TRAFFIC FLOW EVALUATION OF PAVEMENT INSET LIGHTS FOR USE DURING FOG—BEFORE PHASE

by

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(The opinions, findings, and conclusions expressed in this report are those of the author and not necessarily those of the sponsoring agencies.)

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PURPOSE AND SCOPE

It was, therefore, the purpose of this research to investigate the traffic flow characteristics during fog within the system of pavement inset lights installed on Interstate 64 across Afton Mountain.

This phase of the project was limited to the collection of before data for the inset lights installed on the main line only. It was felt that the amount and reliability of before data should be assured before embarking on an after data collection phase. The time period available for collection of before data was limited since the inset lights will be placed in regular operation as soon as possible, making it difficult to accurately predict the amount of data which would be available for analysis as a result of the variability in the frequency of fog adequate for the purpose of the study.

It is the intent of this report to summarize the data accumulated to date and evaluate their reliability. Detailed analyses of each parameter observed will not be made, though various comments concerning the data will be included.

EVALUATION OF TRAFFIC FLOW

Traffic Flow Data Collection

One location on the westbound lanes of interstate 64 over Afton Mountain was chosen for data collection. This location is on the level section of the mountain top with a slight horizontal curve to the right. There were no interchanges prior to the site for a distance of 7 miles (11.3 km).

Data were collected using a system of tapeswitches placed in the configuration shown in Figure 1. The tapeswitches were placed on the highway using two methods, depending on weather conditions. First, during clear, dry conditions, they were attached to the road surface with double-faced tape over which 6-inch (15.24 cm) tape was placed. During adverse weather conditions, i.e., rain, fog, etc., the tapeswitches were attached to thin (0.022" or 0.56 mm) metal ribbons stretched across the highway and attached on the shoulder and median. This method allowed the quick, safe installation of the switches during any weather condition. Also, switches placed by this method proved to be the most durable and reliable during adverse weather conditions.

Data from all the tapeswitches were recorded simultaneously on a 4-channel chart recorder with each particular switch being identified by assigning different voltages. By knowing the distance between the tapeswitches on the road and the speed of the chart recorder, vehicular speeds and headways were determined by measuring the distances between impulses on the chart.

Vehicle placements were obtained by installing different length tapeswitch on the right edge of the traffic lane (lane 1) and noting which switch combinations were activated.

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INTRODUCTION

Reduced visibility resulting from fog presents a very hazardous condition on the highway because of the inability of motorists to readily observe pavement markings and signs, and other vehicles. Afton Mountain, which is traversed by Interstate 64, often is the site of such reduced visibility because of the low cloud covering the mountain top during periods of rain.

An acute awareness of the fog problem on Afton Mountain led to a decision by the Virginia Department of Highways and Transportation to install a lighting system consisting of pavement inset lights and low level illumination lights to aid motorists during periods of fog. In addition to the lighting system, a series of variable speed signs will be installed in an attempt to regulate vehicular speeds.

The installation is being made on a 5.8-mile (9.4 km) section of highway encompassing the top of Afton Mountain. Since fog often occurs on only a portion of the mountain, the installation was divided into 3 sections with each section separated at points observed to most often correspond with the fog patterns. Each section will be controlled by 2 fog detectors located at or close to the endpoints of the section and capable of detecting 5 levels of fog density. The light intensity within each section will be controlled by the fog at each detector.

The fog guidance system will consist of unidirectional airport runway lights in the pavement edge line along each side of the highway in both directions, with a spacing of 200 ft. (61 m) for tangent sections and 100 ft. (30.5 m) for curved sections. In addition to the white inset lights on the main line, amber lights will be installed on the off ramps, however, only on one side. Also, a small section of low level illumination lights are installed on an on-ramp.

It is felt that the lighting system will aid in highway delineation and thus lead to a reduction of vehicle stopages within the highway and instances of vehicles running off the highway. However, it is not known how the system of lights will affect vehicle speeds, headways, and placement. There has been some concern over the possibility that the system will present a false sense of security to some motorists and lead to higher speed along with greater differentials that may increase the possibility of accidents.

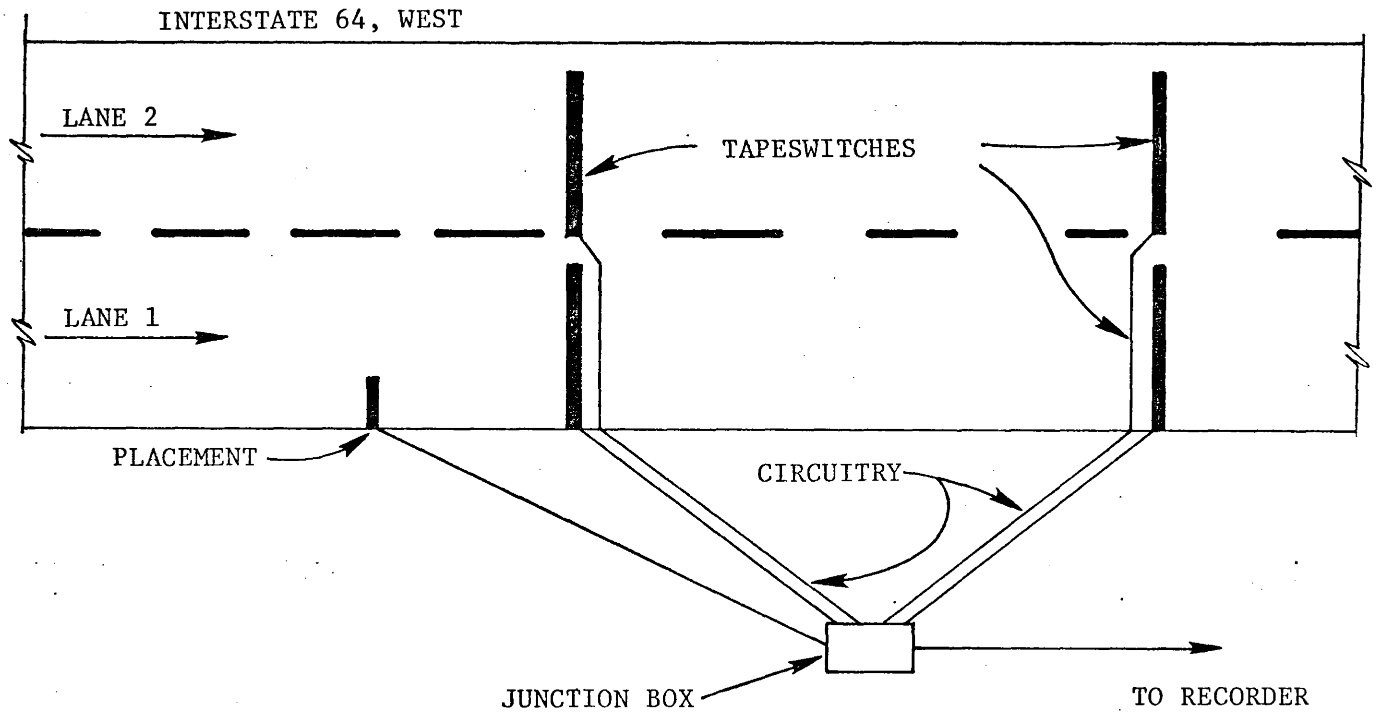

Figure 1. System of tapeswitches used for data collection.

The chart recorder used for data collection was placed in a vehicle parked approximately 1,000 ft. (304.8 m) past the site, which eliminated any influence the parked vehicle may have had on traffic flow.

Weather Conditions

The fog problem considered here is caused by low cloud cover in the mountainous areas. The fogs are relatively dense and uniform. However, variable fog conditions, fog banks, etc., do occur in the area where the highway enters the cloud cover and during periods when broken clouds are prevalent as a result of clearing weather.

It should be noted that data were taken only during uniform fog conditions extending at least 500 ft. (152.4 m) to 1,000 ft. (304.8 m) in advance of the site.

Fog Density

It is very important that the fog density be obtained as it influences the traffic flow characteristics. The density was determined by noting the number of visible centerline stripes on the pavement during daylight hours and the number of reflectorized shoulder delineators during hours of darkness. These distances are used for the purposes of identifying relative fog densities in the analysis of data. It should be noted that vehicles are visible for distances greater than those shown, the amount depending on vehicle type and taillight size and intensity (when illuminated).

Since the tapeswitches were approximately 1,000 ft. (304.8 m) from the data recorders, sight distances and fog uniformity were monitored by driving through the site at regular intervals.

DATA SUMMARY

The collection of traffic flow data during fog presented a situation in which one variable—fog density or sight distance—could change instantaneously, making it difficult to detect and consider small changes. As a result, sight distances were broken into five categories; 0-40 ft. (0-12.2 m), 50-80 ft. (15.2-24.4 m), 90-110 ft. (27.4-33.6 m), 120-150 ft. (36.6-45.8 m), and 160-200 ft. (48.8-61.0 m) which encompassed the uniform fog conditions encountered during the study.

Traffic flow data were classified within these sight distances and are presented accordingly. The traffic flow and sight distance data were then categorized according to daylight or darkness, morning peak, off-peak, and evening peak. Table 1 gives the hours for which data were accumulated along with the associated traffic volumes. A plot of the volume in terms of the time intervals for which data were collected is shown in Figure 2. Table 2 gives a summary of the time periods during which the 48.74 total hours of data were accumulated.

Speeds

Vehicular speeds were obtained from lane 1 and lane 2 for cars, trucks, and tractor-trailers. Table 3 gives a summary of speeds for cars, tractor-trailers and all vehicles, along with the associated standard deviations and volumes. Trucks were not included because of the low volume encountered. As expected, car speeds were higher than tractor-trailer speeds, and those in lane 2 (passing) were higher than in lane 1. In most cases speeds decreased with sight distance, however, there were instances when speeds increased slightly with a decrease in sight distance as was the case for daylight hours, off-peak traffic, and sight distances between 50-80 ft. (15.2-24.4 m) and 90-110 ft. (27.4-33.6 m).

TABLE 1

TOTAL HOURS OF DATA COLLECTED WITH ASSOCIATED TRAFFIC VOLUMES

	Hours of Data	Lane 1 Volume	Lane 2 Volume	Total Volume
Day				
Clear				
Off Peak (8:00 P.M.-4:30 P.M.)	5.95	1,307	196	1,503
P.M. Peak (4:30 P.M.-6:00 P.M.)	3.25	1,075	265	1,340
Fog				
A.M. Peak 50-80 (6:30 A.M.-8:00 A.M.)	0.45	89	24	113
A.M. Peak 120-150	2.0	51	8	59
Off Peak 50-80	3.72	600	67	667
Off Peak 90-110	7.95	1,532	508	2,041
Off Peak 120-150	6.58	1,466	425	1,891
Off Peak 160-200	4.12	914	167	1,081
P.M. Peak 90-110	2.00	620	235	855
P.M. Peak 120-150	2.88	875	310	1,185
Night				
Clear				
A.M. Peak (6:30 A.M.-8:00 A.M.)	0.67	73	9	82
Off Peak (6:00 P.M.-1:00 A.M.)	3.35	456	72	528
Fog				
A.M. Peak 0-40	0.75	36	13	49
Off Peak 50-80	2.35	239	83	322
Off Peak 90-110	2.72	236	69	305
TOTAL	48.74			

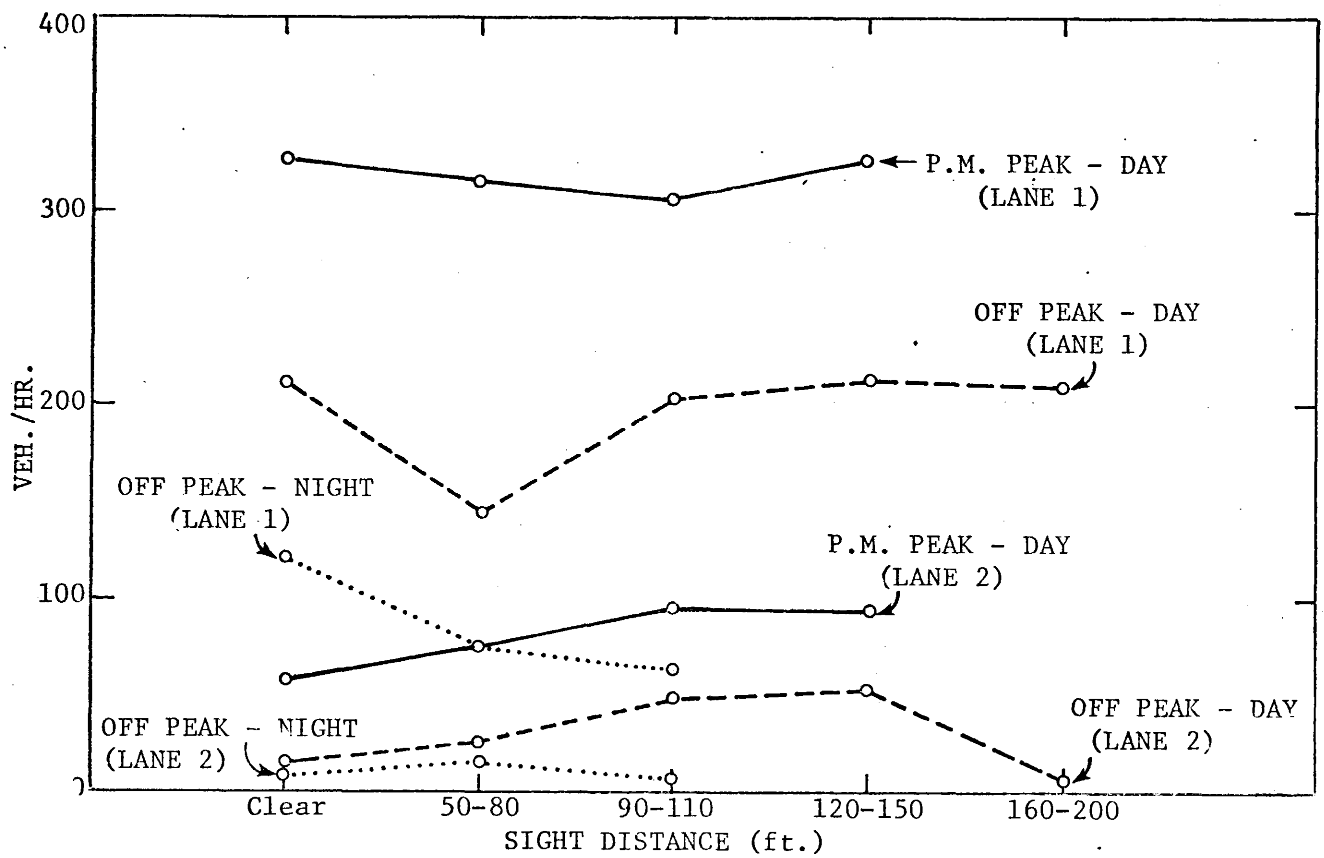

Figure 2. Volumes per hour for each sight distance (1 ft. = 0.30 meter).

TABLE 2

Time Period	Weekday	Weekend	Winter-Spring	1973	1974	1975
% of Total	93.3	6.7	100%	11.2	49.5	39.3

TABLE 3

SUMMARY OF VEHICLE SPEEDS AND ASSOCIATED VOLUMES
(1 foot = 0.30 meters)

	Time	Veh. Type	Clear Lane 1	Clear Lane 2	Fog 0-40 Lane 1	Fog 0-40 Lane 2	Fog 50-80 Lane 1	Fog 50-80 Lane 2	Fog 90-110 Lane 1	Fog 90-110 Lane 2	Fog 120-150 Lane 1	Fog 120-150 Lane 2	Fog 160-200 Lane 1	Fog 160-200 Lane 2
DARKNESS	A.M. PEAK	Car	48.0 6.6 57	51.4 4.6 8	24.5 4.6 24	31.0 5.7 11								
DARKNESS	A.M. PEAK	TT	36.5 5.3 10	---	25.7 5.4 10	---								
DARKNESS	OFF PEAK	Car	49.4 8.9 390	51.9 9.6 69			25.7 5.7 168	32.2 7.4 73	30.6 7.1 185	36.2 7.2 60				
DARKNESS	OFF PEAK	TT	34.8 8.5 54	---			28.3 5.8 15	36.0 5.4 3	30.0 4.9 31	34.7 7.3 3				
DAYLIGHT	A.M. PEAK	Car					39.3 7.3 62	46.6 4.9 18			48.8 8.2 44	56.6 7.7 5		
DAYLIGHT	A.M. PEAK	TT					32.9 5.1 8	---			---	---		
DAYLIGHT	OFF PEAK	Car	53.2 7.0 1026	56.7 5.4 171			41.0 6.6 150	46.7 7.9 56	40.0 6.6 1172	45.2 6.0 476	43.1 7.2 1176	49.3 6.0 382	46.1 7.1 665	50.0 6.7 50
DAYLIGHT	OFF PEAK	TT	38.9 10.5 158	---			32.0 5.7 26	---	34.0 6.7 170	41.5 5.4 11	34.9 7.4 158	43.1 7.1 7	36.8 7.9 85	---
DAYLIGHT	P.M. PEAK	Car	53.5 6.7 940	58.1 5.0 245					44.4 7.0 512	46.3 7.3 224	45.8 7.3 790	49.8 6.3 295		
DAYLIGHT	P.M. PEAK	TT	39.1 10.5 80	---					36.5 7.7 52	---	35.3 8.1 56	49.3 5.9 7		

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Headways

A summary of headway data is given in Table 4, which includes mean headway, standard deviation, and the average volume per 15 minute interval for each lane. It should be noted that all headways below 58 seconds are included in the table.

Headways were also obtained for 1-second time intervals up to 10 seconds, and 10-second time intervals between 10 and 60 seconds. Plots of the percentages of vehicles with headways in the intervals 1-2, 2-3, 3-4, and 4-5 seconds are shown in Figures 3 through 6. Presented another way, Figures 7-10 show the percentages of headways less than 2, 3, 4, and 5 seconds.

Vehicle Queuing

Data concerning the queuing of vehicles in each lane for various sight distances and time intervals are shown in Tables 5, 6, and 7 for the off-peak night, off-peak day, and p.m. peak day, respectively. Specifically, data on the volumes with headways below 58 seconds from which queuing was obtained along with the number of queues per 100 vehicles, the average number of vehicles in each queue, and the average queue speed are given in the tables. Queuing as shown in those tables was a direct function of the headway cutoff times (1, 2, 3, 4, and 5 seconds), i.e., for a 3-second cutoff time all vehicles (2 or more) with a headway of 3 seconds or less was considered as a queue. Therefore, as the cutoff time increased to 5 seconds the number of queues and vehicles per queue increased.

Vehicle queuing within 1-second headway intervals up to 5 seconds is shown in Figures 11 through 16 for various sight distances. These graphs show that there were more queues within the 1 to 2 second headway interval for all sight conditions. It is also noted that for the 1 to 2 second headway interval there was a higher queuing rate under restricted sight distances than for clear conditions; however, this trend changed as the headway intervals increased to the 4 to 5 second headway.

Vehicle Placement

The placement of vehicles relative to the right edge line of the traffic lane was obtained for two placement categories as follows:
(1) Tires on right side (as viewed by driver) of vehicle were 3 feet (.91 m) or less from the edge line, and
(2) Tires were 3 feet (.91 m) or more from the edgeline.

A summary of the placement data is given in Table 8, where the number of cars and tractor-trailers positioned 0-3 ft. (0-.91 m) and 3 ft. (.91 m) or more from the edge line are shown. Figure 17 shows the percentages of vehicles positioned from 0-3 ft. (0-.91 m) from the edge line for the off-peak periods. As noted in Figure 17 cars tended to drive further from the right edge line for sight distances in the 50-80 ft. (15.2-24.4 m) range than during clear conditions; however, within the 90-100 ft. (27.4-33.6 m) range this was reversed. In the

TABLE 4

SUMMARY OF VEHICLE HEADWAYS (CUTOFF TIME 58 SECONDS)
(1 foot = 0.30 meters)

	Time	Headway (Sec.)	Weather Condition											
			Clear		Fog Sight Distance (ft.)									
					0-40		50-80		90-110		120-150		160-200	
			Lane 1	Lane 2	Lane 1	Lane 2	Lane 1	Lane 2	Lane 1	Lane 2	Lane 1	Lane 2	Lane 1	Lane 2
DARKNESS	A.M. PEAK	Mean	20.7	17.4	22.6	2.7								
		Standard Deviation	15.7	12.0	17.3	1.1								
		Veh./15 min.	22.5	1.5	6.4	1.7								
	OFF PEAK	Mean	16.0	19.0			14.7	18.0	15.4	16.0				
		Standard Deviation	13.4	19.8			14.8	17.9	15.3	18.7				
		Veh./15 min.	30.1	2.6			19.4	4.4	15.4	2.0				
DAYLIGHT	A.M. PEAK	Mean					11.7	31.6			22.4	---		
		Standard Deviation					12.5	18.4			17.2	---		
		Veh./15 min.					42.8	7.2			21.0	---		
	OFF PEAK	Mean	14.5	20.2			15.8	28.4	15.3	18.5	13.3	18.1	14.1	21.6
		Standard Deviation	12.1	17.4			8.6	17.7	14.7	17.2	13.9	16.8	13.0	18.7
		Veh./15 min.	53.2	3.2			36.3	6.5	50.5	11.9	53.5	10.6	52.5	1.8
	P.M. PEAK	Mean	10.6	18.7					11.0	16.4	10.9	15.5		
		Standard Deviation	9.8	16.6					11.6	16.8	11.2	15.3		
		Veh./15 min.	82.0	14.5					76.8	23.8	81.6	23.6		

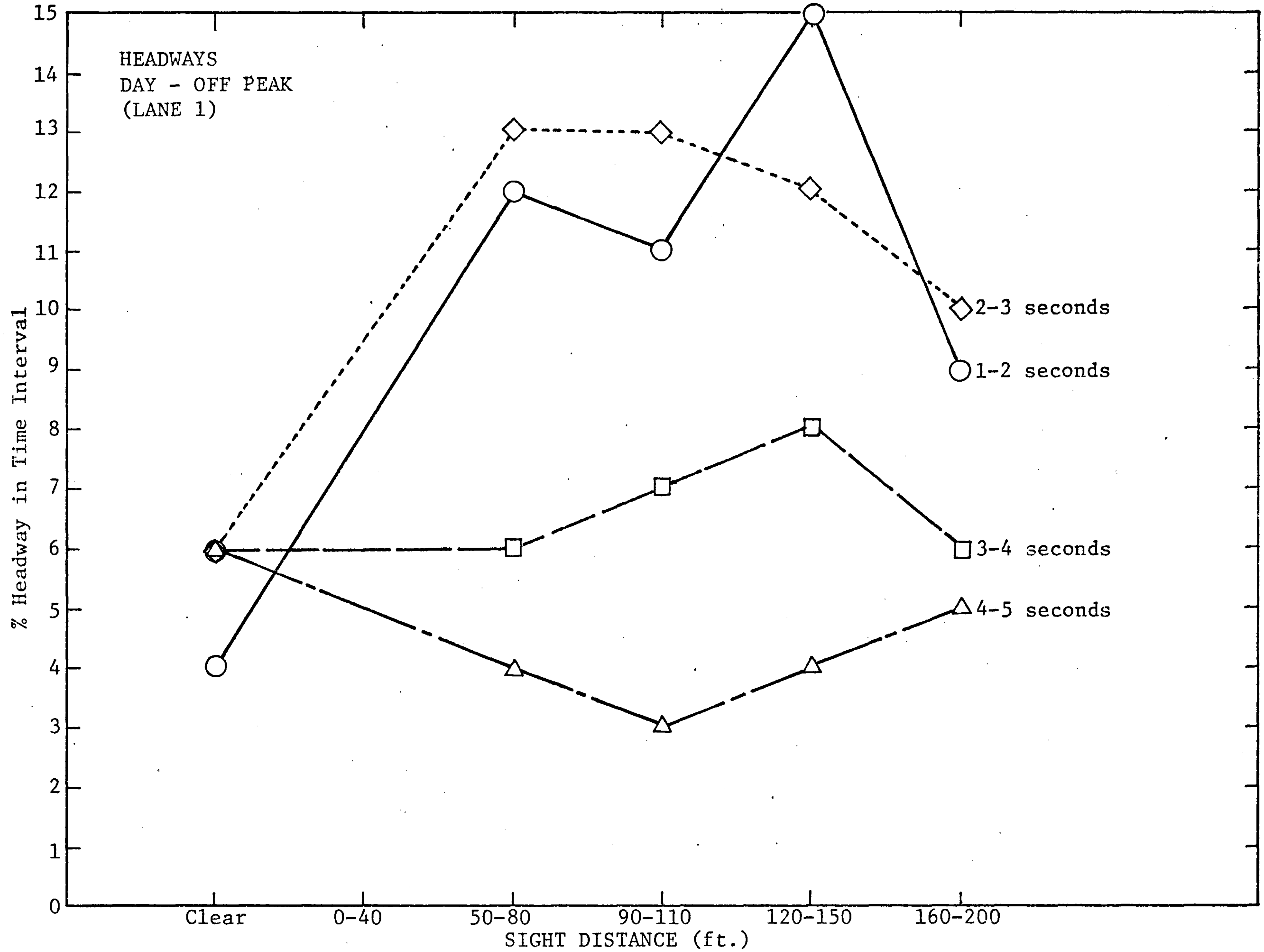

Figure 3. Percentages of headway in lane 1 during daylight off peak hours (1 foot = 0.30 meter).

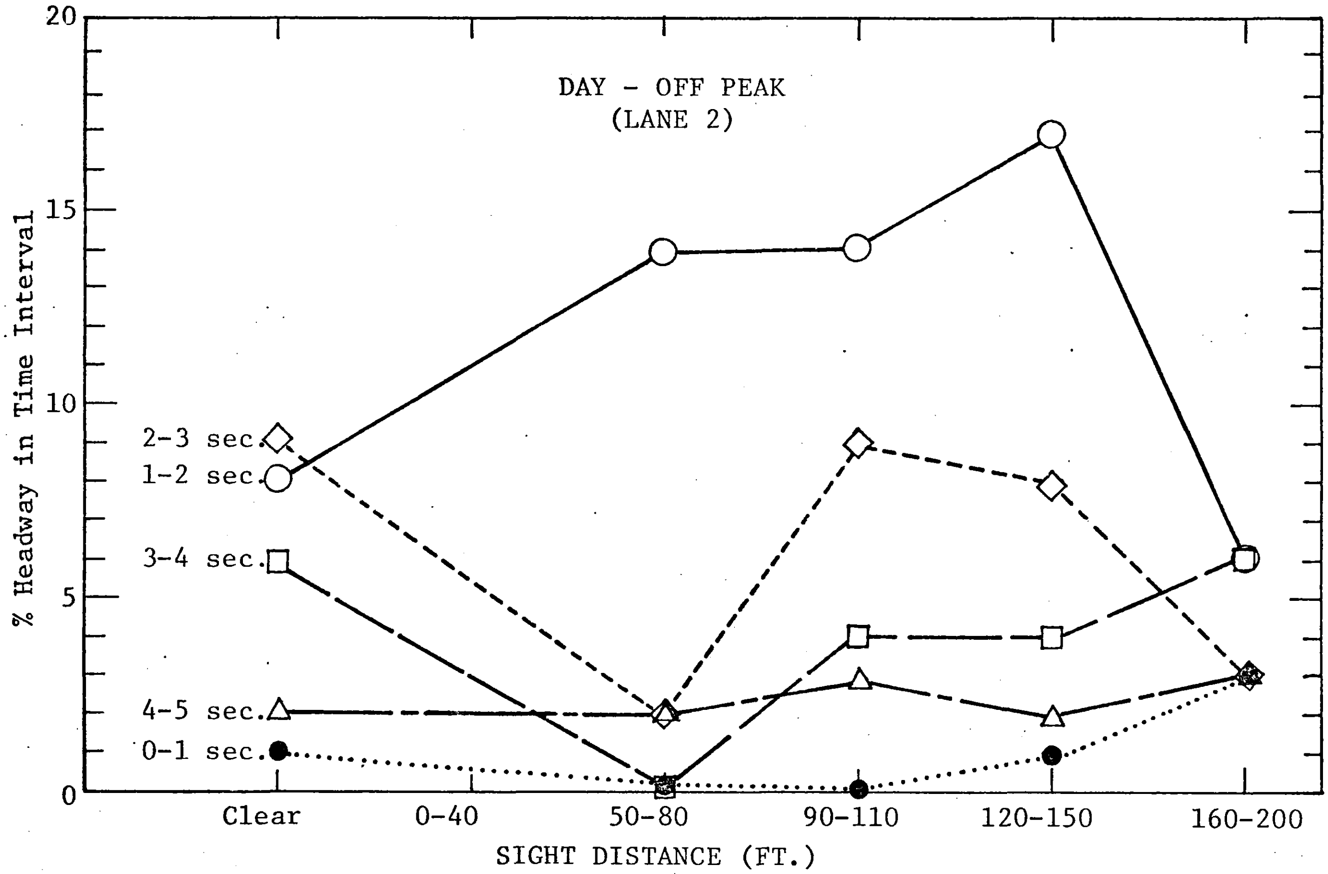

Figure 4. Percentages of headway in lane 2 during daylight off peak hours.

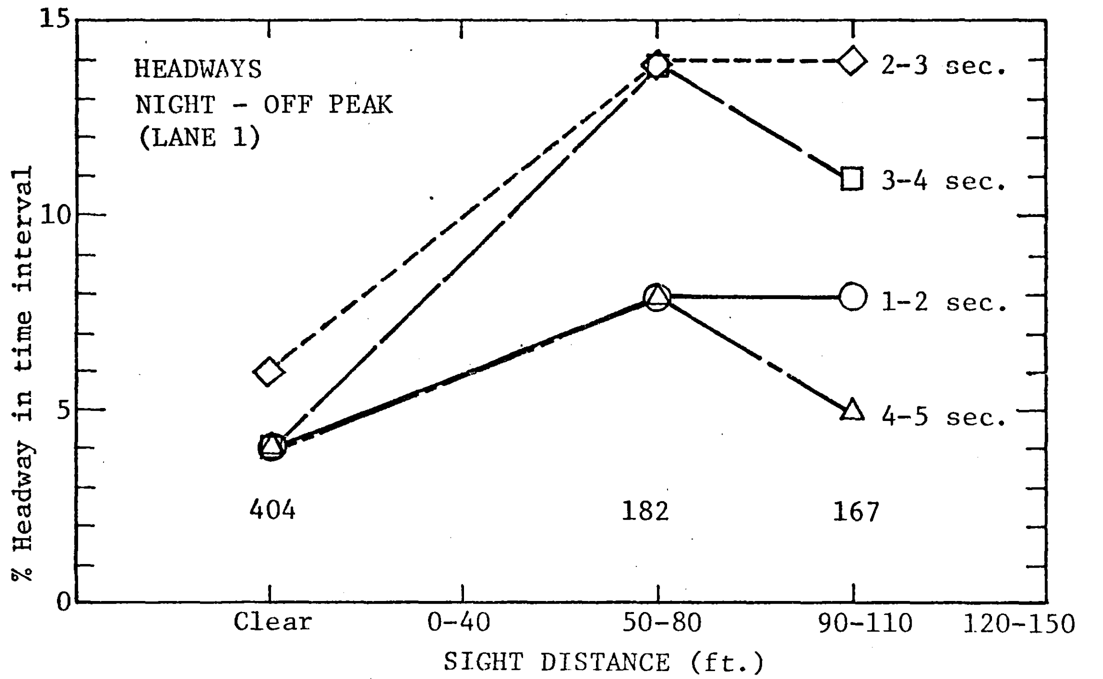

Figure 5. Percentages of headways in lane 1 during nighttime off-peak hours (1 foot = 0.30 meter).

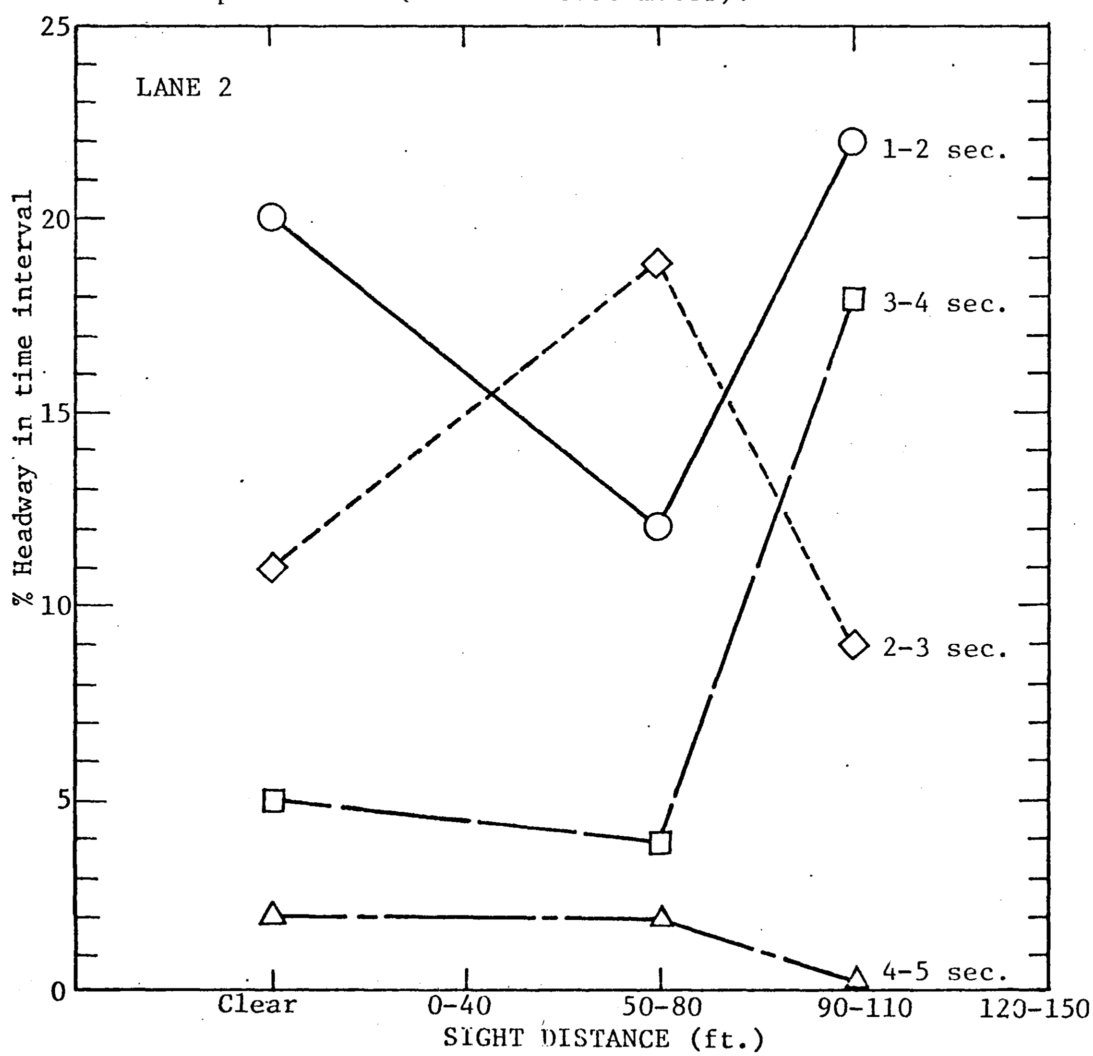

Figure 6. Percentages of headways in lane 2 during nighttime off-peak hours (1 foot = 0.30 meter).

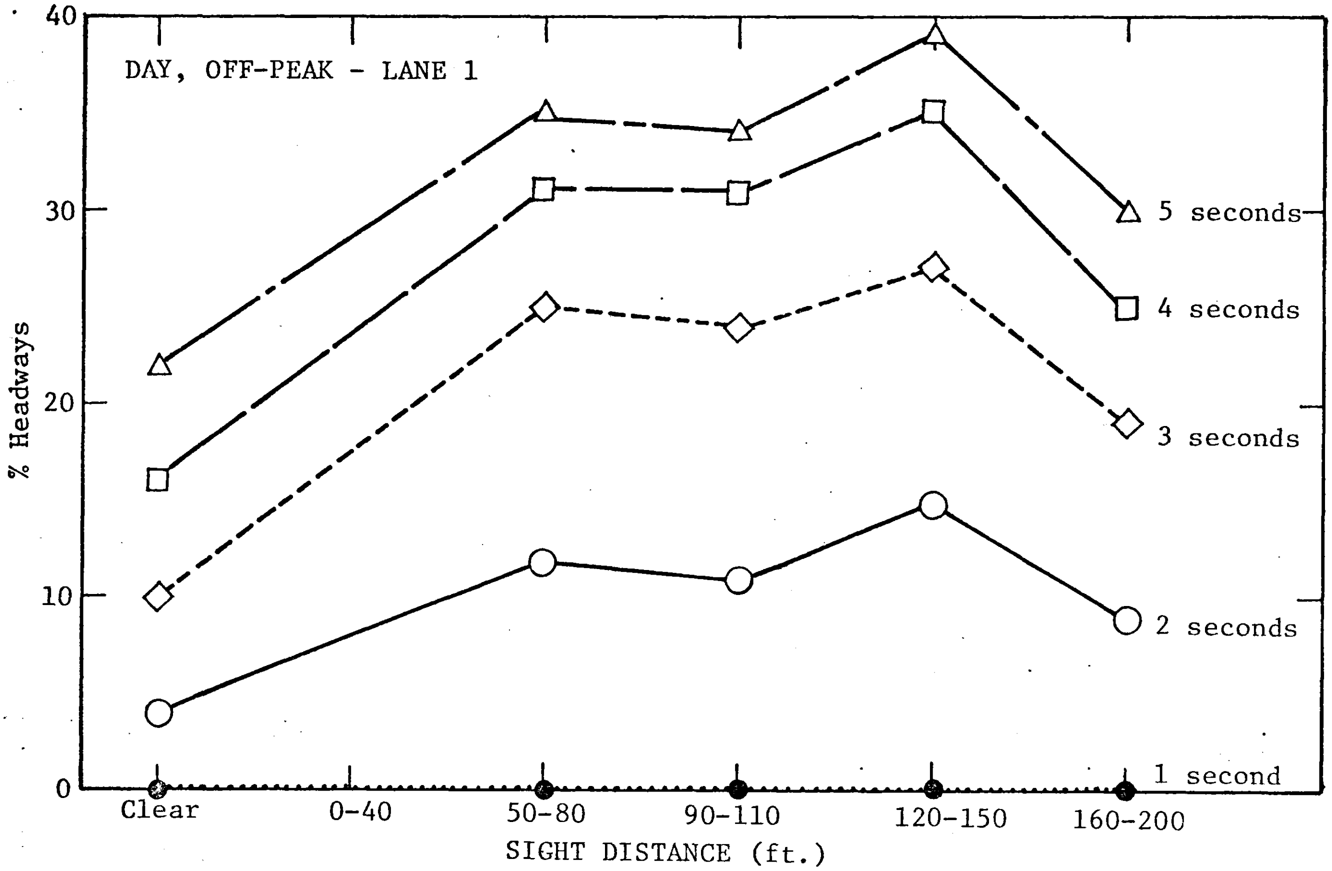

Figure 7. Percentages of headways less than time shown (1 foot = 0.30 meter).

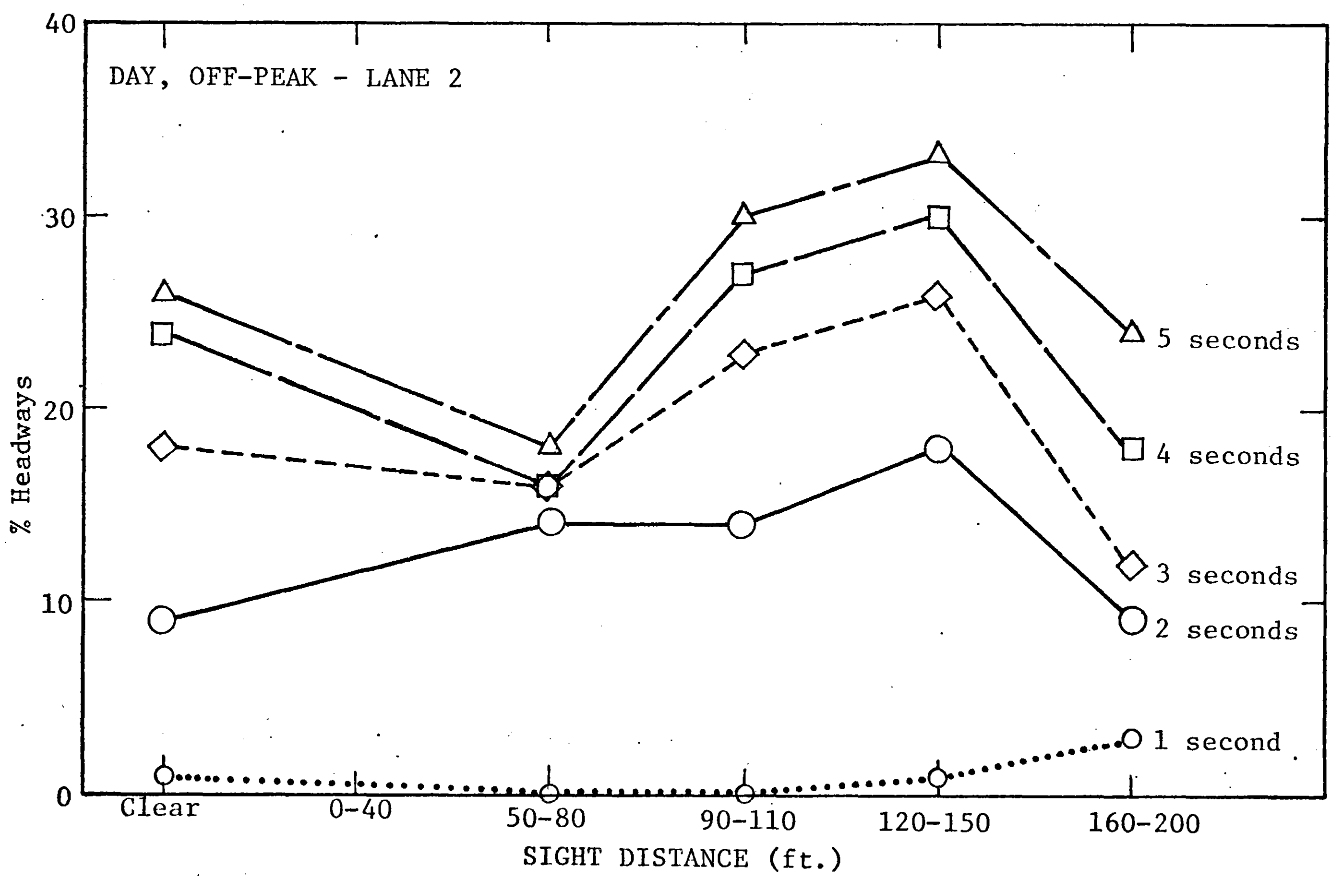

Figure 8. Percentages of headways less than time shown (1 foot = 0.30 meter).

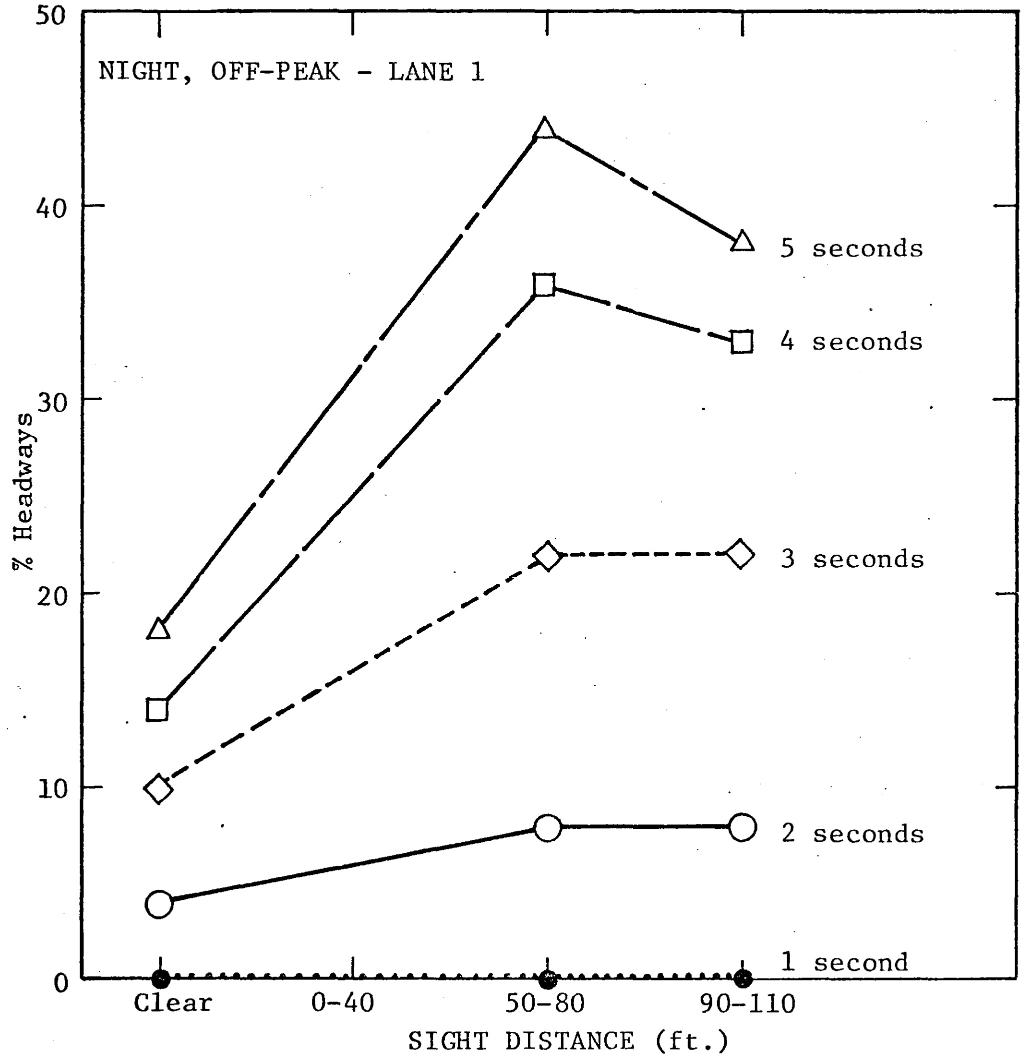

Figure 9. Percentages of headways less than time shown (1 foot = 0.30 meter).

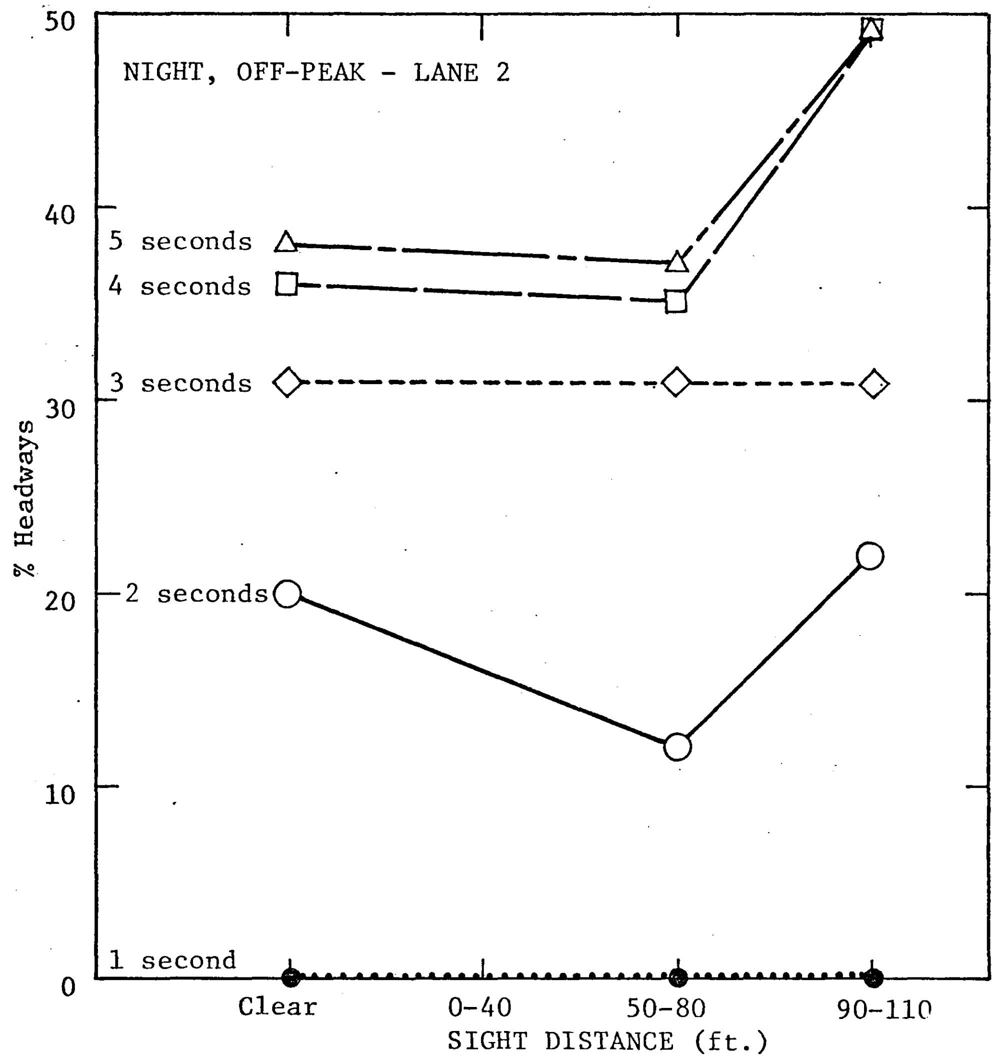

Figure 10. Percentages of headways less than time shown (1 foot = 0.30 meter).

TABLE 5

VEHICLE QUEUING—NIGHTTIME, OFF PEAK

Sight Condition	Queue	HEADWAY CUTOFF TIME									
		1 Sec.		2 Sec.		3 Sec.		4 Sec.		5 Sec.	
		Lane 1	Lane 2	Lane 1	Lane 2	Lane 1	Lane 2	Lane 1	Lane 2	Lane 1	Lane 2
Clear	Vol.	404	---	404	35	404	35	404	35	404	35
	Q/100	0.4	---	7.4	14.3	12.2	17.1	15.9	22.8	18.3	25.7
	Av. No.	2	---	2.1	2.8	2.1	3.0	2.1	2.8	2.2	2.7
	Av. Vel.	46.5	---	46.9	55.6	47.8	54.8	47.4	51.2	47.2	51.5
50-80	Vol.	---	---	182	41	182	41	182	41	182	41
	Q/100	---	---	9.3	12.2	18.7	26.8	23.6	34.2	26.4	34.2
	Av. No.	---	---	2.1	2.6	2.3	2.3	2.5	2.2	2.5	2.2
	Av. Vel.	---	---	26.7	29.3	26.3	32.1	26.2	33.8	26.5	33.8
90-110	Vol.	167	---	167	22	167	22	167	22	167	22
	Q/100	0.6	---	12.0	27.3	19.2	31.8	24.6	41.0	28.2	41.0
	Av. No.	---	---	2.1	2.2	2.3	2.4	2.5	2.4	2.5	2.4
	Av. Vel.	---	---	30.8	38.4	30.4	39.0	30.7	38.4	30.2	38.4

TABLE 6

VEHICLE QUEUING—DAYLIGHT, OFF-PEAK
(1 foot = 0.30 meters)

Sight Condition (ft.)	Queue	HEADWAY CUTOFF TIME									
		1 Sec.		2 Sec.		3 Sec.		4 Sec.		5 Sec.	
		Lane 1	Lane 2	Lane 1	Lane 2	Lane 1	Lane 2	Lane 1	Lane 2	Lane 1	Lane 2
Clear	Vol.	1264	72	1264	72	1264	72	1264	72	1264	72
	Q/100	0.8	1.4	4.8	11.1	10.3	16.7	15.3	20.8	18.4	20.8
	Av. No.	2	2	2.1	2.3	2.1	2.3	2.2	2.4	2.3	2.5
	Av. Vel.	48.1	45.0	50.4	54.6	51.1	54.0	50.9	54.5	50.9	54.5
50-80	Vol.	---	35	540	35	540	35	540	35	540	35
	Q/100	---	5.7	3.5	14.3	6.9	17.1	7.6	17.1	8.2	20.0
	Av. No.	0	2	2.2	2.2	2.2	2.2	2.3	2.2	2.4	2.1
	Av. Vel.	0	46.0	40.8	45.9	40.6	46.2	40.0	46.2	40.1	45.4
90-110	Vol.	1435	343	1435	343	1435	343	1435	343	1435	343
	Q/100	0.62	1.1	12.1	13.7	18.0	19.2	20.9	21.6	22.0	23.4
	Av. No.	2	2	2.1	2.3	2.4	2.3	2.5	2.4	2.6	2.4
	Av. Vel.	36.9	45.6	39.2	43.3	38.8	44.0	38.6	44.2	38.7	44.2
120-150	Vol.	1407	280	1407	280	1407	280	1407	280	1407	280
	Q/100	1.3	4.6	13.1	16.4	19.4	22.9	22.1	25.0	23.9	26.4
	Av. No.	2	2	2.3	2.2	2.5	2.2	2.7	2.3	2.8	2.3
	Av. Vel.	42.4	49.9	42.1	50.1	42.0	49.3	42.0	48.9	42.0	49.0
160-200	Vol.	864	---	864	30	864	30	864	30	864	30
	Q/100	0.8	---	8.7	20.0	14.0	20.0	17.0	23.4	18.3	23.4
	Av. No.	2	0	2.1	2.0	2.4	2.5	2.5	2.0	2.6	2.0
	Av. Vel.	46.6	0	44.6	54.6	44.8	54.6	45.0	53.4	45.0	53.4

TABLE 7

VEHICLE QUEUING—DAYLIGHT, P.M. PEAK

Sight Condition (ft.)	Queue	HEADWAY CUTOFF TIME									
		1 Sec.		2 Sec.		3 Sec.		4 Sec.		5 Sec.	
		Lane 1	Lane 2	Lane 1	Lane 2	Lane 1	Lane 2	Lane 1	Lane 2	Lane 1	Lane 2
Clear	Vol.	1064	188	1064	188	1064	188	1064	188	1064	188
	Q/100	1.3	2.1	8.7	10.6	14.6	15.4	18.0	19.6	20.7	21.7
	Av. No.	2	2	2.2	2.3	2.3	2.3	2.5	2.6	2.6	2.6
	Av. Vel.	51.9	56.1	52.9	57.8	52.7	58.1	52.5	58.2	52.5	58.1
90-110	Vol.	613	190	613	190	613	190	613	190	613	190
	Q/100	1.5	3.4	13.1	15.8	21.7	19.0	23.2	21.0	24.2	21.0
	Av. No.	2	2	2.2	2.5	2.4	2.7	2.6	2.8	2.8	2.9
	Av. Vel.	43.8	44.4	43.4	45.2	43.8	45.6	44.2	45.3	43.9	45.1
120-150	Vol.	860	249	860	249	860	249	860	249	860	249
	Q/100	0.8	2.8	13.0	16.9	20.6	19.7	23.7	20.5	24.9	22.5
	Av. No.	2	2	2.1	2.2	2.4	2.5	2.5	2.8	2.7	2.8
	Av. Vel.	45.1	49.1	45.2	49.2	44.6	49.9	45.0	49.9	44.9	49.7

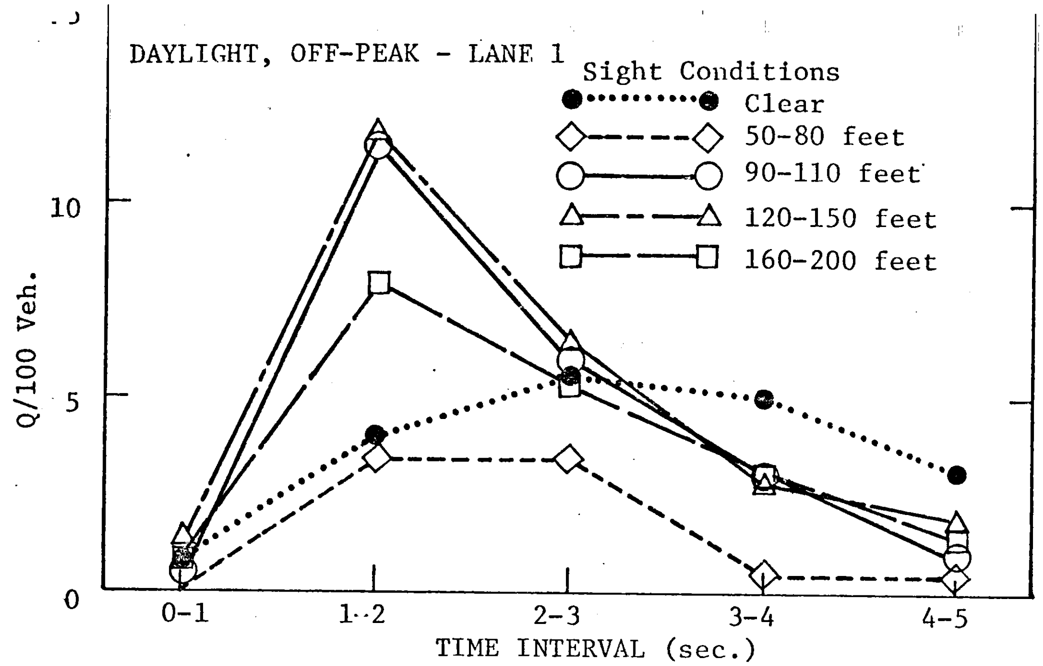

Figure 11. Vehicle queuing for headway intervals shown (1 foot = 0.30 meter).

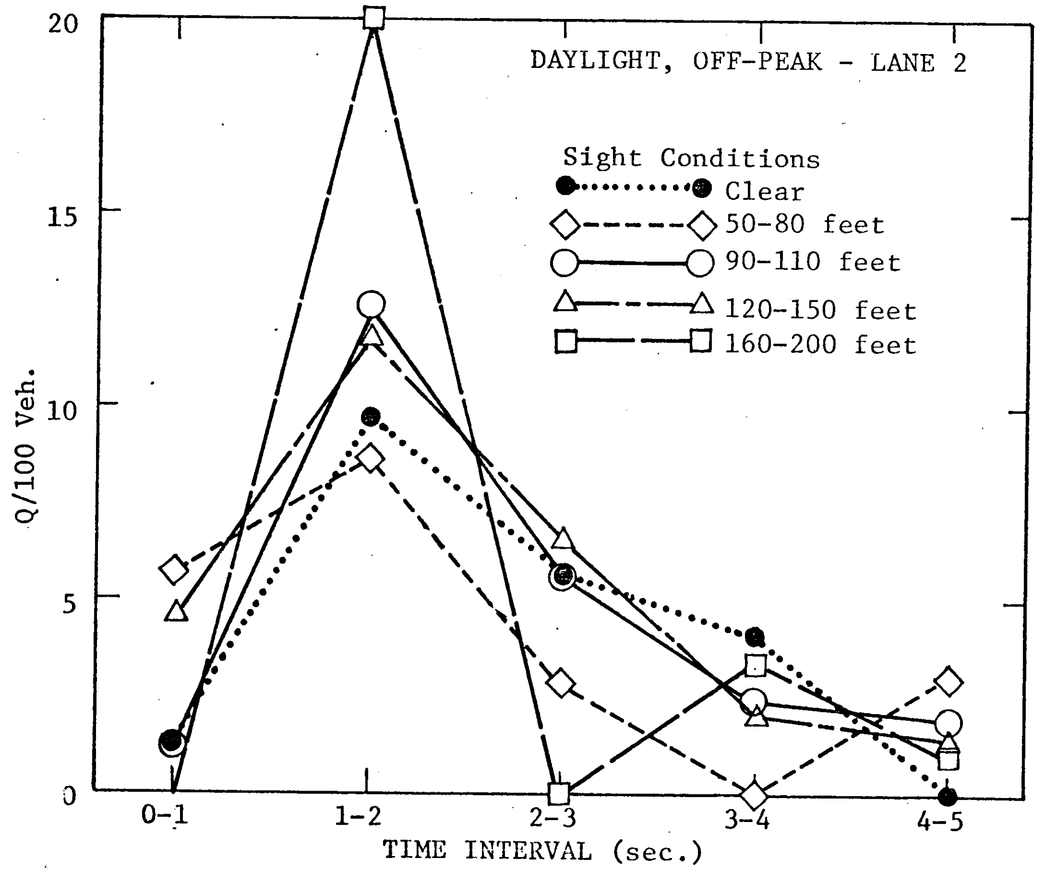

Figure 12. Vehicle queuing for headway intervals shown (1 foot = 0.30 meter).

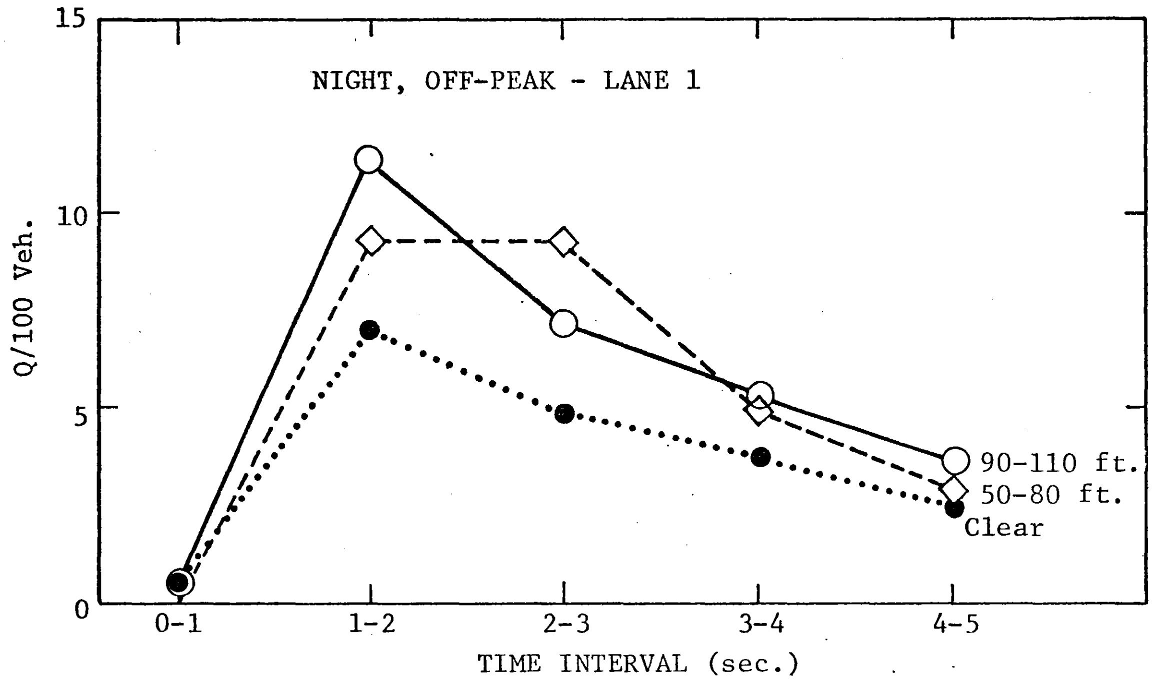

Figure 13. Vehicle queuing for headway intervals shown (1 foot = 0.30 meter).

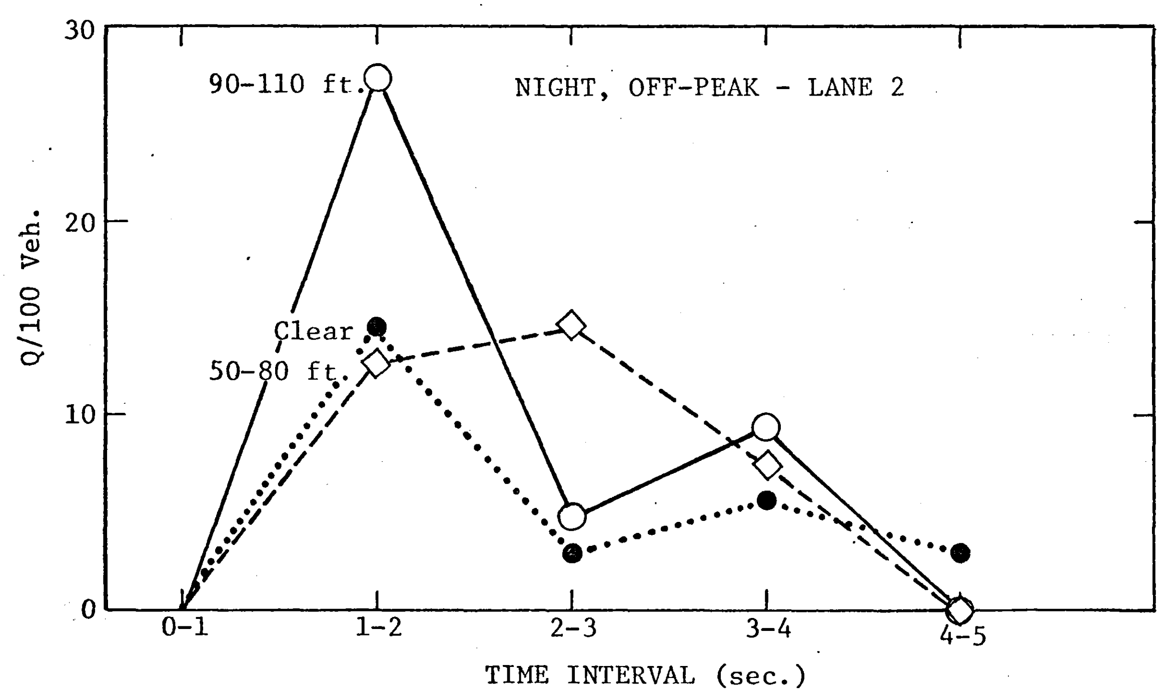

Figure 14. Vehicle queuing for headway intervals shown (1 foot = 0.30 meter).

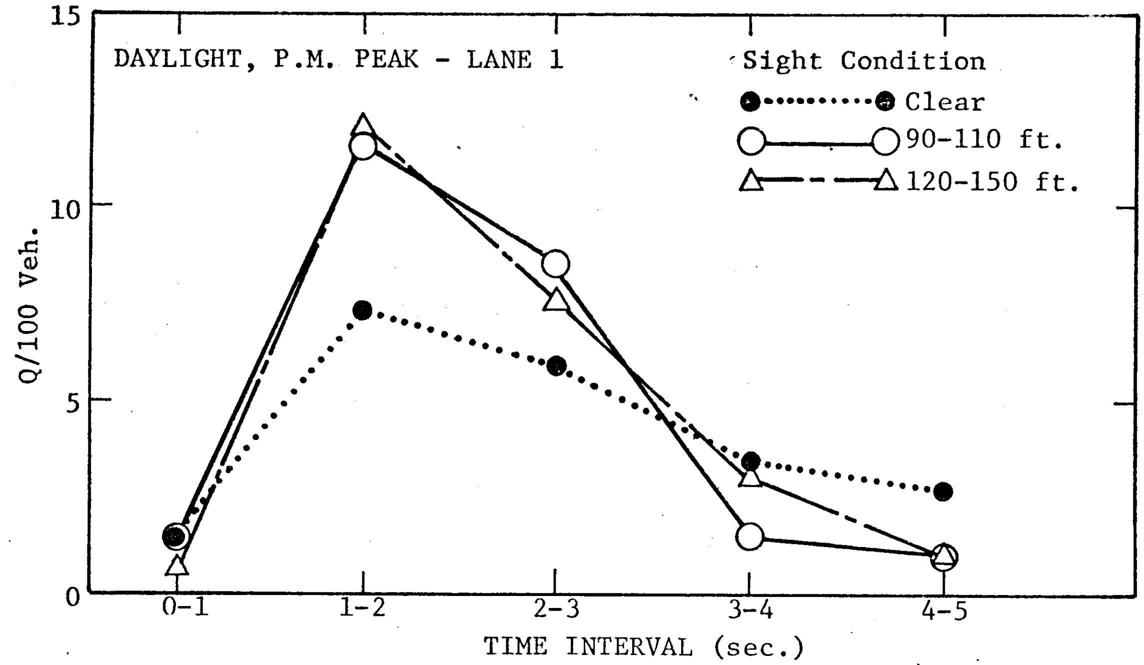

Figure 15. Vehicle Queuing for headway intervals shown (1 foot = 0.30 meter).

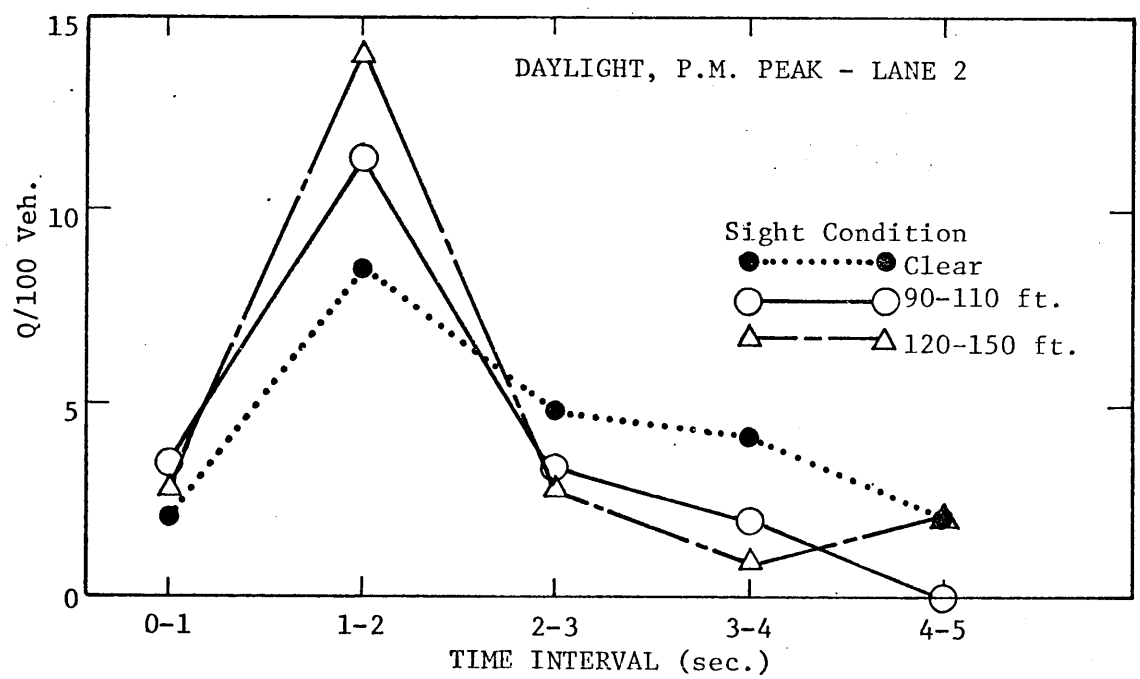

Figure 16. Vehicle Queuing for headway intervals shown (1 foot = 0.30 meter).

TABLE 8

SUMMARY OF PLACEMENT DATA FOR EACH TIME AND SIGHT CONDITION

Time		Vehicle Position (ft.)	Weather Condition											
					Fog-Sight Distance (ft.)									
			Clear		0-40		50-80		90-110		120-150		160-200	
			Cars	TT	Cars	TT	Cars	TT	Cars	TT	Cars	TT	Cars	TT
DARKNESS	A.M. PEAK	0-3			11	6								
		3+			14	4								
	OFF PEAK	0-3					1	1	14	6				
		3+					28	4	25	1				
DAYLIGHT	A.M. PEAK	0-3					34	8						
		3+					44	0						
	OFF PEAK	0-3	189	53			102	41	300	91	543	135	223	75
		3+	329	4			361	61	308	29	631	3	327	4
	P.M. PEAK	0-3							122	25	184	21		
		3+							184	0	118	1		

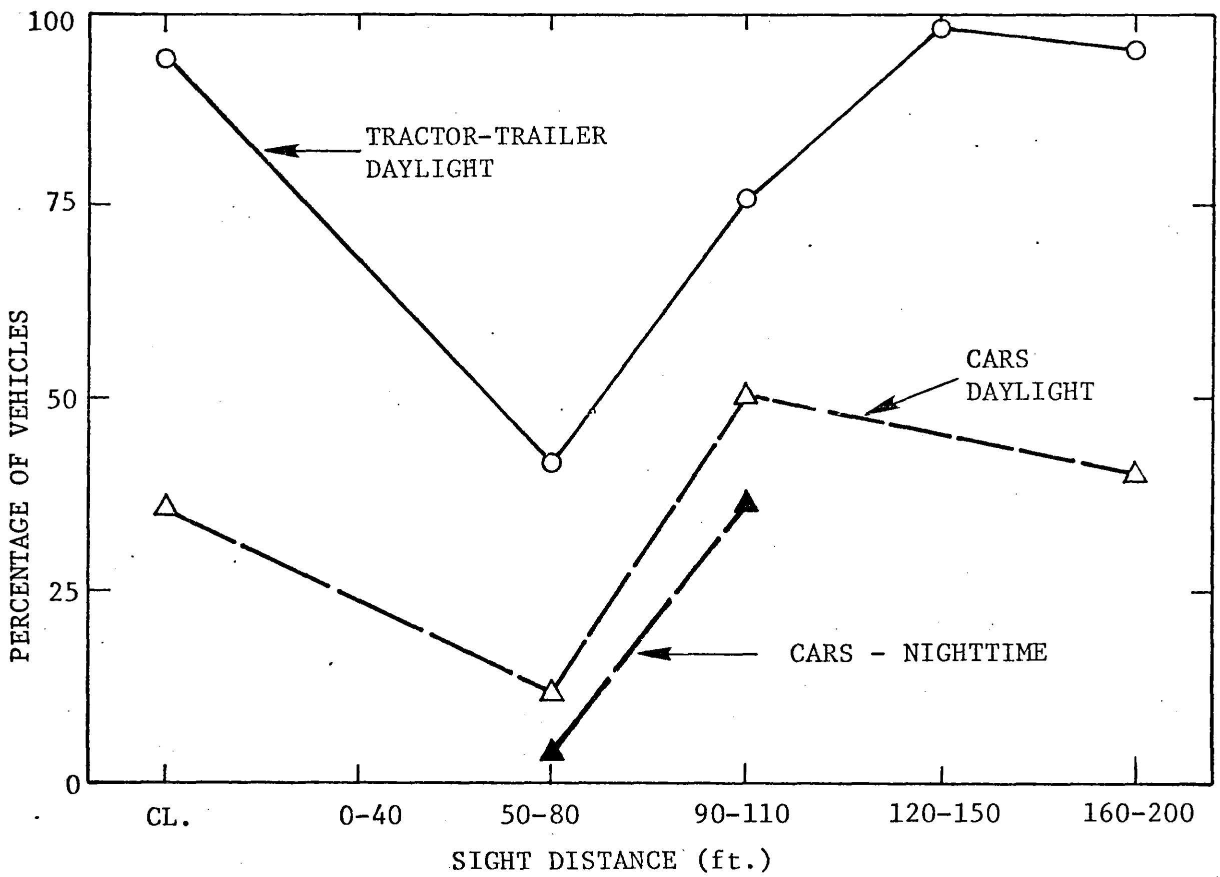

Figure 17. Placement of vehicles from 0-3 feet from edge line for off-peak periods.

120-150 ft. (36.6-45.8 m) and 160-200 ft. (48.8-61.0 m) sight distance ranges there was a tendency to approach the placements observed under clear conditions.

For tractor-trailers, 93% of the trailers were less than 3 feet from the right edge line during clear weather conditions, however, this figure decreased to 40% for visibility distances of 50-80 ft. (15.2-24.4 m). As the sight distance increased from 90 to 200 ft. (27.4 to 61.0 m) the percentages increased to those found initially for clear conditions.

Accident Analysis

An accident analysis was made of all accidents occurring from December 22, 1972, when the highway was opened, through February 28, 1975. Only accidents within the 5.8-mile (9.4 km) section of highway on which the pavement inset lights are being installed was considered. Table 9 is a compilation of all data from the 2.16-year survey.

TABLE 9

SUMMARY OF ACCIDENT ANALYSIS

Total Accidents	64
Injury Accidents	18
Persons killed	1
Weather conditions	
1) Clear	26
2) Cloudy	11
3) Ice, snow or sleet	17
4) Rain (no fog)	7
5) Fog	9
Daylight	36
Darkness	28

An in-depth analysis was made of the 9 accidents occurring during fog conditions and is summarized in Table 10. Also comments concerning each accident are listed.

TABLE 10

SUMMARY OF FOG RELATED ACCIDENTS

Total Accidents	9
Injury Accidents	3
Persons Killed	0
Ice on Road	4
Skid on Ice	3
Daylight	4
Darkness	5

(1) Vehicle stopped in traffic lane after being lost in fog and was struck by another vehicle. Driver was 84 years old (daylight); charged with unlawful stopping on highway.

(2) Vehicle turning from center crossover and struck by vehicle.

(3) Vehicle stopped on roadway and hit by two others. Road covered with ice; driver 70 years old.

(4) Vehicle went out of control on ramp. Driver charged with reckless driving.

(5) Vehicle stalled on icy bridge hit by two other vehicles. A short time later another vehicle skidded across ice onto vehicle involved in previous accident (3:00 a.m.).

(6) Vehicle hit truck when attempting to pass.

(7) Vehicle ran into patch of fog and driver lost control. Charged with reckless driving.

(8) Vehicle skidded on icy bridge.

(9) Vehicle skidded on icy bridge.

It was difficult to determine how many accidents were a direct result of fog, however, many of the incidents were obviously caused by restricted sight conditions.

RELIABILITY OF DATA

The numerous variables associated with this project, coupled with problems encountered in data collection and the time frame in which it was possible to collect the data, have limited the quantity of data that have been collected for analysis. Therefore, the sufficiency of the data, in terms of quantity, that have been accumulated for this before phase is questioned. It should also be noted that although the data anticipated and thought possible to collect under the work plan would be inadequate for the purpose of deciding the success or failure of the proposed lighting system, it would add to the data base concerning traffic flow during fog conditions for various types of delineation, in this case pavement inset lights, for which very little data are available.

As noted earlier, data were broken down in various categories depending on sight conditions, time of day and certain vehicle characteristics. The short time periods associated with the a.m. and p.m. peak periods along with the infrequency of fog with various sight conditions limited the available data in some categories, whereas in other categories there are substantially more data. An attempt will be made to determine the reliability of the available data in considering an after project phase, using statistical estimates along with engineering judgments.

Speeds

An estimate of the sample size required to detect prescribed differences between averages was used in determining the adequacy of the speed data. It should be noted that it was assumed that the standard deviation was the same in the before and after phase. By assuming a difference in the average before and after speeds the sample size needed for various levels of confidence may be estimated. Table 11 gives the sample sizes required for statistical significance for 1, 2, 3, 4 and 5 mph differences in the before and after average speeds for $\alpha = 0.5$ and $(1-\beta) =$ 0.7, 0.8, 0.9 and 0.95. Only those sample sizes are included which are within the sample size obtained in the before phase, as statistical significance could not be associated with the data if the sample size required was larger than those shown.

Referring to Table 11 for conditions of darkness during the a.m. peak, average speed differentials in the 3-4 mph (1.3-1.8 meter/sec.) range would have to be found between the before and after phase to obtain valid comparisons. However, a look at the data acquired within the off-peak indicates that speed differences in the 2-3 mph (0.9-1.3 meter/sec.) range would be sufficient for statistical significance. Table 11 shows a 4-5 mph (1.8-2.2 meter/sec.) average speed differential necessary for reliable comparison for the a.m. daylight peak, however, the off-peak and p.m. peaks would require only 1-2 mph (.4-.9 meter/sec.) differences.

Headways

The same procedure was used to determine the sample size needed for significant headway results as was used for the speeds. For data taken during off-peak periods of darkness (Table 4), after data would have to reflect mean headway differences in the 4 to 6-second range for results which would have high confidence levels associated with statistical analysis. Before data taken during darkness for the a.m. peak periods is insufficient for any statistical analysis because of the small sample sizes.

For time periods (Table 4) during daylight hours, average headway differences would have to be in the 2 to 3-second range for lane 1 and 3 to 5-second range for lane 2.

With reference to Figures 3 and 5, there seems to be definite trends in the percentages of headway within lane 1 for each sight condition in the 1 to 2-second, 2 to 3-second and 3 to 4-second time intervals. The plots in Figures 4 and 6 for lane 2 were more erratic because of the smaller value as compared to lane 1. Also, Figures 7 through 10 show definite trends in the percentages of headways less than 1, 2, 3, 4, and 5 seconds.

Vehicle Queuing

Only data for nighttime off-peak, daylight off-peak, and p.m. peak hours were included because of the small amount of queues associated with the low volume of data collected within the other time periods. Referring to Figures 11 through 16, definite trends emerge when comparing the queuing rates for various time intervals for the different sight distances. The queuing rates are generally higher in the 1 to 2-second time interval for all fog sight conditions than those found for clear conditions.

TABLE 11

ESTIMATE OF SAMPLE SIZE REQUIRED TO DETECT SPEED DIFFERENCES SHOWN (α = 0.5)

		MPH Diff.	Clear								0-40								50-80							
			Lane 1				Lane 2				Lane 1				Lane 2				Lane 1				Lane 2			
			.7*	.8	.9	.95	.7	.8	.9	.95	.7	.8	.9	.95	.7	.8	.9	.95	.7	.8	.9	.95	.7	.8	.9	.95
DARKNESS	A.M. PEAK	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--								
		2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--								
		3	--	--	--	--	--	--	--	--	35	--	--	--	--	--	--	--								
		4	48	52	61	--	--	--	--	--	19	21	36	--	--	--	--	--								
		5	30	36	59	68	--	--	--	--	8	16	21	36	15	--	--	--								
	OFF PEAK	1	--	--	--	--	--	--	--	--									--	--	--	--	--	--	--	--
		2	336	400	--	--	--	--	--	--									100	122	170	--	--	--	--	--
		3	140	176	240	285	--	--	--	--									42	38	78	100	75	--	--	--
		4	79	100	136	170	--	--	--	--									20	22	40	51	40	54	75	94
		5	48	61	88	115	43	59	82	105									15	19	30	37	21	28	43	56
DAYLIGHT	A.M. PEAK	1																	--	--	--	--	--	--	--	--
		2																	--	--	--	--	--	--	--	--
		3																	--	--	--	--	--	--	--	--
		4																	40	54	--	--	17	--	--	--
		5																	21	28	45	56	7	15	20	--
	OFF PEAK	1	919	1120	--	--	--	--	--	--									--	--	--	--	--	--	--	--
		2	255	305	420	497	110	135	--	--									158	--	--	--	--	--	--	--
		3	118	145	200	140	41	56	78	100									65	84	120	150	--	--	--	--
		4	60	80	110	141	21	25	41	53									38	46	63	81	43	--	--	--
		5	38	50	70	85	15	19	30	38									20	24	40	55	28	34	56	--
	P.M. PEAK	1	760	950	--	--	--	--	--	--																
		2	221	274	370	439	35	40	60	75																
		3	91	115	659	197	18	20	34	40																
		4	51	65	94	119	--	--	--	--																
		5	31	38	56	70	2	10	19	25																

		MPH Diff.	90-110								120-150								160-200							
			Lane 1				Lane 2				Lane 1				Lane 2				Lane 1				Lane 2			
			.7*	.8	.9	.95	.7	.8	.9	.95	.7	.8	.9	.95	.7	.8	.9	.95	.7	.8	.9	.95	.7	.8	.9	.95
DARKNESS	OFF PEAK	1	--	--	--	--	--	--	--	--																
		2	140	175	--	--	--	--	--	--																
		3	62	80	114	141	--	--	--	--																
		4	36	40	60	75	39	50	--	--																
		5	20	21	38	48	21	25	41	53																
DAYLIGHT	A.M. PEAK	1									--	--	--	--	--	--	--	--								
		2									--	--	--	--	--	--	--	--								
		3									--	--	--	--	--	--	--	--								
		4									--	--	--	--	--	--	--	--								
		5									36	42	--	--	--	--	--	--								
	OFF PEAK	1	618	782	1010	1300	456	--	--	--	760	958	1165	--	456	--	--	--	760	--	--	--	--	--	--	--
		2	140	173	240	282	110	135	183	223	176	218	297	350	110	135	183	223	221	255	370	439	--	--	--	--
		3	64	80	118	141	45	61	86	112	79	100	136	170	45	61	86	112	91	116	159	198	--	--	--	--
		4	37	45	62	80	22	27	45	59	41	58	78	100	22	27	45	59	48	52	61	116	36	40	--	--
		5	20	22	40	50	16	20	32	38	22	28	45	59	16	20	32	39	30	36	59	68	18	20	37	45
	P.M. PEAK	1	--	--	--	--	--	--	--	--	761	--	--	--	--	--	--	--								
		2	176	218	--	--	176	217	--	--	198	241	331	393	128	160	219	260								
		3	79	100	136	170	75	91	125	160	82	108	148	182	55	63	94	119								
		4	40	34	78	93	38	50	70	85	43	58	81	102	27	32	56	62								
		5	22	27	45	39	21	28	43	56	28	34	56	63	18	21	35	41								

*(1 - β)

Placement

Referring to Table 8, it is seen that most of the vehicle placement data were obtained during the daylight hours with that gathered during the off-peak being the highest. The table shows that placement data (off-peak, daylight hours) were obtained from 518 cars during clear sight conditions, 463 cars for sight distances of 50-80 ft. (15.2-24.4 m), 608 cars in the 90-110 ft. (27.4-33.6 m) range, 1,174 cars in the 120-150 ft. (36.6-45.8 m) range, and 550 cars in the 160-200 ft. (48.8-61.0 m) range.

Accident Analysis

It would be difficult to develop a before-after accident analysis as 2 years of after data would be desirable, and an after phase would be completed prior to that time. Also, the number of fog related accidents within the 2 year after period would probably be inadequate for statistical analysis. However, it is felt that an in-depth analysis of accidents in an after phase would be beneficial as a means of determining any influence of the guidance system on the accident experience.

CONCLUSIONS

As it was the intent of this report to summarize the data accumulated to date as the before phase of the project and evaluate their reliability, conclusions will be limited to these aspects of the project.

1. Speed data collected during the off-peak periods, during both daylight and darkness conditions, along with data collected during the p.m. daylight peak seems sufficient for statistical analysis with high levels of confidence (α = 0.5, 1- β = .9-.95).

2. Although statistical analyses would be difficult for the majority of headway data collected because of the high standard deviations, definite trends are apparent when plotting headways as a function of sight conditions for the night- and daytime off-peak periods.

3. Sufficient data concerning vehicle queuing were collected for darkness off-peak and daylight off-peak and p.m. peak periods only. Plots of queuing as a function of time intervals show definite tendencies when comparing queuing during clear conditions as opposed to limited fog sight distances.

4. Vehicle placement data appear to be satisfactory only for the daylight off-peak hours.

5. A valid before-after accident analysis is questionable because of the limited fog related data; however, it is felt that an in-depth investigation of any fog related accidents in an after phase would be desirable to determine any possible interrelationships between the guidance system and the accidents.

RECOMMENDATIONS

Based on the data collected and the analysis made, it is felt that sufficient information is available for consideration to be given for an after phase study, however, certain limitations are recommended as follows:

(1) All data would be obtained from the one location considered in the before phase.

(2) Data would be collected only for off-peak periods during both daylight and darkness, e.g., between the hours of 8:30 a.m.-4:30 p.m. and 6:30 p.m.-12:00 p.m., with only weekdays being considered.

(3) One year should be allowed for collection of data during the after phase for the guidance system involving the pavement inset lights only.