Effect of Traffic Improvements on Operation Of an Urban Arterial Street

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● IN 1959, a study was undertaken to evaluate methods for "Increasing the Traffic Carrying Capability of Urban Arterial Streets." This study, which was made on 4½-mi-long Wisconsin Avenue in Washington, D.C., became popularly known as the "Wisconsin Avenue Study" (1).

In 1960, the first of a proposed continuing series of Wisconsin Avenue "after" studies was made, the basic objective being to determine to what extent certain traffic engineering improvements adopted in the interval of time since the original study was made, had affected the capacity, the traffic volumes carried, the speeds, and the travel time. Essentially, these improvements on the arterial included removal of streetcars and loading platforms, establishment of new parking and turn regulations, and changes in signal timing.

The after study consisted of an inventory of the traffic engineering features as they existed on Wisconsin Avenue during the spring of 1960, of field studies of eight critical intersections during peak periods, and of test vehicle runs to determine current speeds and travel times. Speed data, traffic counts, and intersection studies supplied by the District of Columbia Department of Highways and Traffic also were used in evaluating the results. No attempts were made to restudy traffic friction events, to conduct further galvanic skin resistance (GSR) tests, or to repeat several related studies made in the original 1959 study. Figures 1 through 3 show the study street.

CHANGES IN THE STREET

The improvements recommended in the original Wisconsin Avenue report were classified into three phases, as follows:

Phase 1—those possible at relatively little or no cost;
Phase 2—those requiring moderate expenditures; and
Phase 3—those requiring major expenditures and construction.

An inventory, comprising a series of field checks complemented by information received from the District of Columbia Department of Highways and Traffic, was made to determine by phase the improvements that had been effected. Of the eleven improvements suggested for phase 1, only one, the conversion of the transit line from streetcar to bus operation, had been fully adopted at the time this study began in April 1960. Three other phase 1 improvements pertaining to turning movement controls, removal of parking, and one-way streets had been partially adopted. Lane markings, control of U-turns, controls on turning movements in midblock, and improvements to off-street parking area operation had not been effected. Except for the signal progression, none of the improvements recommended in phases 2 and 3 had been undertaken.

The specific changes revealed by the inventory were as follows:

1. The transit system had been converted from a streetcar to a bus operation for about 3 months. The loading platforms had been removed, but the streetcar tracks still remained.

2. All parking on Wisconsin Avenue in Georgetown had been prohibited during peak hours. From R Street to Massachusetts Avenue "no standing" regulations were in force from 7 to 9:30 a.m. on the west side and from 4 to 6:30 p.m. on the east side. "No parking" regulations were in force on the opposite side of the street during these

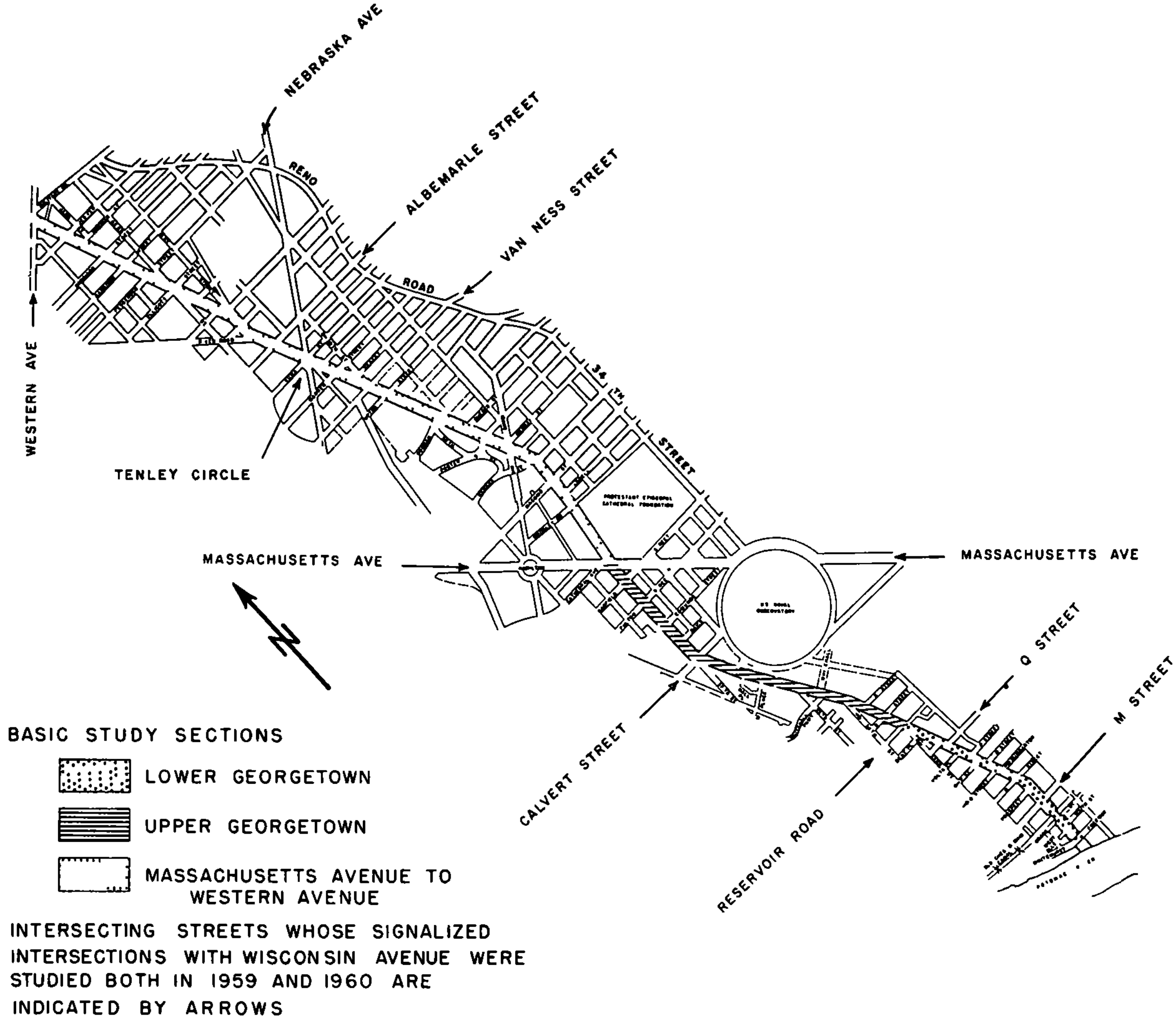


Figure 1. Wisconsin Avenue and vicinity, Washington, D. C.

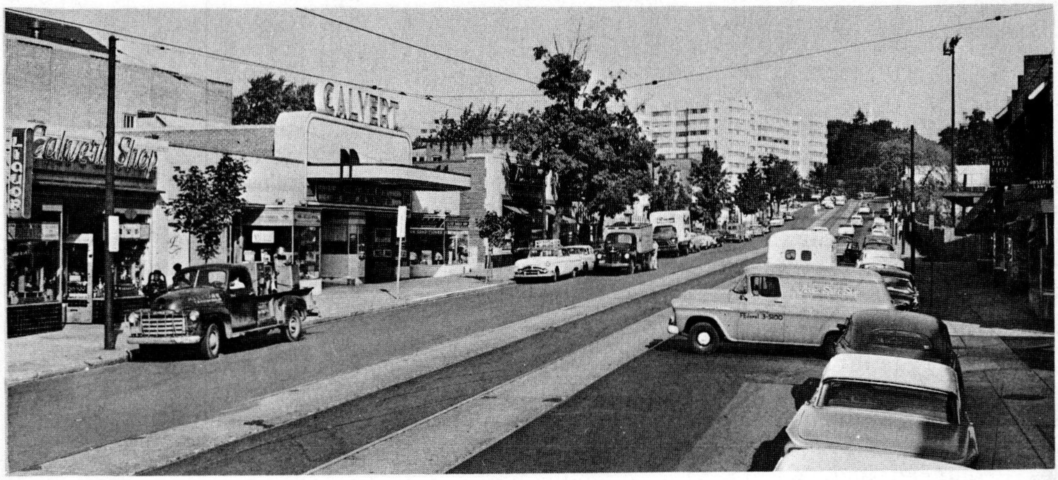


Figure 2. Looking north on Wisconsin Avenue toward the Calvert Street intersection, from Observatory Lane, during off-peak conditions.

periods, except that "no standing" regulations were in force between Garfield Street and Massachusetts Avenue from 4 to 6:30 p.m. on the west side.

3. There had been relatively little change in parking regulations north of upper Georgetown since the original study. Areas north of Massachusetts which were scheduled to be affected by similar new "no parking" and "no standing" regulations had not yet been signed, except at the intersections at Van Ness Street and at Western Avenue.

4. Left turns had been prohibited from Wisconsin Avenue into Massachusetts Avenue, Tenley Circle, and Western Avenue. Also traffic westbound on M Street and on Western Avenue, and traffic both eastbound and westbound on Massachusetts Avenue, had been denied left turns into Wisconsin Avenue. At Tenley Circle direct left turns into Wisconsin Avenue had been eliminated; instead, traffic was routed around the circle to turn right into the Wisconsin Avenue traffic stream.

5. Thirty-seventh Street had been made one-way southbound from Wisconsin Avenue to Tunlaw Road, and Thirty-ninth Street one-way northbound from Veazey Street to Albemarle Street.

6. A progressive signal system had been provided with progression set for 25 mph. It favored the northbound traffic during the afternoon peak period and the southbound traffic during the morning peak period and was radio-controlled from Q Street to Massachusetts Avenue. A 65-sec cycle was being used in the off-peak hours at all intersections except M Street and Western Avenue where a 90-sec cycle and an 80-sec cycle, respectively, were used at all times. The other intersections were on an 80-sec cycle during peak hours. Rodman Street was the only intersection which was signalized during the after study but not during the before study.

BASIC FACTORS CONSIDERED

For the purposes of comparison, Wisconsin Avenue was divided into three sections as in the original study. These are (a) lower Georgetown—K Street to Reservoir Road; (b) upper Georgetown—Reservoir Road to Massachusetts Avenue; and (c) north of Massachusetts—Massachusetts Avenue to Western Avenue. The factors to be compared for each section, as indicators of improved operation, were intersection traffic volumes, number of "loaded" (that is, fully utilized) signal cycles, and speeds, including average speeds, running speeds, and number of stops.

Careful consideration was given to the choice of factors to be used as indicators of improved operation. The following paragraphs contain brief justifications for the use of each factor as an indicator, and discuss the methods used for obtaining and using the data.

Volumes

Generally on a well-established arterial, only gradual increases in volume are noted, year after year. If larger than expected increases are noted, it is very likely that something has been done to attract this increased traffic. Any improvement in the traffic-carrying capability of the street would of course provide such an attraction.

Manual counts were used to obtain volumes on Wisconsin Avenue at selected intersections. Because it was not possible to study all of the intersections included in the before study, it was necessary to consider two methods of comparing the volume data obtained in the two studies, as follows:

1. Average directional peak-hour volumes for the selected intersections in the after study were compared with the corresponding average directional volumes for all of the intersections in the before study. Use of this method meant, for each of the three street sections, comparing a small number of intersections in the after study with the larger number included in the before study.
2. Average directional peak-hour volumes for the selected intersections in the after study were compared with the average directional volumes for only the same intersections in the before study. This method limits the before and after comparisons to the

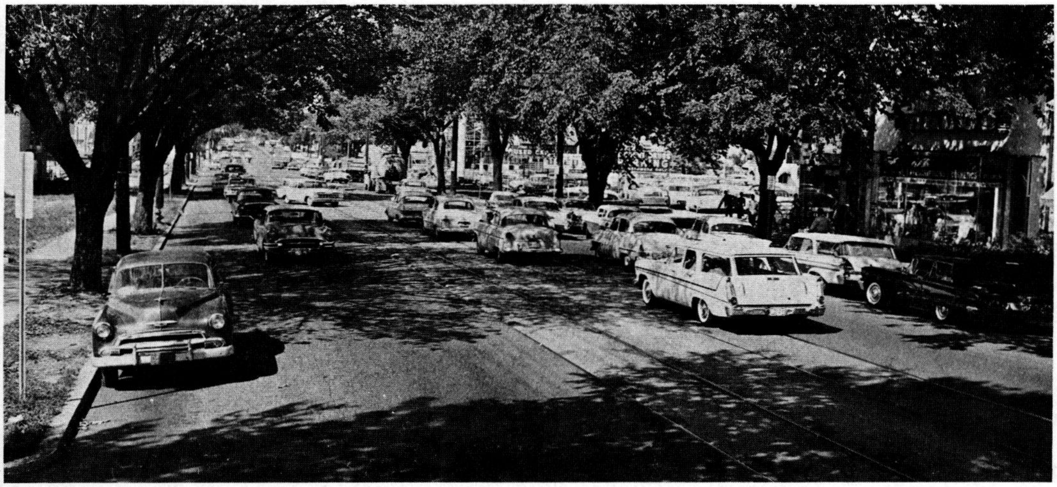


Figure 3. Looking north on Wisconsin Avenue toward the D. C.-Md. line at Western Avenue, Northern terminus of the study, from north of Jenifer Street, shortly before the P.M. peak period.

intersections studied in the after study. It was concluded that the second method, although not using all of the available 1959 data, gave the most valid comparisons. Consequently, this is the method on which the volume comparisons cited in the report were based, although both methods are treated in the tabular summaries of data.

Generally, approach volumes at the intersections were used in computing average volumes for each of the three sections of Wisconsin Avenue. Three exceptions were made at points where it was felt that a true picture of the actual volumes within the section being discussed required use of the volumes leaving the intersection, due to major turning movements occurring at the intersection. For the northbound traffic flow it was felt that volumes leaving the intersection at M Street were more representative of lower Georgetown as a whole than the approach volumes at the same point. Similar reasoning dictated that traffic leaving the intersection at Calvert Street should be used in computing southbound volumes for the upper Georgetown section, and that traffic leaving Massachusetts Avenue should be used in computing the northbound volumes for the section north of Massachusetts Avenue.

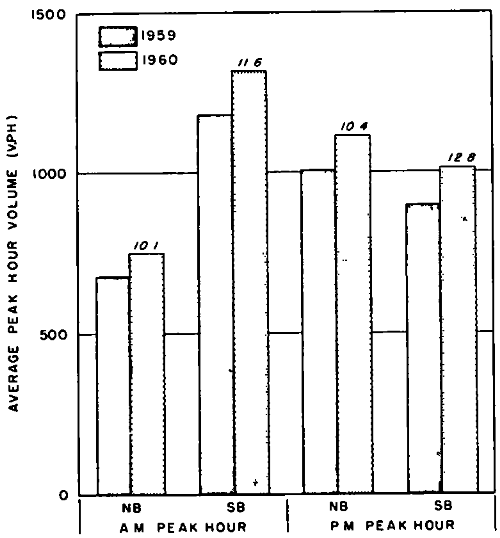
Loading

A good index of the congestion at a signalized intersection is the number of "loaded," or fully utilized, cycles at that intersection. Briefly, a loaded cycle on a specific intersection approach is one in which all lanes of that approach are fully utilized throughout the green period, either by a continuous flow of traffic or by traffic present and ready to move, but blocked by conditions within that intersection. For any given intersection, loading is usually expressed as the percentage of loaded cycles among the total number of cycles occurring during the peak hour.

In analyzing the intersection data it became necessary to relate loaded cycle time to intersection capacity. In theory it is possible to have 100 percent loaded cycle time when the intersection is operating at practical capacity. Again, according to theory, it is possible for the intersection to be operating very close to practical capacity and not have any loaded cycles during the period studied.

In actual practice the occurrence of either of these conditions is very rare. The following conclusions were reached based on field observations:

1. If the recorded data indicate intermittent cycle loading, the intersection is carrying volumes close to the practical capacity of that intersection.
2. If the recorded data show a sustained period of loaded cycles, the intersection, during that period, is carrying volumes greater than the practical capacity of that intersection.



(FIGURES IN ITALICS ARE PERCENT INCREASE, 1960 FROM 1959)

Figure 4. Average peak-hour traffic volumes at eight intersections on Wisconsin Avenue (K Street to Western Avenue), which were studied both in 1959 and 1960.

In the original Wisconsin Avenue study it was pointed out that, insofar as the study street was concerned, the capacity was governed more by frictional features throughout the street than by intersection considerations. It was further pointed out that the first step in increasing the capacity of the street was the elimination of the turbulence produced by frictional factors.

If intersection considerations are to become governing factors in the operation of the street, midblock sections must be capable of supplying the intersection with sufficient traffic to permit them to operate at least at practical capacity. If this happened, development of a small amount of loaded cycle time would be evident at those intersections previously operating below practical capacity.

However, to insure a smooth flow of traffic, it is necessary to insure that the intersections do not so limit the traffic that they become bottlenecks or metering points. This situation would be indicated by a large increase in loaded cycle time. Of course the most desirable objective is to produce an integral system in which the practical capacities of the street sections are equal to the practical capacities of the intervening intersections.

Loading conditions were recorded for each signal phase of each signal cycle by the field parties making the intersection studies. Direct comparisons were made of the before and after loading values of the eight intersections studied both times. In addition, a general picture was given by comparing loading within study sections, as a whole. The percent of loaded cycles reported for each of the three sections of the street is an average of the loading occurring at the selected intersections studied in that section.

TABLE 1

PEAK-HOUR TRAFFIC VOLUMES, APPROACHING AND LEAVING ALL INTERSECTIONS STUDIED ON WISCONSIN AVENUE (VEHICLES PER HOUR) 1959-1960

	Northbound A.M.				Southbound A.M.				Northbound P.M.				Southbound P.M.			
	Approaching		Leaving		Approaching		Leaving		Approaching		Leaving		Approaching		Leaving	
Intersection	1959	1960	1959	1960	1959	1960	1959	1960	1959	1960	1959	1960	1959	1960	1959	1960
M Street	216	249	538	583	597	748	537	538	319	563	549	832	551	710	251	289
Prospect Street	527		537		572		619		607		554		551		565	
N Street	529		514		502		519		547		546		549		536	
P Street	605		517		756		558		634		717		721		772	
Q Street	475	577	508	667	737	861	608	748	572	812	647	936	573	705	492	639
Reservoir Rd.	511		405		523		734		668		465		504		458	
R Street	527		619		633		565		624		962		594		595	
34th Street	605		569		1,090		866		1,067		1,052		728		528	
Whitehaven St.	563		533		1,006		1,155		1,103		955		734		793	
35th Street	553		739		1,192		1,008		952		1,105		1,007		738	
W Place	755		749		985		1,101		1,122		1,079		931		963	
Hall Place	779		769		1,094		1,073		1,292		1,289		1,039		1,073	
Calvert Street	696	779	781	769	747	888	1,062	1,100	1,075	1,267	868	1,107	720	910	946	1,050
Edmunds Street	588		615		845		832		872		936		763		847	
Mass. Avenue	537	610	826	868	1,105	1,160	611	1,297	744	796	1,008	1,112	926	995	672	1,202
Woodley Road	790		797		1,124		1,161		945		1,004		976		1,011	
Macomb Street	800		886		1,160		1,194		1,020		1,064		931		963	
Newark Street	803		754		1,077		1,104		1,134		1,096		921		919	
Idaho and Ordway	746		688		1,221		1,152		1,081		1,042		1,026		1,035	
Porter Street	752		879		1,178		1,258		1,139		1,283		993		1,027	
Rodman Street	879		896		1,220		1,167		1,021		1,053		912		869	
Van Ness Street	851	938	816	881	1,426	1,561	1,506	1,674	1,395	1,376	1,366	1,357	1,019	1,105	1,130	1,201
Tenley Circle So.	677	786	740	844	1,219	1,603	1,269	1,641	1,089	1,169	1,193	1,244	1,014	1,112	1,075	1,159
Tenley Circle No.	740	844	758	851	1,338	1,607	1,219	1,603	1,193	1,244	1,221	1,284	1,045	1,250	1,014	1,112
Albemarle Street	781	817	821	878	1,514	1,689	1,561	1,698	1,192	1,197	1,328	1,337	1,118	1,148	1,106	1,111
River Road	770		662		1,189		1,180		1,281		1,044		831		818	
Fessenden Street	586		611		1,136		1,230		950		1,000		824		837	
Western Avenue	566	578	753	809	1,636	1,539	1,339	1,204	1,009	1,017	1,196	1,224	889	1,042	683	784

The average for a section was computed by totaling the number of loaded cycles occurring during the peak hour at the selected intersections within that section and dividing that total by the total number of cycles in that section for the peak hour.

For example, suppose there are six intersections in a section, five of which have 80-sec cycles and one has a 90-sec cycle. The intersections with an 80-sec cycle have 45 cycles during the peak hour and the intersection with the 90-sec cycle has 40 cycles during the peak hour. Thus, the base number of cycles is the total number of cycles occurring in the section during the peak hour. In this case, it is 265 total cycles. Assume that the total number of loaded cycles occurring in that section is 27, then the result is 27 divided by 265, or 10.2 percent loaded cycle time.

Speeds

An increase in average speeds through a section of highway indicates that traffic is encountering fewer stops, or that it is moving faster between stops, or both. Increases in running speeds (that is, speeds between stops) more directly reflect midblock performance because most of the effect of stops is eliminated. However, running speed values do reflect decelerations to and accelerations from stops.

The travel speed studies were made by means of the test car in exactly the same manner as in the original study, the study street again being divided into ten control sections. This being the case, the results are directly comparable and all of the data obtained in both studies have been used in making these comparisons. The speed data for the ten control sections were consolidated into the same three basic sections used for comparative purposes.

TABLE 2

AVERAGE PEAK-HOUR TRAFFIC VOLUMES ON WISCONSIN AVENUE (VPH)

		Volume 1959		Volume 1960	Percent Increase	
Location	Direction and Time	All Available Intersections	Intersections Studied Both Years	All Intersections Studied	All Available Intersections	Intersections Studied Both Years
Lower Georgetown	NB AM	531	506	580	+9.2	+14.6
	SB AM	615	667	805	+30.9	+20.9
	NB PM	596	561	822	+37.9	+46.5
	SB PM	575	562	708	+23.1	+26.0
Upper Georgetown	NB AM	633	696	779	+23.1	+11.9
	SB AM	988	1,062	1,100	+11.3	+3.6
	NB PM	1,013	1,075	1,267	+25.1	+17.9
	SB PM	843	946	1,050	+24.6	+11.0
North of Mass. Ave.	NB AM	755	740	805	+6.6	+8.8
	SB AM	1,253	1,373	1,526	+21.8	+11.2
	NB PM	1,104	1,148	1,186	+7.4	+3.3
	SB PM	959	1,002	1,109	+15.6	+10.7
Over-all	NB AM	672	683	752	+11.9	+10.1
	SB AM	1,041	1,182	1,319	+26.7	+11.6
	NB PM	969	1,009	1,114	+15.0	+10.4
	SB PM	843	898	1,013	+20.6	+12.8

The speeds obtained from these data are the average speed and the average running speed as determined by the test car method. The average speed is based on the total time needed to traverse a section and includes all stops. The average running speed is the average obtained when the test car was traveling at speeds above 2 mph when decelerating and above 5 mph when accelerating.

"BEFORE" AND "AFTER" RESULTS

Volumes

The intersection studies showed increases in traffic volumes on Wisconsin Avenue, as given in Tables 1 and 2. In considering the results, it must be stressed that at the time of the after study the streetcars and loading platforms had been removed for only 3 months, and the major changes in parking regulations below Massachusetts Avenue had been in effect for less than 2 months. Still, over-all increases for the entire street ranged from about 10 to 13 percent, whereas average traffic volumes in the District of Columbia as a whole showed no change from 1959 to 1960. Average peak-hour volumes in the after study, for the street as a whole (Fig. 4), ranged from a minimum of 752 vph northbound during the morning to a maximum of 1,319 vph southbound during the morning, as compared, respectively, to 683 vph and 1,182 vph in the before study. For the individual sections (Fig. 5), the increases in directional peak period volumes ranged from a maximum of 47 percent for p.m. northbound traffic in lower Georgetown to a minimum of only 3 percent for p.m. northbound traffic on the section of the street north of Massachusetts Avenue.

Northbound volumes in lower Georgetown during the afternoon peak period increased from an average of 561 vph in the before study to an average of 822 vph in the after study, or an increase of about 47 percent. Increases in the southbound direction amounted to 26 percent during the same period. During the morning peak hour in this section increases of 21 percent southbound and 15 percent northbound were recorded. In the heavy direction of flow, southbound in the morning, the increase was considerably less than the 50 percent predicted in phase 1 in the Wisconsin Avenue Report. Nevertheless, it is evident that, considering the short period of time elapsing since the improvements were effected and the fact that all of the improvements included in phase 1 had not yet been undertaken, the results are impressive.

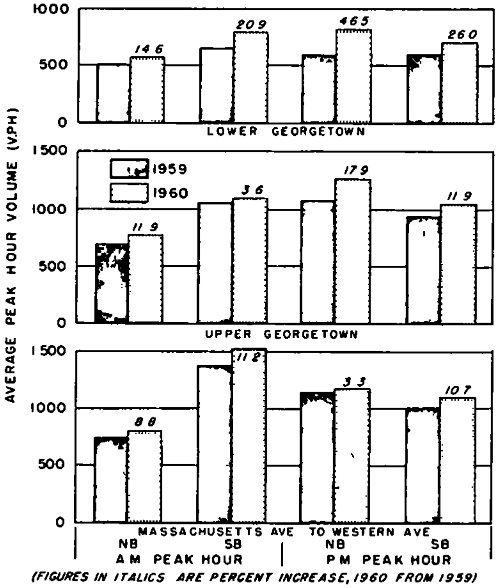


Figure 5. Average peak-hour traffic volumes, by section, at intersections on Wisconsin Avenue studied both in 1959 and 1960.

Volumes in upper Georgetown, northbound in the afternoon, increased from an average of 1,075 vph in the before study to an average of 1,267 in the after study. This is an increase of about 18 percent. However, the morning peak showed an increase of only 4 percent in the southbound, heavy flow direction, from 1,062 vph to 1,100 vph. Traffic which formerly turned left from the east leg of Calvert Street into the southbound traffic flow on Wisconsin Avenue now has been diverted from the entire area. Most of this traffic turned left into Observatory Circle from westbound traffic on Massachusetts Avenue. These left turns at Observatory Circle are no longer allowed; thus a relatively large southbound traffic volume has been removed from Wisconsin Avenue in this area. It would be purely a matter of conjecture to try to define the new route of this traffic. However, a study of the available traffic data and of the geographical nature of the area in question indicates that the traffic which formerly entered this section via Observatory Circle and Calvert Street now does not enter Wisconsin Avenue anywhere in this neighborhood.

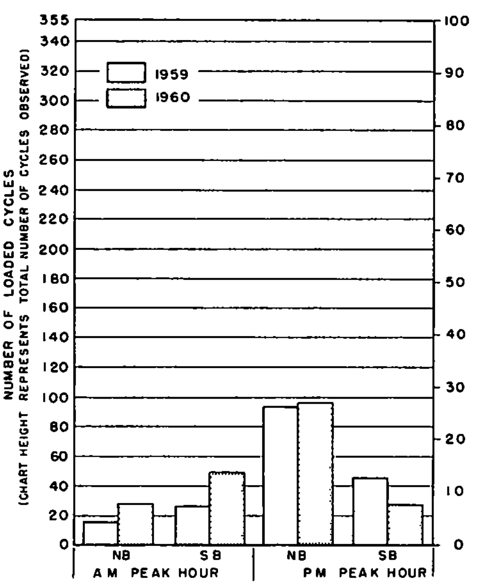


Figure 6. Number of loaded cycles at eight intersections on Wisconsin Avenue, (K Street to Western Avenue), studied both in 1959 and 1960.

In the section north of Massachusetts Avenue, the volume southbound in the morning peak increased from 1,373 vph during the before study to 1,526 vph during the after study, or an increase of 11 percent. The increase in volume northbound in the afternoon amounted to 3 percent.

Observations of the traffic on Wisconsin Avenue indicate that the remaining streetcar tracks affect the capacity of the street to a greater degree than was anticipated, due, at least in part, to the absence of lane markings. It was noted that most drivers will not drive in the area containing the tracts if they can possibly avoid it. It is estimated that removal or covering of the car tracks combined with provision of lane markings will further increase the volumes by 10 to 15 percent.

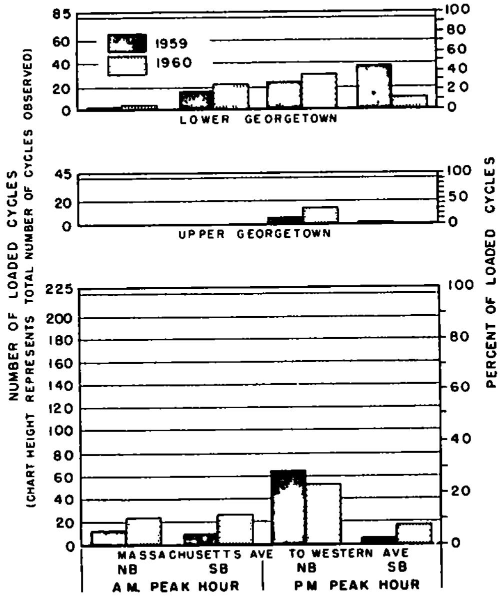


Figure 7. Number of loaded cycles by section, direction, and time period, at intersections studied both in 1959 and 1960.

Loaded Signal Cycles

Table 3 gives the signal cycle data, and Tables 4 and 5 the loaded cycle conditions, at the eight intersections along the entire length of Wisconsin Avenue which were studied, both in 1959 and 1960. Average before and after loading conditions at these intersections are shown in Figure 6. The total number of cycles studied, including all of the selected intersections, is 355 as indicated by the left-hand scale of the figure. Subsequent Figures 7 through 9 show loading conditions by section and by intersection, the base number of cycles studied being similarly shown by the left-hand scale. The right-hand scale in these four figures shows the percentage of loaded cycles.

For all practical purposes there was no change in average loading in the northbound traffic flow in the afternoon. Loaded cycle time increased by 4 percentage points, northbound in the morning. A 7 percentage point increase in loaded cycle time was noted for the southbound traffic flow in the morning and a decrease of about 5 percentage points for the same direction in the afternoon.

TABLE 3

SIGNAL CYCLE DATA FOR PEAK PERIODS, AT INTERSECTIONS ON WISCONSIN AVENUE STUDIED BOTH YEARS

Intersecting Street	Cycle Length, Sec., (Same in Both A.M.&P M.)		Percent Green Time on Approach: N.B., A.M.		S.B., A.M.		N.B., P.M.		S B., P.M	
	1959	1960	1959	1960	1959	1960	1959	1960	1959	1960
M St.	90	90	23.3	23.3	23.3	23.3	23.3	23 6	23.3	24.6
G St.	80	80	43.8	43.8	43.8	43.8	43.8	43.8	43.8	43.8
Calvert St.	80	80	42.5	58.8	37.5	48.8	42.5	56.2	37.5	38.8
Garfield St.[a]	—	80	—	22.5	—	70.0 T. 45.0 L.	—	40.0	—	72 5 T. 32.5 L.
Mass. Ave.	80	80	18.8	42.5	48.8 T. 30.0 L.	42.5	27.5	36.2	51.3 T. 23.8 L.	36.2
Van Ness St.	80	80	63.8	63.8	63.8	63.8	63.8	63.8	63.8	63.8
Tenley, So.	80	80	52.5	57.5	52.5	57.5	52.5	57 5	52.5	57.5
Tenley, No.	80	80	52.5	57.5	52.5	57.5	52.5	57 5	52.5	57.5
Albemarle St.	80	80	57.5	57.5	57.5	57.5	57.5	57 5	57.5	57.5
Western Ave.	80	80	40.0	37.5	57 5 T.&R. 12.5 L.	57.5 T.&R. 12.5 L.	40.0	57.5	57 5 T.&R. 12.5 L.	57.5 T.&R. 12.5 L.

[a] Garfield Street was not signalized in 1959. It is included in this table because it was an integral part of the Massachusetts-Wisconsin intersection "complex" in 1960.

TABLE 4

COMPARISON OF LOADED SIGNAL CYCLE CONDITIONS ON WISCONSIN AVENUE BY SECTIONS, 1959-1960

Section of Street	Total No. of Cycles Studied in Peak Hour (same both yrs.)	No. of Loaded Cycles		Difference in No. of Loaded Cycles	Percent Loaded Cycles		Difference in Percent Loaded Cycle Time	No. of Loaded Cycles		Difference in No. of Loaded Cycles	Percent Loaded Cycles		Difference in Percent Loaded Cycle Time
		1959	1960		1959	1960		1959	1960		1959	1960	
(a) A.M.													
		Northbound						Southbound					
Lower Georgetown	85	2	4	+2	2.3	4.7	+2.4	16	22	+6	18.8	25.8	+7.0
Upper Georgetown	45	0	0	0	0	0	0	0	0	0	0	0	0
North of Mass	225	13	24	+11	5.8	10.7	+4.9	10	27	+17	4.4	12.0	+7.6
Over-all	355	15	28	+13	4.2	7.9	+3.7	26	49	+23	7.3	13.8	+6.5
(b) P.M.													
		Northbound						Southbound					
Lower Georgetown	85	24	30	+6	28.2	35.2	+7.0	37	10	-27	43.5	11.7	-31.8
Upper Georgetown	45	5	13	+8	11.1	28.9	+17.8	2	0	-2	4.4	0	-4.4
North of Mass.	225	65	53	-12	28.9	23.6	-5.3	6	17	+11	2.7	7.6	+4.9
Over-all	355	94	96	+2	26.4	27.0	-0.6	45	27	-18	12.7	7.6	-5.1
(c) A.M. and P.M. Combined													
Entire Street[a]	1,420	180	200	+20	12.7	14.1	+1.4	-	-	-	-	-	-

[a] Northbound and Southbound

When each section is examined individually, however, sizeable changes in percent of loaded cycle time become evident, ranging from a decrease of 32 percentage points for the southbound traffic flow in the afternoon in lower Georgetown to an increase of 18 percentage points for the afternoon peak traffic northbound in upper Georgetown. Figure 7 compares the number of loaded cycles for each of the three sections for the before and after studies.

Table 4, which summarizes the differences in percent of loaded time by seconds, shows that in lower Georgetown there have been 7 percentage point increases in loaded cycle time in the direction of heavy flow during both the A.M. and P.M. peaks, from 19 percent to 26 percent in the morning and from 28 percent to 35 percent in the afternoon. This increase in loading indicates that intersections are governing capacity to a

TABLE 5

LOADED CYCLE CONDITIONS FOR PEAK PERIODS, AT INTERSECTIONS ON WISCONSIN AVENUE STUDIED BOTH YEARS

Intersecting Street	Total No. of Cycles (Same in A.M. & P.M.)		No. of Loaded Cycles on Approach							
			N.B., A.M.		S.B., A.M.		N.B., P.M.		S.B., P.M.	
	1959	1960	1959	1960	1959	1960	1959	1960	1959	1960
M St.	40	40	0	1	13	3	0	26	17	1
Q St.	45	45	2	3	3	19	24	4	20	9
Calvert St.	45	45	0	0	0	0	5	13	2	0
Garfield St.[a]	—	45	—	0	—	6	—	0	—	5
Mass. Ave.	45	45	7	0	0	0	15	0	5	11
Van Ness St.	45	45	6	9	5	6	42	12	1	0
Tenley, So.	45	45	0	0	—	—	8	0	—	—
Tenley, No.	45	45	—	—	5	17	—	—	0	6
Albemarle St.	45	45	0	15	0	1	0	32	0	0
Western Ave.	45	45	0	0	0	3	0	9	0	0

[a] Garfield Street was not signalized in 1959. It is included in this table because it was an integral part of the Massachusetts-Wisconsin intersection "complex" in 1960.

greater degree than before. In upper Georgetown the only significant change is an increase of 18 percentage points northbound in the afternoon.

North of Massachusetts Avenue changes in loaded cycle time ranged from a decrease of 5 percentage points northbound in the afternoon to an increase of 8 percentage points southbound in the morning. This indicates an increase in volumes in the morning greater than proportional to the increase in capacity developed by the traffic engineering improvements. Conversely the decrease in loading during the afternoon peak period indicates that the present increase in capacity is not being fully used for this period.

When each intersection is examined individually, as shown in Table 5 and in Figures 8 and 9, a greater range of change is apparent. The largest increase in percent loaded cycle time occurred northbound in the afternoon at Albemarle Street (Fig. 9). In 1959 at this point, there was no loaded cycle time; in 1960 the intersection was loaded at this point, 71 percent of the time. The largest decrease in loading occurred at Van Ness Street, also in the northbound afternoon peak period. In 1959, loading occurred during 93 percent of the peak hour; in 1960, loaded time dropped to 25 percent of the peak hour.

In the original study Van Ness Street was pointed to as a prime example of an intersection becoming a bottleneck. In the period of time between the original study and the after study, improvements were made to alleviate this condition, mainly parking restrictions. The after study shows a large reduction in loaded cycle time and a change in a portion of the remaining loaded cycle time from the "sustained" type of loading to the "intermittent" type of loading. Thus, it can be seen that this intersection is no longer operating at or close to its possible capacity as it was originally; it now is operating near its new practical capacity.

The after study shows that in the northbound direction Albemarle Street is assuming the characteristics of a bottleneck although not to the extent that Van Ness Street was originally. Q Street and Tenley Circle appear to be potential trouble spots, southbound.

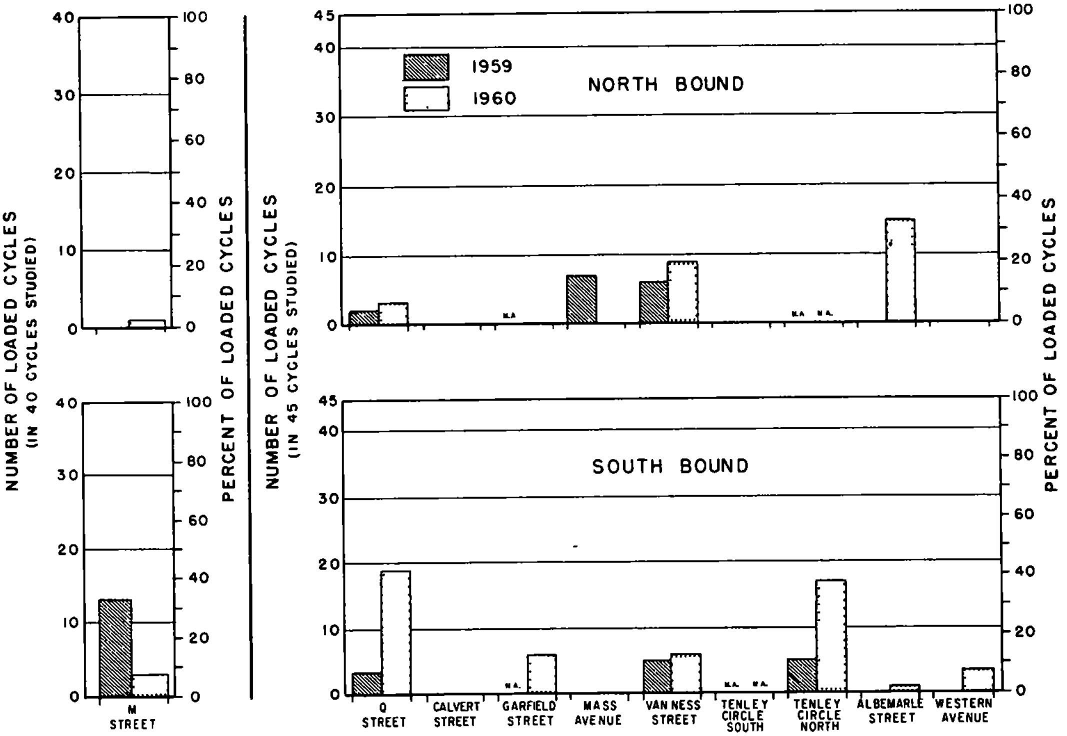


Figure 8. Number of loaded cycles at those intersections studied both in 1959 and 1960-A.M. peak.

Further examination of Figures 6 to 9, and especially of Figures 8 and 9, shows that generally an equalizing influence has been effected on Wisconsin Avenue. Those intersections which showed little or no loading in the original study, generally show a small increase in loading in the after study, indicating an increase in the capacity of the mid-block sections. Conversely, intersection improvements at Van Ness removed a bottleneck at that point.

The development of increased loading northbound in the afternoon on Wisconsin Avenue at Albemarle Street is not surprising, because improved operation at Van Ness Street and at Tenley Circle permits more traffic to reach this point. Neither is the Q Street problem unexpected. Such transfers of problem points were predicted in the original report where it was pointed out that there will be a continuous need for study and correction of new spot bottlenecks as the improvement program is carried out.

Speeds

Average Speeds.—In the after study, average speeds ranged from 18 to 21 mph when classified by direction and time periods for the entire Wisconsin Avenue test section. The average speed of all runs showed a gain of 8 percent, from 17.8 mph in the before study to 19.2 mph in the after study. As shown in Figure 10, there was an over-all increase in speed for all the periods studied except for the northbound traffic in the morning. The northbound A.M. off-peak shows no change in speed since last year; the northbound morning peak period shows an over-all decrease in speed of about 1 mph. Table 6 compares the average speeds for the before study and after study by section, direction, and time.

Figure 11 compares average speeds, by sections. In lower Georgetown the over-all average speed increased 8 percent. It increased about $1\frac{1}{2}$ mph, from 13 mph to about $14\frac{1}{2}$ mph, in the southbound morning peak hour. The largest change in speed in this section was a $2\frac{1}{2}$-mph increase in the southbound morning off-peak hours. The only decrease in average speed in this section occurred in the northbound morning off-peak hour, and amounted to 1 mph. The northbound peak traffic in the afternoon averaged only 0.2 mph faster than in the before study, 12.3 mph, an insignificant increase.

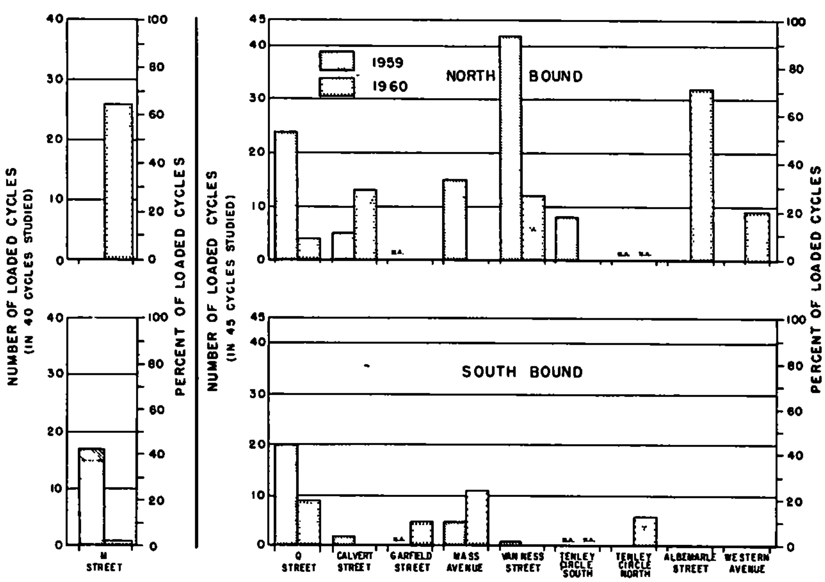


Figure 9. Number of loaded cycles at those intersections studied both in 1959 and 1960-P.M. peak.

Increases in average speed in upper Georgetown ranged from 0.5 mph to 6 mph. The over-all average speed gain was 11 percent. Southbound in the morning peak the speed changed from an average of 21 mph during the before study to 23 mph in the after study. The increase in speed northbound in the afternoon peak amounted to about 4 mph, from 15 mph to 19 mph.

At the time of the after study, average speeds in the section north of Massachusetts Avenue ranged from 18 to 23 mph, registering an over-all average speed gain of 7 percent. Both peak hour heavy traffic flows in this section showed speed increases of

TABLE 6

COMPARISON OF AVERAGE SPEEDS ON WISCONSIN AVENUE, 1959-1960

Location	Average speeds														
	A.M. Peak			A.M. Off-Peak			P.M. Off-Peak			P.M. Peak			All Time Periods, Combined		
	1959	1960	% Change	1959	1960	% Change	1959	1960	% Change	1959	1960	% Change	1959	1960	% Change
(a) Northbound															
Lower Georgetown	14.4	15.0	+4.2	13.0	11.7	-10.0	11.9	12.9	+8.4	12.3	12.5	+1.6	13.1	13.5	+3.1
Upper Georgetown	19.0	19.4	+2.1	18.1	19.7	+8.8	16.4	19.2	+17.1	15.1	18.9	+25.2	17.3	19.2	+11.0
Mass.-Western Ave.	23.0	21.4	-7.0	20.8	20.8	0	18.5	18.8	+1.6	16.1	19.8	+23.0	19.9	20.5	+3.0
Over-all	20.4	19.4	-4.9	18.2	18.2	0	16.8	17.6	+4.8	15.1	17.8	+17.9	19.9	18.5	+3.3
(b) Southbound															
Lower Georgetown	13.0	14.3	+10.0	11.0	13.3	+20.9	10.7	11.3	+5.6	11.3	12.9	+14.2	11.7	13.2	+12.8
Upper Georgetown	21.1	23.0	+9.0	19.3	25.1	+30.1	19.6	22.9	+16.8	19.0	20.4	+7.4	19.9	22.3	+12.1
Mass.-Western Ave.	19.2	22.9	+19.3	19.7	22.4	+13.7	20.9	20.1	-3.8	18.3	21.0	+14.8	19.5	21.7	+11.3
Over-all	18.6	21.2	+14.0	17.5	20.2	+15.4	17.9	18.5	+3.4	17.0	19.1	+12.4	17.8	19.9	+11.8
(c) Average Speed															
Over-all street[a]	-	-	-	-	-	-	-	-	-	-	-	-	17.8	19.2	+7.8

[a]Both directions combined.

about 4 mph, and most of the remaining time periods in both directions showed increases in speed. However, the speeds in this section were decreased 1½ mph for the northbound traffic during the morning peak period. This probably represents the slight adverse effect of the new progression, favoring peak direction traffic, on the opposing flows.

Running Speeds. —The changes in running speeds consistently amounted to two-thirds of the corresponding changes in average speeds in all cases. Running speeds increased from an average of 21.8 mph in the before study to 22.8 mph in the after study.

Stops

Data concerning the number of stops on the street are presented in Table 7. For Wisconsin Avenue as a whole in the before study, as shown in Figure 12, the average number of stops per run ranged from 13

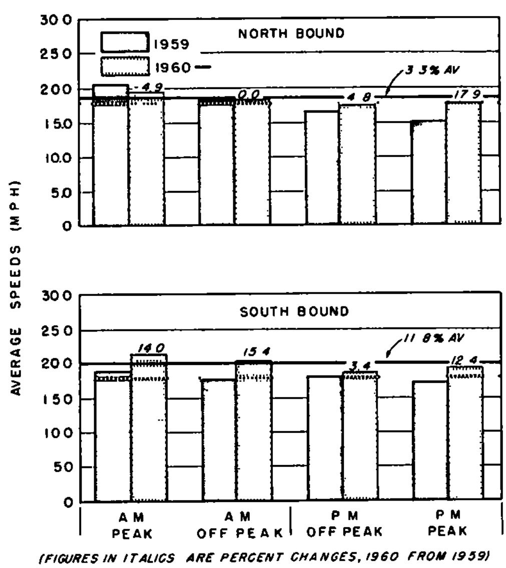


Figure 10. Comparison of average speeds on Wisconsin Avenue.

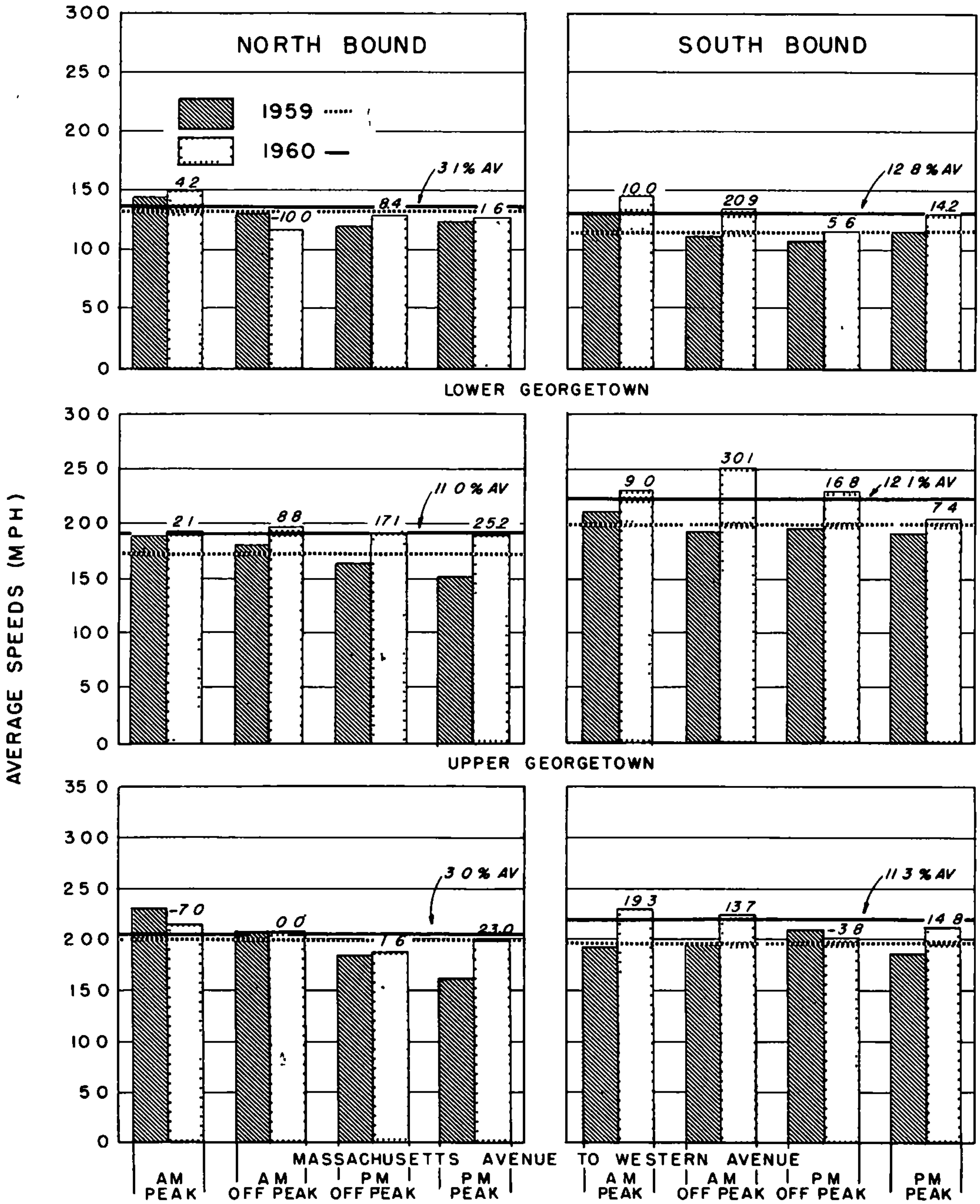


Figure 11. Comparison of average speeds by section and time of day.

to 25 depending on the time of day. In the after study the average number of stops per run ranged from 4 to 8. The average number of stops per run for all periods combined was reduced by 65 percent. During peak periods the reduction has been even greater, amounting to 76 percent southbound in the morning and 70 percent northbound in the afternoon.

TABLE 7

COMPARISON OF AVERAGE NUMBER OF STOPS PER RUN ON WISCONSIN AVENUE, 1959-1960

Location	Average No. of Stops per Run														
	A.M. Peak			A.M. Off-Peak			P.M. Off-Peak			P.M. Peak			All Time Periods, Combined		
	1959	1960	% Change	1959	1960	% Change	1959	1950	% Change	1959	1960	% Change	1959	1960	% Change
(a) Northbound															
Lower Georgetown	2.7	0.6	-77.8	2.2	1.4	-36.4	2.8	0.8	-71.4	3.2	1.0	-68.8	2.7	0.9	-66.7
Upper Georgetown	3.9	1.7	-56.4	3.8	1.4	-63.2	4.9	1.5	-69.4	6.5	1.3	-80.0	4.7	1.1	-76.6
Mass.-Western Ave.	3.9	3.3	-15.4	5.4	3.8	-29.6	9.5	4.3	-54.7	13.1	4.1	-68.7	7.6	3.8	-50.0
Total	12.5	6.5	-48.0	14.5	7.8	-46.2	18.5	8.2	-50.3	24.5	7.3	-70.2	17.2	7.1	-59.1
(b) Southbound															
Lower Georgetown	4.5	1.6	-64.4	7.3	2.0	-72.6	7.4	2.4	-67.6	5.5	1.6	-70.9	6.0	1.8	-70.0
Upper Georgetown	4.2	0.6	-85.7	4.9	0.3	-93.9	4.9	1.0	-79.6	4.7	1.7	-63.8	4.6	1.0	-78.3
Mass.-Western Ave.	9.4	2.0	-78.7	9.0	2.0	-77.8	6.4	4.0	-37.5	10.2	3.2	-68.6	8.8	2.7	-69.3
Total	18.5	4.4	-76.2	21.0	5.0	-76.2	19.0	7.6	-60.0	20.5	6.8	-66.8	19.6	5.9	-69.9
(c) Average No. of Stops per Run															
Over-all street[a]	-	-	-	-	-	-	-	-	-	-	-	-	18.4	6.5	-64.7

[a] Both directions combined.

Data for the individual sections are shown in Figure 13. The average number of stops per run for lower Georgetown has decreased 75 percent since the before study. Then, stops per run ranged from two to seven. In the after study the range was one to two stops per run. The number of stops decreased 65 percent southbound in the morning and 69 percent northbound in the afternoon.

The average number of stops per run in upper Georgetown, which ranged from four to seven in the before study, decreased to a range of zero to two in the after study. This over-all decrease amounts to 75 percent. The number of stops per run has decreased by 80 percent for the northbound afternoon peak period traffic flow and 86 percent for the southbound morning peak period flow.

For the section north of Massachusetts Avenue, the average number of stops per run in the before study ranged from 4 to 13; in the after study the average number of stops per run ranged from two to four. This is an over-all decrease of 60 percent. The peak period heavy traffic flows showed decreases of 69 percent northbound and 79 percent southbound.

Significance of Speed Data

The over-all increase in average speed can be attributed to the smoother traffic flow provided by the new traffic signal progression and to reduction in midblock friction. Reduction in delay time at signalized intersections contributed approximately 40 percent of the northbound average speed increase and 10 percent of the southbound average speed increase. Reduction in midblock friction helped increase both average and running speeds. The marked decrease in all kinds of stops reduced the time lost in deceleration and acceleration with resultant benefits to average speed and running speed.

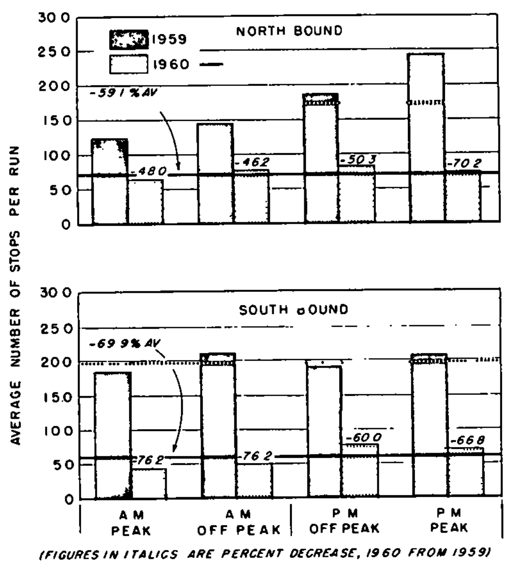


Figure 12. Average number of stops by time of day—K Street to Western Avenue (deceleration to 2 mph or below was identified as a stop).

Capacity

The over-all increases in volume indicate that, on the whole, the capacity of Wisconsin Avenue has been improved. Development of slight loading at several intersections which previously showed none indicate that the volume at those intersections has increased to the point where efficiently full use is being obtained; that is, practical capa-

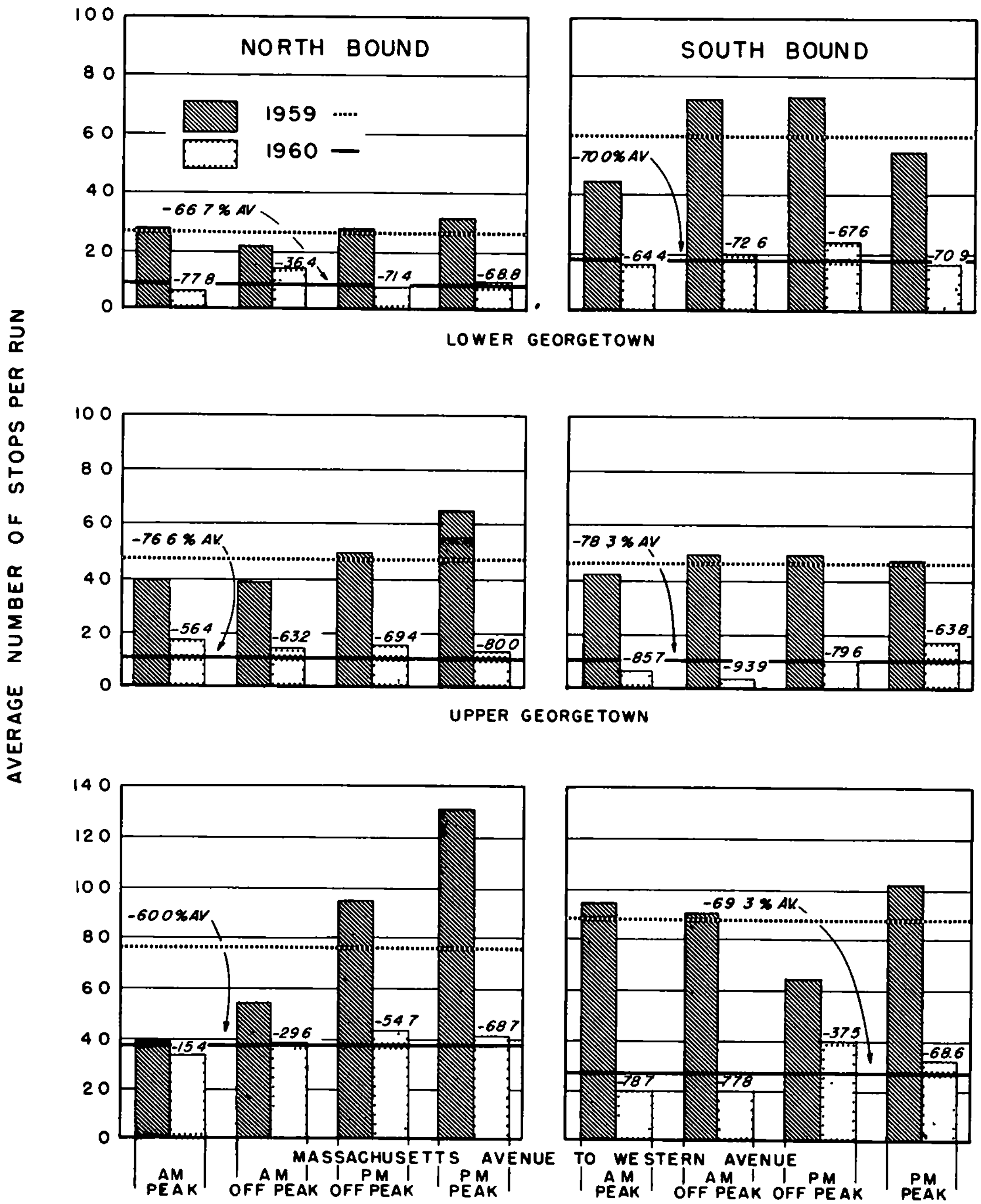


Figure 13. Average number of stops by section and time of day (deceleration to 2 mph or below was identified as a stop).

city has been attained. Conversely, decreases in loading at other intersections indicate that their capacity has been improved to such an extent that they no longer are being as fully used. Over-all increases in speed and the large reductions in the average number of stops per run also indicate a substantial improvement in the traffic carrying capability of the street.

It is interesting to note that the foot of Wisconsin Avenue between K and M Streets, a steep grade which in the before study had the characteristics of a local feeder street, seems to be in the process of assuming the urban arterial characteristics of the remainder of Wisconsin Avenue. This is borne out by a 76 percent increase in volume and a 65 percent increase in loading northbound during the afternoon peak hour. The volume between K and M was 319 vph in the before study and 563 vph in the after study. Thus, although this section is not yet operating at practical capacity it is rapidly approaching that condition and could prove to be troublesome in the future if the present trend continues. This situation has not yet appreciably affected the general traffic conditions for lower Georgetown as a whole. It is, nevertheless, an example of unforeseen changes in the habits of the driving public which frequently occur, disrupting carefully-thought plans.

The fairly large increases in volumes in the heavy flows during peak hours, the increase in speed during the southbound peak period, and the large decrease in the number of stops are all indications that the capacity of the lower Georgetown section has been greatly improved, probably primarily through elimination of midblock friction produced by the streetcar transit operation.

For the upper Georgetown section it was noted that for the northbound traffic flow in the afternoon peak period the volume had increased 25 percent, the over-all speed had increased 4 mph, and the number of stops per run had decreased by 80 percent. These figures illustrate the effect that removal of the streetcars and loading platforms, the new parking regulations, and the changes in signal timing have had in greatly increasing the capacity of this section. Undoubtedly, the street is currently capable of carrying even greater volumes. The volumes will probably continue to increase as more drivers discover the improved conditions on the street.

The changes in the traffic engineering features north of Massachusetts Avenue were the same as the changes south of that street, except that the new parking regulations were in effect only at the Van Ness Street and Western Avenue intersections. It was previously mentioned that up to a 67 percent decrease in loaded cycle time occurred at the Van Ness Street intersection where the signs pertaining to the new "no parking" and "no standing" regulations had been installed. The substantial increase in the capacity of this intersection which this reduction represents has not yet been matched by the section as a whole. In fact, it cannot be expected that when the new parking regulation signs are finally erected throughout this section, the capacity of this section will be increased proportionately because Van Ness was previously a known "bottleneck." However, it is believed that substantial increases for this section as a whole can be realized.

Generally, however, the increases in volumes, combined with fairly large increases in speed for the heavy flow directions during the peak periods, the large decreases in the number of stops, and the reduction in loading in the northbound afternoon peak hour traffic flow seem to indicate an increased capacity which is not being fully used. This being the case, the practical capacity under prevailing conditions will not be reached until further volume increases occur.

SUMMARY OF RESULTS

The following results are evident from the comparison of the data obtained in the before and after studies:

1. Over-all peak hour volumes for Wisconsin as a whole increased by an average of 11 percent. The increases in lower Georgetown amounted to 27 percent, in upper Georgetown 11 percent, and north of Massachusetts Avenue 9 percent.
2. For Wisconsin Avenue as a whole and for the three sections as well, the trend was toward a small increase in percent loaded cycle time.

3. Average speed for all runs increased from 17.8 mph to 19.2 mph. The largest peak-hour increases in speed, amounting to 4 mph, occurred north of Massachusetts Avenue in the heavy flow directions. Southbound in the morning the speed increased from 19 to 23 mph, and northbound in the evening the increase was from 16 to 20 mph. In general, lesser increases were noted at other times, and in Georgetown at all times. However, soutbound in the A.M. off-peak in upper Georgetown, a 6-mph increase occurred.

4. Changes in average running speeds consistently averaged two thirds of the corresponding changes in average speeds. Running speeds increased from an average of 21.8 mph to 22.8 mph.

5. For Wisconsin Avenue as a whole, the number of stops per run has been reduced on the average by 65 percent. In both lower and upper Georgetown the average number of stops per run for all periods combined has been reduced by 75 percent. North of Massachusetts Avenue the reduction in the average number of stops per run for off-peak and peak periods combined amounted to 60 percent. Generally the reduction in the average number of stops per run was greater in the heavy flow directions during the peak periods.

6. The concurrent increases in speed and volume coupled with the decrease in number of stops indicate that the capacity of Wisconsin Avenue as a whole has been substantially increased. The increases in capacity vary within the three sections studied. Use of the increased capacity also varies within the three sections, but this use was greatest in lower Georgetown.

7. In upper Georgetown and north of Massachusetts Avenue the street is currently capable of carrying greater volumes. Further increases in volumes must occur before these sections reach their capacity under prevailing conditions.

REFERENCE

1. "Increasing Traffic Capacity of Arterial Streets." HRB Bull. 271 (1960).