REFERENCES

1. BERRY, DONALD S. AND GREEN, FOREST H., "Techniques for Measuring Over-all Speeds in Urban Areas", HRB PROCEEDINGS, v. 29, 1949, pp. 311–318.
2. BERRY, DONALD S. AND BELMONT, DANIEL M., "Distribution of Vehicle Speeds and Travel Times", Berkeley Symposium on Mathematical Statistics and Probability, *Proceedings*, 2nd, 1951, pp. 589–602.
3. SAWHILL, ROY B. *Travel-time Techniques on a Two-lane Rural Highway*, Student Research Report #3. Berkeley, University of California, Institute of Transportation and Traffic Engineering, January 1952. 55 pp.
4. AMERICAN SOCIETY FOR TESTING MATERIALS. *Manual on Presentation of Data.* Phialdelphia, 1941. 73 pp.

TRAVEL-TIME AND GASOLINE-CONSUMPTION STUDIES IN BOSTON

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SYNOPSIS

TRAVEL-TIME runs were made over highways and streets which will be most affected by diversion of traffic to the Boston central artery (John F. Fitzgerald Expressway) now under construction. These runs were made as the before part of a before-and-after study of traffic conditions in the central business district, which is to be traversed by the new elevated highway.

Runs were made in different hours and on different days to obtain representative averages of weekday travel conditions as well as of conditions prevailing during hours of peak traffic flow. Runs were made over a number of routes with a test car equipped with statistical instruments developed by the Highway Research Board Committee on Motor Vehicle Characteristics for measuring speed, gasoline consumption, braking effort, engine torque, and throttle opening.

Considerable information was gained on the characteristics of general city driving. Average speeds on congested streets in downtown Boston were found to to range from 7 to 12 mph. with a low of 3 mph. on some streets in peak hours; average gasoline mileage on these streets varies from 9 to 13 mi. per gal. with a low of 5 mi. per gal. on some runs. At speeds below 10 or 12 mph., when the speed of traffic is controlled by congestion, a close relationship apparently exists between miles per hour and miles per gallon. This relation should be useful in estimating gasoline consumption on congested streets from the traffic speed without the use of a gasoline meter.

A comparison of travel times on city streets with those possible after the expressway is completed indicates that there should be an average saving in time of 4.5 min. per mi. of expressway by its use. Some sections will save as much as 8 min. per mi. Gasoline savings per trip over the expressway will average about 0.04 gal. per mi.; on some sections there will be no savings, and on others the savings will be as much as 0.10 gal. per mi. A forecast of probable savings on one 0.85 mi. section of the expressway indicates that in 1955 there should be an annual saving in time cost of $420,000 and in gasoline cost of $65,000 when time is evaluated at $1 per hr. and gasoline at 27 cents per gallon.

●DURING THE MONTHS of July, August and September 1951 travel time runs were made over a number of important streets in downtown Boston and vicinity to obtain a record of travel conditions on them prior to the construction of the Boston Central Artery (John F. Fitzgerald Expressway). After the new highway is in service it is planned to repeat the tests to determine the influence of the new facility on the speed of city traffic and to appraise the benefits in time and fuel savings made possible by the expressway.

The study was undertaken as a joint highway research project of the Massachusetts Institute of Technology and the Massachusetts Department of Public Works.

The Boston central artery is the key link in an expressway system proposed in the master highway plan for the Boston metropolitan area submitted to the governor in February 1948. This plan calls for a number of radial expressways converging on a belt highway surrounding the central business district. The central artery will form that portion of the belt passing through the most congested downtown sections of the city (Fig. 1) and is to be elevated throughout its entire length with three-lane roadways 40 ft. wide between curbs in each direction. The section through the city is single deck, while that over the Charles River and the tracks of the Boston and Maine Railroad is on two levels. Ramps 28 ft. wide are provided at frequent intervals to distribute and pick up surface street traffic. Although the highway is an expressway in the sense that it will provide uninterrupted traffic flow, it is definitely not a speedway. The design speed is 35 mph., dictated by the curves and grades which had to be introduced to meet the limitations imposed upon the location by the densely built-up districts through which the highway passes.

The section of the expressway now designed or under construction extends from the southerly end of the double-deck Mystic River Bridge opened in 1949 to North Street opposite the entrance to the Sumner Tunnel to East Boston, with a branch passing over the tracks of the North Station leading to the traffic circle at the end of the Charles River Dam (Northern Artery). There a connection is to be made with the new Embankment Highway built in 1950 along the south bank of the Charles River. Plans are in preparation for the extension of the expressway southward from North Street to Oliver Street near the Northern Avenue Bridge to South Boston. The total length of the expressway under construction and in the design stage is a little less than 2 mi. The estimated cost of this work, including right of way and engineering, is about $53,000,000, or $27,000,000 per mi.

TEST PROCEDURE

Travel-time runs were made by the floating-car method. The driver travelled with the traffic stream and an observer recorded stopwatch readings at important intersections along the route. The routes covered in the central Boston area are shown in Figure 2. Other runs were made farther out from the city on the major streets paralleling the proposed future extensions of the expressway system to the north and south of the city. In all 44 routes were covered totaling 204 mi.

The runs were made at different hours and on different days in order to obtain a representative average of weekday travel conditions. The observations were made during the months of July, August, and September 1951 on weekdays, Monday through Friday, between 8 A.M. and 6 P.M. The test car and driver were furnished by the traffic division of the Massachusetts Department of Public Works.

In August 1951, runs were made over a number of the routes with a test car and driver provided by the Bureau of Public Roads. This car was a 1951 Pontiac Six equipped with instruments developed by the Highway Research Board Committee on Motor Vehicle Characteristics[1] for measuring speeds, gasoline consumption, braking effort, engine torque, and throttle opening. For this study the gasoline consumption data were of particular interest.

Traffic volumes on the different routes were available from counts made during 1949 and 1950 at all important intersections in the city by the traffic division of the Massachusetts Department of Public Works. Automatic traffic counters were installed on some of the routes during the test runs. Traffic estimates were made for other routes using the hourly, daily, and seasonal trends of city traffic obtained from automatic counters installed periodically at certain key points.

EXAMPLE OF TEST RUN

An example of the data obtained from typical travel-time runs is shown in Table 1. These runs were made in a southeasterly direction from the expressway ramp at the traffic circle near Charles River Dam through the city to rejoin the expressway route in Atlantic Avenue opposite the South Station (Run A G H in Fig. 5). This route most nearly parallels that of the expressway across the city.

The runs were broken into short sections

[1] See "A Study of Vehicle, Roadway and Traffic Relationships by Means of Statistical Instruments" by Thomas J. Carmichael and Charles E. Haley, Proceedings, Thirtieth Annual Meeting of Highway Research Board, pp. 282-296 (1950).

. Belt highway and connections proposed in 1948 master highway plan for the Boston metropolitan area.

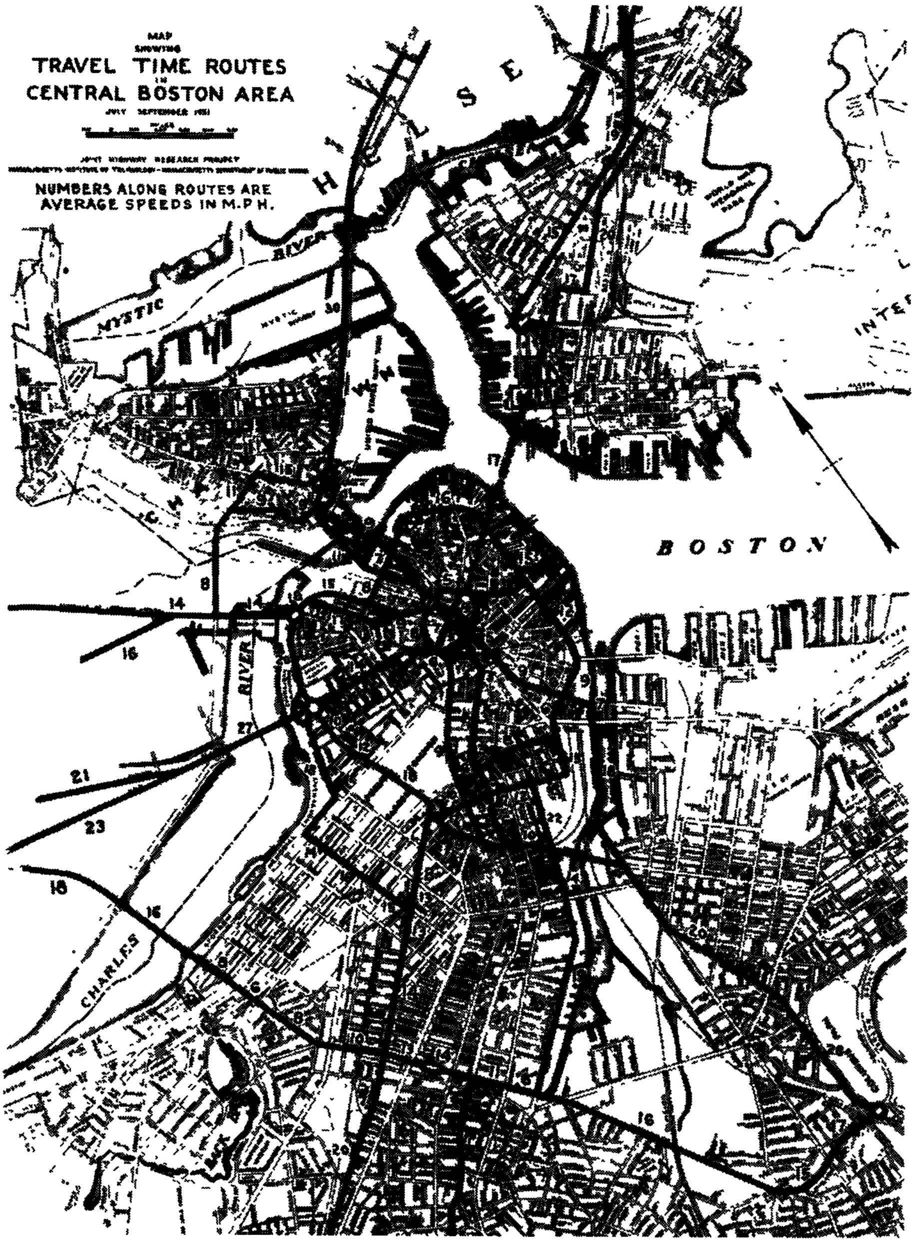


Figure 2. Travel time routes and average speeds recorded during eight-hour period 8 A.M. to 6 P.M., August 1952.

between control points located at important intersections. This was done so that different segments of a route could be studied separately, and also so that portions of different runs could be combined where they meet or so that future runs could be started from intermediate points if desired. For example, when the expressway is completed, the locations of the on and off ramps will change the pattern of traffic flow on many streets. At that time

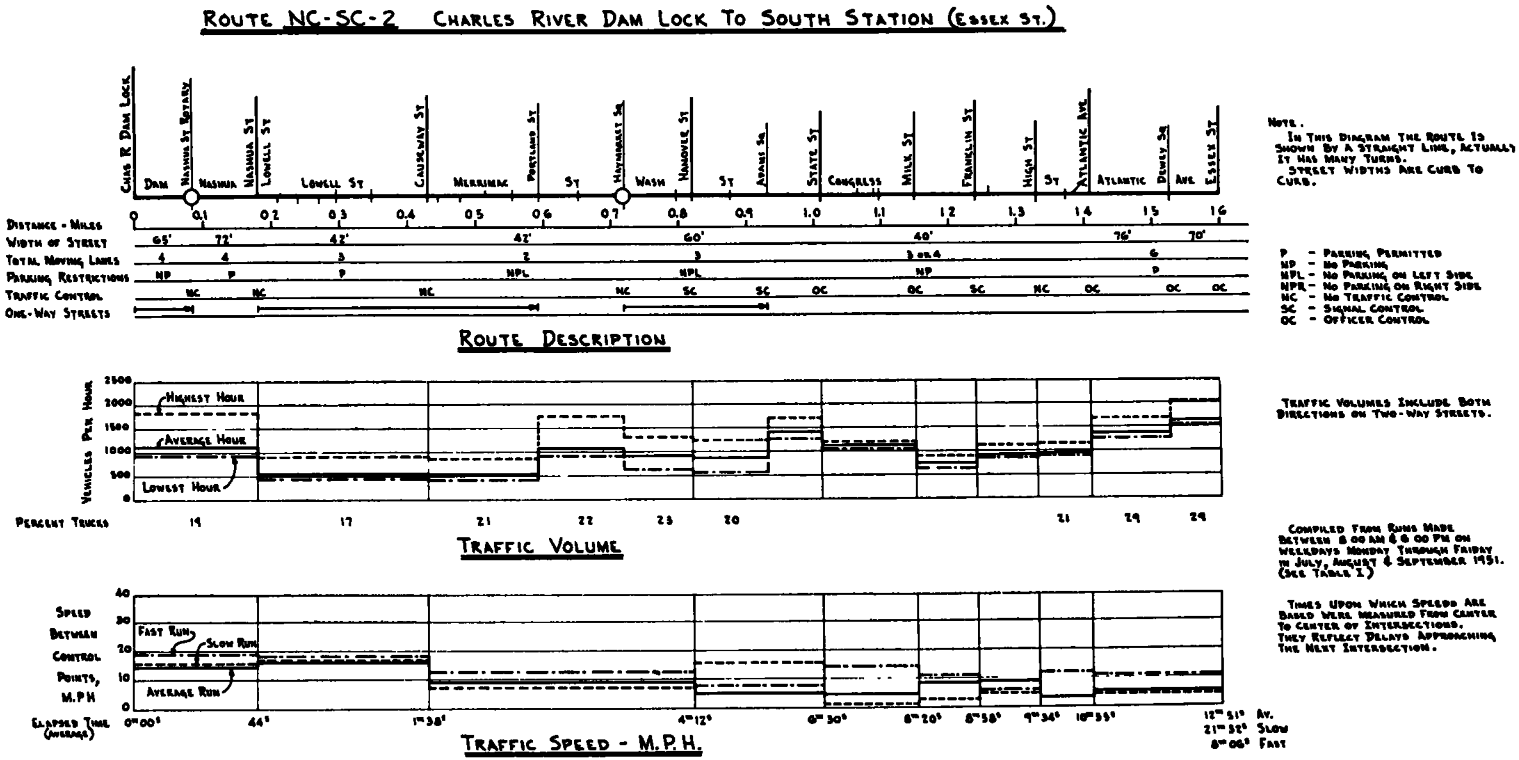

ROUTE NC-SC-2 CHARLES RIVER DAM LOCK TO SOUTH STATION (ESSEX ST.)
CHAS R DAM LOCK
NASHUA ST ROTARY
NASHUA ST
LOWELL ST
CAUSEWAY ST
PORTLAND ST
HAYMARKET SQ
HANOVER ST
ADAMS SQ
STATE ST
MILK ST
FRANKLIN ST
HIGH ST
ATLANTIC AVE
DEWEY SQ
ESSEX ST
DAM
NASHUA
LOWELL ST
MERRIMAC
ST
WASH
ST
CONGRESS
ST
ATLANTIC
AVE
DISTANCE - MILES
WIDTH OF STREET
TOTAL MOVING LANES
PARKING RESTRICTIONS
TRAFFIC CONTROL
ONE-WAY STREETS
ROUTE DESCRIPTION
NOTE.
IN THIS DIAGRAM THE ROUTE IS SHOWN BY A STRAIGHT LINE, ACTUALLY IT HAS MANY TURNS.
STREET WIDTHS ARE CURB TO CURB.
P - PARKING PERMITTED
NP - NO PARKING
NPL - NO PARKING ON LEFT SIDE
NPR - NO PARKING ON RIGHT SIDE
NC - NO TRAFFIC CONTROL
SC - SIGNAL CONTROL
OC - OFFICER CONTROL
VEHICLES PER HOUR
HIGHEST HOUR
AVERAGE HOUR
LOWEST HOUR
PERCENT TRUCKS
TRAFFIC VOLUME
TRAFFIC VOLUMES INCLUDE BOTH DIRECTIONS ON TWO-WAY STREETS.
COMPILED FROM RUNS MADE BETWEEN 8 00 AM & 6 00 PM ON WEEKDAYS MONDAY THROUGH FRIDAY IN JULY, AUGUST & SEPTEMBER 1951. (SEE TABLE I)
SPEED BETWEEN CONTROL POINTS, M.P.H
FAST RUN
SLOW RUN
AVERAGE RUN
ELAPSED TIME (AVERAGE)
TRAFFIC SPEED - M.P.H.
12m 51s AV.
21m 32s SLOW
8m 06s FAST
TIMES UPON WHICH SPEEDS ARE BASED WERE MEASURED FROM CENTER TO CENTER OF INTERSECTIONS. THEY REFLECT DELAYS APPROACHING THE NEXT INTERSECTION.

Figure 3.

spur runs can be made between control points and the nearest ramp.

In Table 1 the runs have been arranged in the sequence of the time at which they were started. As a general rule the slower ones occur near 9 A.M. and 5 P.M. each weekday; they can, however, occur occasionally at any time during business hours of the day. The downtown streets are flowing so near capacity most of the time that the slightest interruption will stall traffic. On Boston's narrow and crooked streets a double-parked car or truck can hold up traffic for several minutes.

The distance between control points in the downtown area are very short, and the travel times between them vary considerably between different runs, depending upon the vicissitudes of traffic control. Often the delays encountered at one intersection are made up by easier going at others so that the total delay for runs taken at a given time of day tends to be the same, though it will occur at different places on different runs.

The slowest run recorded in Table 1 occurred between 5 and 5:30 P.M. and required 21.5 min. at an average rate of 4.5 mph. The fastest run was observed between 4 and 4:30 P.M. and required only about 8 min. at a rate of 11.9 mph. The average of the 13 runs was about 13 min. at 7.5 mph.

RELATION OF SPEED AND VOLUME TO PHYSICAL LAYOUT

In Figure 3 speed data from Table 1 are shown graphically together with a description of the route and hourly traffic volumes. For convenience the route layout is represented by a straight line. Actually it is quite crooked, as shown in Figure 5 (A G H). The description gives distances, number of lanes normally available for moving traffic (in both directions on two-way streets), parking restrictions, traffic control and sections of one-way streets. Approximately 40 percent of this route was over one-way streets.

Traffic volumes are shown per hour for both directions of travel (except on one-way streets). An average hourly volume for the 10-hr. period covered by the tests (8 A.M. to 6 P.M.) is shown and also the highest and lowest traffic hour during this period. Traffic volumes were derived from 6-hr. counts made by the traffic division of the Massachusetts Department of Public Works by applying factors obtained from the automatic counter installed on Congress Street near the middle of the run.

In the bottom diagram of Figure 3 the average speed in miles per hour for each segment of the route is plotted and also the speeds in each segment obtained during the slowest and fastest run over the entire route. It will be seen that as traffic increases along the route speed decreases and vice versa. The fastest average time was made on the one-way sections of Lowell Street where the traffic was relatively light. The slowest times were made in the heart of the city where the route weaves through Haymarket, Adams, and Post Office squares. Another bottleneck was encountered in approaching Atlantic Avenue on Congress Street.

The average speeds on routes in the Boston central area are shown in Figure 2 by the numbers recorded alongside of these routes. Each number is the average speed to the nearest mile per hour for both directions of travel. The numbers may be considered as the speed ratings of the different portions of the routes covered within the scope of Figure 2.

GASOLINE CONSUMPTION RUNS

During the first two weeks of August 1951 a number of runs were made over test routes with the Bureau of Public Roads Pontiac equipped with a gasoline meter. Time did not permit making enough runs on each route to determine a representative average of gasoline consumption for each one. The intention was rather to run this test over a sample of roads and streets of different traffic characteristics.

In order to apply the gasoline consumption data to a particular route it seemed desirable to adjust the gasoline consumption to a value consistent with the average speed over the route obtained from the larger number of runs made with the speed test car. A plot was therefore made of gasoline consumption in miles per gallon against speed in traffic in miles per hour to see if a usable relation existed between these two variables.

Figure 4 shows the relation obtained for all test runs except those over the Mystic River Bridge. The latter were omitted because the grades on this bridge were the principal factor in determining the gasoline consumption. All other runs were divided into five groups according to the nature of the street or highway

TABLE 1

SUMMARY OF TRAVEL TIME RUNS—BOSTON METROPOLITAN AREA

ROUTE *NC-SC-2* FROM *Charles River Dam Lock* TO *South Station (Essex St. and Atlantic Ave.)* VIA *Lowell, Merrimac, Washington, Congress Streets and Atlantic Ave.*

Time of Start		8 03 A.M.		8 35 A.M.		8:41 A.M.		8:50 A.M.		1 47 P.M.		2:22 P.M.		2:32 P.M.		3.04 P.M.		4·16 P.M.		4 31 P.M.		4.38 P.M.		5 01 P.M.		5 02 P.M.		Average of All Runs	
Date		9-20-51		7-18-51		9-20-51		7-17-51		7-16-51		7-17-51		7-24-51		7-16-51		9-13-51		9-14-51		9-13-51		9-14-51		7-24-51			
Day of Week		Thurs.		Tues.		Thurs.		Tues.		Mon.		Tues.		Tues.		Mon.		Thurs.		Fri.		Thurs.		Fri.		Tues.			
Run Number		11		5		12		3		1		4		6		2		8		10		9		13		7			
Control Points	Dist., Mi.	Time sec.	Speed mph.	sec.	mph.	sec.	mph.	sec.	mph.	sec.	mph.	sec.	mph.	sec.	mph.	sec.	mph.	sec.	mph.	sec.	mph.	sec.	mph.	sec.	mph.	sec.	mph.	Time sec.	Speed mph
Charles River Dam Lock	0.18	54	12.0	35	18.5	52	12.5	64	10.1	52	12.4	49	13.2	29	22.4	48	13.5	34	19.1	39	16.6	28	23.1	46	14.1	40	16.2	44	14.7
Lowell Street	0.25	70	12.9	45	20.0	60	15.0	90	10.0	65	13.8	36	25.0	42	21.4	51	17.6	49	18.4	38	23.7	49	18.4	52	17.3	52	17.3	54	16.7
Causeway Street	0.39	190	7.4	160	7.8	185	7.6	245	5.7	137	10.2	142	9.9	120	11.7	97	14.5	115	12.2	102	13.8	140	10.0	178	7.9	190	7.4	154	9.1
Hanover Street	0.19	63	10.8	75	9.1	73	9.4	412	1.7	131	5.2	202	3.4	196	3.5	147	4.6	81	8.4	101	6.8	150	4.6	125	5.5	45	15.2	138	5.0
State Street	0.14	61	8.3	85	5.9	136	3.7	132	3.8	29	17.4	82	6.2	67	7.5	60	8.4	36	14.0	36	14.0	166	3.0	183	2.8	352	1.4	110	4.6
Milk Street	0.09	20	16.2	19	17.0	54	6.0	79	4.1	21	15.4	29	11.2	30	10.8	25	13.0	31	10.5	25	13.0	24	13.5	21	15.4	114	2.8	38	8.5
Franklin Street	0.09	18	18.0	49	6.6	30	10.8	18	18.0	21	15.4	29	11.2	20	16.2	74	4.4	50	6.5	52	6.2	14	23.0	21	13.5	64	5.1	36	9.0
High Street	0.08	112	2.6	81	3.6	37	7.8	100	2.9	18	16.0	36	8.0	99	2.9	208	1.4	25	11.5	18	16.0	20	14.4	17	16.9	288	1.0	81	3.6
Atlantic Avenue	0.19	137	5.0	167	4.1	137	5.0	108	6.3	132	5.2	107	6.4	98	7.0	72	9.5	65	10.5	151	4.5	95	7.2	88	7.8	147	4.7	116	5.9
Essex Street																													
Total distance	1.60																												
Total time		$12^m 0.5^s$		$11^m 56^s$		$12^m 44^s$		$20^m 48^s$		$10^m 06^s$		$11^m 52^s$		$11^m 41^s$		$13^m 02^s$		$8^m 06^s$		$9^m 22^s$		$11^m 26^s$		$12^m 14^s$		$21^m 32^s$		$12^m 51^s$	
Average mph.		7.9		8.0		7.5		4.6		9.5		8.1		8.2		7.4		11.9		10.3		8.4		7.8		4.5		7.5	

and the characteristics of the traffic as indicated in the legend. Figure 4 is not a plot of the performance of the Pontiac such as would be obtained on a straight level road; it is a random plot of the results obtained while driving under a wide variety of traffic conditions on substantially level streets and highways. The gasoline consumption is influenced by so many variables that no clear-cut relation is to be expected over the entire range of driving speeds. In the lower range of speeds, below 10 mph., when the speed of the vehicle is controlled by the density of traffic, a fairly close relation does appear to exist between gasoline consumption and speed. As the traffic becomes less dense and the average speed rises, other factors come into play and the points begin to scatter. Even in the higher speed

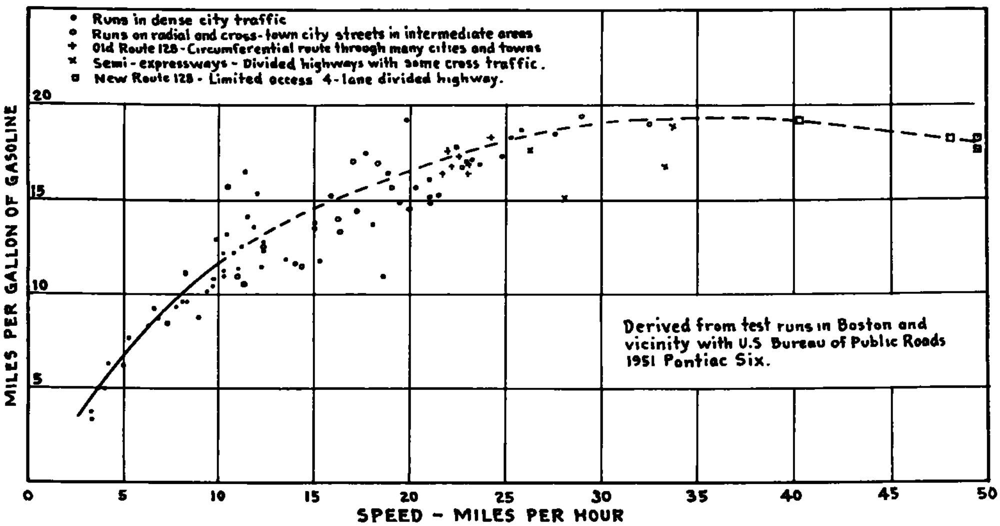


Figure 4. Relation between speed in traffic and gasoline consumption.

TABLE 2

ASOLINE CONSUMPTION AND SPEED RUNS ROUTE NC-SC-2 CHARLES RIVER DAM LOCK TO SOUTH STATION (ESSEX ST.) VIA LOWELL, MERRIMAC, WASHINGTON, CONGRESS STREETS AND ATLANTIC AVE.

Distance 1.60 Miles

Date (1951)	Day of Week	Time of Start	Time for Run	Average mph.	Gallons of Gas	Average mpg.
Sept. 20	Thur.	8 03 A.M.	$12^{m}\ 05^{s}$	7 9		
July 18	Wed.	8 35	$11^{m}\ 56^{s}$	8 0		
Sept. 20	Thur.	8:41	$12^{m}\ 44^{s}$	7.5		
July 17	Tues.	8:50	$20^{m}\ 48^{s}$	4.6		
Aug. 13	Mon.	10.27	$25^{m}\ 07^{s}$	4.0	.332	5.0
July 16	Mon.	1.47 P.M.	$10^{m}\ 06^{s}$	9 5		
Aug. 14	Tues.	1:55	$12^{m}\ 28^{s}$	8.2	.153	11.1
Aug. 13	Mon.	2:10	$26^{m}\ 42^{s}$	3.8	.339	5 0
July 17	Tues.	2:22	$11^{m}\ 52^{s}$	8.1		
July 24	Tues.	2.32	$11^{m}\ 41^{s}$	8.2		
July 16	Mon	3:04	$13^{m}\ 02^{s}$	7.4		
Sept. 13	Thur.	4:16	$8^{m}\ 06^{s}$	11.9		
Sept. 14	Fri.	4·31	$9^{m}\ 22^{s}$	10.3		
Aug 8	Wed.	4.35	$10^{m}\ 39^{s}$	9.6	.161	10 6
Sept. 13	Thur.	4.38	$11^{m}\ 26^{s}$	8.4		
Sept. 14	Fri.	5:01	$12^{m}\ 14^{s}$	7.8		
July 24	Tues.	5 02	$21^{m}\ 32^{s}$	4.5		
Average speed runs only			$12^{m}\ 51^{s}$	7 5		
Average gasoline consp. runs*			$18^{m}\ 44^{s}$	5.5	.246	7.0
Average all runs (1.60 mi.)			$14^{m}\ 05^{s}$	6 8		
Miles per gallon adjusted for average speed of 6.8 mph.						8 7

* Gasoline consumption runs were 1.71 mi. long from traffic circle at Charles River Dam to Atlantic Ave. and Kneeland St. near South Station.

ranges, however, a trend is definitely indicated as shown by the dashed line in Figure 4.

The few points which do not conform to the average trend may be the result of errors in recording the data or they may represent unusual runs. For example, a slow run made in traffic at uniform speed without stops will show a high gasoline mileage, whereas a fairly fast one made up of spurts of speed between stops will show a low gasoline mileage.

The trends shown in Figure 4 apply only to conditions in Boston and vicinity. In other cities the driving characteristics and the street layout will be different and the relations between speed and gasoline consumption found in this study may not apply.

In Table 2 the speed runs from Table 1 have been combined with the four gasoline consumption runs made over this route. Two of the latter were unusually slow with average speeds of about 4 mph.; they cause the average of the gasoline consumption runs alone to be lower in both speed and gasoline mileage than is typical for this route. When the travel times for both gasoline and speed runs are averaged on the basis of equal mileage, an average speed of 6.8 mph. is obtained. The gasoline mileage corresponding to 6.8 mph. from Figure 4 is 8.7 mpg. which is chosen as more typical of this route than the 7.0 mpg. found for the gasoline runs alone.

It is interesting to note that the slowest runs in Table 2 came in the middle of the day rather than during an expected peak hour. As mentioned earlier, delays of this kind can occur on Boston streets at any time; therefore these slow runs have not been excluded from the average.

TIME AND GASOLINE SAVINGS

In Figure 5 several surface-street routes across the city are shown in their relation to the new route that will be provided by the expressway.

As a preview of the future, time and gasoline consumption comparisons are made between present surface street routes and alternate routes that will be provided by the expressway. In these comparisons surface route A G H is the same as that shown in Tables 1 and 2 and in Figure 3.

The two most practical street routes between the traffic circle at Charles River Dam (A) and the South Station (H) are via Congress Street (A G H) and via Atlantic Avenue (A F H). The Congress Street route is the shorter in distance, but the slower in time. The better time on Atlantic Avenue is made possible because the pavement is, for the most part, over 70 ft. wide and there are fewer intersections than on the Congress Street route.

The probable travel time between A and H on the expressway is estimated as 27 mph. by assuming speeds of 15 mph. on streets leading to ramps, 25 mph. on the ramps and 35 mph. on the expressway proper. As previously mentioned the expressway is not designed as a fast road. Even at the estimated speed of 27 mph., the expressway route will be much faster than the present surface routes, as indicated in the boxes in the upper right corner of Figure 5.

In estimating gasoline consumption expected on the expressway it was necessary to take into account the grades that must be climbed and descended. The surface streets at A and H are at about Elevation 13. In the southeasterly direction from A to H the expressway rises to a maximum elevation of 65 ft. over the tracks of the Boston and Maine Railroad. In the northwesterly direction from H to A it rises to 58 ft. over the elevated railway structure in Causeway Street. The rate of rise and fall in feet per 100 ft. is 1.3 southeast bound and 1.2 northwest bound.

Several trips were made with the Pontiac over the high-level Mystic River Bridge. From these runs a relation was developed between rate of rise and fall and gasoline mileage; this was used in selecting the miles per gallon assigned to different parts of the expressway. Even after making a deduction for rise and fall, the gasoline requirements estimated for the expressway are much less than found for surface street routes.

In Figure 5 a comparison is also drawn between surface and expressway routes between Longfellow Bridge (K) and the South Station (H). See boxes in upper left corner of Figure 5. In this comparison a portion of the new Embankment Road (A K), which is of expressway design, is added to the central artery route.

The irregular street pattern and one-way street systems (shown by small arrows) in Boston do not provide any practical direct-surface-street route between K and H. The routes K J H and K I H are obviously round about, but they are practical routes. Other shorter routes can be found by plunging into Boston's unique labyrinth of narrow and crooked streets, but it is doubtful whether much time can be saved this way, at least not by many drivers, as the capacity of these narrow streets is very low. The one-way directions of Charles and Tremont Streets favor route H J K and penalize K I H, as shown by the large differences in travel times between these routes. Because of the greater length of the expressway route K A H, no saving in gasoline is anticipated when this route is compared with route H J K, and only a slight saving when compared with route K I H. Substantial time savings will be possible, however.

The estimated savings in time and gasoline per vehicle trip are summarized at the bottom of Figure 5. The time savings are more impressive than the savings in gasoline. It should be kept in mind though, that the gasoline results apply only to the Pontiac Six; they are probably reasonably typical of passenger car operation. The heavier trucks and buses which comprise about 20 percent of Boston street traffic will use more gasoline per mile than passenger cars and may be expected to show larger gasoline savings per trip than recorded for the Pontiac Six.

Figures 6 and 7 show similar comparisons for sections of the central artery which are now under construction and which will be the first parts to be opened.

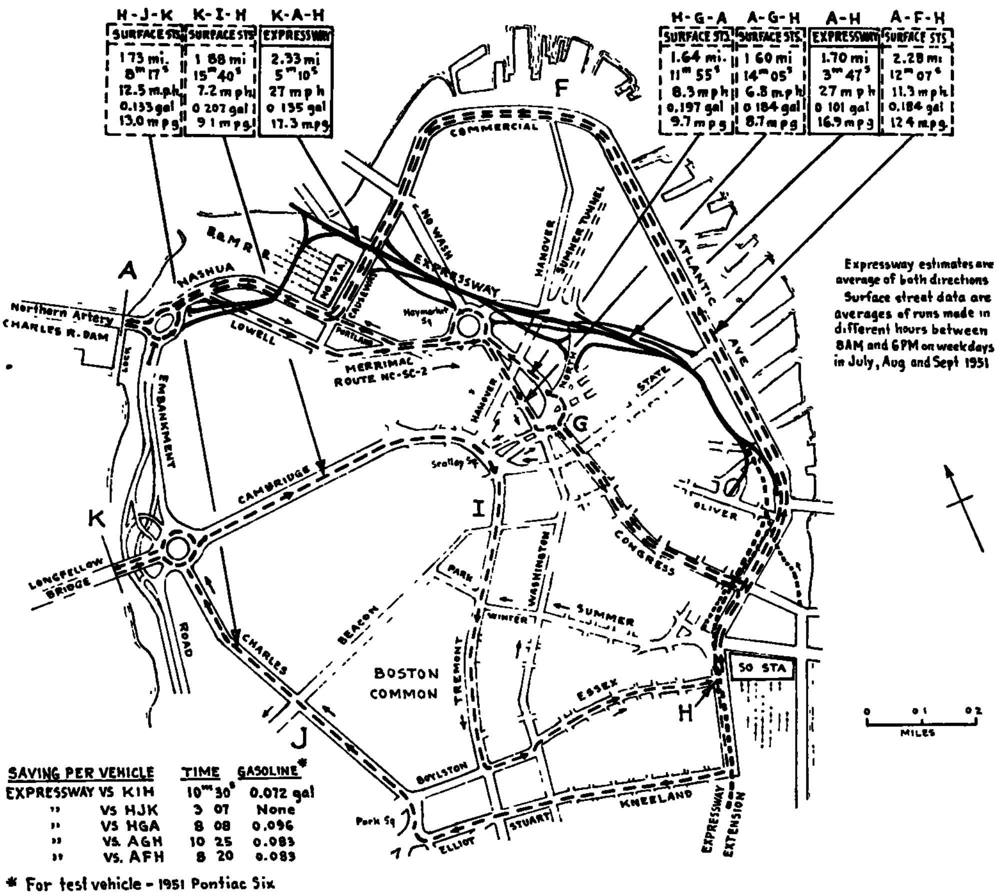
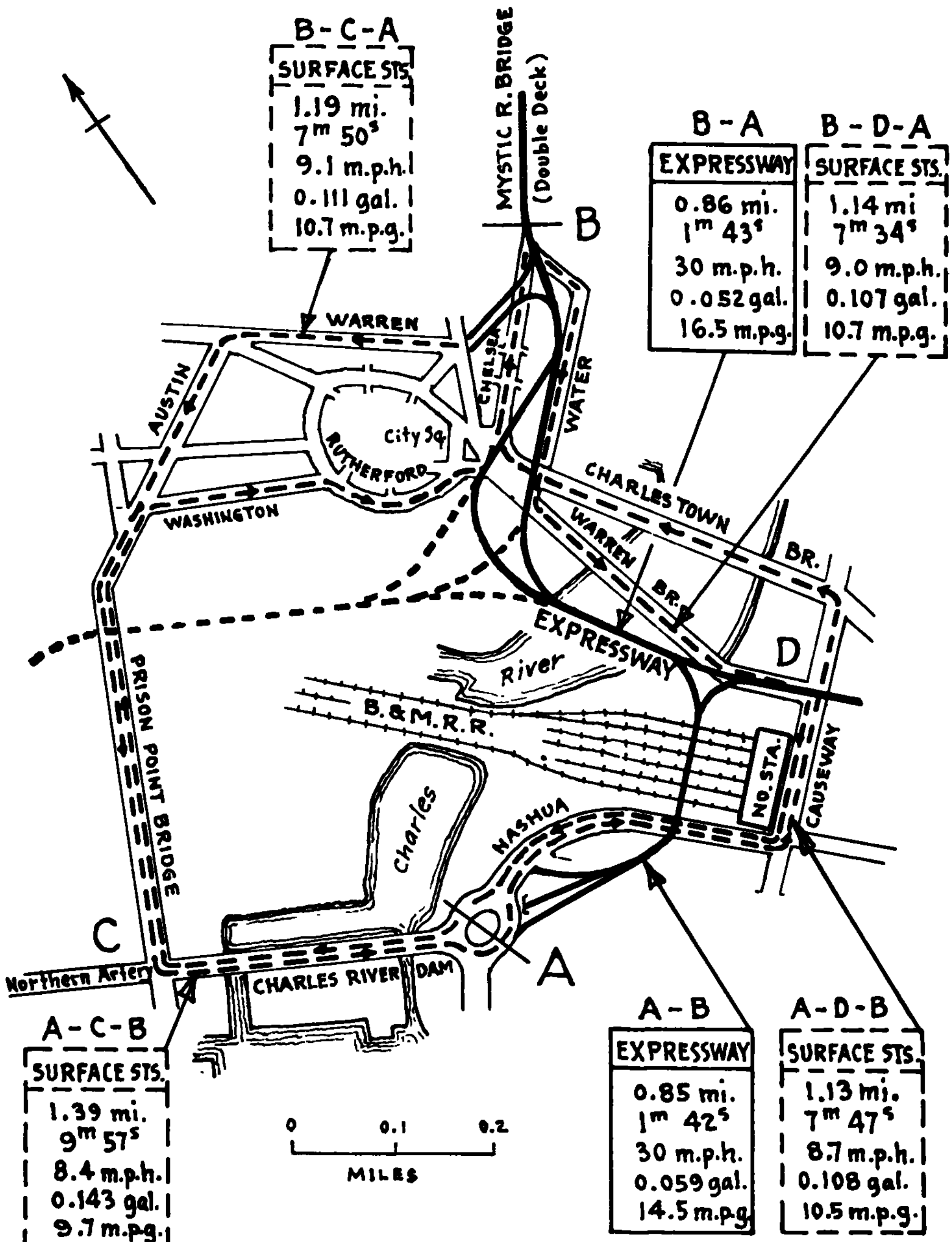


Figure 5. Comparison of travel time and gasoline consumption for future expressway routes versus present street routes across downtown Boston.



SAVINGS PER VEHICLE		TIME	GASOLINE *
EXPRESSWAY AB	VS. ADB	6m 05s	0.049 gal.
”	VS. ACB	8 15	0.084
EXPRESSWAY BA	VS. BDA	5 51	0.055
”	VS. BCA	6 07	0.059

* For test vehicle - 1951 Pontiac Six.

Figure 6. Time-and-gasoline comparisons: Expressway versus surface streets between traffic circle at Charles River Dam and Sumner Tunnel entrance and between Mystic River Bridge and Sumner Tunnel entrance.

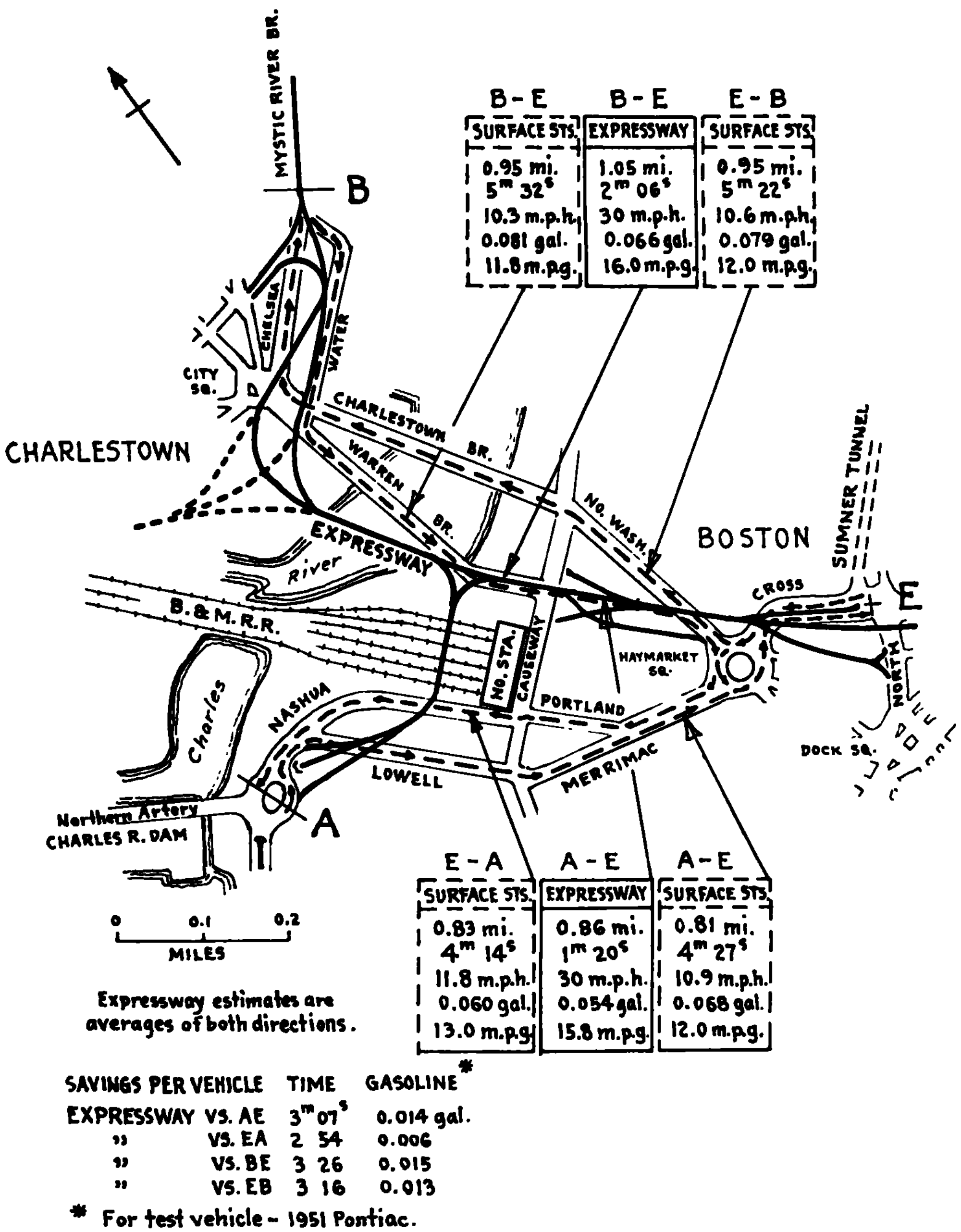


Figure 7. Time-and-gasoline comparison: Expressway versus surface streets between traffic circle at Charles River Dam and Mystic River Bridge.

The link A B promises to relieve two of the worst bottlenecks in the city, Causeway Street and Prison Point Bridge Routes A E and B E permit direct access from such well developed highways as Embankment Road, Northern Artery, and Mystic River Bridge to the heart of Boston via the North Street and Haymarket Square ramps. The forecast for these routes shows substantial time savings but relatively small gasoline savings, largely because of the rise and fall introduced in passing over the elevated railway structure in Causeway Street, the tracks of the Boston and Maine Railroad and the Charles River. The upper deck of the Charles River Bridge rises to about 70 ft. above street level in that vicinity.

FORECAST OF SAVINGS IN 1955

The unit savings developed in Figures 5, 6 and 7 do not appear large in themselves. However, when applied to the many thousands of vehicles which will use the expressway in preference to city streets, they will amount to a considerable sum. Table 3 gives a forecast of the probable annual savings in time and gasoline cost for one section of the new facility in 1955. The year 1955 is used because it is the one considered typical of the *initial* stage of expressway operation in the master highway plan.

The expressway route analyzed extends from the traffic circle at the Charles River Dam to the Mystic River Bridge (Route A B in Fig. 7). This link will bypass two of the worst bottlenecks in the city, the Prison Point Bridge in Charlestown and Causeway Street in Boston under the elevated railway in front of the North Station. It will probably be the first part of the new route to be open for traffic.

Traffic volumes shown in Table 3 are derived from "desires" expanded to 1955 from an origin-and-destination survey of Metropolitan Boston made in 1945. Much of the estimated traffic will be diverted from adjacent city streets, but an additional amount will be attracted from more distant routes now used by drivers in an effort to avoid the congestion now existing in this area.

The unit savings of time and gasoline from Figure 7 were applied to the traffic volumes estimated for the hours 8 A.M. to 6 P.M. on all 260 weekdays (Monday through Friday) in the year. These values were then expanded to an annual basis by applying a factor of 1.6, made up of two parts: first, a 40 percent increase to include time and gasoline savings in the hours of the day outside the 8 A.M. and 6 P.M. period, and a further increase of 15 percent to include such savings occurring on Saturdays and Sundays. These expansions were based on relative traffic volumes and upon the results of certain spot runs made in the periods not covered by the recorded tests.

In order to give more significance to the savings developed in Table 3, time has been evaluated at $1 per hour and gasoline has been priced at 27 cents per gallon. It is realized that the value of time savings as such is a debatable question. However, as a measure of the willingness of highway users to pay for expressway facilities in congested areas, $1 per hour is not It was chosen roughly on the assumption of 1 cent per minute for passenger cars comprising about 80 percent of the total traffic and

TABLE 3

FORECAST OF SAVINGS IN TIME AND GASOLINE COST BY USERS OF EXPRESSWAY BASED ON 1955 TRAFFIC ESTIMATES

Charles River Dam to Mystic River Bridge

Routes (Fig. 7)	Average Daily Traffic 1955	Average Traffic 8 A.M. to 6 P.M. 1955	Time Saved Per Vehicle Per Trip 8 A.M. to 6 P.M.	Estimated Time Savings in 1955: On All Weekdays 8 A.M. to 6 P.M.	Estimated Time Savings in 1955: Total For Year	Gasoline Saved Per Vehicle Per Trip	Estimate of Gasoline Saving in 1955: On All Weekdays 8 A.M. to 6 P.M.	Estimate of Gasoline Saving in 1955: Total For Year
				Hours	*Hours*		*Gallons*	*Gallons*
AB vs. ADB	3850	2310	$6^m\ 05^s$	60,800	97,000	.049	29,400	47,000
AB vs. ACB	3850	2310	$8^m\ 15^s$	82,500	132,000	084	50,600	81,000
BA vs. BDA	3850	2310	$5^m\ 51^s$	58,500	94,000	.055	33,100	53,000
BA vs. BCA	3850	2310	$6^m\ 07^s$	61,200	98,000	.059	35,400	57,000
				263,000	421,000		148,500	238,000
Money saving assuming time at $1 per hour and gasoline at 27 cents per gallon				$263,000	$421,000		$40,000	$65,000
Cost of portion of Expressway chargeable to above traffic					$8,200,000			
Estimated savings per year in time and gasoline (1955).					$486,000			
Percent savings of cost					5 9%			

5 cents per minute for trucks and buses comprising the remaining 20 percent. Gasoline is taken at 27 cents per gallon which is one-half cent higher than the price of regular grade gasoline in Boston and 1.5 cents less than the price of premium gasoline when the estimates were made.

Applying these unit cost values to the annual time and gasoline savings in Table 3 produces an annual savings of about $500,000. This in turn amounts to about 6 percent of the investment in this portion of the expressway chargeable to the traffic travelling between A and B.

In addition to the savings in gasoline, there will be savings in other items of operating cost because the expressway route is about 0.3 mile shorter southbound and 0.4 mile shorter northbound than possible over existing streets. The operating costs saved will be for oil, tires, repairs, and certain depreciation. Evaluating these costs roughly at 2.5 cents per mile, the distance saving will amount to about $50,000 per year in 1955.

The traffic and costs estimated presented in Table 3 are minimums, since they apply to the initial stage of operation. As the expressway system is expanded, more traffic will be attracted to the central-artery section and increasing volumes of traffic will use the link illustrated in Table 3.

TRAVEL-TIME STUDIES IN 1939 AND 1951

In 1939, travel-time studies were made on seven routes in downtown Boston.[2] Four of them were covered again in the 1951 runs. A comparison of the findings is given in Table 4.

On Congress and Cambridge streets there have been no important changes in physical conditions or in traffic regulations since 1939. And traffic moves as slowly today as it did in 1939. Counts in 1939 and 1951 show little change in traffic volume on Congress Street, which long ago reached maximum capacity. They do show that Cambridge Street has absorbed some additional volume, diverted to it when Charles Street was made one way.

The other two streets show a marked improvement in travel time or vehicle volume during the period, in each case caused by physical changes having been made. Removal of the elevated railway structure and its supporting columns from Atlantic Avenue and Commercial Street opened up additional traffic capacity; while the speed of traffic has not changed, the volume has nearly doubled. Since 1939, the rough pavement of Charles Street was resurfaced, and this artery was changed to one-way operation. As a result the speed of traffic has now increased by 50 percent and the traffic volume by 60 percent.

This comparison shows that speed and volume are increased by major improvements. On the other hand, traffic speeds and volumes remain about the same on those downtown

TABLE 4
COMPARISON OF TRAVEL TIME AND TRAFFIC VOLUME OBSERVED ON CERTAIN BOSTON STREETS IN 1939 AND IN 1951

Route	Distance[a]		Travel-Time		Miles per Hour		Total Vehicles 7 A.M. to 7 P.M.	
	1939	1951	1939	1951	1939	1951	1939	1951
North Sta.[b] to South Sta. via Causeway and Commercial Streets and Atlantic Ave.	1.74	1.74	$9^m\ 15^s$	$9^m\ 18^s$	11.3	11.2	12,100	23,000
Congress St. Dock Sq. to Dorchester Ave.	0.58	0.60	$4^m\ 31^s$	$5^m\ 27^s$	7.7	6.6	14,200	15,000
Charles St.[c] Boylston St. to Longfellow Bridge	0.43	0.43	$3^m\ 13^s$	$2^m\ 15^s$	8.0	11.5	18,300	30,000
Cambridge St. Longfellow Bridge to Scollay Sq.	0.55	0.54	$3^m\ 09^s$	$3^m\ 0^s$	10.5	10.8	16,900	20,000

[a] Distances differ between 1939 runs and 1951 because runs were made between slightly different points.
[b] Between 1939 and 1951 an elevated railway with columns in the center of the street was removed from Atlantic Avenue.
[c] Charles Street was changed from two-way to one-way operation between 1939 and 1951.

[2] "Effect of Traffic Delays on Gasoline Consumption" by A. J. Bone, HRB Proceedings, pp. 99-125 (1939).

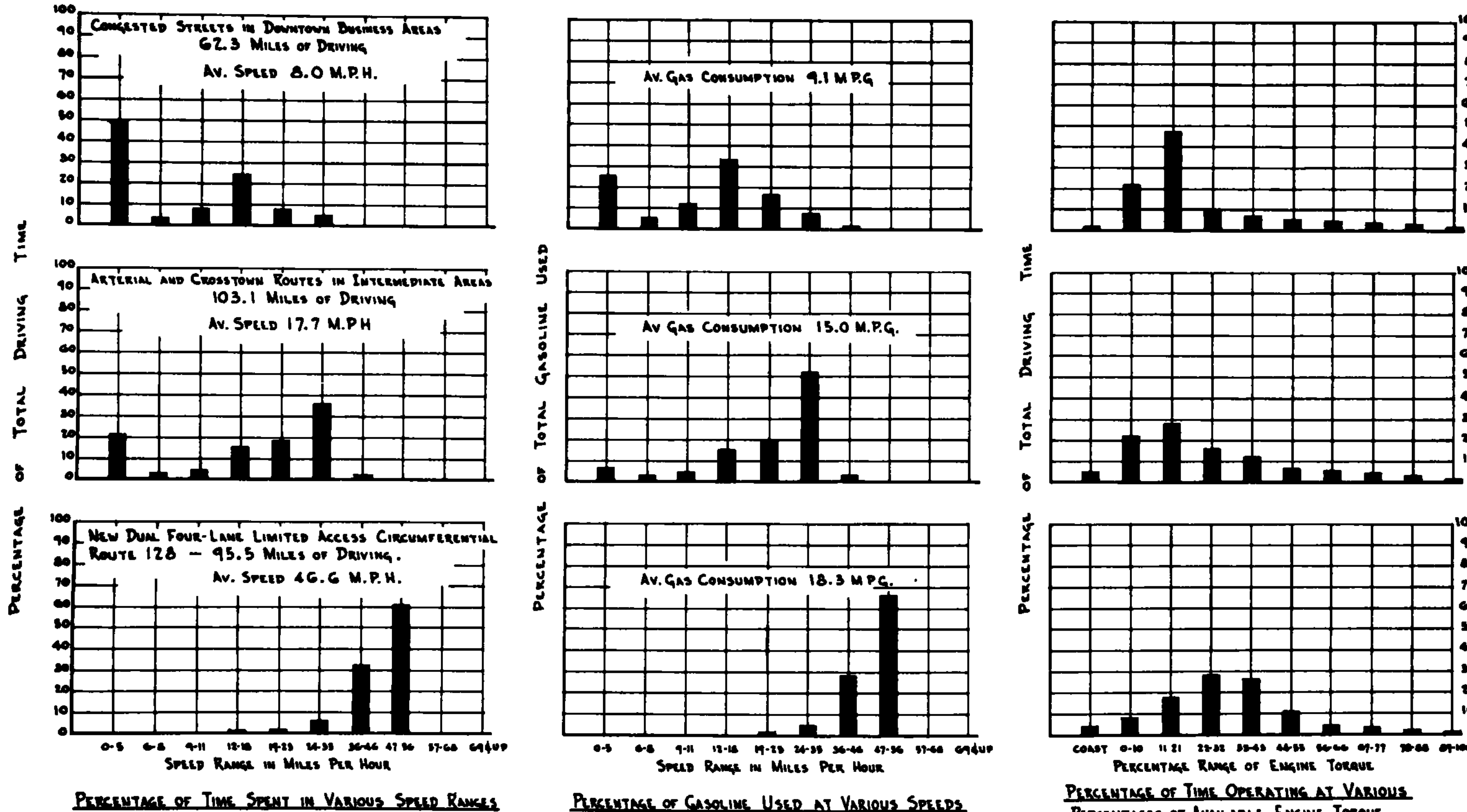


Figure 8. Percentage distribution of speed, gasoline consumption, and engine torque on different types of streets and highways in Boston and vicinity obtained with instrument in 1951 Pontiac Six, August 1951.

streets which have undergone no changes in physical layout or traffic control during the period.

EFFECT OF CONGESTION ON VEHICLE OPERATING CHARACTERISTICS

Some of the results obtained from the statistical instruments mounted in the Bureau of Public Roads' Pontiac Six are shown graphically in Figure 8 for three types of driving: On congested downtown streets, on partly congested streets with frequent intersections in the "intermediate," or fringe area, around the central business district, and on a modern, limited-access rural expressway with no cross traffic (New Circumferential Route 128).

On the congested streets, 50 percent of the time in traffic is spent either standing still or travelling under 5 mph During this time, 26 percent of the gasoline is consumed in getting nowhere.

On intermediate-type streets, 22 percent of the time is spent at speeds below 5 mph. and 7 percent of the gasoline is consumed in this speed range.

On the limited-access highway (Route 128) a negligible percentage of time is spent in speeds below 24 mph.

The most-used speed range on congested streets (excluding stops) is 12 to 18 mph.; on intermediate streets it is 24 to 35 mph. On Route 128 the speed is determined more by the driver's choice than by traffic conditions. The test car was driven mostly in the 47- to 56-mph. range, but within this range it was driven closer to the lower figure Most Massachusetts drivers travel this highway between 35 and 50 mph.

The graphs in Figure 8 show that most of the time only a portion of the available engine torque (or power) is used; occasionally, however, in all types of driving the upper ranges are utilized During 90 percent of the driving time, the demand on engine torque does not exceed 55 percent of that available.

On city streets, the lower ranges of engine torque appear to be used more than on the expressway, but the extreme upper ranges are used about as frequently as on the limited-access facility

All of the runs with the test instruments were made by the same driver.

SUMMARY

Although this study was undertaken primarily to obtain information for future comparisons with traffic conditions after the central artery is in use, considerable information has been gained regarding the characteristics of city driving:

(1) Average speeds on congested streets in downtown Boston range from 7 to 12 mph. with a low of 4 mph. on some streets in peak hours.

(2) Average gasoline mileage on city streets ranges from 9 to 13 mi per gal. with a low of 5 mi. per gal. on some runs.

(3) At speeds below 10 or 12 mph. when the speed of traffic is controlled by congestion, a close relationship apparently exists between miles per hour and miles per gallon. This relation should be useful in estimating gasoline consumption on congested streets from the traffic speed without the use of a gasoline meter.

(4) A comparison of travel times on city streets with those possible after the expressway is completed indicates that there will be an average saving in time of 4 5 min. per mi. of expressway by its use. Some sections will save as much as 8 min. per mi Gasoline savings per trip over the expressway will average about 0 04 gal. per mi.; on some sections there will be no saving, and on others the saving will be as much as 0 10 gal. per mi. Part of the gasoline saved by the relief from traffic congestion will be used on the grades introduced into the expressway design in order to provide the required clearance over the elevated railway tracks and over the Charles River.

(5) Although the savings in time and gasoline appear small per trip, they become large when applied to the number of vehicles expected to use the expressway in preference to surface streets A forecast of probable savings on one 0.85 mi. section of the expressway indicates that in 1955, the initial stage of operation, there will be an annual saving in time cost of $420,000 and in gasoline cost of $65,000 when time is evaluated at $1 per hour and gasoline at 27 cents per gallon As the expressway system is extended these savings will increase.

(6) A comparison of travel time runs made in 1951 with those made in 1939 shows an

increase in both traffic volume and speed on one thoroughfare that was changed from two-way to one-way operation and an increase in volume, but not in speed on another street from which an elevated structure was meanwhile removed. When no changes had been made in physical conditions or in traffic regulations, volumes increased only slightly while traffic speeds were nearly the same in 1951 as in 1939.

(7) The runs studied with the statistical instruments for measuring speed, gasoline consumption, braking, engine torque, and throttle opening showed that on congested streets, the vehicle was either standing still or travelling at less than 5 mph. for 50 percent of the time, and that during this time 26 percent of the gasoline was consumed. On the other hand, little time was lost while driving on the expressway routes outside the downtown area. The instruments also showed that for city and expressway driving the higher ranges of available torque in the automobile are actually used for only a small percentage of the time that the vehicle is being operated.

(8) This paper has discussed only two direct benefits to city drivers, savings in time and in gasoline consumption. The construction of the central artery will accomplish much more than that. For the first time the heart of the city will be made accessible to large volumes of highway traffic. Changes in travel habits are certain to result which will have a marked effect on the economic life of the downtown area. Before-and-after studies of land use, property valuation, volume of business, and public transit riding are contemplated at some future date to appraise some of the other and broader influences of this new expressway.

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TRUCK-NOISE MEASUREMENT

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SYNOPSIS

The problem of evaluating truck noise has been studied by engineers of the University of California's Institute of Transportation and Traffic Engineering for the past two years. In recent years the highway has become a serious source of disturbing noise. In many instances the level of the noise has increased to a critical value and has provoked action by local groups and state legislatures. This discussion deals entirely with the problems of measurement, first with specific equipment and techniques for measuring and recording and secondly with equipment and techniques for evaluating the measurements.

Instrumentation is described in which noise measurements may be made either by integrating (total-noise) devices or by instruments which divide the noise into frequency bands and give a reading for each band.

Field and laboratory tests have been made on noises produced by large trucks equipped with different mufflers. Field tests were conducted on three occasions in 1950 in conjunction with the California Motor Transport Associations and the California Highway Patrol. Analyses have been made of the tests to determine the correlation between measurements on 16 different mufflers and jury evaluations of the noise. The results of the analyses indicate that the American Standards Association sound-level meter can be used as a satisfactory instrument to indicate the annoyance value of truck noise, if used on the proper scale and set up in the proper manner.