Pressurized Intersections

A STUDY OF INTERSECTION APPROACH CAPACITIES ON UNDIVIDED STREETS IN AN INTERMEDIATE-TYPE AREA

ROBERT C. BLUMENTHAL and JOHN W. HORN, Consulting Engineers
Bruce Campbell and Associates, Boston, Massachusetts

This report on capacities of signalized intersections is the first part of a series of comparison studies between results presented in the 1950 issue of the Highway Capacity Manual and results as found for specific "pressurized" intersections in the Boston Metropolitan Area.

Data from 21 pressurized intersections (that is, intersections where the approach under study had a continual backlog of waiting vehicles) indicated capacities in excess of those reported in the "Highway Capacity Manual." Specifically, volumes on approaches with a total street width of 31 to 46 ft averaged 14 percent higher than "Manual" averages. On streets 47 to 64 ft in total width, volumes were 65 percent greater; on streets 65 ft and wider, the average volumes were 106 percent higher than corresponding volumes in the manual.

It is not intended that the results of the study be used as general criteria for higher basic design volumes. Rather it indicates a much higher capacity potential, especially in the wider street width, under pressurized conditions which motorists are currently tolerating in larger metropolitan areas.

The reductive effect of commercial vehicles and turning movements under pressurized conditions was compared with those in the manual. The factor found locally to have the greatest influence on the capacities was the turning movement. Left turns appeared to have a greater initial effect under pressurized conditions than the manual indicates. However, this effect appears to lessen on approaches carrying more than 20 percent of left-turning traffic. Also, the local data indicate that when left-turning volumes are equal to or greater than 50 percent of the total approach, they operate as through traffic with little reductive effect. This is believed to be peculiar to intersections where the major movement is the left turn and the peak condition involves primarily the same daily commuter traffic.

The effect of commercial vehicles was found consistent with that proposed by the manual (in the range of 0 to 20 percent). The data indicate a greater effect than that outlined in the manual due to the presence of commercial vehicles when they make up more than 20 percent of the total approach volume.

Finally, the study indicates that the reductive effect of the opposing left turn is sufficient to be evaluated alongside the usual lefts, rights, and commercial percentages.

● **THE APPROACH CAPACITY** of a signalized intersection is undoubtedly the greatest retardant to the basic capacity of a highway or street. When the intersection approach has become continuously backlogged with waiting vehicles, the intersection becomes "pressurized" with impatient vehicles.

The Highway Capacity Manual (1) has attempted to determine the capacity of various intersectional approaches by summarizing and plotting a wide variety of field measured data. The analytical study of the manual consists of classifying intersections in accordance with their geographical location; downtown areas, intermediate areas, and rural or outlying areas. Each location is considered with both parking prohibited and parking permitted. The classes are further sub-divided into two-way, one-way and divided type streets.

Having standardized the intersections, the actual traffic volumes are then standardized in order to compare relative conditions. This is done by adjusting the various

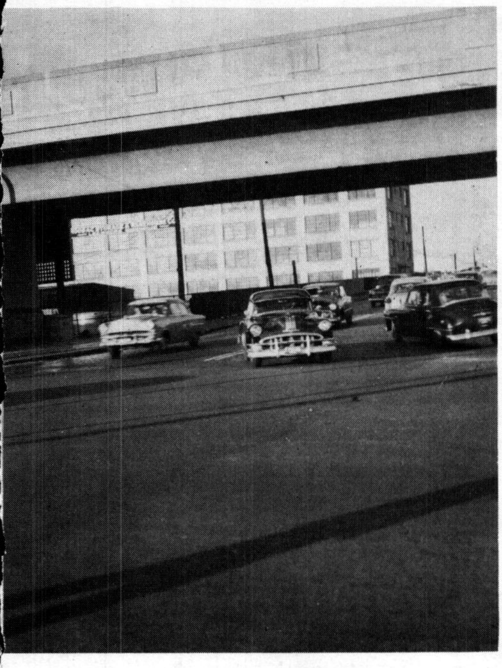


Figure 1. Maximum possible capacity.

influencing factors to a common unit. The basic reference or "average condition" is 10 percent commercial, 10 percent right turns and 10 percent left turns. Characteristics differing from this are adjusted to the common unit of measure by a combined adjustment factor, obtained as follows: Subtract or add 1 percent for each 1 percent commercial traffic differing, subtract or add ½ percent for each 1 percent of right turns differing, subtract or add 1 percent for each 1 percent of left turn differing; and subtract 10 percent for bus stops on the near side, subtract 15 percent for bus stops on far side, or add 5 percent if no bus stops. For intersections with unusual conditions, the adjustments are subdivided in more detail as outlined in the manual.

With the intersection capacity depending upon the approach capacity, the approach capacity, in turn, depends primarily upon two fundamental features, time and space. The time is measured in seconds of green signal, or by subdividing the cycle and phase lengths per hour of total elapsed time. The space is measured in units of 10-ft lanes. The capacity is therefore expressed in units of vehicles per 10 ft width per hour of green signalization.

The intended unit of field measure was the "possible capacity," the maximum number of vehicles that actually can be accommodated under prevailing conditions with a continual backlog of waiting vehicles (Fig. 1). O.K. Normann summarizing the data in the manual concluded that not all data met this requirement. Hence, it was determined that the average condition (as plotted for Curve 1, Fig. 8) was midway between the possible capacity and a "practical capacity" — practical capacity defined as the

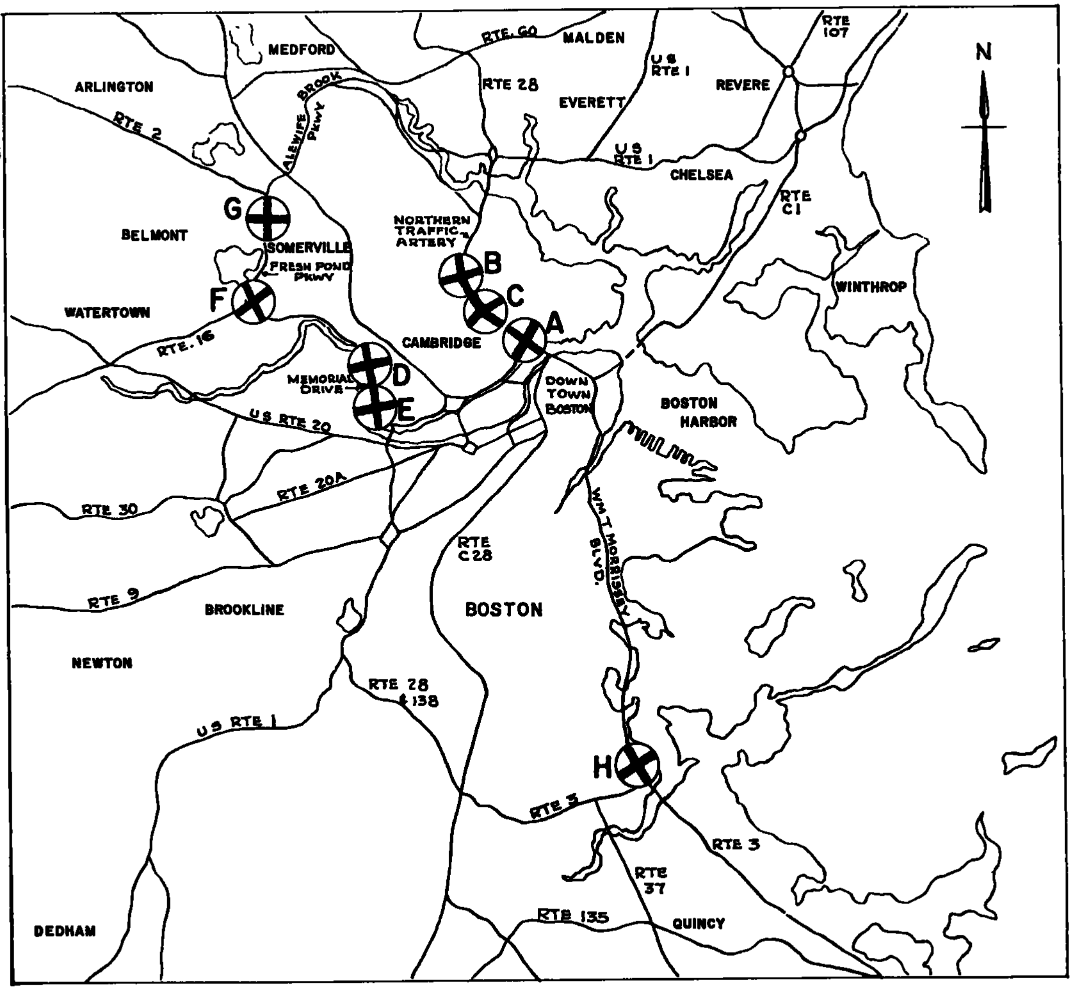
Figure 2. Practical capacity.

Figure 3. Congested intersection with continuous backlog of vehicles.

maximum volume that can enter from an approach during one hour, with most of the drivers being able to clear the intersection without waiting for more than one complete signal cycle (Fig. 2).

Figure 4. Congested intersection with continuous backlog of vehicles.

PRESSURIZED INTERSECTIONS
BOSTON METROPOLITAN AREA
LOCATION MAP



KEY

LETTER	INTERSECTION
A -	NORTHERN TRAFFIC ARTERY & PRISON POINT BRIDGE
B -	" " " & WASHINGTON ST
C -	" " " & SOMERVILLE AVE
D -	MEMORIAL DRIVE & RIVER ST
E -	" " & WESTERN AVE.
F -	FRESH POND PARKWAY & HURON AVE.
G -	ALEWIFE BROOK PARKWAY & RINDGE AVE
H -	WM. T. MORRISSEY BLVD & REDFIELD ST.

Figure 5.

This report has derived the average condition by dividing actual possible capacity field counts by a capacity load factor of 1.1 or dividing actual practical capacity field counts by a factor of 0.9. The actual field counts, after being divided by the combined adjustment factor and by the capacity load factor, are plotted against the total street width for the intermediate type areas.

Basis capacity was adopted as 1,250 vehicles per 10 ft width per hour of green, stemming from the basic capacity of 1,500 vehicles per 12 ft width per hr for 1 lane of continuous moving traffic at 12 mph.

SELECTION OF INTERSECTION APPROACHES

Twenty-one intersection approaches of the undivided, 2-way intermediate class were selected for study. Each was known to carry large volumes of peak hour traffic (Figs. 3 and 4). The approaches were part of eight intersections (Fig. 5) widely dispersed over the Metropolitan Area. Each was definitely an intermediate type intersection, located between the downtown area and the outlying residential areas. During peak hours, they served primarily commuting traffic, and during off-peak hours served considerable cross-town traffic. They varied in total width from 30 to 94 ft, and contained a variety of traffic type and movement. There were no streetcars, nor was parking permitted on any approach.

COLLECTION OF DATA

The first method of data collection was by the use of standard one-half hour traffic counts, as available on office file (Fig. 6). The traffic count furnished actual volumes of passenger vehicles, commercial vehicles and turning movements per period of one-half hour elapsed time. Additional office files furnished dial timing of signals, intersection dimensions and other relevant information. All file data used was less then one year old.

The second method of data collection served as a check on the first. It consisted of using special phase counting forms, similar to those used by the U.S. Bureau of Public Roads for collection of data (Fig. 7). Five intersection approaches were double checked in this manner. This method of traffic count furnished traffic volumes and turning movements for each green phase of the signal, and specifically indicated those phases that had a continuous backlog of waiting vehicles. By grouping a series of these fully loaded phases, and omitting any phase not fully loaded, volumes of average maximum possible capacity were found per unit of green time.

SAMPLE CALCULATIONS

The eastbound approach on Washington Street at the Northern Artery, Somerville, Mass. (Table 1, line 8) will be used in demonstrating the method used in the calculations.

The physical characteristics were (a) intermediate type intersection, (b) street width of 80 ft at approach, and (c) parking prohibited on both approach and exit.

The traffic characteristics were (a) count taken on Friday, 3:00 - 4:00 p.m., (b) continuous backlog of waiting vehicles, (c) traffic count of 882 vehicles per hour, (d) 35 percent commercial traffic, (e) 1.6 percent right turns, (f) 52 percent left turns, and (g) bus stops at curb on near side.

The signalization characteristics were (a) 140 sec, three-phase signal, (b) the apprach is on a separate phase, and (c) 33 sec green per cycle.

Adjustments were as follows:

Influence	Adjustment (percent)	Factor
35 percent commercial (10-35)	-25	0.75
1.6 percent right turns (10-1.6)½	+ 4.2	1.042
52 percent left turns (10-0)	+10	1.10
Bus stops	-10	0.90

Because of intersection design and volume left turns were treated as through traffic. The combined adjustment factor (0.75 x 1.042 x 1.10 x 0.90) = 0.77. The capacity load factor, measured at maximum possible capacity, was 1.1.

COMMONWEALTH OF MASSACHUSETTS METROPOLITAN DISTRICT COMMISSION

PARKS DIVISION

TRAFFIC MOVEMENT SUMMARY TABLE

LOCATION---------------------------------------CITY OR TOWN-------------------

DATE-----------DAY OF WEEK---------WEATHER---------RECORDER------ STA.NO.--

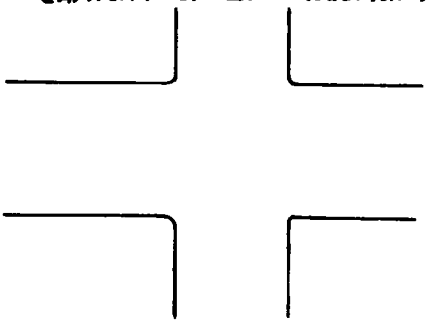
OVER FOR SKETCH

TIME STARTS ------M	BOUND ON ST			BOUND ON ST.			BOUND ON ST			BOUND ON ST			TOTAL HALF HOURLY TALLY	
	L	S	R	L	S	R	L	S	R ·	L	S	R		
700-730														
730-800														
800-830														
830-900														
900-930														
930-1000														
1000-1030														
1030-1100														
1100-1130														
1130-1200														
1200-1230														
1230-100														
100-130														
130-200														
200-230														
230-300														
300-330														
330-400														
400-430														
430-500														
500-530														
530-600														
600-630														
630-700														
700-730														
730-800														
800-830														
830-900														
900-930														
930-1000														
1000-1030														
1030-1100														
TOTAL													GRAND TOTAL	
TOTAL OF L.S & R														

Figure 6.

SHEET No ____

CAPACITY OF INTERSECTION APPROACH ST. PER GREEN TIME



IF PARKING PERMITTED, CROSS-HATCH (▨)

IF BUS STOPS PERMITTED, PLACE "B" AT STOP LOCATION

PLACE ARROW FOR EACH LANE MOVEMENT (⟶)

LIST SEPERATE TURNING ARROW DATA ON SEPERATE LINE

SKETCH UNUSUAL CIRCUMSTANCES

________ BOUND ON ____________ ST.
AT ____________ ST.

STARTING TIME ______________ M
FINISHING TIME ______________ M

SEC GREEN	CARS			COMMERCIAL			✔ IF LOADED	SEC GREEN	CARS			COMMERCIAL			✔ IF LOADED
	L	S	R	L	S	R			L	S	R	L	S	R	

Figure 7.

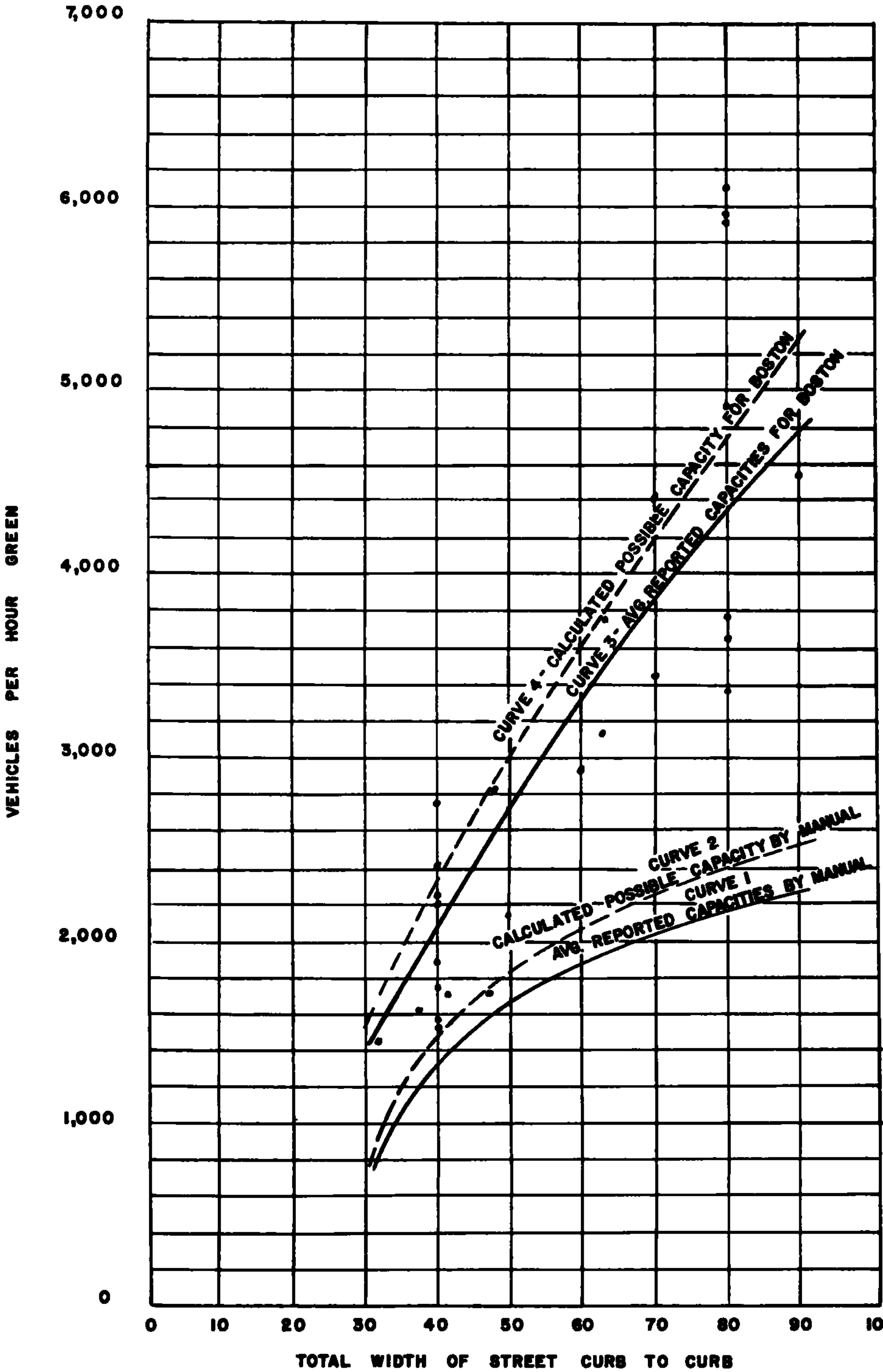


Figure 8. Average reported intersection capacities for two-way intermediate type streets with parking prohibited.

The manual reports the average capacity for an 80-ft street as 2,180 veh per hr of green when under an average condition of 10 percent commercial, 10 percent left turns and 10 percent right turns (Fig. 8). Therefore the possible capacity of the above approach would be: 2,180 x 33/140 x 0.77 x 1.1, equaling approximately 435 vehicles per hour of time. The actual field counts indicated that 882 veh per hr were passing through the intersection under the above conditions.

Knowing the existing capacity of the approach, the calculations may be reversed in order to solve for an adjusted capacity, comparable to the average condition presented by the manual, or 882 x 140/33 x 1/0.77 x 1/1.1 equals 4,420 vehicles per hour green

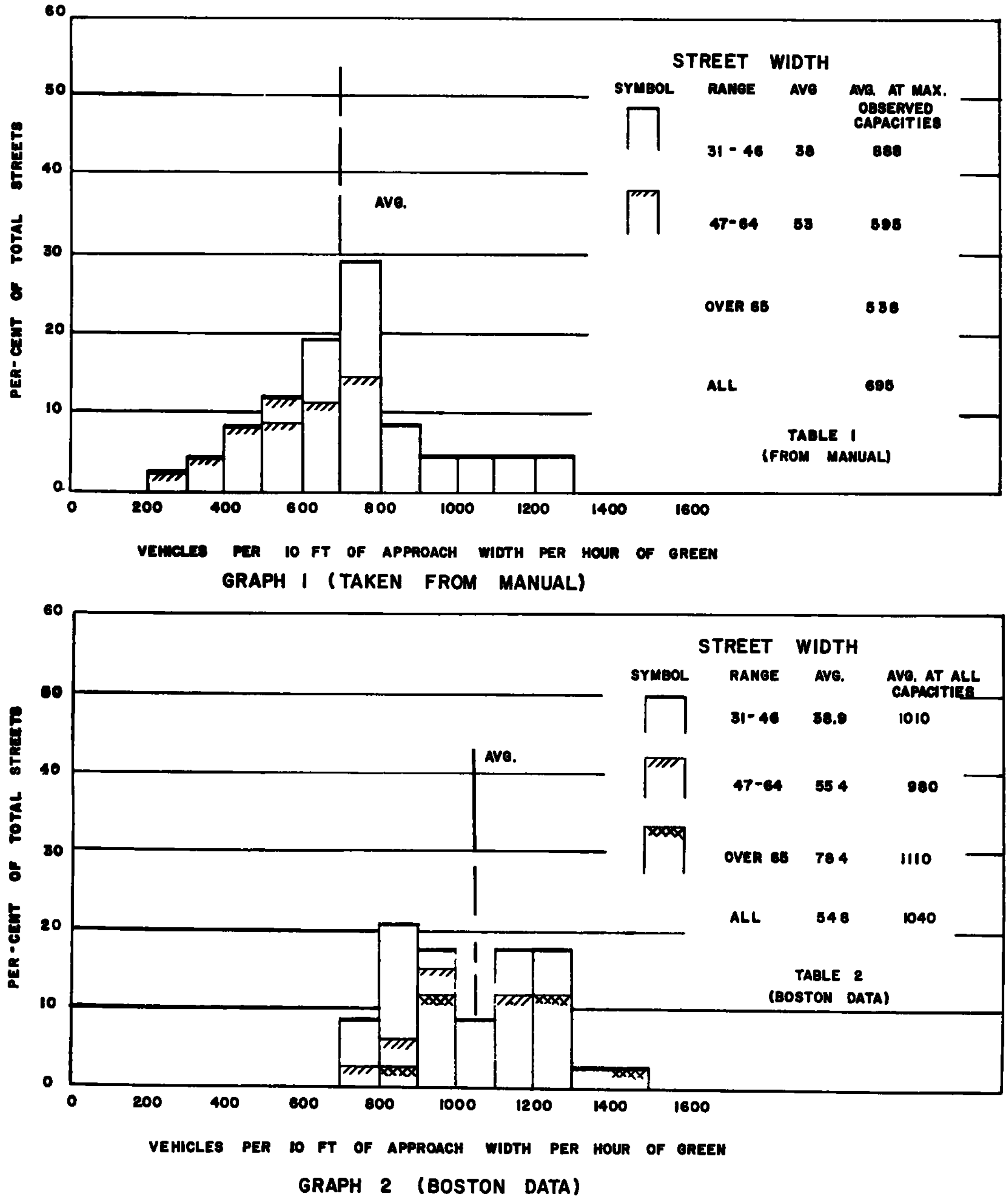


Figure 9. Frequency distribution of intersection capacities for intermediate type areas with parking prohibited.

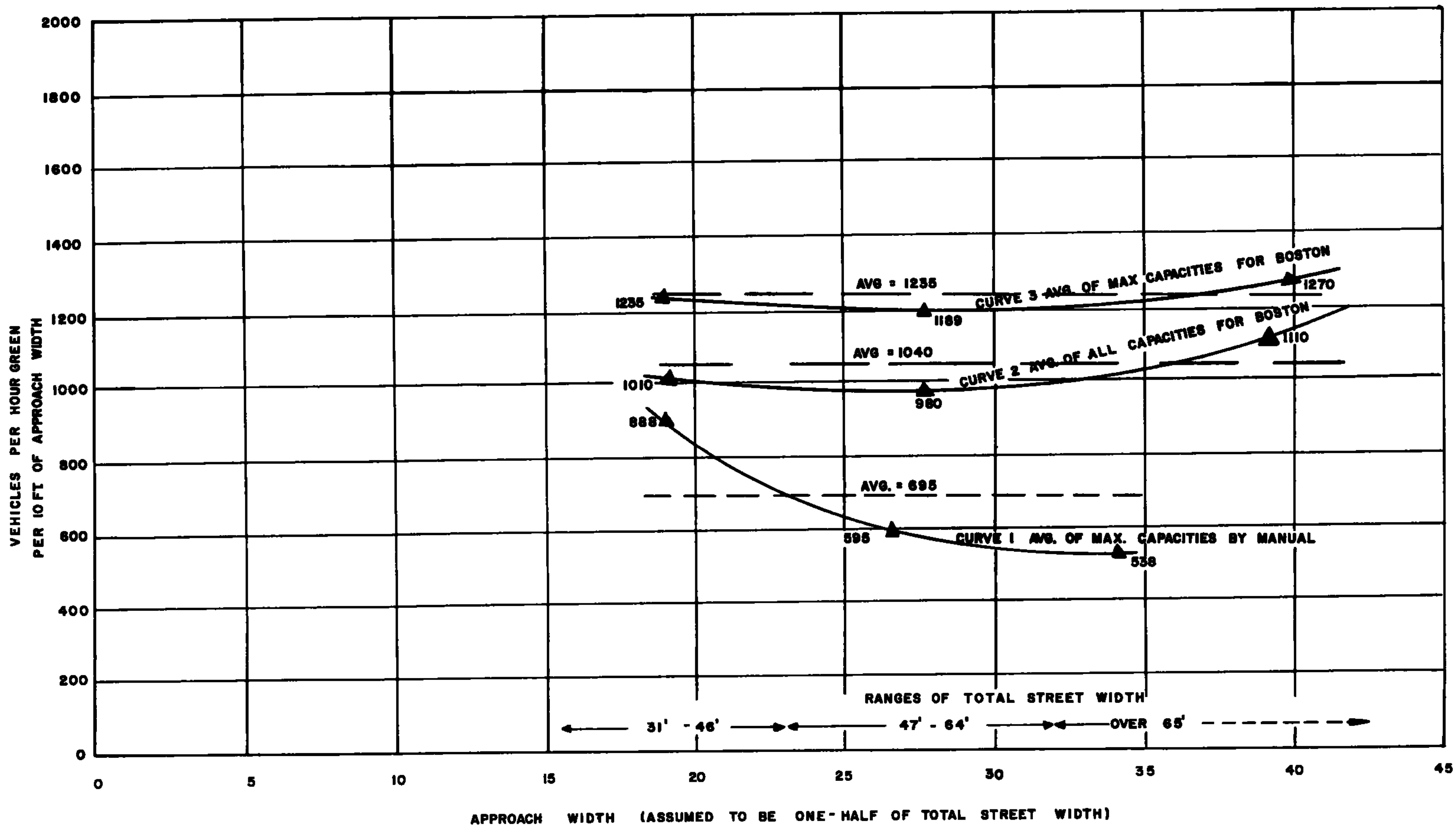


Figure 10. Average maximum reported approach capacities per range of street width.

at average conditions, thus, 4,420 veh per hr green per 80-ft total width, or 550 veh per hr green per 10-ft total street width, or 1,105 veh per hr green per 10-ft approach width.

PLOTTED DATA

Figure 8 is a direct comparison of average reported capacities. Curve 1 is the average reported capacities of many U.S. cities and has been taken from the Capacity Manual for purposes of comparison. Curve 2 is the maximum possible capacity of the reported cities, and is obtained by multiplying the average condition by the load factor of 1.1.

Curve 3 is a mean plot of the raw data for Boston as presented in this study. Curve 4 is the maximum possible capacity obtained by multiplying the average capacity of Curve 3 by 1.1.

Curves 3 and 4 indicate two significant findings: (1) the average reported capacities are considerably higher than expected, and (2) the capacity of an approach increases almost in direct porportion to its increase in width. A street 80 ft in total width carries over twice the approach volume of a street 40 ft in total width. This finding is not applicable for normal highway capacities, but instead probably results from the intensive pressure of backlogged traffic in a congested urban area.

Figure 9 indicates the frequency distribution of the intersection capacities found. Graphs 1 and 2 present a comparison between study data and data presented by the Capacity Manual. The total street widths have been sub-divided into common width ranges. The manual presents an average of maximum observed capacities, whereas the study presents the over-all average of all capacities as found. No precise determination has been made as to what determines the dividing line between maximum and average figures. In later comparisons, this study uses the upper one-third as maximums for comparable purposes.

The differences between the capacities shown in Figure 9 and the basic intersection capacity of 1,250 vehicles per hour of green per 10 ft of width, can be attributed primarily to the combind effect of the adjustments previously mentioned.

Graph 2 (Fig. 9) indicates that 100 percent of the approaches studied had an approach capacity of at least 800 vehicles per 10 ft of approach per hour of green, as compared to 27 percent of the approaches summarized by the Capacity Manual. This study has found an over-all average of 1,040 as compared to the manual's 695 vehicles per 10 ft of approach width per hour of green.

Figure 10 indicates the trend of maximum approach capacities in relation to the range of total street width. The capacities for each range of street width have been plotted against the approach width. Curve 1 indicates a plot of the average maximum capacities as summarized by the Capacity Manual, whereas Curve 3 is the average maximum capacities found in this study (upper one-third of each range). Curve 2 is a plot of the over-all average capacities as found for the width ranges.

The over-all average of this study is even higher than the maximum reported capacities of the manual.

Figure 11 indicates the trend of average reported capacities per 10 ft of approach width in terms of actual approach width, rather than ranges of width as previously shown. This data is obtained by dividing the plotted volumes of Figure 8 by the approach width. Approach widths of 5-ft increments have been used in establishing the plotted points. This figure not only indicates higher reported capacities, but indicates the range of approach width most efficiently used, 25 to 35 ft.

REDUCTIVE EFFECT OF TRAFFIC MOVEMENTS

Because of the very high volumes of traffic on the intersection approaches, a brief study was made in an attempt to evaluate and correlate the average reductive effect that each individual traffic movement has on the capacity of an intersection approach.

Nine of the intersection approaches previously studied and six additional ones were selected for further study. All approaches were 40 ft wide with 20 ft approaches. All corner radii were less than 20 ft.

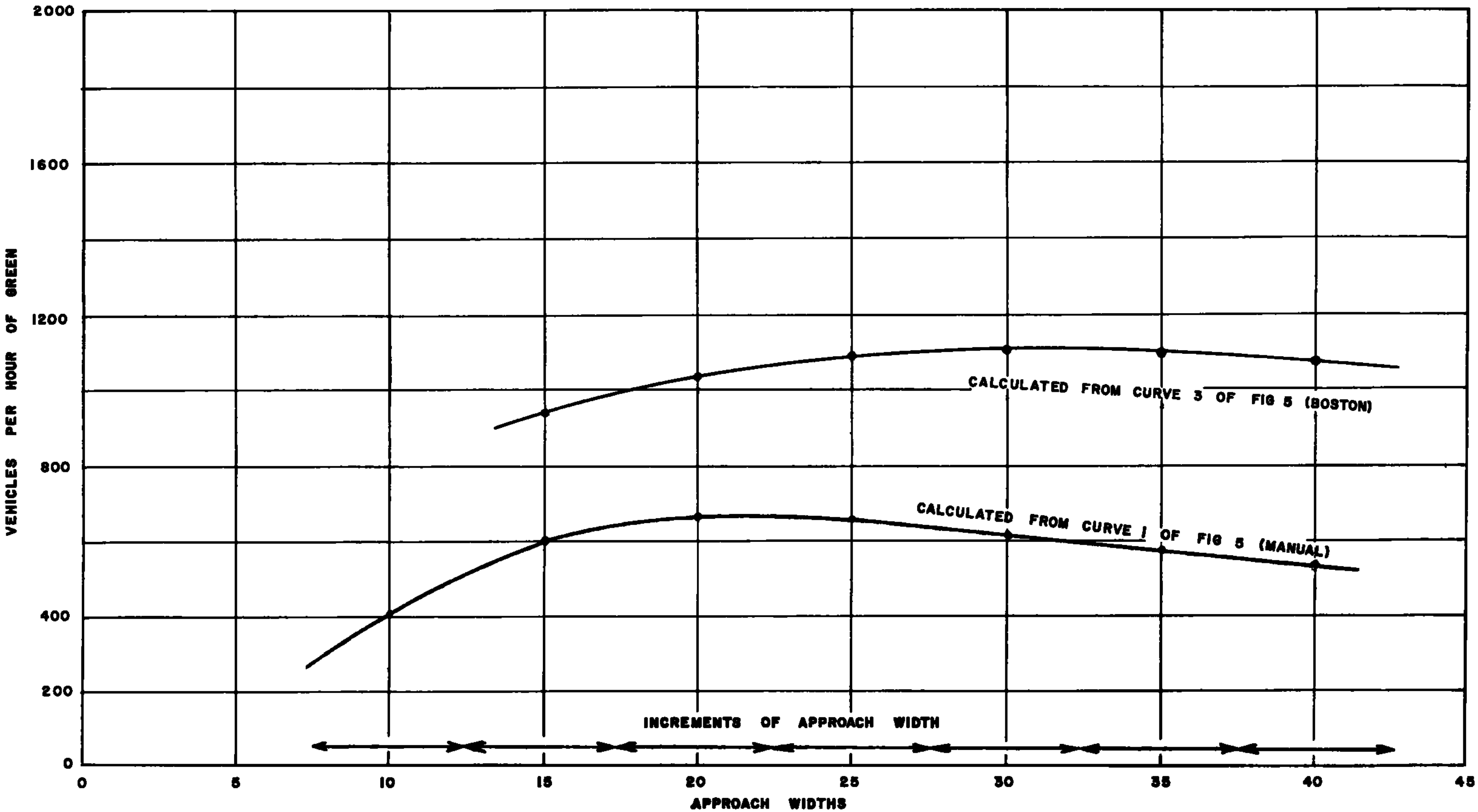


Figure 11. Average reported approach capacities per 10 ft of approach width.

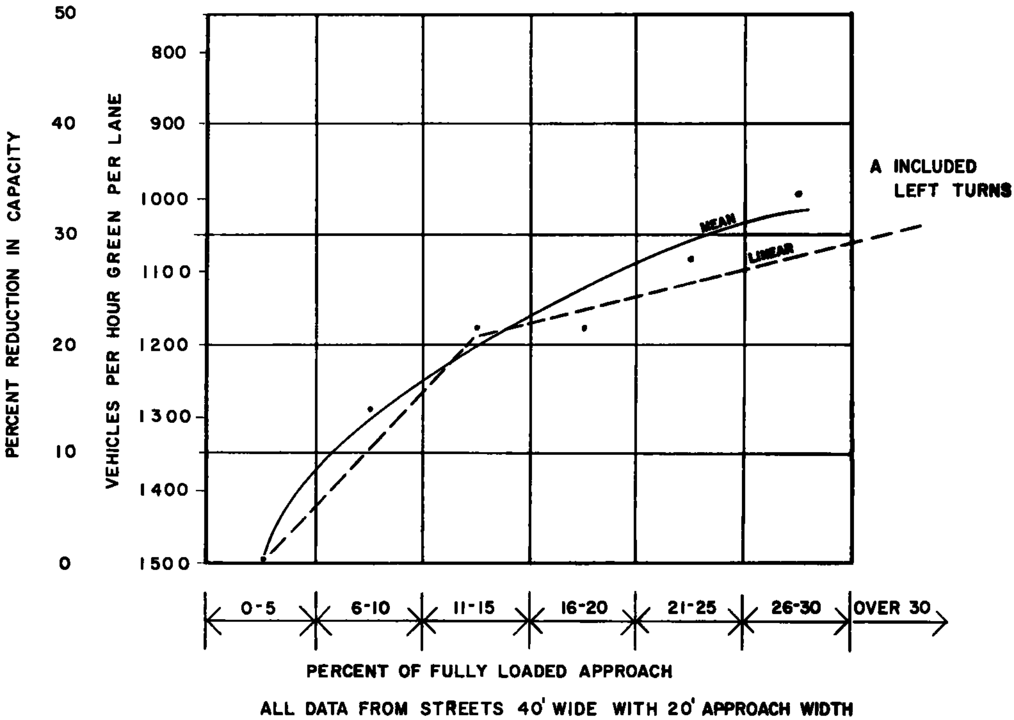


Figure 12. Reductive effect of traffic movements.

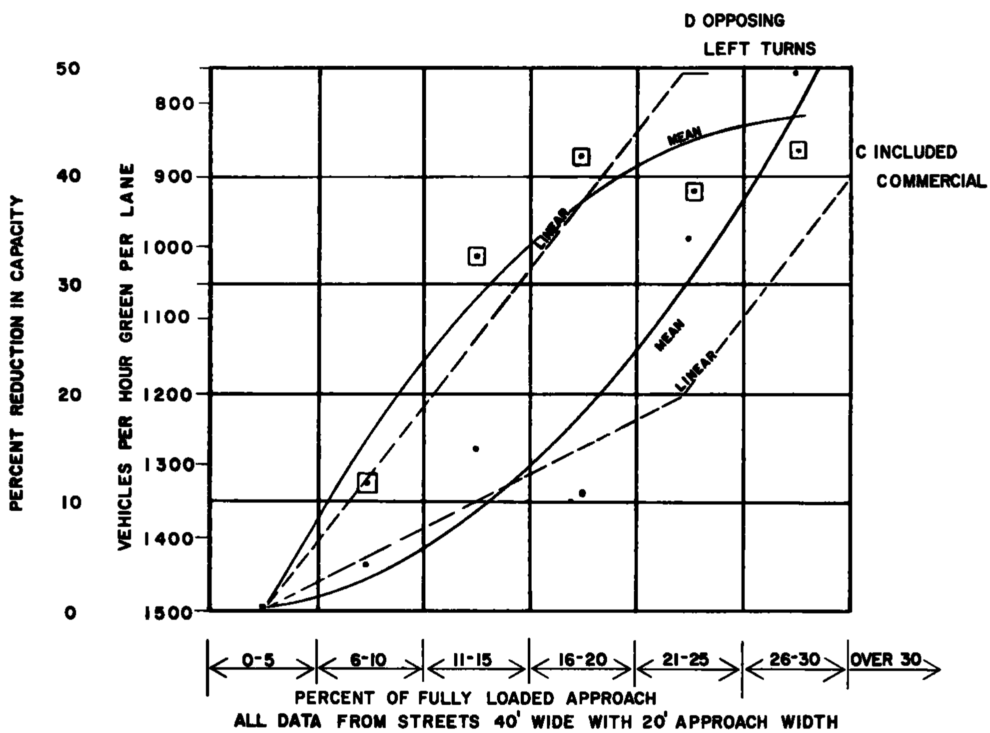


Figure 13. Reductive effect of traffic movements.

After field observations, it was found that the following movements were significantly effective in reducing the capacity of fully loaded approaches: (a) included left turns, (b) included commercial traffic, and (c) opposing left turns.

The first two items were used by the manual, but the last one was not. Buses were too few to be influential in the study. The reductive effects of right turns and total opposing traffic were also included, however the samples available were not sufficient to provide any basis for correlation or linear interpretation.

The study was made by counting traffic volumes, types and directions on each phase of the signal. Counts were made during both morning and evening peaks. Only those phases fully loaded with traffic were recorded. Approximately 2 hours of phase counting was made on each approach.

The data were recorded under each movement as a percentage of the approach volume as shown in Figures 12 and 13. For instance, if the included left turns were 18 percent of the total approach volume, it was listed under the range 16 - 20 percent of fully loaded approach (opposing left turn traffic is expressed in percent of the fully loaded approach).

All data could not be used. For example, if there were 24 percent left turns and 28 percent commercial traffic, it was impossible to measure which item effectively reduced the approach capacity. Therefore, it was decided to select limiting percentages of each movement, and to permit only the movement in question to exceed its limit in the recorded data. This required much tabulation and sorting of data. The limits used are as follows: (a) included left turns, 5 percent; (b) included commercial vehicles, 5 percent; and (c) opposing left turns, 5 percent.

As an example, to measure the effect of a left turn, only those phases were used when the percentage of left turns was high and all other factors were below their limit.

Figures 12 and 13 are mean plots of the summarized data for the selected percentage ranges shown.

An attempt has been made to show the linear interpretation of each plot as follows:

(1) Included left turns — Subtract 2 percent for each 1 percent of left turning traffic less than 10 percent of the total approach, and subtract ½ percent for each 1 percent of left turning traffic over 10 percent of the total approach volume.

(2) Included commercial vehicles — Subtract 1 percent for each 1 percent of commercial traffic less than 20 percent of the total approach, and subtract 2½ percent for each 1 percent of commercial traffic over 20 percent of the total approach volume.

(3) Opposing left turns — Subtract 2½ percent (max. 50 percent) for each 1 percent that the opposing lefts are of the fully loaded approach.

SUMMARY

The preceding study is not an attempt to introduce new theories of intersection capacity measurement, but instead attempts to compare existing local capacities to the average reported capacities of the Highway Capacity Manual.

The comparisons indicate that existing intersection approach volumes, when under pressure, are greater than might be expected. One of the narrowest streets studied, 33 ft wide with 16.5-ft approaches, showed an adjusted capacity of 1,470 vehicles per hour of green as compared to the average reported capacity of 1,030. This is an increase of 43 percent over those calculated from the manual.

Thirteen streets of the common 40 ft width were analyzed and averaged an adjusted capacity of 2,100 vehicles per hour of green, compared to 1,340 as reported in the manual.

Very wide streets of approximately 80 ft widths, with 40-ft approaches indicated adjusted capacities as high as 5,780 vehicles per hour of green compared to reported capacities of 2,160 vehicles per hour of green. The average adjusted capacity of all streets in the range over 65 ft has been found to be 106 percent greater than that reported in the manual.

As outlined, 10 ft is the width deemed standard for one approach traffic lane. It is not uncommon at local intersections to have pressurized traffic form 8 or 9 ft traffic

TABLE I

SUMMATION OF CALCULATIONS

Part A Approach	Tot. St. Width (Ft.) 1	Time of Day 2	Cycle Length (sec) 3	Signal Phase 4	Veh/Hr. 5	% Comm. 6	% Right Turn 7	% Left Turn 8	Bus Stops on Near Side 9	Combined Adjustment Factor 10	Sec Green/Cycle 11	Capacity Load Factor 12	Approach Width (Ft.) 13	Veh/Hr Gr Per Approach Width 14	Veh/Hr Gr Per Tot. Width 15
1	64	3-4 pm	90	thru & left	1098	12.3	0	0	No.	1.188	26	1.1	21.5	2900/21.5	3768/64
				right	730	9.5	-	-	No.	1.06	65	1.1	10.5	868/turn	
2	64	3-4 pm	90	thru & left	983	10.0	0	9.9	No.	1.102	26	1.1	21.5	2800/21.5	3075/64
				right	155	5.5	-	-	No.	1.102	51	.9	10.5	275/turn	
3	40	3-4 pm	90	thru & left	895	10.1	0	14.0[1]	No.	1.08	33	1.1	10.0	2050/10	2250/40
				right	131	25.0	-	-	No.	.892	61	1.1	10.0	200/turn	
4	50	3-4 pm	90	thru & left	646	10.0	0	20.0[1]	No.	1.05	22	.9	20.0	2800/20	2916/60
				right	115	5.5	-	-	No.	1.102	90	.9	10.0	116/turn	
5	80	3-4 pm	140	full	1653	14.6	11.3	0.4	Yes	.935	67	1.1	40.0	3370/40	3370/80
6	94	7-8 am	140	full	2440	7.6	6.1	1.3	Yes	1.02	67	1.1	47.0	4550/47	4550/94
7	70	7-8 am	140	full	676	22.0	1.3	41.0[1]	Yes	.70	36	1.1	35.0	3430/35	3430/70
8	80	3-4 pm	140	full	882	35.0	1.6	52.0[4]	Yes	.77	33	1.1	40.0	4420/40	4420/80

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
9	78	7-8 am	140	full	2248	7.7	0.3	69.5(4)	Yes	.97	51	1.1	39.0	5780/39	5780/78
10	40	3-4 pm	78	full	1176	0.6	4.7	18.1	No	1.08	45	.9	20.0	2090/20	2090/40
11	40	12-1 pm	78	full	983	0.0	6.2	25.6	No	1.00	45	.9	20.0	1895/20	1895/40
12	40	10-11 am	78	full	984	1.1	13.6	1.0	No	1.22	45	.9	20.0	1550/20	1550/40
13	33	12-1 pm	78	full	323	15.5	10.8	13.4	No	.95	20	.9	16.5	1470/16.5	1470/33
14	40	1-2 pm	76	full	878	0.5	2.3	7.5	No	1.21	40	.9	20.0	1530/20	1530/40
15	38	3-4 pm	76	full	1160	0.0	5.7	1.3	No	1.22	50	.9	19.0	1610/19	1610/38
16	42	12-1 pm	76	full	405	18.2	18.7	7.2	No	.95	21	.9	21.0	1710/21	1710/42
17	40	3-4 pm	40	full	1061	0.3	1.4	2.6	No	1.29	21	.9	20.0	1750/20	1750/40
18	40	7-8 am	40	thru & left right	1589 212	0.6 7.6	0.5 -	0 -	No No	1.32 1.075	21 37	.9 .9	10.0 10.0	2540/10 235/turn	2775/40
19	50	4-5 pm	40	full	600	5.2	2.7	53.0	Yes	.78	13	1.1	25	2150/25	2150/50

TABLE 1 (Continued)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
20	40	3-4 pm	110	full	1202	8.3	1.6	10.2	No	1.115	75	.9	20	1755/20	1755/40
21	40	7-8 am	110	full	2174	3.6	1.2	7.0	No	1.205	75	1.1	20	2410/20	2410/40
22	40	4-5 pm	110	full	1928	3.2	0.6	10.1	No	1.17	75	1.1	20	2200/20	2200/40
23	40	3-4 pm	110	full	1570	3.9	1.7	11.0	No	1.15	75	.9	20	2220/20	2220/40
24	30	4-5 pm	110	full	551	4.3	83.0	14.5	No	.88	25	1.1	20	2500/20	2500/40
Part B															
25	80	3:30-4 pm (2)		full	866	16.2	10.0	0.0	Yes	.93	810	1.1	40		3760/80
26	80	3-4 pm (3)		full	1596	16.5	10.0	1.0	Yes	.915	1550	1.1	40		3680/80
27	70	3:30-4 pm (2)		full	261	44.5	29.1	3.4 (1)	Yes	.551	436	.9	35		4350/70
28	70	3-4 pm (3)		full	233	50.0	24.2	4.3 (1)	Yes	.515	336	1.1	35		4410/70
29	80	3:30-4 pm (2)		full	435	23.6	5.0	54.0 (4)	Yes	.797	375	1.1	40		4760/80
30	80	3-4 pm (3)		full	748	25.8	3.2	51.8 (4)	Yes	.783	644	1.1	40		4850/80

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
31	40	4-4:30 pm (2)		full	935	0.0	3.0	0.5	No	1.305	1020	1.1	20		2310/40
32	47	3:30-4 pm (2)		full	575	0.5	0.0	3.0	No	1.31	1020	.9	23.5		1720/47
33	47	3-5 pm (3)		full	646	1.0	0.0	4.2	No	1.27	589	1.1	23.5		2820/47

(1) 3 Phase Signal, Treat Left Turns same as Right Turn Adjustments
(2) Peak 1/2 Hour
(3) Using Fully Loaded Phases Per Peak Hour
(4) Because of Intersection Design & Volume Treat Left Turns As Through Traffic

Part A - Using Standard Hourly Traffic Count Data
Part B - Using Special Phase Count Data

lanes. At one approach it was recorded that traffic formed a 6-car approach front on approximately 42 ft of an 80 ft street (Fig. 14). This is an exceptional case.

Further study might prove that specific ranges of approach widths increase greatly in capacity during pressurized congestion, due primarily to the possibility of an extra lane.

An attempt has been made to check the reductive effect of the included commercial traffic and of the various traffic movements. The effective reductions are similar to those presented by the manual. However, the reductive effect of the opposing left turn is probably sufficient to be evaluated alongside the usual lefts, rights and commercial percentages.

Figure 14. An approach loaded to maximum possible capacity. (Note 6 lanes of vehicles)

The basic theory and principles used in the outlined theory of analysis somehow lack certain tangible influences. The manual, under its introduction to signalized intersections, has expressed concern that no existing data is available on certain perlexing factors influencing the capacity. Is it possible that such factors as local highway laws, the degree of highway law enforcement, driver habits, the quality of vehicles, or the degree of over-all congestion have such an effect? No allowance has been made, by either the manual or this study, for side clearances, type of curb, etc. The majority of the intersections in this study are not of a high design, and if additional adjustments providing for poor clearances were made, it is possible that the comparable adjusted capacities would be somewhat higher. The factor having the greatest influence on the capacities found locally was the turning movement. The right turns appeared to cause far less congestion, for a given percent right turning, than the manual indicates.

The indications are that locally 40 percent right turns cause about the same percent reduction (10 percent) in capacity as the 10 percent right turns shown in the manual.

Left turns studied appeared to have a greater initial effect under "pressurized conditions" than the manual indicates. However, this effect appears to lessen on approaches carrying over 20 percent left turning traffic. The local data also indicates that when left turning volumes are equal to, or greater than, 50 percent of the total approach they operate as through traffic with little reductive effect. This is believed to be peculiar to intersections where the major movement is the left turn and the peak condition involves primarily the same daily commuter traffic.

The effect of commercial vehicles was found consistent with that proposed by the manual in the range of 0 to 20 percent. The data indicates a greater effect than that outlined in the manual due to the presence of commercial vehicles when they make up over 20 percent of the total approach volume.

SUMMATION OF CALCULATIONS

All raw data and calculations have been summarized in Table 1. The combined adjustment factor, standardizing traffic to average conditions, is listed under column 10. It is obtained by multiplying together the group of individual adjustments obtained by the traffic characteristics (see sample calculations).

The capacity load factor, indicating if measurements were made under possible or practical conditions, is listed under column 12. A factor of 1.1 indicates that actual field measurements were made under maximum possible capacity condition, whereas 0.9 indicates the traffic count taken during periods of practical capacity condition.

The vehicles per hour of green, comparable to the plot of average reported capacities, is obtained by dividing the volume count by the combined adjustment factor, the capacity load factor, and the seconds of green per seconds of total cycle.

Capacities have been listed for total street widths and for approach widths. Approach widths are equal to one-half of the total street width except for those specific streets where lane marking indicates otherwise. On approaches with separate signal phases, the left-turn movement has been adjusted as right turns, because of the lack of conflicting traffic. Left turn movements were treated as through traffic when in the order of 50 to 70 percent of the total approach volume and protected by signals.

KEY TO APPROACH NUMBERS

	Approach	Map Key
1.	Northern Artery northbound at Prison Point Bridge	A
2.	Northern Artery southbound at Prison Point Bridge	A
3.	Prison Point Bridge at Northern Artery	A
4.	Commercial Avenue at Northern Artery	A
5.	Northern Artery northbound at Washington Street	B
6.	Northern Artery southbound at Washington Street	B

KEY TO APPROACH NUMBERS (Continued)

		Map Key
7.	Washington Street westbound at Northern Artery	B
8.	Washington Street eastbound at Northern Artery	B
9.	Northern Artery southbound at Somerville Avenue	C
10.	Memorial Drive westbound at River Street	D
11.	Memorial Drive westbound at River Street	D
12.	Memorial Drive eastbound at River Street	D
13.	River Street southbound at Memorial Drive	D
14.	Memorial Drive westbound at Western Avenue	E
15.	Memorial Drive eastbound at Western Avenue	E
16.	Western Avenue southbound at Memorial Drive	E
17.	Fresh Pond Parkway northbound at Huron Avenue	F
18.	Fresh Pond Parkway southbound at Huron Avenue	F
19.	Huron Avenue eastbound at Fresh Pond Parkway	F
20.	Alewife Brook Parkway southbound at Rindge Avenue	G
21.	Alewife Brook Parkway southbound at Rindge Avenue	G
22.	Alewife Brook Parkway northbound at Rindge Avenue	G
23.	Alewife Brook Parkway northbound at Rindge Avenue	G
24.	Rindge Avenue westbound at Alewife Brook Parkway	G
25.	Northern Artery northbound at Washington Street	B
26.	Northern Artery northbound at Washington Street	B
27.	Washington Street westbound at Northern Artery	B
28.	Washington Street westbound at Northern Artery	B
29.	Washington Street eastbound at Northern Artery	B
30.	Washington Street eastbound at Northern Artery	B
31.	Wm. T. Morrissey Boulevard southbound at Redfield Street	H
32.	Wm. T. Morrissey Boulevard northbound at Redfield Street	H
33.	Wm. T. Morrissey Boulevard northbound at Redfield Street	H

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REFERENCES

1. Highway Capacity Manual, Committee on Highway Capacity, Department of Traffic and Operations, Highway Research Board, United States Government Printing Office, Washington, D.C., 1950.