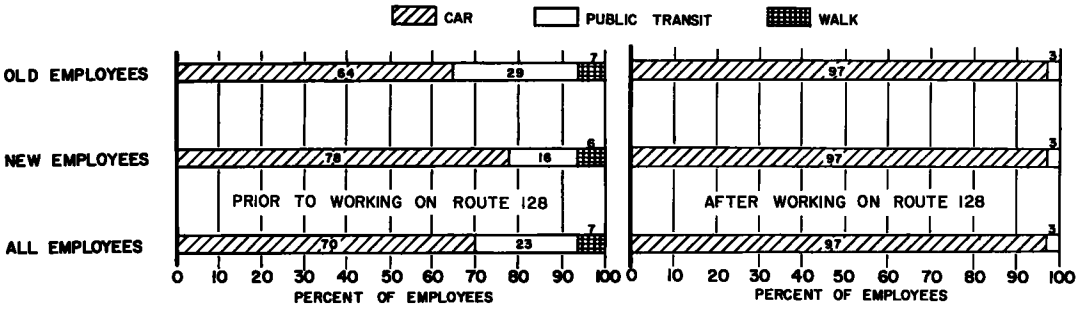


Figure 8. Mode of transportation used by employees of industries located on Route 128, September, 1957.

are limited in their choice of route to work and access to Route 128. Consequently, only those workers living east of the Route 1 and 128 interchange where this locational area industry is concentrated (Fig. 1) would gain access to Route 128 at Route 138 and find any advantage in using the circumferential highway. Otherwise, workers would find Route 1 most convenient for the trip to work. As industrial expansion takes place in areas at other Route 128 interchanges in this general region, more use of that route may be expected.

A comparison of travel patterns of employees who have moved with those who have not moved is given in Table 11. These data indicate that the average distance to work for those employees who have moved was about 1.2 miles less than the average distance to work for those employees who have not moved. The corresponding difference in time was about 3 min. and in speed about 1 mph. The average distance to work for those employees who have moved and use Route 128 was about 1.6 miles less than the average for all Route 128 users. These data give a general indication that there is a slight shortening of the distance to work when employees move. However, this is not true. A comparison of the distance to work before and after moving is shown in Table 12. The data in Table 12 are based on employee questionnaires from 47 industries. The difference in the average distance to work before and after moving for all or either new or old employees is negligible. Thirty-nine percent of the employees moved closer to work, 43 percent moved farther away from work, and there was no change in the distance to work of 18 percent of the employees. The employees who moved closer to their place of work shortened their work trip by an average of 53 percent, while those employees who moved farther from their place of work increased their work trip by an average of 80 percent. Perhaps a more significant comparison could be made on the basis of travel times; however, these data were not available.

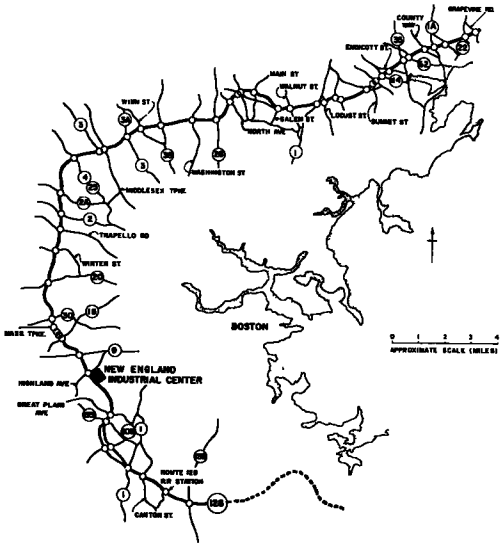
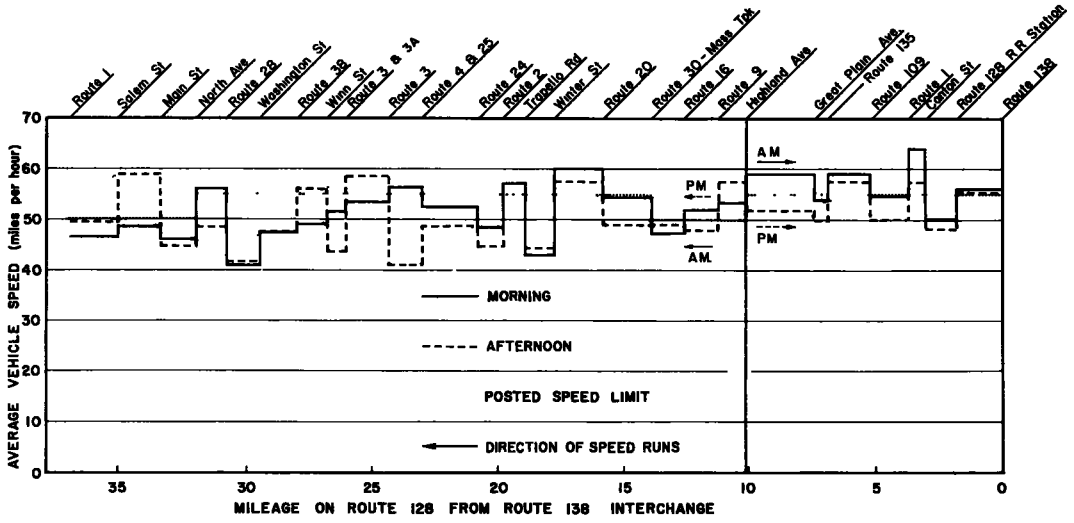
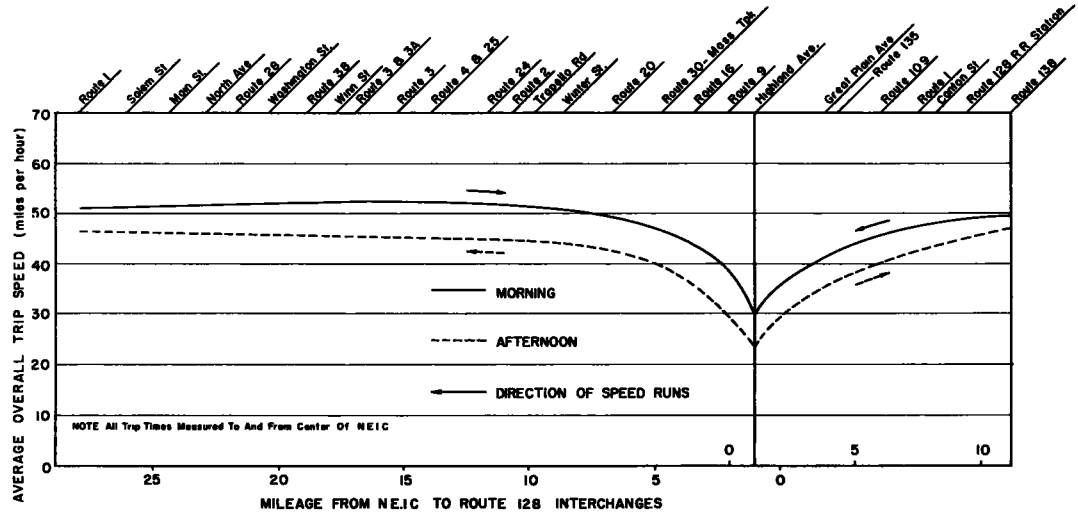


Figure 9. Layout of Route 128 showing interchange locations.

Modes of Travel Used by Route 128 Employees Before and After Working at a Route 128 Plant. Modes of travel utilized by new and old employees before and after starting to work at a Route 128 plant are summarized in Figure 8. Nearly all Route 128 employees now travel to work by motor vehicle whereas 30 percent formerly used public transportation or walked. Before working at a Route 128 plant, 64



AVERAGE SPEEDS BETWEEN ROUTE 128 INTERCHANGES DURING A.M. & P.M WEEKDAY PEAK HOURS FOR TRIPS TO AND FROM NEW ENGLAND INDUSTRIAL CENTER



AVERAGE OVERALL TRIP SPEED BETWEEN THE NEW ENGLAND INDUSTRIAL CENTER AND ROUTE 128 INTERCHANGES DURING A.M. & P.M. WEEKDAY PEAK HOURS

Figure 10.

percent of the old employees used cars in the trip-to-work in contrast to 78 percent of the new employees; after starting to work on Route 128, the use of cars by both groups was about the same. Consequently, there has been a 51 percent increase in automobile usage by old employees and a 27 percent increase by new employees.

Often statements are made that Route 128 employees are forced to use automobiles in their trip-to-work and this is the cause of the high percent using cars. This is not entirely true, however. Many companies have set up bus systems at their own expense to provide their employees with means of connecting with public transit; also, the Middlesex and Boston Street Railway provides a scheduled public transit service to the NEIC. Experience has shown, however, that within 6 months of starting opera-

tion on Route 128 nearly every company has abandoned special transportation service because the employees did not use it. Public transportation is not available to most of the locational areas, although it seems obvious that public or private transportation agencies would provide the service if they thought it would pay for itself. The great majority of Route 128 employees evidently do not want to use public transit; they prefer to use their cars or join car pools.

TABLE 13

AVERAGE TRAVEL TIMES AND SPEEDS OF EMPLOYEES AT NEW ENGLAND INDUSTRIAL CENTER

Type of Trip	Distance (miles)	Time (minutes)	Average Speed (mph)
Trip-to-work, a. m.:			
From north			
On streets	6.6	18 5	22
On Route 128	7.7	8.3	56
Into NEIC	1.1	2 2	29
Total trip	15.4	29.0	32
From south			
On streets	6.8	18.8	22
On Route 128	7.7	8 3	56
Into NEIC	0.9	1 9	28
Total trip	15.4	29.0	32
Trip home, p m.:			
To north			
NEIC to Route 128	0.9	2.4	16
On Route 128	7.7	9.2	50
To south			
NEIC to Route 128	1.1	2.8	22
On Route 128	7.7	8.7	53

Average Speeds on Route 128 and From the Highway into an Industrial Center. A series of speed runs were made along Route 128 and from the Highland Avenue interchange (Fig. 9) to a point near the center of the New England Industrial Center (NEIC). In the a. m. peak hours one set of runs started at Route 1 on the northern end of Route 128 and proceeded south to the NEIC, and another set was started at Route 138 in Canton and proceeded north to the center. These trips were made along Route 128 and into the NEIC in the morning to simulate the employee travel conditions in the trip from home-to-work. In the p. m. peak hours, the runs were reversed, simulating the trip from work-to-home. Two types of speed information were obtained: (1) the average running speed en route between interchanges; and (2) the average over-all speed from the middle of the NEIC to the first contact with a through lane of Route 128 at each interchange (or in the reverse direction). The "floating car" method was used, maintaining as closely as possible the average speeds of other drivers. The average speeds were based on ten runs over each of the four courses.

The results of this investigation are plotted in Figure 10. The top graph shows the average speeds being maintained on various sections of Route 128 and the bottom graph shows the average over-all speed of trips from the NEIC to various points along Route 128. The average speeds on Route 128 during the p. m. peak hours were lower than those during the morning. There are two reasons for this. First, the hourly volume and density are considerably higher in the afternoon peak than in the morning, causing a drop in speed as the road approaches capacity use. Second, in the morning the workers' times of arrival at the NEIC are spread over a longer period than in the afternoon when many of the employees leave work at the same time causing traffic congestion and delay at the plant parking lots and between them and the nearest entrance to Route 128. The results of these factors are apparent in Table 13 which shows average speeds on streets, on Route 128, and into the NEIC from Route 128. In compiling this table the speeds on Route 128 and into the NEIC were obtained from the speed runs, while those on streets were derived from the speed and distance of the average home-to-work trip reported on NEIC employee questionnaire forms. Since the total trip data were obtained by asking the employees the time and distance of their trip from home-to-work, the on streets

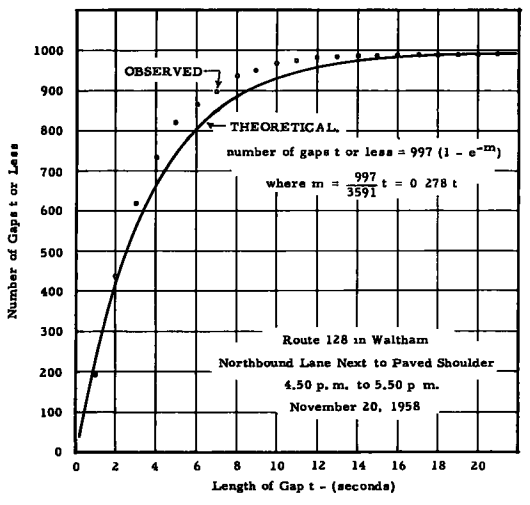


Figure 11. Distribution of gaps on Route 128.

TABLE 14

MODES OF TRANSPORTATION AND CAR-POOLING BY ROUTE 128 EMPLOYEES

Locational Area	Average Number of: Vehicles Per Employee	Employees Per Vehicle	Percent of Rte. 128 Users Who: Drive Alone	Car-Pool	Percent of Non-Users of Rte. 128 Who: Drive Alone	Car-Pool	Walk	Public Transit	Percent of Total Route 128 Employment
North of US 1 (N)	0.431	2.32	22	78	22	74	1	3	14.3
Burlington	0.589	1.70	38	62	39	60	1	[1]	17.5
Waltham	0.578	1.73	33	67	31	65	1	3	26.2
NEIC	0.610	1.64	41	59	35	62	1	2	12.8
Newton	0.654	1.53	45	55	40	50	2	8	10.4
Needham	0.800	1.25	49	51	43	45	6	6	2.2
South of Needham	0.426	2.35	34	66	23	66	4	7	16.6
All areas	0.546	1.83	35	65	32	62	2	4	100.0
Types of Industry									
Distribution	0.645	1.55	46	54	40	55	1	4	11.7
Production	0.535	1.86	36	64	32	62	2	4	72.5
R and D	0.555	1.80	32	68	37	62	[1]	[1]	12.8
Service	0.467	2.14	25	75	24	72	0	4	3.0

[1]Less than 0.5 percent.

data in Table 13 were computed only for a. m. trips.

The average speeds maintained along Route 128 during peak commuting periods are relatively high, and in many cases higher than the posted speed limit. The section having the heaviest hourly volume is a 4-lane divided highway with limited access and with daily peak lane volumes of about 1,000 vehicles per hour. If the distribution of headways occurring in this flow is taken into account, it is apparent that the users are traveling at short headways much of the time. An actual observation of the time gaps shows that over 60 percent are less than 3 seconds and 44 percent less than 2 seconds. The actual distribtuion of these gaps closely follows a theoretical curve, where 56 percent would be less than 3 seconds and 43 percent less than 2 seconds. Curves showing actual and theoretical gap spacings are plotted in Figure 11. The median gap spacing of this particular flow is about 2.5 seconds. At an average vehicle speed of 50 mph, this means the average distance between these vehicles would be in the order of 180 ft, with over 40 percent traveling less than 150 ft apart. These distance spacings are dangerously close, and have resulted in multiple rear-end collisions.

The standard geometric design of sections along Route 128 generally follows the period of the construction of the road, with the poorer design occurring in the older sections. The road was constructed for the most part in three stages, with the portion north from Wakefield being built first, that from Wakefield south to Route 9 next (1951), and the portion from Route 9 south following in 1955 and 1956. While the standards have improved considerably since the northern end was built, most of the ramps are of low-speed design and have inadequate speed change (acceleration-deceleration) lanes. Consequently, the driver is forced in most cases to reduce his speed when leaving (or gain his speed when entering) on through-lane portions of the highway, thus causing a reduction in the traffic carrying capacity of the route. Nevertheless, the improvements in the design of the highway over the years are apparent when the average speeds on the three design sections are taken into account. The average speeds on the southern section, that of newest design, are definitely higher than on the other portions; also, on the Route 9-Wakefield section speeds are slightly higher than those to the north, even though the northern section carries the lightest volumes of traffic.

In July 1951, prior to the opening of new construction of Route 128 between Wakefield and Route 9, travel time runs were made over the old Route 128 which ran through the business centers of Newtonville, Waltham, Lexington, Woburn, Stoneham and Wakefield. The average speed of trips over this old Route between Needham and Wakefield was 23 mph or less than half of that on the new Route.

Car Pooling Information Obtained from Employee Questionnaire Forms and Gate

TABLE 15

PARKING SPACE PER EMPLOYEE RATIOS OF THOSE COMPANIES HAVING ADEQUATE PARKING FACILITIES

Employment Range	Number of Plants	Average Number of Employees per Plant	% of Total Rte. 128 Employment in Range	Parking Space per Employee Ratio	Average Number of Vehicles per Employee
0-50 employees	39	24	7.7	1.43	0.870
51-100	13	78	8.4	1.01	0.746
101-150	3	120	3.0	0.85	0.657
151-200	5	163	6.8	1.06	0.606
201-500	9	322	23.9	0.84	0.561
501-1,000	2	788	13.0	0.71	0.520
Over 1,000	3	1,500	37.2	0.54	0.476
All ranges	74	163	100.0	0.79	0.594

Counts. The questionnaire form distributed to the Route 128 employees included a question designed to obtain information on car pooling among these employees. This information was desired to determine the number of vehicles and vehicle trips resulting from the industrial development.

In order to provide a check on the questionnaire form data regarding car pools, vehicle and passenger "gate" counts were made at 9 separate industries and at the NEIC. The gate counts showed approximately the same percent of Route 128 users as were tabulated from questionnaire forms. A serious discrepancy developed, however, between the number of vehicles counted and the number represented by questionnaire form data. Since each questionnaire represents one employee, the number of occupants per vehicle must be accurately known to establish a relation between number of questionnaires and number of vehicles. The question on car pooling was intended to accomplish this, but apparently it did not.

In all areas where gate counts were made, the number of vehicles per employee as computed from gate count data were significantly lower than the number computed from employee questionnaires. Two possible explanations are offered for this discrepancy. A disproportionate number of forms may have been submitted by those who actually drive alone, or those persons riding with or driving with others misunderstood the question regarding "car pool." For example, if an employee drives his own car to work every day and a fellow worker rides with him every day, the driver may not consider the arrangement a car pool. Another possibility is that a car pool may have been interpreted to mean only an arrangement where the owner of the car receives monetary compensation for carrying passengers on a regular basis.

The data from the 10 field counts were compared with that developed from the questionnaire forms of the same 10 industry groups (9 companies and the NEIC). At 8 of the 10 places where a field count was taken, more questionnaires were returned marked "drive alone" than the number of employees actually observed. Thus, it appears that most of the error resulted from car poolers with one rider misunderstanding the question. Further analysis of the data revealed that no correlation exists between the percentage of returns and the error in the number of vehicles reported on questionnaire forms.

The questionnaire data from the companies where gate counts were made were compared with that from all of the companies in the same locational area. A close correlation was apparent which indicated that the results obtained at plants where gate counts were taken were representative of those at all plants in the same locational area, and supported the validity of the application of an "adjustment factor" based on the gate counts. The adjusted data appear in Tables 14 and 15, and Figure 12.

Table 14 not only shows adjusted modes of transportation, but it also reveals some

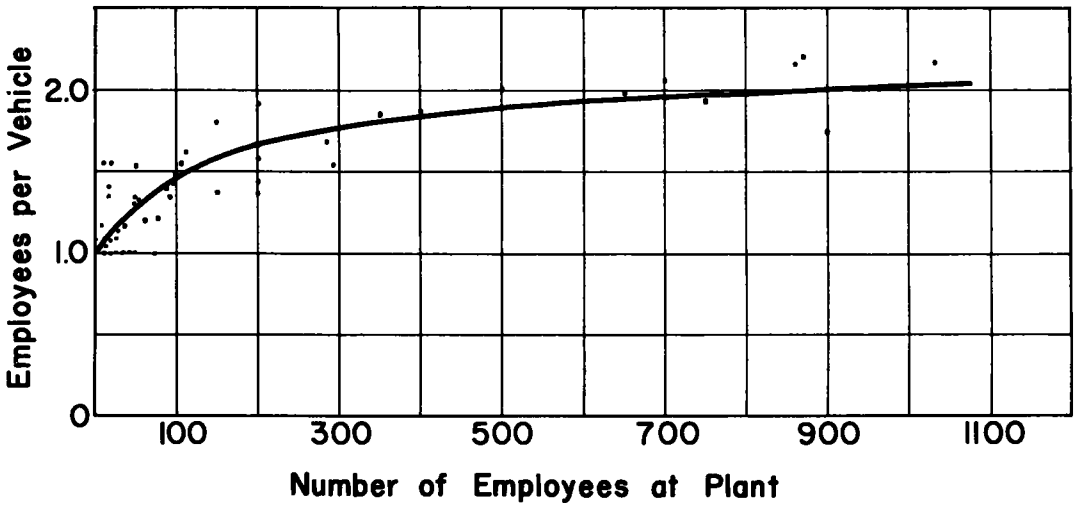


Figure 12. Relationship between employees per vehicle and plant employment.

relations between car pooling and concentrations of employment on Route 128. Table 14 shows that in a general way the larger the percent of employment in a given area the greater is the number of employees per automobile. This trend is also brought out by a plot (Fig. 12) of employees per vehicle against number of employees at each plant on Route 128. Each point represents one company, and the curve is a least squares fit. Although there are exceptions, it is evident that car pooling tends to increase as employment concentration increases.

Parking Lot Characteristics at Route 128 Plants. In the industrial survey, management personnel of the Route 128 plants were asked to give the number of parking places provided for employees and to comment as to whether or not their lot was adequate. Information was also obtained on the number of employees working on each shift and the starting and ending times of these shifts.

Parking space per employee ratios are tabulated in Table 15, grouped by employment ranges, for those companies that considered their parking lots adequate. Of those 86 companies giving information on parking spaces 74 had adequate facilities.

In computing the parking space ratios, the shift times and number of employees on each shift were checked in order to determine the maximum number of workers using the parking lot at one time. This number was then used to compute the ratios. If a company had two shifts which did not overlap, the employment during the largest shift was used in computing the ratio; if they overlapped, the total employment in the two shifts was used.

The lowest ratios of spaces per employee are found in the larger plants, while the ratios in the smallest plants are almost three times greater. This trend is consistent with the finding that car pooling is more prevalent at the larger companies and, therefore, their parking needs are less. It is also consistent with the vehicles per employee data given in Table 15 for each of the employment ranges. The companies with adequate parking facilities are providing an extra 30 percent ($\frac{0.79 - 0.594}{0.594} = 0.30$) of parking space over their needs to account for losses from improper parking, snow accumulation, and variations from average conditions.

Origin-and-Destination Study Conducted on Route 128. An origin-and-destination (O-D) study was conducted on Route 128 to determine the traffic characteristics of all the users of Route 128 and to provide information for determining the impact of the traffic contributed by the Route 128 industrial development. This survey was conducted by the Traffic Division of the Massachusetts Department of Public Works.

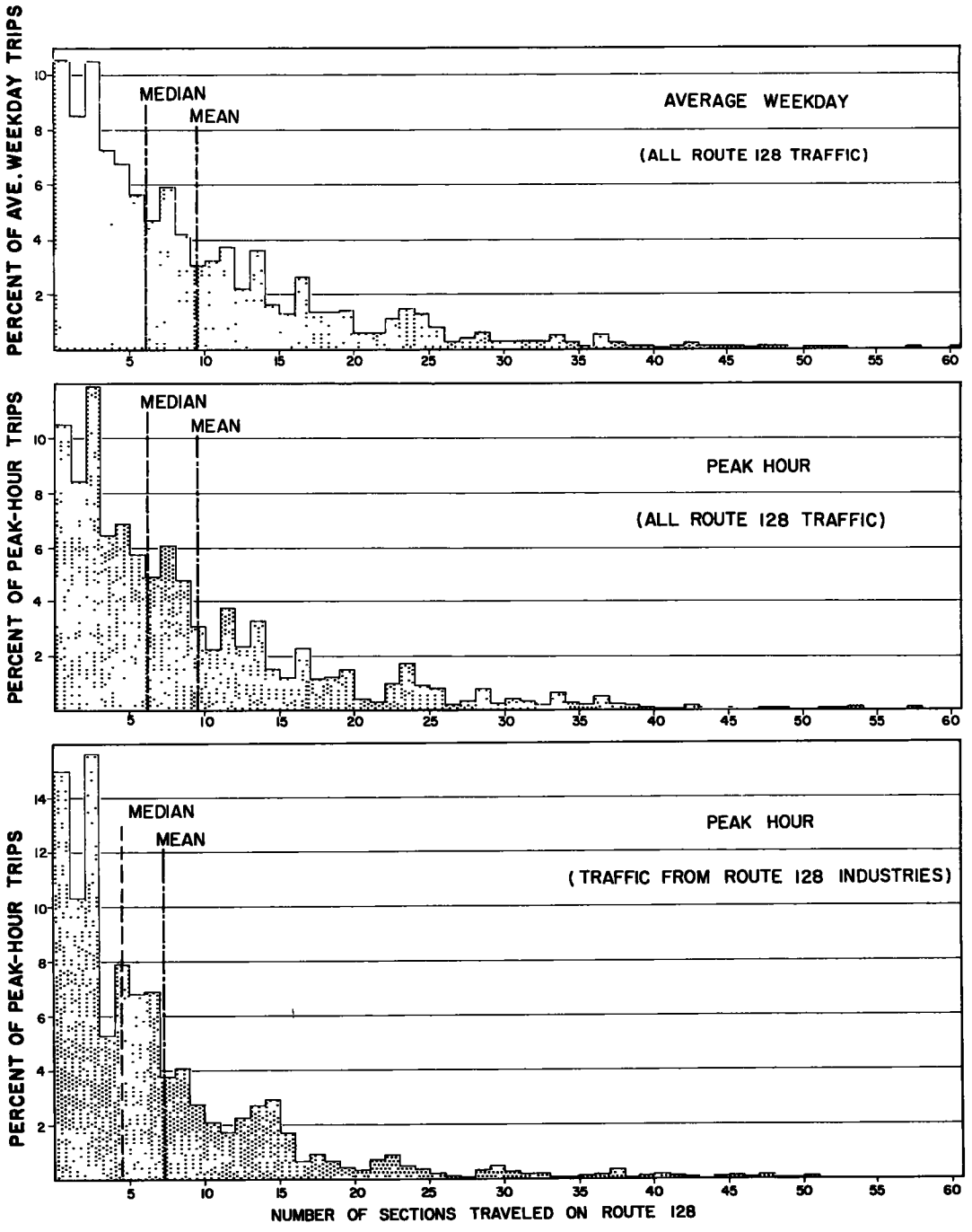


Figure 13. Distribution of traffic according to number of sections traveled on Route 128.

O-D stations were occupied on all southbound exit ramps between Grapevine Road in Wenham and Route 138 in Canton (Fig. 9). The interviews were all conducted on weekdays and for a minimum of 8 hr. The survey was started on October 15, 1957 and continued through January 24, 1958. Over 97 percent of all traffic leaving the ramps was interviewed. Manual volume counts were taken at all stations. The inter-

view and manual count data were adjusted by the Traffic Division of the Massachusetts Department of Public Works, as follows:

"From various manual and recorder counts which were available, a 24-hour count was selected as the average volume for the ramp on the day on which the interview station was operated. All of these counts were then doubled to take care of the assumed matching northbound movement. From analysis it was determined that the counts taken in October were representative of an average annual weekday volume. Counts taken during the following months were adjusted by factoring:

November	1.05
November and December	1.10
December or January	1.15

TABLE 16

SUMMARY OF AVERAGE ANNUAL WEEKDAY TRIPS ON MASSACHUSETTS ROUTE 128

Trip Description	No. of Avg. Weekday Trips	% of Avg. Weekday Trips
Trips within Zone I (in-town)	237	0 1
Trips within Zone II (intermediate)	65,880	38.2
Trips within Zone III (outlying)	6,063	3.5
Trips between Zones I and II	19,868	11.5
Trips between Zones I and III	15,152	8.8
Trips between Zones II and III	46,017	26.7
Trips with origin or destination out-of-state	17,476	10.2
Trips with origin and destination out-of-state	1,807	1.0
All trips	172,500	100.0

Source: 1957 O-D Study, M. D. P. W.

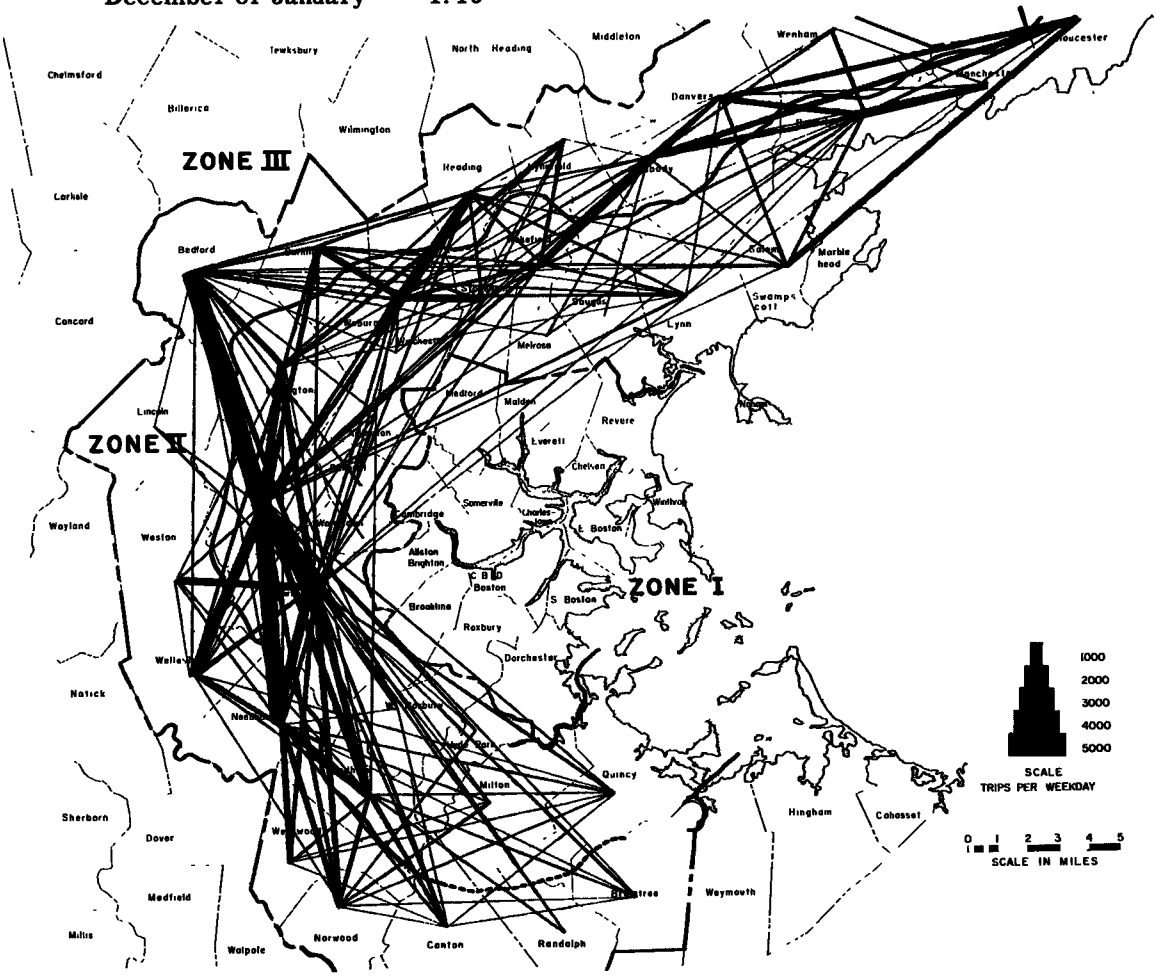


Figure 14. Desire lines for 1957 average weekday traffic on Route 128 with both origin and destination in Zone II.

Interviews were expanded to the volumes resulting from the above procedure."

After adjusting the data obtained from the roadside interviews, the M. D. P. W. prepared tabulations of average annual weekday trips and average weekday peak hour trips according to origin, destination, entrance ramp and exit ramp. Additional tabulations were made for trips between and within three regional zones: in-town, intermediate, and outlying (Fig. 3). The information regarding purpose of trip asked for on the survey form could not be used, however, because of incomplete data obtained in the field survey.

In interpreting the results of the O-D data (desire lines, etc.) it must be kept in mind that they apply to weekday traffic in the months of October through January. Most of this traffic would logically be of an "essential" nature such as trips to work and for business, shopping, etc. During the summer months, considerable recreational use is made of Route 128, particularly on weekends, by motorists driving to north or south shore resorts, and to places in Maine and New Hampshire. The extent of this seasonal variation is shown in Figure 2. This summer traffic tends to increase volumes on the northerly and southerly ends of Route 128, producing a somewhat different desire-line pattern than is presented in this report.

Error Introduced by Interviewing Only Southbound Exit Ramps. Since only the traffic on one side of the road was interviewed, it had to be assumed that the traffic mov-

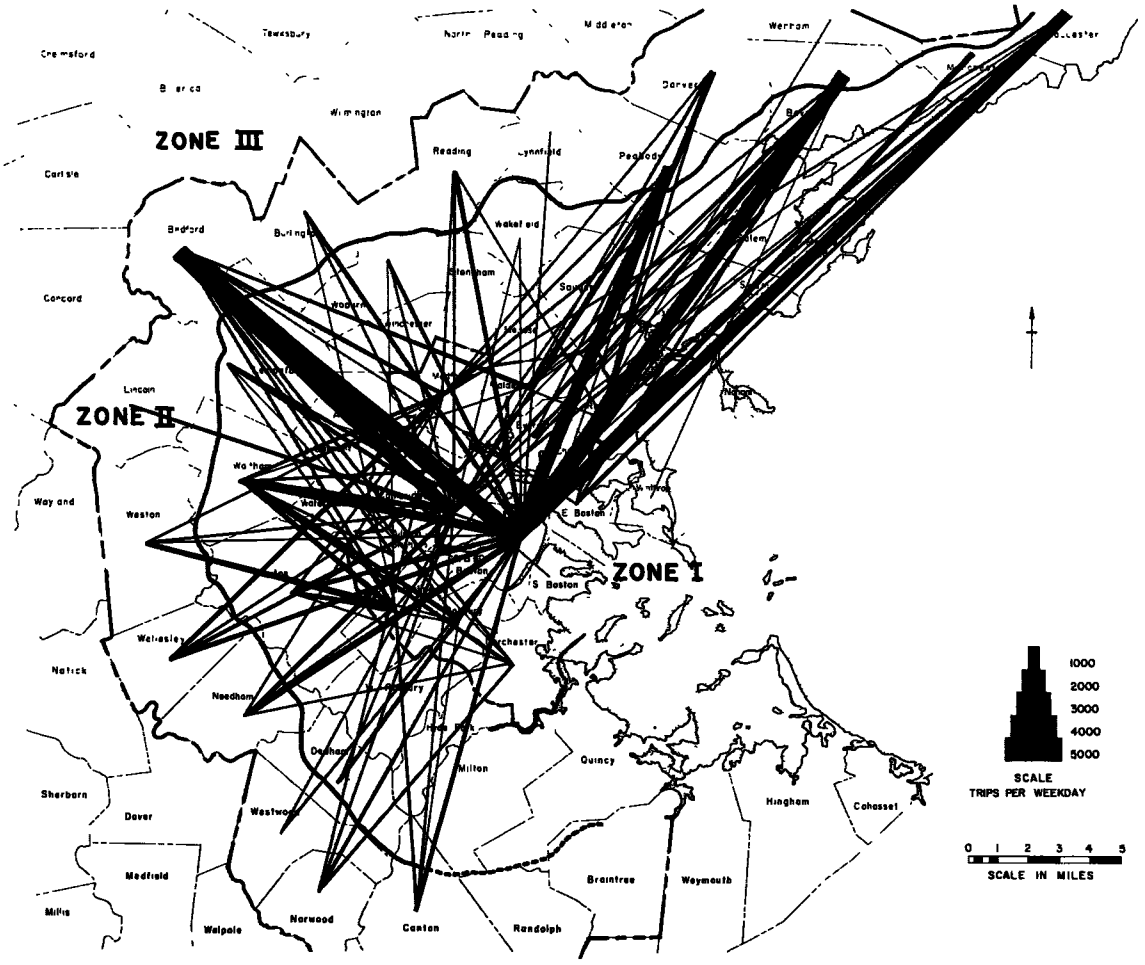


Figure 15. Desire lines for 1957 average weekday traffic on Route 128 between Zone I and Zone II.

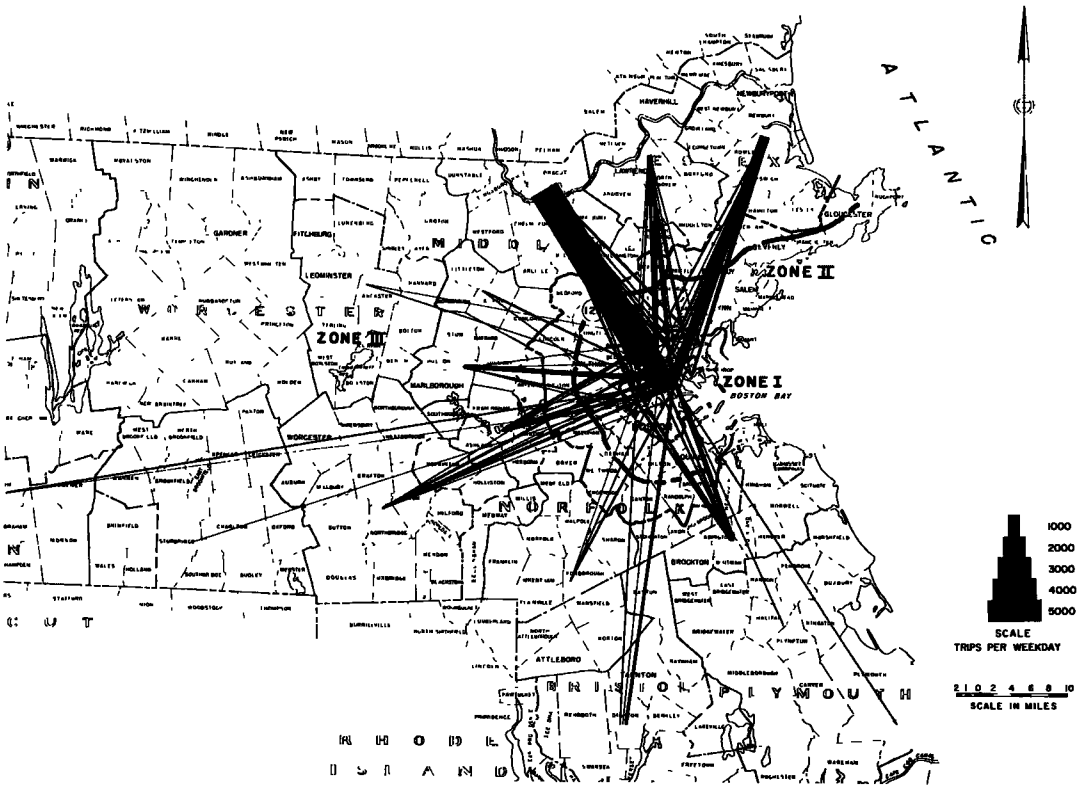


Figure 16. Desire lines for 1957 average weekday traffic on Route 128 between Zone I and Zone II.

ing in the opposite direction on the other side of the road followed a similar though reverse pattern. Traffic counts were made on all ramps of thirteen interchanges along Route 128 to determine whether or not this "reflection" principle was valid. The counts showed a 2.0 percent over-all difference between southbound and northbound ramp traffic, and a 0.9 percent difference between southbound exit and northbound entrance traffic. However, larger variations occurred at the individual interchanges. The differences were computed for the individual interchanges and weighted according to interchange ramp volume giving a weighted difference of 11 percent between southbound exit and northbound entrance traffic. The error thus introduced was not considered great enough to justify the extra expense that would have been necessary to interview both sides of the road.

Trip Characteristics of All Traffic Using Route 128. The average weekday trips were grouped into trips occurring between and within the in-town, intermediate, and outlying zones (Zones I, II, and III, respectively). The trips with an origin and/or destination out-of-state were tabulated separately. These results were summarized in Table 16. Part of this information is presented in desire-line form in Figures 14 through 17.

At least 76 percent of all the average weekday trips have either origin and/or destination in Zone II, the intermediate zone. Also, 65 percent of all trips were between Zones II and III, or within Zone II. Consequently, it is evident that the primary use of the Route 128 is being made by persons living, working, or shopping in towns close to it.

Only 20 percent of Route 128 trips start or end in Zone I which contains the central business district. The traffic generated in this internal area is mostly radial and appears to make little use of Route 128.

There is little evidence that Route 128 is being used much as a complete bypass for

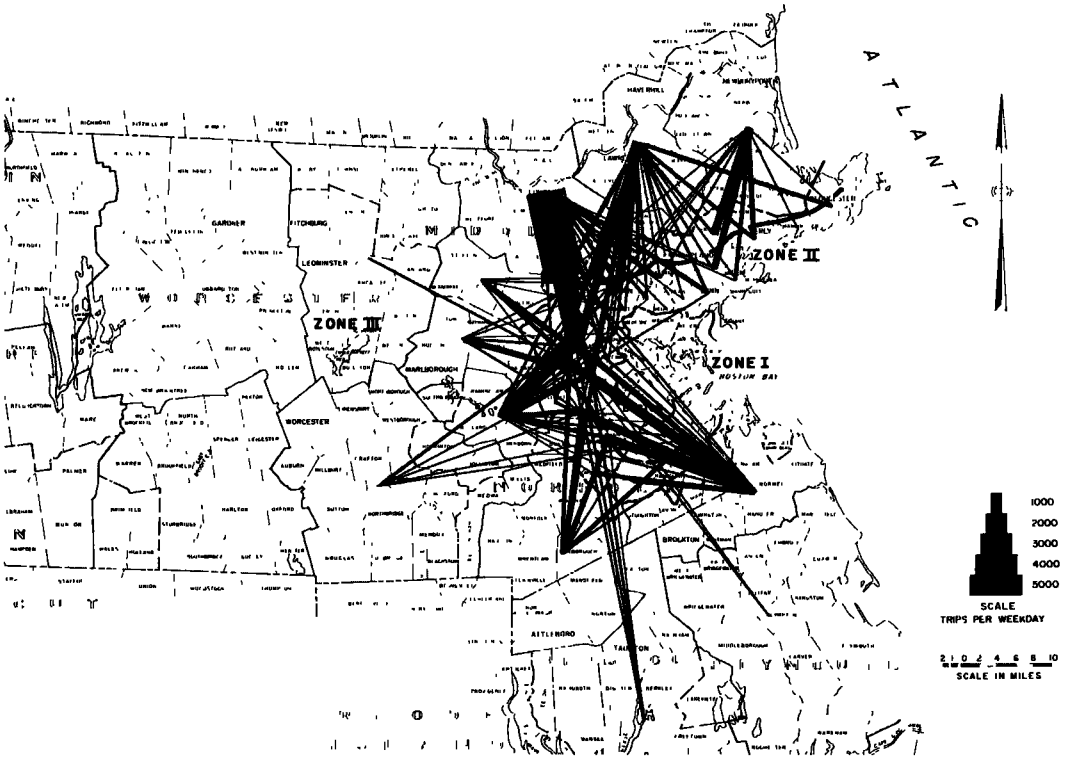


Figure 17. Desire lines for 1957 average weekday traffic on Route 128 between Zone I and Zone II.

the in-town area. For example, only 6 percent of average weekday trips on Route 128 have origins or destinations both out-of-state or both in Zone III or start or end in Zone III from out-of-state. Also, only 11 percent of all weekday Route 128 trips are from or to out-of-state points, and 91 percent of these trips have destinations or origins in Zones I, II, or III; 66 percent have origins in Zone I or II.

The trip data were tabulated according to Massachusetts towns, or, if outside Massachusetts, by state or origin and destination. The town data were further grouped according to regional zones (that is, in-town, intermediate, or outlying) or out-of-state. A summary is given in Table 17. All trips between these towns comprise about 80 percent of the total number of weekday trips. These data again emphasize the importance of the towns along the route as generators of traffic on the route and also emphasize the small contribution made by out-of-state and in-town traffic. The passenger vehicle and truck trips follow relatively similar patterns, though more trucks than passenger cars have in-town origins and out-of-state destinations.

The average weekday and peak hour trips on Route 128 were separated according to the number of sections of Route 128 used in each individual trip. A section is the length of road between two successive interchanges on Route 128. The average length of a section on Route 128 is about 1.2 miles. Figure 13 shows the percentages of the weekday and peak-hour trips using the route for different numbers of sections. The same information is also included for peak-hour traffic from Route 128 industrial developments.

The peak-hour and weekday trip length distributions for all Route 128 traffic are almost identical.[1] Nearly one-half of the weekday and peak-hour trips cover 6 sections or less, and about 30 percent of trips are 3 sections or less. Less than 20 percent of

[1]This "trip length" refers only to the portion of the trip made on Route 128.

the trips extend over 15 sections. Trucks follow patterns similar to those of passenger vehicles, except that trucks use the route for one section trips more than do passenger cars. The median trip length for both trucks and passenger cars, however, is the same. Again it is evident that the principal use of the route is for short distances rather than for long, bypass-type trips.

The average trip length of all route users is 9.5 sections, and the median trip length only 6.1 sections. On the other hand, the average trip length of the Route 128 industrial employees was only 7.2 sections, and the median length was

TABLE 17

PERCENT OF AVERAGE WEEKDAY TRIPS HAVING ORIGIN OR DESTINATION IN ZONE I, II, III, OR OUT-OF-STATE

Zone	Origin	Destination
Zone I (in-town)	10.6	12 4
Zone II (intermediate)	61.9	58.1
Zone III (outlying)	21.0	18 3
Out-of-state	6 5	11.2

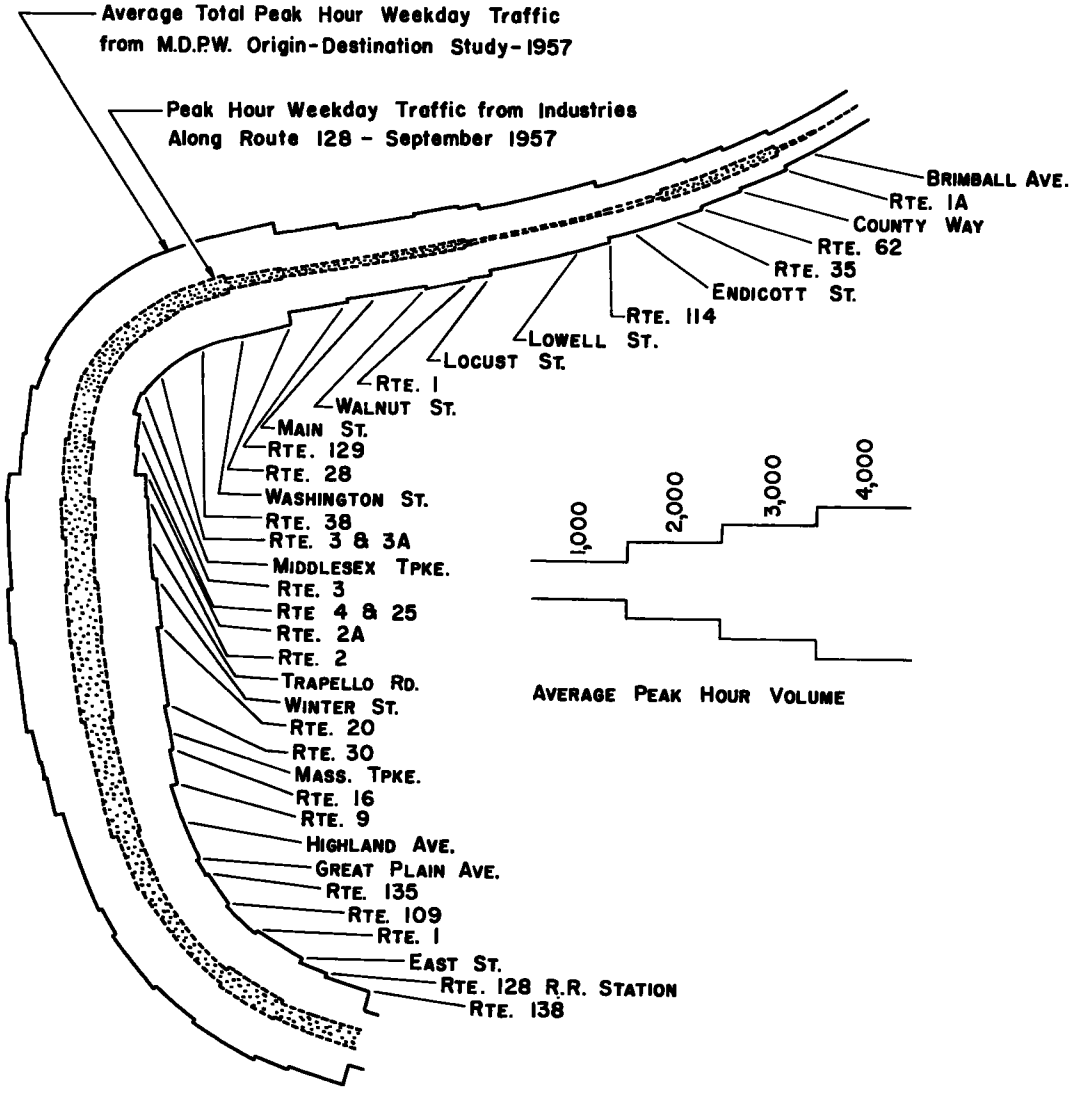


Figure 18. Average weekday peak hour traffic volumes on Route 128 in 1957.

4.5 sections. Thus, the median trip of the Route 128 employees is over 25 percent shorter than that for all Route 128 users.

From general observation it is known that much of the long-distance traffic approaching or leaving the metropolitan area uses Route 9 and the Massachusetts Turnpike on the west, and Routes 28 or 1 to the north. This traffic travels between these radial highways, using Route 128 for a range of 23 to 29 sections. An inspection of Figure 13 shows a jump in daily trips between this range, adding to about 6 percent of all daily trips or about 10,000 vehicle trips.

Figures 14 through 17 show desire-line charts of intrazonal weekday trips for the intermediate zone and interzonal trips for the in-town, intermediate, and outlying areas. Intrazonal trips for the in-town and outlying areas are not shown, as they represented only 0.1 and 3.5 percent of the weekday trips, respectively.

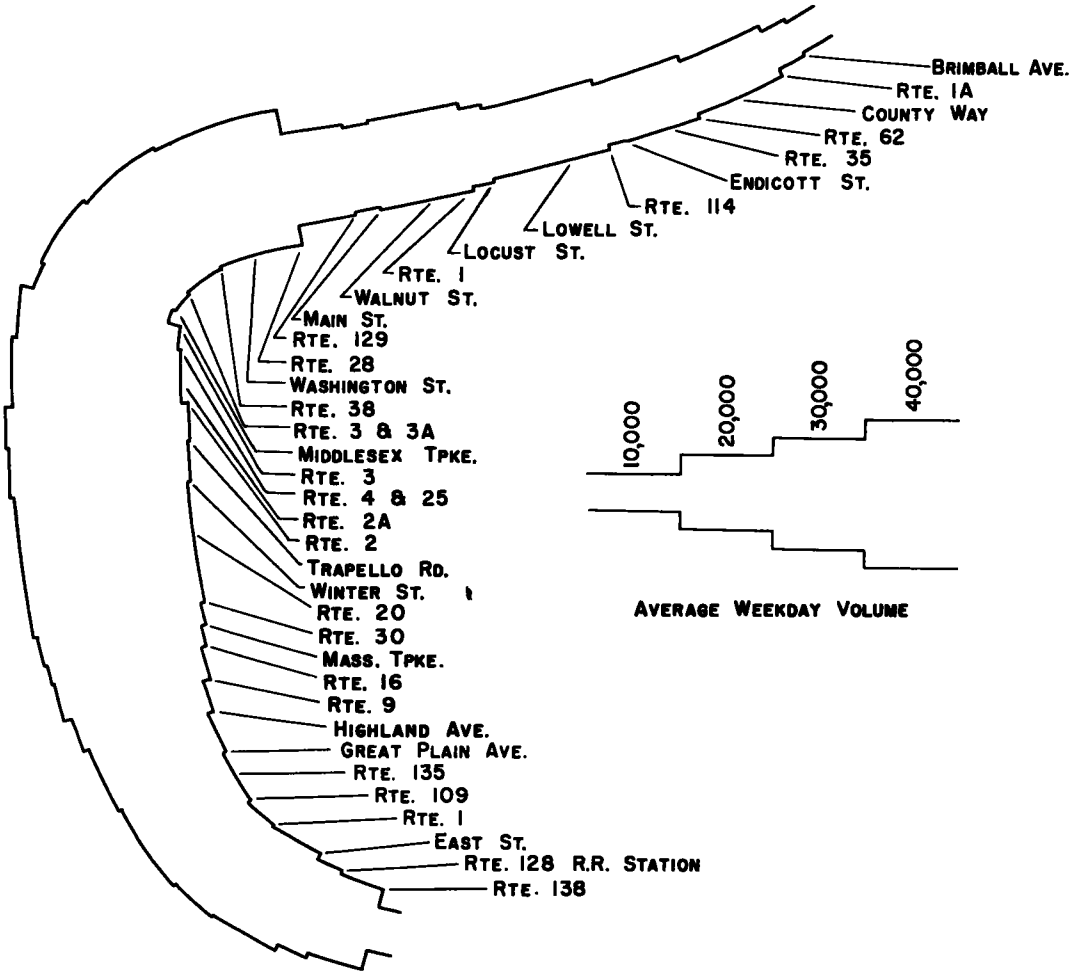
The average weekday trips which have both origins and destinations in Zone II are plotted as desire-lines in Figure 14; these Zone II internal trips represent 38 percent of the total weekday trips on Route 128. For clarity, only 35 percent of them are shown on the chart.

The advantages of using Route 128 for people making trips within Zone II are apparent. Inspection of Figure 14 shows that these internal trips follow the general location of the route; consequently, little transverse or radial movement is necessary in order to reach the route. Most of these trips appear to be relatively short; that is, in range of 7 to 8 miles. It seems reasonable to speculated that many of these trips would have been impossible without the circumferential highway, as most of them are made between or across radial highways where no adequate street connections formerly existed. This traffic might well be considered "generated traffic."

Part of the internal trips in Zone II are a result of Route 128 industrial employment. But it is not known how many other trips are also using the route for work purposes, and how many for shopping, etc. Of the Route 128 industrial employees (a total of 17,000), about 9,300 were living in Zone II as of September, 1957; the average number of vehicles per employee for these workers was 0.546, indicating 5,100 vehicles used by employees living in Zone II. Since each vehicle makes two trips per day to a Route 128 plant, and since 52 percent of these vehicles use Route 128, these industrial development workers contribute over 5,300 Route 128 trips a day, or about 8 percent of the internal Zone II weekday trips on Route 128. Considering that an estimated additional 11,000 employees are expected to be working at Route 128 plants completed or under construction since September 1957, the traffic contributed by suburban industry will become an increasingly important component of Route 128 traffic.

The desire-lines of the interzonal transfers between Zones I and II are plotted in Figure 15. These trips account for 11.5 percent of the average weekday trips. The great majority of the Zone I (in-town) trip ends are found in CBD Boston, though a sizeable number are found in Cambridge. The Zone II trip ends are spread along the towns adjacent to Route 128. Bedford serves as the largest source of trips, followed by Beverly, Gloucester, and Peabody. The fact that the desire-lines between Zone I and Bedford, Beverly, Gloucester, and Peabody are so large is not due to the fact that these towns are so highly populated or have many places of employment (relative to the other suburban towns), but rather it is due to the character of the radial access to these towns. Because of congestion on local radials, people living in Peabody, Gloucester, and Beverly use Route 128 in order to get on Route 1 or Route 28, which are the nearest radial highways leading into Zone I which offer reasonably good travel for the motorist. Similarly, the people living or working in Bedford find it highly advantageous to use Route 128 in shifting to the better radial routes; this is particularly true since Route 4-25 east of Route 128 goes through the congested center of Lexington and is therefore unattractive to motorists. Since Route 3 (north of Route 128) ends at the circumferential highway, the users of Route 3 must use Route 128 in order to continue their trip. Again the Route 128 industrial development contributes to this Zone I to II traffic. Over 4,000 of the Route 128 employees live in Zone I, and use Route 128 for 31 percent of their work trips and make approximately 1,450 trips per weekday on Route 128. This represents over 7 percent of the Zone I to II traffic.

In 1958 a very large shopping center was opened in Peabody, which eventually will



Source: Origin-Destination Study, Massachusetts Department of Public Works

Figure 19. Average weekday traffic volumes on Route 128 in 1957.

change the patterns in the northeastern section of the road considerably. However, at the time of the survey, only a small portion of the shopping center was in operation, and therefore it probably had little effect on the desire-lines.

The Zone I to Zone III trip desire-lines are shown in Figure 16. These trips represent only 8.8 percent of the average weekday trips on Route 128, and generally have the same characteristics as those from Zone I to II, in that they follow a radial pattern. The Lowell area serves as the largest generator of this traffic and is followed by the Newburyport and Ipswich areas. Most of this traffic has its other trip end in the CBD.

The extremely heavy desire-line from the Lowell area results from a temporary situation where a new relocation of Route 3 from Lowell dead-ends at Route 128 and Route 3 traffic is routed northerly for about 2 miles over Route 128 to make a connection with old Route 3 going in-town. Consequently, users of Route 3 from the Lowell region must use Route 128 for a portion of their journey.

The Zone II and III interzonal desire-lines in Figure 17 account for 26.7 percent of the Route 128 traffic. It is evident that these trips are of a different character than

those internal trips in Zone II and those between Zone I and II or III. Whereas the others followed the axis of the road or were essentially radial, these trips are a combination; that is, they are partly radial and parly longitudinal. Motorists travel onto Route 128 by the nearest radial and then follow it until they find the radial which will take them closest to their destination. These trips making a portion of their trip along radials and part between or across radial highways where no adequate street connections existed prior to Route 128 were probably "generated" by the construction of the circumferential highway.

Approximately 3,400 Route 128 industry employees live in Zone III, and account for about 2,250 weekday trips on Route 128 (61 percent of the workers in this zone use Route 128). These industrial employee trips thus represent about 5 percent of the total Zone II to III trips.

The desire-lines for trips within Zone III are not included as they only represented 3.5 percent of the total weekday trips on Route 128. Most of these trips are in the range of 25 to 30 miles and tend to be of a bypass nature. It is quite evident that most of the trips would be much more difficult to make in the absence of Route 128.

The total trip distances of all Route 128 users have not as yet been analyzed to determine what percent of the trip is being made on Route 128. However, an inspection of the desire-line charts seems to indicate that this will vary according to nature of the zonal movement. The trips which are essentially radial in character, or the trips between Zone I and II or III, are apparently on Route 128 for only a few sections representing a small percent of the total trip. On the other hand, it would seem that the internal Zone II movement would use the Route for the majority of the trip distance.

Proportion of Industrial Employee Trips on Route 128 During Average Weekday and Peak Hour. Of the 172,420 average weekday trips only 5.4 percent or 9,224 were made by Route 128 industrial plant employees. However, this industrial traffic is concentrated in the afternoon peak hour when 3,147 of a total of 14,225 trips, or 22 percent, are contributed by Route 128 employees. These employee trips (3,147) represent 68 percent of all work-to-home trips of Route 128 industry employees.

During much of the year the percentage of employee traffic will be higher than the average, since total traffic reaches a peak in the summer months while employee traffic remains nearly constant all during the year.

Of the total average weekday trips, passenger cars comprise 147,458 trips, or 86 percent, and trucks 24,962, or 14 percent. During weekday peak hours the percentages are 88 and 12. During the peak hours Route 128 employee trips amount to 25 percent of the total 12,448 passenger car trips.

Figure 18 shows the manner in which the peak hour traffic is distributed along Route 128 and, by the inside band, the traffic which industry adjacent to Route 128 contributed to these peak volumes. The largest percentages of employee traffic are to be found in Needham, Waltham, and Newton areas, where most of the industrial development is located and where total Route 128 volumes are the largest. The importance of considering adjacent industrial development in traffic prediction is evident. New plants and business establishments under construction and planned for the future will further swell the volume of employee traffic, especially in the central portions. For example, 11,000 additional employees are predicted for plants completed or under construction since September 1957. If they produce the same proportion of Route 128 trips as did 1957 industry, 5,200 additional peak-hour employee trips may be expected. If all trips follow the trend indicated in Figure 2, the total peak hour trips will increase to 15,500. On the basis of these estimates, the employee traffic in 1959 would be 33 percent of all peak-hour traffic on Route 128.

Figure 19 shows average weekday flow along the highway. A maximum of nearly 50,000 per day is reached in the Waltham area. This is about 30 percent higher than at Route 38 in Burlington where the automatic counter is located, and from which data in Figure 2 were compiled.

During 1958 plans were under way for widening the central portion of Route 128 from 4 to 6 lanes with provision for possible 8 lanes. The traffic contributed by industry along Route 128 has been an important factor in requiring this widening only 8 yr after the highway was opened to traffic in 1951.

SUMMARY

Information on employee travel patterns was obtained from 7,500 employee questionnaires, from 10 gate counts at selected plants and from an origin-and-destination survey of the traffic using Route 128.

In September 1957, the employment at 96 companies located along Route 128 was approximately 17,000. About 52 percent of this employment was concentrated at plants located in a 6-mile section of the central portion of the route. Twenty-five percent of the employees lived in-town, 55 percent in the intermediate zone (towns adjacent to Route 128) and 20 percent in the outlying zone (towns beyond Route 128).

The average work trip for all employees was 11.7 miles which took 24 min for an average speed of 29 mph. Forty-nine percent of the employees used Route 128 during some portion of their trip to work. These employees had an average work trip of 15.0 miles which took 28 min for an average speed of 32 mph. Employees who did not use Route 128 in their trip to work had an average trip of 8.5 miles which took 21 min for an average speed of 21 mph.

Old employees (employees who are working for a company both before and after its move to a Route 128 site) comprised 52 percent of the total employment at Route 128 plants. Thirty-seven percent of these employees lived in-town, 46 percent in the intermediate zone, and 17 percent in the outlying zone.

New employees (employees who joined a company after it moved to a Route 128 site) comprised 48 percent of the employment at Route 128 industries. Twelve percent of these employees lived in-town, 65 percent in the intermediate zone, and 23 percent in the outlying zone.

The travel patterns of the new and old employees were quite different. Both the average time and average distance of the work trip of old employees were over 30 percent higher than those of new employees; however, the average trip speeds for both were practically the same.

Approximately 18 percent of the employees had moved since starting to work for a Route 128 company. The change in the average distance to work before and after moving for all, new or old employees was negligible. Of the employees who changed residence 43 percent moved farther from their place of work, while 39 percent moved closer to it.

Although the distance to work for Route 128 users was over 75 percent greater than that for non-users, the time required to make the trip was only 33 percent greater. Route 128 users had consistently longer distances, longer travel times and higher speed than non-users. As the percentage use of Route 128 increased, the distance to work increased, but the average speed increased at an even greater rate so that the time to work was nearly the same for all percentage uses. The higher speeds on Route 128 apparently compensated for the longer distances. Speed runs on Route 128 indicated a range of 45 to 55 mph during the peak hours.

The automobile was used almost exclusively in the trip to work by employees at Route 128 plants. Thirty-six percent of the old employees had used public transit or walked to work prior to working at Route 128 plants. After starting to work at Route 128 plants, only 3 percent of the old employees used these modes of travel. Special arrangements for public transportation have been tried at some Route 128 plants but have been abandoned because of lack of patronage.

The average number of employees per vehicle was 1.8; however, the greater the employment of a company the higher the number of employees per vehicle. This ratio was also higher for service industries and lower for distribution industries.

An origin-and-destination survey of all traffic on Route 128 revealed that the greatest use of the route was made by people starting or ending their trip in towns close to the route (the intermediate zone). Seventy-six percent of all weekday trips had origin and/or destination in the intermediate zone.

The average use of Route 128 by all trips was 9.5 sections or about 11 miles. Route 128 industrial employees used the route for an average of 7.2 sections or about 9 miles. In addition, 30 percent of all trips were for 3 sections (about 4 miles) or less, and 80 percent of all trips were for 15 sections (about 17 miles) or less.

On an average weekday (1957) about 5 percent of the total Route 128 traffic volumes were due to employee traffic from Route 128 plants. During peak hours this employee traffic amounted to 22 percent of all trips on the route.

The desire-line patterns illustrated vividly the lateral type of movement made possible by Route 128. Prior to the construction of the route no road system existed that could accommodate these desires.

ACKNOWLEDGMENTS

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Also appreciated was the help given by Lawrence V. Hammel, Egons Tons, and A. Scheffer Lang of the Civil and Sanitary Engineering Department of the Massachusetts Institute of Technology.

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