CONCLUSIONS

The conclusions drawn from this study of the standard deviations and coefficients of variation of the fixed automatic traffic recorder data are:

1. The extraction of the standard deviation and coefficient of variation of the fixed automatic traffic recorder data makes available knowledge which greatly extends the utilities of these data.

2. The use of these statistics will permit the design of more efficient traffic counting schedules for either short manual counts or short portable recorder operations.

3. The schedules designed with the aid of the knowledge of traffic behavior provided by these statistics will produce more accurate and more reliable estimates for either average annual daily traffic or average annual weekday traffic.

ACKNOWLEDGEMENT

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EFFECTS OF REVERSIBLE LANE MOVEMENT SIGNALIZATION OF THREE LANE HIGHWAYS

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SYNOPSIS

There is a 1½-mi. section of 28-ft. width 3-lane State Highway numbered as US Routes 29 and 211 extending westward from the District of Columbia line at the Francis Scott Key Bridge into Arlington County, Virginia. This stretch of highway carried in 1949 in excess of 20,000 vehicles per day, and traffic was expected to be materially increased upon completion by the District of the Whitehurst Freeway on the east side of the river. The highway is intersected by numerous lateral streets serving local residential areas. While there were no really large volumes on any of these intersecting streets, they were sufficiently large to result in considerable accumulated delay to side street traffic, so that the situation was regarded as intolerable by nearly all users of the side streets. There were no funds for additional construction, so it was agreed that the artery must be signalized to apportion some of the side street delay to the artery by giving side street traffic more opportunity for entrance. Since the arterial, directional movements during peak hours were found to be exceptionally unbalanced, it was decided that greatest efficiency would result from a plan of off-center lane, or reversible center lane movement, signalization. Accordingly, 11 intersections were signalized and controlled by master equipment to provide two inbound lanes during morning peak, two outbound lanes during afternoon peak, and two-way center lane use between unbalanced flows.

A comprehensive study of lane use, travel time, capacity, over-all volumes, parallel route use, and delay was made three months before signals were installed. A similar follow-up study was made nine months after signals began operation.

Analyses of these studies reveal that the signalization handles larger volumes, requires slightly longer travel time, results in more orderliness of all movements, more over-all standing delay, more traffic accidents, little or no diversion to parallel routes, limited illegal use of lanes, remarkable acceptance by users, and vastly improved public relations.

Among possible conclusions to be derived from the effects are: that the motoring public will always accept traffic signals as being the best means of traffic control where conflicting volumes are large, regardless of decreased efficiency of one or both streets; that the average motorist will tolerate delay only when he knows that his turn will come up in some predetermined schedule; that the average motorist will respect the authority of a traffic signal far more readily than he will respect the rights of other drivers; that the maximum practical capacity of the subject highway has been reached for only very short intervals of time; that signalization of any artery will decrease the maximum theoretical arterial capacity but by promoting orderliness of conflicting movement may increase the over-all practical capacity; that theoretical economic losses resulting from delay may be very much overrated where a large proportion of the travel is of the home-to-work and return type; and that reversible center lane use of three-lane roads by means of traffic signals is entirely workable.

In Virginia, the tremendous increases in traffic volumes in the past decade have been most pronounced in the vicinity of Washington. Of course, any sizable city whose metropolitan population has practically doubled in the short space of ten years could be expected to have trouble with its traffic arteries, and Washington has been no exception. But such fast development would not normally be expected to create almost insurmountable problems on its approach arteries in the outlying districts, as is proving to be the case in the Virginia area adjacent to the City. Here, there were rural roads which have suddenly been completely engulfed by city development that shows no signs of leveling off.

One of the roads so affected was the Lee Highway carrying US Rt. 29 and US Rt. 211 westward through Arlington County from the District of Columbia line at the Francis Scott Key Memorial Bridge. There are two other arteries which parallel Lee Highway also having access to the Key Bridge by means of short cross street connections—US Rt. 50 (Lee Boulevard) and Wilson Boulevard.

The easternmost 1¾ mi. of the Lee Highway is a three-lane highway only 28 ft. in width on a narrow winding right-of-way. Since it was built in 1927, the grades, as well as the alignment, lack much to be desired. Adjacent rugged terrain and a nearby parallel railroad line have discouraged roadside development; however, the stretch is intersected by numerous cross streets serving well-developed suburban residential areas. West of this stretch, the terrain flattens, the road becomes a four-lane facility with extensive ribbon commercial development through the Cherrydale community. West of Cherrydale, the highway drops back to three lanes in width.

Traffic volume on the eastern three-lane section was 15,000 vehicles per day in 1940. By the end of 1948, it had increased to an average daily traffic of 19,000 vehicles. Of course, volumes of traffic from the sideroads also increased, with the result that these vehicles found fewer and fewer opportunities suitable for entering the arterial streams. This condition resulted in an increasingly insistent clamor for traffic signals from the residential areas served by the several side streets. Civic groups of all varieties took up the cry.

The State Highway Commission did not have the funds to add more lanes to the road, although the Department's engineers knew that three lanes were hardly sufficient for the volumes being carried. Even if additional lanes could have been added, it would still have been necessary to signalize the principal side street intersections, for there is no possibility of providing service roads and separation structures. Public pressure was so great that signalization became inevitable, even though it was known that signals would almost certainly increase delay to the arterial stream. Thus, it was necessary to design a signal system which would delay the artery the least.

Traffic counts showed traffic to be exceptionally unbalanced during peak movements. In the morning, only 19 percent was outbound while the same movement comprised 75 percent of the total during the afternoon peak.

Therefore, it was decided to try a signal system which would allocate two lanes to inbound and one to outbound in the morning; during the evening rush, one lane would be allocated to inbound, while the remaining lanes would be assigned to the outbound. In between peaks, the center lane would operate under flashing caution signal indications during the arterial green periods, and drivers proceeding in either direction could use it as a passing lane at their own risk, just as any unsignalized three lane road is used.

Eleven of the intersections were signalized with semi-traffic-actuated controllers; that is, there are vehicle detectors on the side streets only. These secondary controllers are connected together with coordinating cable, and are supervised by an arterial master controller which varies the duration of the arterial green periods in accordance with the volume of traffic counted by vehicle detectors placed in the artery at one point. The lane allocation selector and the offset selector are incorporated with the supervisory master. Three types of progression are provided: an ideal for inbound movement, an ideal for outbound, and a compromise for both directions between peaks when the flows are fairly well balanced.

A more complete description of the system will be found in a paper by the writer in the *Proceedings* of the Institute of Traffic Engineers for 1949.

Installation of the signal system was started in July 1949 and the system was turned on September 19, 1949. The before field study was made on Tuesday, Wednesday, Thursday and Friday, June 21 through 24, 1949, almost exactly 3 months before the signals began operating. The after studies were made on the same days of the week, May 23 through 26, 1950, exactly eight months after the lights were turned on. Since the two studies were about a year apart, seasonal variation effects on volume and behavior were substantially eliminated.

Both the before and after studies were divided into several parts designed to answer specific questions. The questions, and our interpretation of the findings, follow:

Will signals increase or decrease volumes by attraction from, or diversion to, alternate parallel routes?—Many of the drivers who use Lee Highway, Wilson Boulevard, or Route 50 can use any one of the three with little difference in travel distance. Therefore, volume counts by 15 minute increments were simultaneously made on all three routes at points as near Key Bridge as practicable. If the signal installation had been the only change influencing traffic on the three routes, this study would have provided a direct answer. However, at least two other changes occurred which confuse the picture. The opening of the Whitehurst Freeway in October, 1949—one month after signals were installed—materially increased volumes on the Key Bridge by making that facility more readily accessible to downtown Washington. Also, certain residential areas of Arlington County served more conveniently by one or another of the three routes had population increases greater than did other areas.

Table 1, Section A, shows that 24-hr. volume on the three routes increased 14.1 percent from 1949 to 1950. In 1949, 35.8 percent of the whole was carried by the Lee Highway, whereas in 1950 the Lee Highway volume increased 19.4 percent and then comprised 37.4 percent of all traffic on the three routes. Thus we may say that on a 24-hr. basis, the Lee Highway after signalization carried a disproportionately greater share of the increased volume than either of the alternates.

Table 1, Section B, shows that this trend was reversed when peak hour movements on the three routes only are considered. For the Lee Highway the ratio of the whole fell from 32.3 percent in 1949 to 31.4 percent in 1950 during the morning rush and from 32.1 percent to 29.4 percent during the evening peak. Thus, it appears that there was some tendency to avoid the signalized route during peak movement hours, but between peaks the signals attracted additional users.

A most surprising fact, indicated by Table 1, Section C, is that the signal system allocation of two lanes to the predominant direction of travel during peak hours appears to encourage increased use of the one lane assigned for the opposite flow. In other words, the principal increase in peak hour flow on the Lee Highway after signalization was in the direction for which only one lane was available.

What is the effect of signalizing a heavily traveled road on the travel time of its users?—This part of the study involved clocking the time required by vehicles to travel from one end of the section to the other, before and after the stretch was signalized. This was accomplished by recording license numbers as vehicles en- lack of suitable power sources for the instruments, it was necessary to time outbound vehicles over a shorter distance than the inbound direction.

TABLE 1

WEEKDAY TRAFFIC FLOWS ON PARALLEL ROUTES IN ARLINGTON COUNTY DURING PERIODS IN 1949 AND 1950 THAT SPECIAL STUDIES WERE BEING CONDUCTED ON LEE HIGHWAY

Section A. Average 24-hour Flows

	Vehicles 1949	Vehicles 1950	Per cent of Total 1949	Per cent of Total 1950
Lee Highway	20,523	24,502	35.8	37 4
Wilson Blvd.	10,167	10,635	17.7	16.3
Lee Blvd. Rt. 50	26,641	30,315	46.5	46.3
Total	57,331	65,452	100 0	100 0

Section B. Morning Peak Hour—Combined Flows

	Vehicles 1949			Vehicles 1950			Per cent 1949			Per cent 1950		
	In	Out	Total	In	Out	Total	In	Out	Total	In	Out	Total
Lee Highway	1,277	305	1,582	1,341	404	1,745	33.2	29.2	32 3	31.6	30.5	31.4
Wilson Blvd	701	176	877	755	173	928	18.2	16.9	17.9	17.8	13.1	16.7
Lee Blvd. Rt. 50	1,873	563	2,436	2,142	747	2,889	48.6	53.9	49.8	50.6	56 4	51.9
Total	3,851	1,044	4,895	4,238	1,324	5,562	100.0	100.0	100.0	100 0	100 0	100.0

Evening Peak Hour—Combined Flows

	Vehicles 1949			Vehicles 1950			Per cent 1949			Per cent 1950		
	In	Out	Total	In	Out	Total	In	Out	Total	In	Out	Total
Lee Highway	470	1,379	1,849	631	1,274	1,905	33.4	31 6	32.1	33.9	27.7	29.4
Wilson Blvd..	357	543	900	464	542	1,006	25.4	12.5	15 6	24.9	11 7	15.6
Lee Blvd. Rt. 50	580	2,436	3,016	769	2,791	3,560	41.2	55.9	52.3	41.2	60.6	55.0
Total	1,407	4,358	5,765	1,864	4,607	6,471	100.0	100.0	100.0	100.0	100.0	100 0

Section C. Morning Peak Hour Flows on Individual Routes

	Vehicles 1949			Vehicles 1950			Per cent 1949			Per cent 1950		
	In	Out	Total	In	Out	Total	In	Out	Total	In	Out	Total
Lee Highway	1,277	305	1,582	1,341	404	1,745	80.7	19.3	100.0	76.8	23.2	100.0
Wilson Blvd	739	155	894	755	173	928	82.7	17.3	100.0	81.4	18.6	100.0
Lee Blvd. Rt. 50	1,873	563	2,436	2,142	747	2,889	76.9	23.1	100.0	74.1	25.9	100.0
Total	3,889	1,023	4,912	4,238	1,324	5,562	79.2	20.8	100.0	76.2	23 8	100.0

Evening Peak Hour Flows on Individual Routes

	Vehicles 1949			Vehicles 1950			Per cent 1949			Per cent 1950		
	In	Out	Total	In	Out	Total	In	Out	Total	In	Out	Total
Lee Highway	470	1,379	1,849	555	1,428	1,983	25.4	74.6	100.0	28.0	72.0	100.0
Wilson Blvd.	378	533	911	464	542	1,006	41.5	58.5	100.0	46.1	53.9	100.0
Lee Blvd. Rt. 50	636	2,394	3,030	769	2,791	3,560	21.0	79.0	100.0	21.6	78.4	100.0
Total	1,484	4,306	5,790	1,788	4,761	6,549	25.6	74 4	100.0	27.3	72.7	100.0

Section D. Peak Directional Flows on Lee Highway—VPH.

Period	1949 Inbound	1949 Outbound	1950 Inbound	1950 Outbound
Morning rush period—7 to 9 a.m.	1,292	381	1,361	516
Evening rush period—4 to 6:15 p.m.	560	1,453	703	1,570
Off peak periods—other hours	672	711	768	832

tered and left the section in each direction of travel, using Audigraphs as the recording instruments. In the field, the exact time was inserted on the record at frequent intervals. In transcribing the records, the use of a stop watch permitted determination of the exact time each vehicle passed the station. Due to

It is fairly obvious that if a number of stop lights are placed on a road where stops were not ordinarily required, the travel time over that section of road must be longer if the same speed limits are maintained. The problem was to select a system which would delay the artery traffic the least.

Table 2, listing travel times before and after signals were installed by type and direction of vehicle for different periods of the day, indicates good success in minimizing delay. Travel time in the morning for outbound (one lane) traffic increased 43 percent while the inbound enjoyed a 5 percent decrease. In the afternoon, the increase for outbound was 12 percent, for inbound seven percent.

TABLE 2
SUMMARY OF TRAVEL TIMES ON LEE HIGHWAY BEFORE AND AFTER SIGNAL INSTALLATION

Time of Day		Inbound Traffic									Outbound Traffic								
From	To	Total Veh [a]	Vehicles in Sample				Travel Time, Minutes for 1.41 Mi.				Total Veh.[a]	Vehicles in Sample				Travel Time, Minutes for 1.26 Mi.			
			P.C.	Tr.	Bus	Total	P.C.	Tr.	Bus	All		P.C.	Tr.	Bus	Total	P.C.	Tr.	Bus	All
1949—Before																			
7·00	7:30 a.m.	505	323	13	8	344	3.70	4 08	6.75	3.79	153	96	27	4	127	3.16	3.78	3.00	3.28
7 30	8:00	778	366	18	7	391	3.78	4 06	5.14	3.82	155	70	30	2	102	2.70	3.43	3.50	2.98
8 00	8:30	599	307	8	12	327	4.05	4 38	5 83	4.12	150	76	30	2	108	3.00	3.80	4.50	3.25
Tot. or Avg[b]		1,882	996	39	27	1,062	3.84	4.13	5.92	3.90	458	242	87	8	337	2.98	3.67	3.50	3.18
1:00	1·30 p.m.	205	102	19	1	122	3.10	3 48	4 90	3.18	227	109	18	3	130	2.86	3.78	3.67	3.02
1:30	2:00	232	114	12	2	128	3.26	3 40	3.40	3.28	228	105	29	4	138	3.14	3.90	3.00	3.30
2 00	2.30	217	110	18	2	130	3.26	3 57	3.90	3 32	229	107	19	4	130	3 12	3.84	3.50	3.24
Tot. or Avg[b]		654	326	49	5	380	3.21	3.49	3.90	3.26	684	321	66	11	398	3 04	3.85	3.36	3.19
4:30	5:00 p.m.	295	140	12	3	155	3.66	3.50	4.00	3.65	527	314	6	4	324	2.73	3.50	5.25	2.77
5:00	5:30	241	114	6	3	123	3.24	3.33	3.33	3 24	657	398	4	8	410	2.94	3.25	4.12	2.99
5.00	6·00	229	101	10	4	115	3 78	3.90	4.00	3.80	722	415	10	15	440	3.11	4 50	3.73	3.16
Tot. or Avg[b]		765	355	28	10	393	3.56	3 61	3.80	3.56	1,906	1,127	20	27	1,174	2.94	3.95	4.07	2.99
1950—After																			
7:00	7 30 a.m.	486	294	11	6	311	3.42	3 27	5.17	3.45	234	101	16	2	119	4.09	5.69	4 00	4.39
7:30	8 00	692	427	13	5	445	3 74	4 54	5.20	3.78	207	76	23	2	101	4.42	5 35	5 00	4.65
8:00	8.30	649	418	21	7	446	3.76	4.29	5.71	3.82	197	103	19	4	126	4.85	5.16	4.75	4.89
8·30	9:00	524	275	18	5	298	3.70	3.94	5.60	3.75	252	93	24	6	123	4.19	5.04	5.17	4.57
Tot. or Avg[b]		2,351	1,414	63	23	1,500	3.67	4.06	5.43	3.72	890	373	82	14	4.69	4.39	5 28	4.86	4.63
1.00	1·30 p.m.										344	114	26	3	143	3 07	3.84	3.33	3.22
1:30	2.00										284	111	23	4	138	3.22	4.22	4.25	3.41
2:00	2.30	258	131	21	3	155	3.04	3.77	3 24	3 15	325	139	26	4	169	3.43	4.50	3.25	3.59
2.30	3:00	259	117	22	5	144	3.22	3.38	3 96	3.25	298	104	22	4	130	3.27	4.54	3.75	3.50
Tot. or Avg[b]		517	248	43	8	299	3.12	3.57	3 69	3.20	1,251	468	97	15	580	3 26	4.26	3.67	3.44
4:00	4:30 p.m.										455	152	5	2	159	3.29	4.40	3.50	3.33
4.30	5:00	330	161	14	3	178	3.41	3 52	4 32	3.44	522	270	15	6	291	3.35	3.93	4.00	3.40
5.00	5·30	327	163	12	4	179	3 64	3.48	4 68	3.67	625	409	6	6	421	3.19	4.00	4 50	3 21
5:30	6 00	267	151	8	6	165	3.30	3.06	3 44	4.41	754	443	14	16	473	3 59	4.71	4 63	3.47
6:00	6:15	124	72	5	0	77	2.98	3.41	—	3 68	307	143	2	3	148	3 35	4 50	5.33	3.38
Tot. or Avg[b]		1,048	547	39	13	599	3.39	3.40	4.02	3 81	2,663	1,417	42	33	1,492	3 37	4 28	4.49	3 36

[a] Number of vehicles on Lee Highway at Rosslyn, Virginia.
[b] Weighted by the number of vehicles in traffic sample rather than by actual traffic volume.

Do traffic signals increase or decrease the arterial delay caused by left turns from the artery?—One of the more heavily traveled side streets was selected for this phase. Rhodes Street does not cross Lee Highway, so the intersection is of the Tee type. Visibility in each direction is somewhat limited. The study was conducted by measuring the time that each vehicle left-turning from Lee Highway was delayed before it could cross the opposing eastbound stream. Also, the delay to following westbound Lee Highway vehicles was measured. After the signals were installed, only one lane was available for westbound traffic in the morning, so left-turn vehicles had to cross two lanes.

Table 3 shows that delays caused by left turns were more than trebled by the traffic signal. The number of left turns involving a delay of some sort was more than tripled, while the average total delay per left turn was doubled. Both of these increases are undoubtedly partly accounted for by the volume increases since more traffic means fewer opportunities for undelayed conflicting maneuvers.

realized that buses stopping in that single lane would cause a great deal of delay to other traffic. Accordingly, a measurement of delay caused at one bus stop (Rhodes Street) was

TABLE 3

DELAY TO TRAFFIC ON LEE HIGHWAY CAUSED BY WESTBOUND VEHICLES TURNING LEFT FROM LEE HIGHWAY INTO RHODES STREET

	June 24	June 23			Total
	7–9 a.m.	2–4 p.m.	4–5 p m.	5–6:15 p.m.	
1949					
No. of vehicles turning left	2	3	12	10	27
Total delay to left-turning vehicles (veh.—sec.)	20	27	156	90	293
Total delay to other traffic (veh.—sec.)	0	0	0	0	0
Total delay to all traffic (veh.—sec.)	20	27	156	90	293
Avg. delay to left-turning vehicles (veh.—sec.)	10.0	9.0	13.0	9.0	10.9
Avg. delay to other traffic per left turn (veh.—sec.)	0	0	0	0	0
Total delay per left turn (veh.—sec)	10.0	9.0	13.0	9.0	10.9
1950					
	May 25	May 26			Total
	7–9 a.m.	1–3 p.m.	4–5 p.m.	5–6:15 p.m.	
No. of vehicles turning left	17	17	19	40	93
Total delay to left-turning vehicles (veh.—sec.)	247	144	317	339	1,047
Total delay to other traffic (veh.—sec.)	133	12	180	490	815
Total delay to all traffic (veh.—sec.)	380	156	497	829	1,862
Avg. delay to left-turning vehicles (veh.—sec.)	14.5	8.5	16.7	8.5	11.2
Avg. delay to other traffic per left turn (veh.—sec.)	7.8	0.7	9.5	12.2	8.8
Total delay per left turn (veh.—sec.)	22.3	9.2	26.2	20.7	20.0

TABLE 4A

DELAY TO TRAFFIC ON LEE HIGHWAY CAUSED BY INBOUND BUSSES STOPPING AT RHODES STREET

	June 24	June 23			Total
	7–9 a.m.	2–4 p.m.	4–5 p.m.	5–6:15 p.m.	
1949					
No. of busses stopping	25	4	4	4	37
Total length of time busses stopped (sec.)	532	36	44	44	649
Total delay to other traffic (veh.—sec.)	6	16	7	3	32
Avg. length of time busses stopped (sec.)	21.3	9.0	11.0	11.0	17.5
Avg. delay to other traffic per bus stop (veh.—sec.)	0.2	4.0	1.8	0.8	0.9
1950					
	May 25	May 26			Total
	7–9 a.m.	1–3 p.m.	4:15–5:15 p.m.	5:15–6:15 p.m.	
No. of busses stopping	30	7	7	4	48
Total length of time busses stopped (sec.)	591	53	64	38	746
Total delay to other traffic (veh.—sec.)	440	0	141	113	694
Avg. length of time busses stopped (sec.)	19.7	7.6	9.1	9.5	15.5
Avg. delay to other traffic per bus stop (veh.—sec.)	14.7	0	20.1	28.3	14.5

When only one lane is allocated by the signals, how much is traffic delayed by bus stops?—One of the chief disadvantages of the signal system is that it confines one direction of travel to a single lane during the peak hours. It was made before and after installation. Tables 4A and 4B confirm our suspicions. Total delay to other traffic increased after signalization by from 224 to as much as 1500 percent. Fortunately, the number of times buses traveling in the direction of lightest flow during peak hours actually stop at a given point are few—8 per hour was the maximum—which means there are long headways between these stops. Thus the total delay in terms of over-all time is not too serious. On the other hand,

TABLE 4B
DELAY TO TRAFFIC ON LEE HIGHWAY CAUSED BY OUTBOUND BUSSES STOPPING AT RHODES STREET

	June 24	June 23			Total
	7–9 a.m.	2–4 p.m.	4–5 p m.	5–6:15 p.m.	
1949					
No. of busses stopping	3	7	8	20	38
Total length of time busses stopped (sec.)	24	61	87	284	456
Total delay to other traffic (veh.—sec.)	0	81	3	146	230
Avg. length of time busses stopped (sec.)	8.0	10.1	10.9	14.2	12.0
Avg. delay to other traffic per bus stop (veh.—sec.)	0	11.6	0.4	7.3	6.1
1950					
	May 25	May 26			Total
	7–9 a.m.	1–3 p.m.	4–5 p m.	5–6:15 p.m.	
No. of busses stopping	8	8	3	22	41
Total length of time busses stopped (sec.)	106	91	23	287	507
Total delay to other traffic (veh.—sec.)	124	9	0	680	813
Avg. length of time busses stopped (sec.)	13.2	11.4	8	13 0	12.4
Avg. delay to other traffic per bus stop (veh.—sec.)	15.5	1.1	0	30 9	19.8

off-pavement bus stops are almost certainly necessary for this type of three lane signal system to return maximum efficiency if the local bus travel is large.

Will delay to vehicles entering an artery from side streets be reduced by signals?—The basic idea behind the installation of any traffic signal is to reduce the delay occasioned by conflicting movements and to apportion that delay equitably. In this case, there was no noticeable delay to the Lee Highway traffic before the signals were installed; on the other hand, there was noticeable delay to vehicles on side streets awaiting an opportunity to enter or cross the artery stream. Therefore we felt that signals would reduce such delay. We were surprised when the study showed that quite the opposite is true. Not only was the average waiting period per side street vehicle approximately doubled after the installation, but there were also more exceptionally long waits. For example, the percentage of vehicles waiting more than 60 seconds increased from 3.2 in 1949 to 13.0 in 1950.

Will drivers comply with lane signal allocation on 3 lane roads?—This study was conducted to determine the effect that the lights had on the use of the center lane where sight distance was adequate. Two locations were chosen for the before and after phase. Table 6 shows

TABLE 5
COMPARISON OF "BEFORE" AND "AFTER" DATA FOR VEHICLES ENTERING LEE HIGHWAY FROM SIDE STREETS BETWEEN 7:30 and 9:00 A.M.

	At Rhodes Street		At Veitch Street	
	1949	1950	1949	1950
No. of vehicles entering from side street.	123	199	33	44
No of queues waiting to enter	90	89	30	40
Avg. no. of vehicles per queue	1.4	2.2	1.1	1.1
Avg. wait per vehicle, sec.	16.2	33.3	17.7	26.5
No. of vehicles with wait of more than:				
30 sec.	21	110	6	14
45 sec.	8	72	4	9
60 sec.	4	26	2	3
75 sec.	1	8	0	0
Percentage of vehicles with wait of more than:				
30 sec.	17.0	55.2	18.1	31.8
45 sec.	6.5	36.1	12.1	20.4
60 sec	3.2	13.0	6.0	6.8
75 sec.	0.8	4.0	0	0

the 1950 observed center lane use in violation of signal indication, compared with 1949 use when there were no restrictions. Figures shown for mid-day periods when lane allocation signals do not control center lane use are for comparison only. At one location, center lane use in violation of the 1950 signals was 13 during 1½ hr. in the morning and 13 in 2 hr. in the afternoon. In 1949, center lane use by comparable directional flows was 62 in the morning and 5 in the afternoon. Thus, a reduction to 26-violation use from 67-non-violation use in 3½ hr. may be assumed. The 26 violations represent but slightly more than 1 percent of the 1700-odd vehicles moving in the single lane during the same period of time.

an 8-month period beginning October 1 after signals were installed, the reported accidents rose to 35, an increase of 218 percent. The ratio of severity and type of accident remained fairly constant; that is, the consequences and number of each accident type in the after period were about 3 times greater than for the before period. We have tinkered with the signal timing, particularly with much longer

TABLE 6

USE OF CENTER LANE ON LEE HIGHWAY BY VEHICLES TRAVELING IN THE DIRECTION OF LIGHTER TRAFFIC FLOW

Time of day		Section 1—Between N Rhodes and N. Uhle Streets						Section 2—Between R R. Underpass & N. Rhodes St					
		1949—Before			1950—After			1949—Before			1950—After		
From	To	Passing	Not Passing	Total	Passing	Not Passing	Total	Passing	Not Passing	Total	Passing	Not Passing	Total
Morning Outbound Traffic													
7:30	8:00	23	0	23	**2**	0	**2**	16	2	18	**9**	0	**9**
8:00	8:30	13	2	15	**5**	0	**5**	19	3	22	**2**	0	**2**
8:30	9:00	24	0	24	**6**	0	**6**	15	4	19	**0**	0	**0**
Total		60	2	62	**13**	0	**13**	50	9	59	**11**	0	**11**
Midday Inbound Traffic													
1:00	1:30	7	1	8	16	1	17	15	4	19	7	1	8
1:30	2:00	11	0	11	14	2	16	13	8	21	3	0	3
2:00	2:30	3	1	4	9	2	11	4	5	9	2	1	3
2:30	3:00	5	1	6	12	2	14	10	4	14	10	1	11
Total		26	3	29	51	7	58	42	21	63	22	3	25
Evening Inbound Traffic													
4:30	5:00	2	0	2	**7**	**0**	**7**	8	3	11	**4**	**1**	**5**
5:00	5:30	1	0	1	**1**	**1**	**2**	6	3	9	**0**	**1**	**1**
5:30	6:00	1	0	1	**2**	**1**	**3**	4	6	10	**1**	**1**	**2**
6:00	6:30	1	0	1	**1**	**0**	**1**	2	1	3	**2**	**0**	**2**
Total		5	0	5	11	**2**	13	20	13	33	7	**3**	10

Note: These two sections have the best sight distance within which to perform passing maneuvers that occur on the entire portion of the route on which the special signals have been installed.

Figures in bold face are the numbers of drivers that use the center lane while the traffic signals indicate that this lane is for use only by the traffic traveling in the opposite direction.

The before and after study included two additional phases: traffic light violations at intersections, and effects of signals on formation of queues and spacing distributions. About the only pertinent fact developed by the violations is that entirely too many drivers violate red indications. Tabulations and condensations of the queue formation observation are not yet complete.

A check of reported accidents by the Arlington County Police Department showed that during an 8-month period from January 1 through August 31, 1949, before signals were installed, 11 traffic accidents occurred. During

amber periods, in an effort to reduce accident occurrence, but so far with little benefit. This experience parallels that which we have noted in studies of other signalized intersections in Virginia, which have shown that almost invariably accident occurrence is more frequent after traffic signals are installed.

With but two exceptions—of which one is debatable—the special signal installation described has failed to yield any of the benefits traffic engineers normally expect from signals. The debatable exception is the fact that the three-lane roadway now satisfactorily carries with signals 20 percent more volume per day than it carried when there were no signals. The question is, if no signals had been installed, would all traffic conditions be as satisfactory as is now the case? I, for one, seriously doubt it. I don't doubt that the 3 lanes could successfully carry the 25,000 daily vehicles, but I do doubt that there could be as many successful conflicting movements from the cross streets. Who can say that such an uninterrupted arterial flow would not choke off side street entry almost completely? And who can say that if this arterial flow did not choke off side street entries, the accident occurrence would not be even greater than is the case with signals?

The other exception, which is not debatable, concerns public opinion. Before these signals were installed, there was almost a unanimity of opinion among the residents of the area and users of the roads that signalization was essential. Nothing has occurred since the installation to change this opinion, perhaps because the disadvantages of greater time loss and accident toll are not perceptible to a sufficient number of people. In my opinion, the public official who dared even suggest that these signals ought to be removed would be figuratively boiled in the oil of wrath of the residents of Arlington County. The realities of public opinion in this situation tempt me to offer the following tentative conclusions.

CONCLUSIONS

1. The general public regards traffic signals as the only satisfactory means of controlling large traffic volumes where there are intersections at grade, regardless of decreased efficiency of movement. This is perhaps due to certain basic factors: (a) The average motorist respects the authority of traffic signals far more than he respects the rights of other drivers. The driver on the artery never gives way to the driver on side street, except when forced by regulation.

(b) The average motorist will tolerate delay only when he knows that his turn will come up in some predetermined schedule. The man on the side street who is delayed 30 seconds at the uncontrolled intersection will yell to high heaven for a traffic signal; after he gets the stop light, which may delay him 60 seconds, he is perfectly happy.

(c) The reason the average motorist tolerates traffic signal delay may be because this type of delay is greatest during peak movement hours when the largest proportion of traffic is of the home-to-work or work-to-home variety. Thus the delay to a high proportion of the drivers involves only loss of non-productive time. In other words, the worker loses only his own time which has no tangible financial value; he receives pay only for portal-to-portal time, and not for home-to-home time. Therefore, the home-to-portal time has no real value.

2. Signalization of any artery will increase over-all delay and decrease the theoretical arterial capacity, but by promoting more orderliness in conflicting movements, the over-all practical capacity is probably increased.

3. The maximum practical capacity of the subject stretch of highway has already been reached for short periods during some peak hours.

4. The plan of reversible center lane use on three-lane roads by means of traffic signals is entirely workable, provided that certain conditions of high volumes and unbalanced flows are present.

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While the signal system was in the planning stage, the Highway Transport Research Branch of the Bureau of Public Roads became interested in the project as a source of additional information on the effects of signalizing a busy thoroughfare. This section, of which Mr. E. H. Holmes is Chief, agreed to collaborate with the Traffic and Planning Division of the Virginia Highway Department in the conduct of comprehensive studies of traffic behavior before the road was signalized, to be followed by similar studies after the signals were installed. Mr. O. K. Norman of the Bureau's Transport Research Branch was assigned the task of organizing and supervising the studies. He and his assistant, Mr. W. P. Walker, graciously provided me with some 32 sheets of tabular data with brief descriptive comments.

A COMPARISON OF LOWER CASE AND CAPITAL LETTERS FOR HIGHWAY SIGNS

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SYNOPSIS

During the last two years the California Division of Highways has experimented with the development and use of lower case letters for overhead destination signs on freeways. Recognition of word patterns is known to be fundamental in close reading of ordinary printed material and it was thought that habit and pattern factors might also make this form of letter desirable for highway signs. Opinion as to their effectiveness has been varied, however. The problem therefore was to measure the distance at which lower case signs could be read as compared to rounded capital letters.

Experiments were undertaken jointly by the California Division of Highways and the University of California Institute of Transportation and Traffic Engineering, to determine the distances at which signs of each kind of alphabet could be read. Letters from 5 in. to 18 in. in height were mounted on a bridge 17 ft. above the ground and a total of 75 observers made 3939 individual observations under daylight and artificial illumination.

White on black, series E capital letters and lower case letters of approximately the same average width-height ratio were used. These letters represented the development of this form of letter for freeway signs by the California Division of Highways. The stroke of the series "E" capital was widened slightly, also to correspond to the letters used by the California Division of Highways. By means of a prearranged series of positions, each size and form of letter was presented an equal number of times on right and left and at top and bottom of the sign background to balance out errors due to position on the sign bridge.

In order to approximate the effects of word pattern (as opposed to letter legibility) and word familiarity, three sets of measurements were made: (1) using scrambled letters; (2) using California place names, being viewed for the first time; and (3) using California place names, being viewed for the second time.

The "scrambled" groups gave control of guessing and equalized familiarity between observers. The familiar place names, unknown to the observers ahead of time, should involve pattern recognition similar to that by drivers somewhat familiar to the territory. The familiar names known ahead of time to the observers might correspond to the reading of signs by drivers who drive the same highway every day—for example, commuters on freeways.

As was expected, for both kinds of alphabet the distances increased with the size of letters and with the degree of familiarity. The increase due to increasing familiarity was greater for lower case letters than for capitals.

The comparison of lower case and capital letters can be stated in several ways. If recognition distance (and legibility distance) is expressed in terms of letter height using the total height of the "risers" of the lower case letters, these letters appeared at some disadvantage, presumably because they were narrower.

On the basis of width, the lower case words could be seen farther than the capital words, presumably because they were higher. Thus where length of sign is the controlling factor, which is often the case, these lower case letters would have the advantage.

On the basis of sign area, the advantage of one type of alphabet over the other depends upon the vertical spacing or margins. Due to the open area between the stems of lower case letters in a word, it would be expected that the margins or space between lines can be less than for capital letters without loss of legibility. Further observations are needed to determine these factors for the two forms of letter.