ADVANCE TRAFFIC CONTROL WARNING SYSTEMS FOR MAINTENANCE OPERATIONS

FINAL REPORT

by

S. C. SHAH

AND

G. L. RAY

Research Report No. 105

State Project No. 736-02-55
Research Project No. 72-1M
Louisiana HPR 1 (14)

Conducted by
LOUISIANA DEPARTMENT OF HIGHWAYS
Research and Development Section
In Cooperation with
U. S. Department of Transportation
FEDERAL HIGHWAY ADMINISTRATION

July 1976

ACKNOWLEDGEMENTS

The authors are grateful for the assistance and cooperation provided by the District Maintenance Engineers and their personnel during the study evaluation. Appreciation is expressed to Messrs. John Melancon and Veto Yoches who managed this study during various phases, and to Messrs. Hirschmann, Vaccaro and Henderson for their assistance in gathering the field data. The authors are especially thankful to the report review committee for their valuable suggestion and to many support personnel and typists who helped in the successful completion of the study.

IMPLEMENTATION

The basic effort in this study was to seek data that would provide quantitative guidelines in making decisions as to the necessity for employing bigger signs at higher mountings. The study confirms the presently used sign standards for controlling traffic through maintenance work areas.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. INTRODUCTION

Advance traffic control warning systems during maintenance operations generally include signs and other supplemental installations such as flags, flashing lights, etc. The basic installations generally perform the task of warning, controlling, protecting and expediting the flow of traffic and also providing safe and effective work areas. Basically, an effective system should, amongst other things, command attention and convey a simple and clear meaning. To ensure these requirements, guidelines have been provided with respect to the design and placement of the various signs (1).* The design is specified in terms of size, shape, color, etc. The placement of these signs has to be within the core of vision of the driver so that the driver has adequate time to respond.

Kentucky (2) has reported effects of sign color on traffic response at construction sites. Information as to the effect of sign size and height of placement on driver responses seems to be minimal. In recent years, however, the tendency has been to go to bigger signs and higher mounting. Although there may be intuitive justification for this tendency, a need exists to quantitatively evaluate the effect of some of the sign design parameters on the driver responses. This study is an attempt to measure, quantitatively, the effect of sign size and sign height on the driver response during maintenance operations involving lane closures in rural areas.

---

*Underlined numbers in parentheses refer to list of references.

2. PURPOSE AND SCOPE

Purpose:

The primary purpose of this study was to evaluate the effect of advance traffic control warning systems on traffic flow and driver alertness, under various sign sizes, sign heights, and sign legend configurations, with and without flashing signs (attention-getting devices) and under different traffic situations in rural areas.

Scope:

All maintenance operations were of prolonged duration requiring single lane closure. Multilane operation was on the Interstate system and was limited to exterior lane closure only. The number of vehicles required to merge under this condition would be larger than any other lane closure since, in rural areas, higher volumes are generally encountered in the exterior lane. All maintenance operations were limited to work zones less than 300 feet (91.4 m). Advance warnings are considered more critical for short work zones because of shorter queues.

The scope of the study did not permit observations at sufficient times to explore the effects of variables such as roadway alignment, weather, terrain, etc. Likewise, situations arising out of detours and sight obstructions were also eliminated from the study design. In order to reduce maintenance scheduling problems, use of simulation or "dummy" maintenance operation was allowed. However, care was exercised to ensure that such simulations duplicated actual maintenance lane closures.

3. PROCEDURE

I. Experimental Design

Factors generally considered to have effect on driver alertness (message comprehension) were defined as follows:

A. Independent Variables	Range of Variation
1. Interstate	
a. Sign size	30"(0.762m), 36"(0.914m), 48"(1.22m)
b. Sign height (from ground elevation to bottom of sign)	1'(0.305m), 5'(1.52m)
c. Sign legend	Specific, General, Diagrammatic
d. Trailer mounted flashing sign	Sequentially Flashing Chevrons
2. Two-Lane	
Only a and b above	

B. Dependent or Response Variables

1. Interstate

a. Average speed in critical zone

b. Traffic conflicts

c. Number of vehicles properly queued in travel lane between the last sign and the first cone taper.

2. Two-Lane

Only a and b above

Experiments were conducted at four different locations or sites within the State for each type of facility, two-lane and Interstate. Furthermore, all test sites were in rural areas with traffic volumes greater than 1000 vehicles per day. All combinations of independent variables were not compared across all test sites mainly because of scheduling constraints. For example, diagrammatic signs were tested at one site only. Likewise, for another location, flashing sign data could not be obtained due to electrical malfunction. Figure 3.1 is a flow chart of the experimental design for the Interstate system.

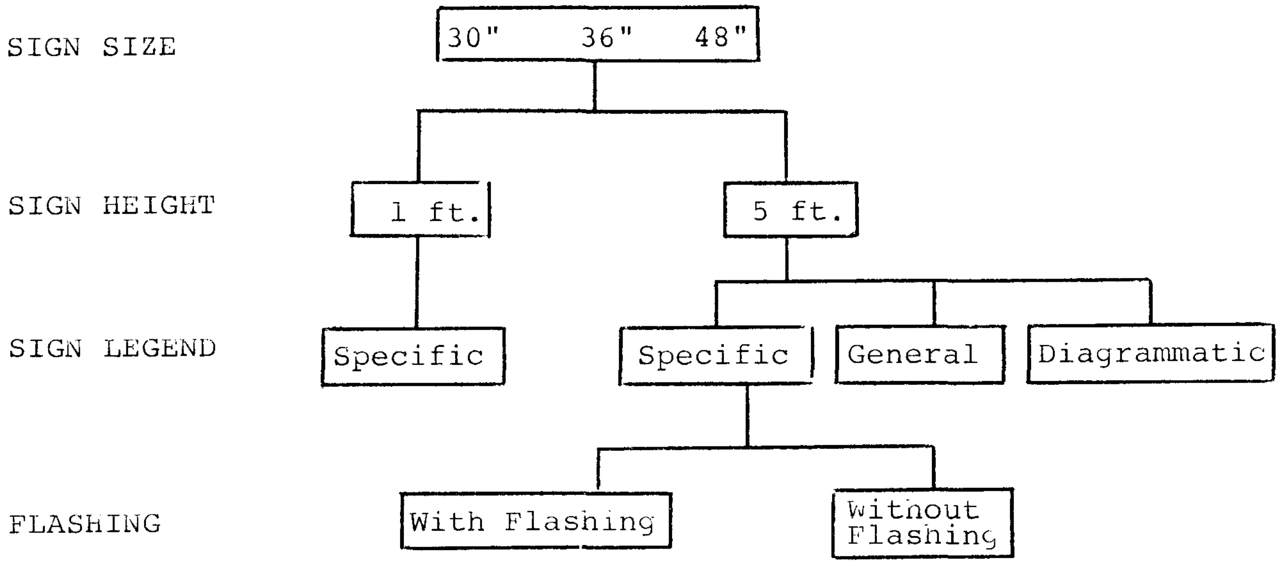


FIGURE 3.1: GENERAL LAYOUT OF EXPERIMENTAL DESIGN ON INTERSTATE SYSTEM

II. Sign System Layout

Figures 3.2 and 3.3 show the generalized three sign series configuration for two-lane and the Interstate system, respectively. These are minimum standards as defined in the Department's Maintenance Traffic Control Handbook (3). The independent variable, sign legend, was evaluated on the Interstate system with respect to the message on the third sign only, namely RIGHT LANE CLOSED 1000 FT. This message was considered specific. The corresponding signs with general (MERGE LEFT) and diagrammatic messages are also shown in the layout. As mentioned before, the diagrammatic message was evaluated at one location only. The location of the trailer-mounted flashing sign is also shown in the layout. Table 3.1 lists the variables that were evaluated at each of the locations on the Interstate system. In this table the location in District 62 involved dummy maintenance operations. All other locations involved maintenance operations that required removal of distressed segment of the pavement section and subsequent replacement with either asphaltic concrete or concrete mixtures. Use of flashing beacons on work vehicles was prohibited at all locations.

III. Measurement of Parameters

A. Spot Speeds

Radar spot speeds were measured within two zones (simultaneously) at each location throughout the evaluation period. One zone was at a location approximately two miles (1.6 km) in advance of the first sign. The other zone was defined as between the last sign and the first cone taper. This zone was considered the critical zone. The first zone was defined to provide normal highway speeds of vehicles unaware of the impending roadway operation ahead. The magnitude of

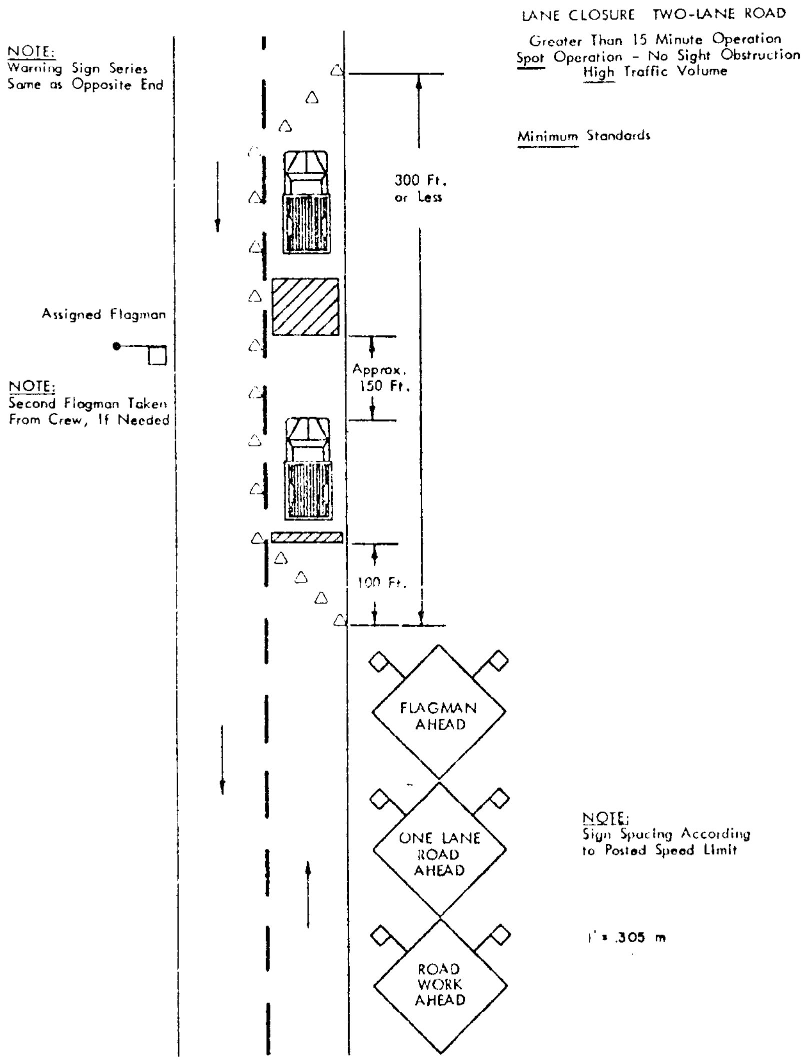


FIGURE 3.2: Sign Scheme for Two-Lane System

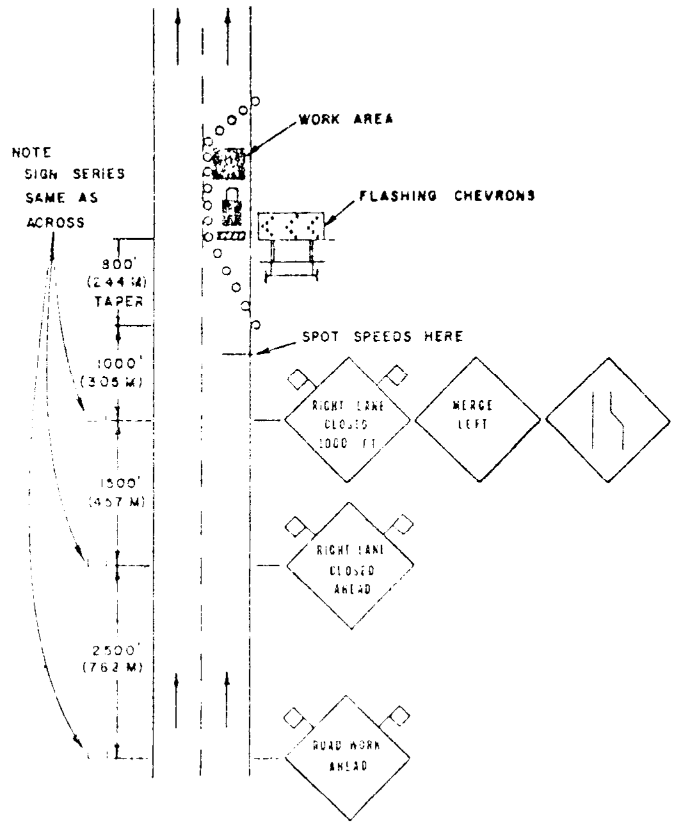


FIGURE 3.3: Sign Scheme for Interstate System

TABLE 3.1
VARIABLES EVALUATED AT THE FOUR LOCATIONS

SIZE/HEIGHT (IN)/ (FT)	LEGEND (LAST SIGN ONLY)	LOCATIONS(DISTRICTS) 03	04	07	62
30 / 1 & 5	SPECIFIC	***	***	***	***
30 / 5	SPECIFIC WITH FLASHING CHEVRON	***	***		***
30 / 5	GENERAL	***	***	***	***
30 / 5	DIAGRAMMATIC				***
36 / 1 & 5	SPECIFIC	***	***	***	***
36 / 5	SPECIFIC WITH FLASHING CHEVRON	***	***		***
36 / 5	GENERAL	***	***	***	***
36 / 5	DIAGRAMMATIC				***
48 / 1 & 5	SPECIFIC	***	***	***	***
48 / 5	SPECIFIC WITH FLASHING CHEVRON	***	***		***
48 / 5	GENERAL	***	***	***	***
48 / 5	DIAGRAMMATIC				***

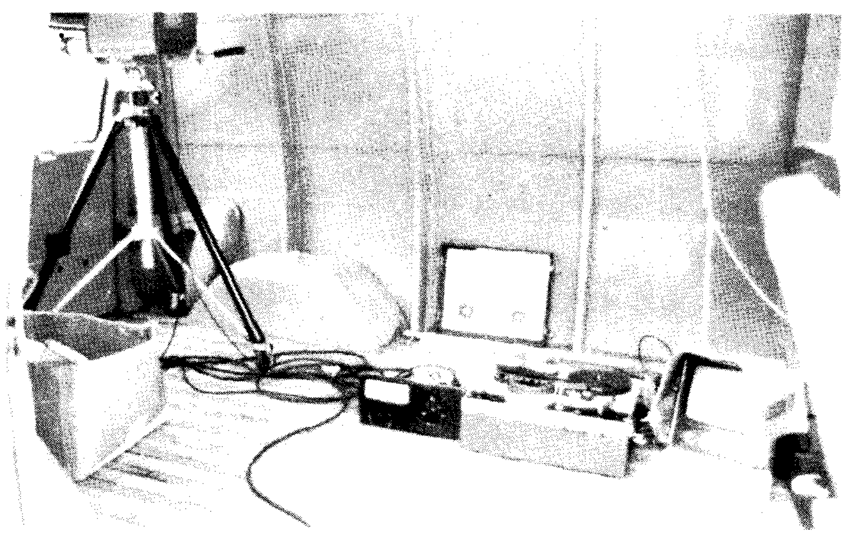


FIGURE 3.4: Video System

speed reduction in the second zone was taken as one of the indicators of effective signing schemes and therefore increased driver responsiveness or obedience to the corresponding configuration of size, height and legend.

B. Traffic Conflicts

This parameter was measured as defined by Kentucky (2) as follows:

1. Forced merge
2. Complete stop

On two-lane roads, the definition was confined to abnormal brake application only.

The above parameters were measured with a time-lapse camera and video system. The system was inconspicuously mounted in a van located within the tapered zone (see Figure 3.3). For two-lane roads, measurements were recorded by an observer located between the last sign and the first cone taper. Figure 3.4 is a photograph of the video system.

C. Queuing of Vehicles

This variable was also measured with the video equipment. An increase in the number of vehicles properly queued in the inside (open) lane was considered as an indicator of effective signing and, consequently, of the effect of the independent variables considered in the study.

D. Traffic Split and Volume Data

Traffic volume at each location was obtained during the sign evaluation period. For the Interstate system, the traffic split between the two lanes, or the percentage of vehicles traveling in each lane at the test site, was measured after the evaluation period. These parameters were measured with the video system. The split information was used to correct for the queuing parameter as defined in subsection C.

E. Sample Size

The sampling at each location (test site) had to be accomplished within the time constraint imposed by the maintenance operation. Therefore, for each sign scheme, measurements of parameters were continued for pre-established time spans. The time span for each location was so established as to provide some uniformity in the traffic volume or the number of vehicles arriving at that maintenance site. In all cases, however, the number of vehicles arriving at the test site was to be no less than twenty-five for speed measurements. This was considered a necessary prerequisite for adequate statistical evaluation of data.

IV. Data Analysis and Evaluation

Data were evaluated in terms of the number of vehicles responding to a given sign scheme as measured by the response parameters defined in Subsections I and II The total number of vehicles was also categorized according to cars and trucks. All data were converted to percent of total for that category. The percent of vehicles properly queued was determined after appropriate correction factors were applied for the split prevalent during that sign scheme evaluation period.

The data were analyzed using the analysis-of-variance procedure. Basically, the analysis of variance technique is just what the name implies - partitioning the variance of an experiment into parts in order to test whether or not certain factors introduced into the design actually produce significantly different results in the variable tested. That is, for example, does the sign size affect the message comprehension of the driver as measured by some variable? Does the legend or message on the sign increase driver awareness of the existing situation? In each case the interest is in testing whether the effect of the factor (sign size) on the variable measured (speed, conflict, etc.) is real when compared with the random variations in the system. Table 3.2 lists the various factors considered in the statistical analysis and their significance with respect to the measured differences in the parameters.

TABLE 3.2

STATISTICAL SIGNIFICANCE OF FACTORS
CONSIDERED IN THE ANALYSIS OF VARIANCE

	Response Variables			
	Speed Reduction		Queue	Conflict
Factors	2-lane	Interstate		
Main				
Location (L)	**	*	**	***
Size (S)	**	*	*	*
Height (H)	NS	NS	NS	NS
Interaction				
L x S	*	NS	**	NS
L x H	NS	NS	**	NS
S x H	NS	NS	NS	NS

* Significant at 0.05 level
** Significant at 0.01 level
*** Significant at 0.001 level
NS-Not Significant

4. STUDY FINDINGS

I. Effect of Size and Height on Measured Responses

A. Two-Lane System

Table 4.1 lists the mean and distribution of speeds for the two zones and the difference between these speeds for each sign scheme. Figure 4.1 is a graphical presentation of these data for each district location. Figure 4.2 is a bar chart showing the mean comparative data for different locations according to size and height.

The variance analysis indicated the decrease in speed in the critical zone to be statistically significant. This means that people do respond to warning signs. However, the statistical significance of the location (Table 3.2) factor indicates that different populations react differently to warning signs.

The most surprising finding in the analysis is reflected by the sign size factor. At all locations, this factor indicated better response due to smaller sizes than larger ones, with two of the locations (08 and 62) indicating a statistically significant difference in the measured parameter. No explanation for such data behavior can be offered here except that sign size or sign height may not be an effective criterion for providing increased awareness during maintenance operations on two-lane systems. Generally, on such rural systems, local traffic is predominant; therefore, such responses may be habituated. This fact is emphasized by data for District 58 where the difference between size is insignificant.

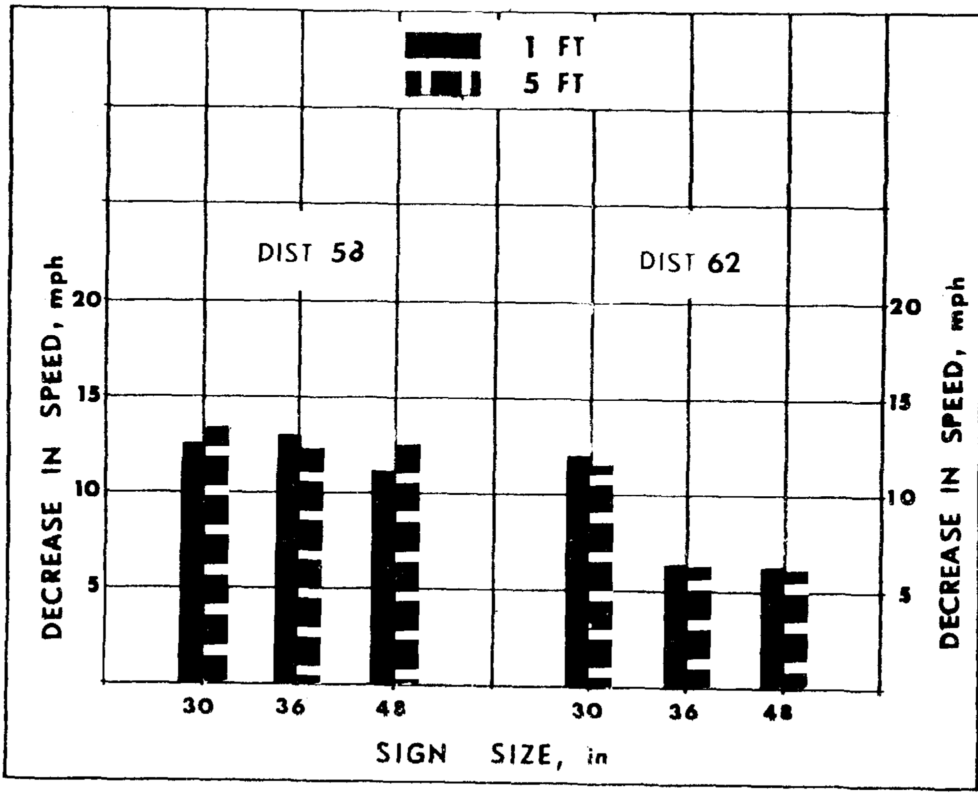
Another aspect during the evaluation of various signs schemes was the total absence of conflict. Furthermore, the normal speed of travel as measured in advance of

TABLE 4.1
SPEED MEASUREMENTS FOR TWO LANE SYSTEM

SIZE (IN)	HEIGHT (FT)	BEFORE CRITICAL ZONE N	SPEED	STD	LOW	HI	- IN CRITICAL ZONE - N	SPEED	STD	LOW	HI	SPEED DIFF.
DISTRICT 07		ADT: 1,050										
30	1	30	42.0	7.7	27	49	30	33.4	5.3	21	49	8.6
30	5	30	42.3	7.6	20	62	30	34.9	7.7	21	55	7.5
36	1	30	42.3	7.5	25	56	30	[illegible]	5.1	21	50	9.4
36	5	30	41.4	9.5	12	60	30	34.6	5.3	21	52	6.8
48	1	30	42.2	7.9	22	57	30	36.2	7.5	22	53	6.0
48	5	30	43.4	5.1	33	51	30	36.9	4.7	30	46	6.5
DISTRICT 08		ADT: 2,600										
30	1	40	49.5	5.7	39	63	40	32.4	7.0	20	50	17.1
30	5	40	51.8	4.8	44	61	40	34.4	5.9	24	49	17.4
36	1	40	51.0	5.8	36	65	40	42.5	5.6	32	57	8.5
36	5	40	49.9	6.1	40	70	40	37.2	6.7	24	51	12.7
48	1	40	47.0	5.4	38	68	40	39.1	6.0	24	51	7.9
48	5	40	47.8	6.0	36	60	40	42.1	7.2	28	61	5.7
DISTRICT 58		ADT: 2,041										
30	1	25	50.7	8.9	35	72	25	38.2	5.1	30	47	12.5
30	5	25	50.7	8.8	35	72	25	37.6	6.2	23	47	13.1
36	1	25	49.9	9.1	29	64	25	37.0	6.0	25	48	12.9
36	5	25	49.9	9.1	29	64	25	37.7	5.7	21	51	12.2
48	1	25	50.0	6.5	39	64	25	38.9	4.7	30	47	11.1
48	5	25	50.2	6.8	28	63	25	37.7	6.1	24	51	12.5
DISTRICT 62		ADT: 1,316										
30	1	30	42.9	6.9	32	57	30	30.8	4.0	24	40	12.1
30	5	30	41.7	7.6	23	55	30	30.3	4.4	23	42	11.4
36	1	30	38.4	4.9	28	50	30	32.2	4.4	24	44	6.2
36	5	30	39.5	6.8	26	53	30	33.4	5.9	24	53	6.1
48	1	30	40.9	6.1	28	52	30	34.7	4.9	29	52	6.2
48	5	30	40.7	8.3	30	60	30	35.5	5.3	28	47	5.2

TABLE 4.2
SPEED MEASUREMENTS FOR INTERSTATE SYSTEM

SIZE (IN)	HEIGHT (FT)	LEGEND	BEFORE CRITICAL ZONE N	SPEED	STD	LOW	HI	- IN CRITICAL ZONE - N	SPEED	STD	LOW	HI	SPEED DIFF.
DISTRICT 03		ADT: 13,000											
30	1	SPECIFIC	65	53.8	4.6	44	65	50	52.0	4.5	42	61	1.8
30	5	SPECIFIC	62	54.5	5.3	40	70	50	52.9	4.9	40	64	1.6
30	5	FLASHER	39	55.8	3.6	49	62	50	50.4	5.5	[illegible]	62	5.4
30	5	GENERAL	40	55.6	4.6	43	68	50	50.3	5.1	35	58	5.3
36	1	SPECIFIC	35	54.6	5.3	47	76	50	50.8	4.9	35	64	3.8
36	5	SPECIFIC	58	55.0	3.6	46	62	50	52.4	5.4	33	55	2.6
36	5	FLASHER	67	55.5	4.7	40	66	50	50.0	5.4	37	62	5.5
36	5	GENERAL	74	54.4	4.8	38	69	50	52.3	4.1	41	61	2.1
48	1	SPECIFIC	55	55.3	3.8	46	64	50	51.6	3.7	47	50	3.7
48	5	SPECIFIC	60	52.7	4.4	40	61	50	[illegible]	3.4	38	53	0.9
48	5	FLASHER	69	54.5	4.0	45	65	50	51.2	3.7	41	54	3.3
48	5	GENERAL	40	53.0	5.3	42	65	50	51.5	5.0	40	60	1.5
DISTRICT 04		ADT: 11,000											
30	1	SPECIFIC	115	54.2	5.7	41	78	42	51.1	5.1	43	53	3.1
30	5	SPECIFIC	90	53.5	4.8	40	76	24	49.7	4.6	39	50	3.8
30	5	FLASHER	60	51.8	4.6	40	63	42	47.5	4.7	38	54	4.3
30	5	GENERAL	80	56.2	5.7	44	77	42	52.6	5.4	40	54	3.6
36	1	SPECIFIC	100	53.7	5.2	39	65	42	49.6	5.5	38	62	4.1
36	5	SPECIFIC	90	53.9	5.9	38	69	42	50.0	4.7	40	55	3.9
36	5	FLASHER	80	54.7	5.0	44	69	42	50.7	4.4	32	59	4.0
36	5	GENERAL	75	53.4	4.0	45	64	42	51.2	4.3	42	53	2.2
48	1	SPECIFIC	80	55.0	4.5	41	70	50	53.0	4.3	41	63	2.0
48	5	SPECIFIC	80	54.2	4.2	43	65	50	51.5	3.9	45	60	2.7
48	5	FLASHER	80	54.8	4.3	45	66	50	51.9	4.5	44	61	2.9
48	5	GENERAL	80	55.8	4.4	46	69	50	53.7	4.1	45	62	2.1
DISTRICT 07		ADT: 15,000											
30	1	SPECIFIC	40	51.9	4.6	44	64	50	50.7	5.4	35	60	1.2
30	5	SPECIFIC	40	52.8	3.9	44	59	50	51.4	4.7	41	64	[illegible]
30	5	GENERAL	40	53.5	4.6	44	65	40	52.7	4.3	45	64	0.8
36	1	SPECIFIC	60	53.9	5.2	36	68	52	51.5	3.7	42	64	2.4
36	5	SPECIFIC	70	53.4	4.7	41	68	53	52.0	3.3	40	59	1.4
36	5	GENERAL	66	55.5	4.6	42	64	52	52.0	5.2	39	69	3.5
48	1	SPECIFIC	70	55.3	6.4	42	74	51	52.7	6.0	35	64	2.6
48	5	SPECIFIC	60	54.6	5.3	39	68	51	50.5	5.1	35	61	4.1
48	5	GENERAL	61	53.3	5.4	44	68	53	52.8	5.9	36	73	0.5
DISTRICT 62		ADT: 6,200											
30	1	SPECIFIC	60	56.1	5.5	47	81	63	54.3	4.7	40	65	1.9
30	5	SPECIFIC	60	56.2	6.5	36	72	56	56.1	5.4	44	77	0.1
30	5	FLASHER	60	56.3	6.3	47	73	55	55.2	4.7	47	67	1.1
30	5	GENERAL	60	54.0	5.9	38	70	52	55.4	5.4	42	72	-1.4
30	5	DIAGR.	58	53.5	6.1	33	71	60	55.3	4.5	41	73	-1.8
36	1	SPECIFIC	76	54.1	5.7	38	67	55	55.3	4.4	47	58	-1.2
36	5	SPECIFIC	80	55.0	5.7	38	76	55	53.7	6.5	34	74	1.3
36	5	FLASHER	90	54.8	7.0	33	73	52	53.5	6.5	35	72	1.3
36	5	GENERAL	103	53.1	5.6	40	69	53	54.8	6.0	38	57	-1.7
36	5	DIAGR.	75	54.0	6.1	42	74	54	53.6	5.5	43	71	0.4
48	1	SPECIFIC	64	55.5	5.3	40	68	53	55.0	5.4	43	70	0.5
48	5	SPECIFIC	62	55.4	4.9	44	68	50	54.1	4.4	44	64	1.3
48	5	FLASHER	79	56.5	5.6	42	70	53	53.1	5.7	39	65	3.4
48	5	GENERAL	70	54.8	6.5	36	69	52	54.2	5.0	38	66	0.6
48	5	DIAGR.	52	48.5	9.7	26	76	51	55.5	6.5	40	64	-7.0



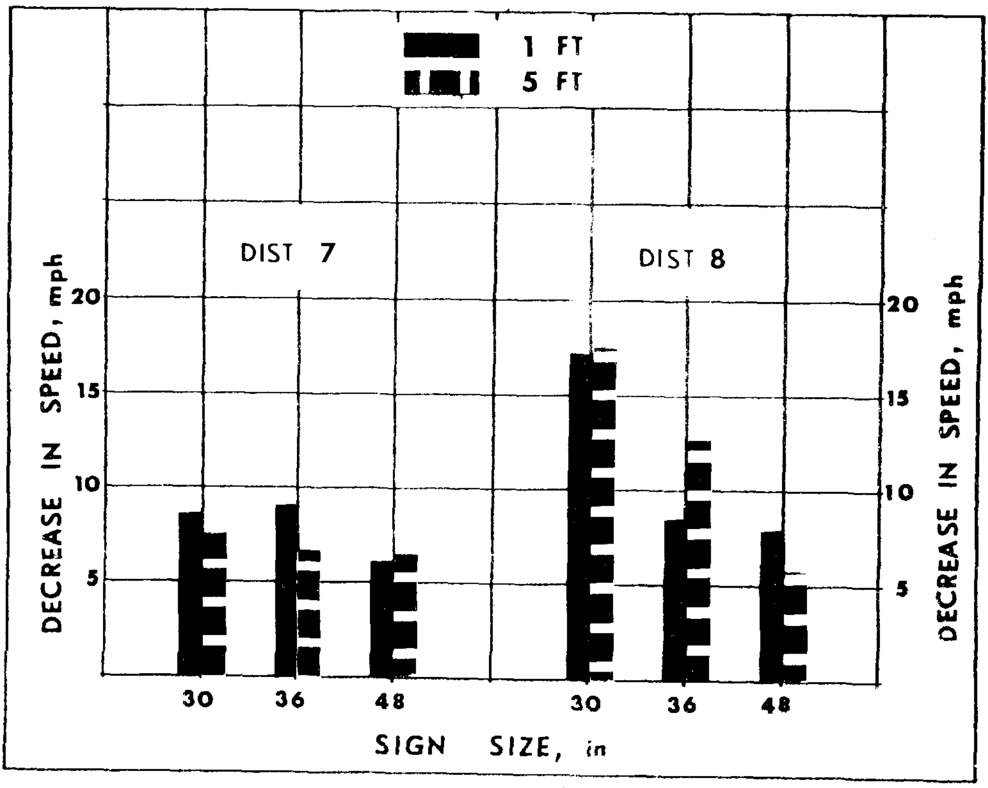
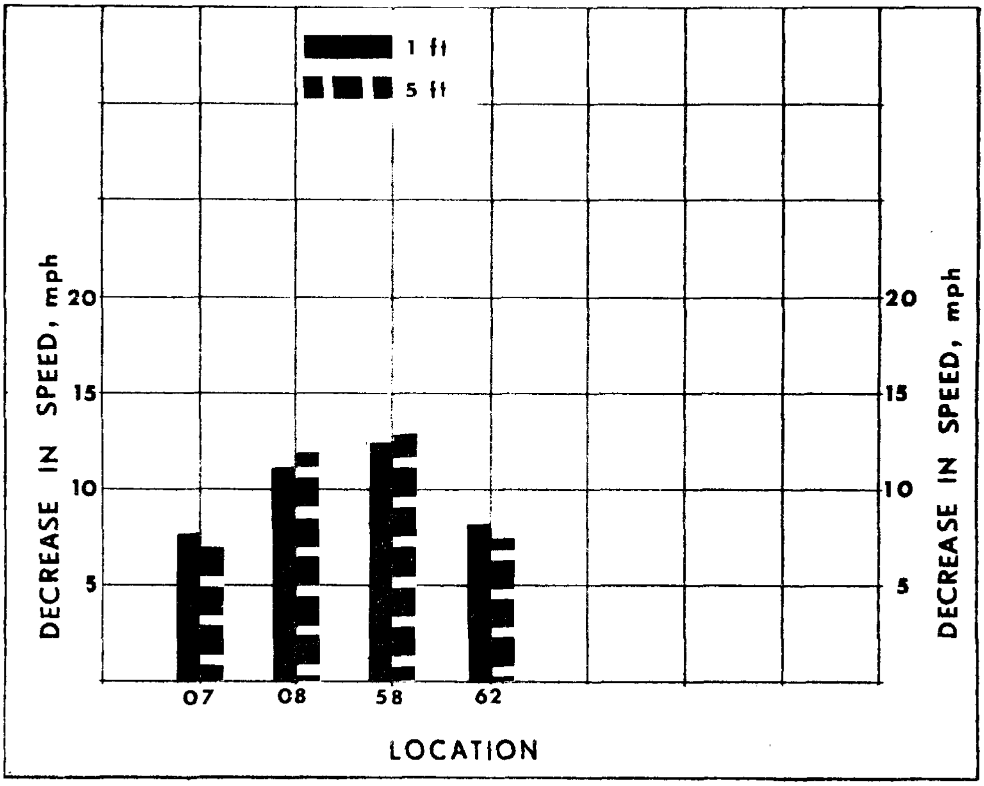


FIGURE 4.1: MEAN SPEED DECREASE AT TWO-LANE LOCATIONS



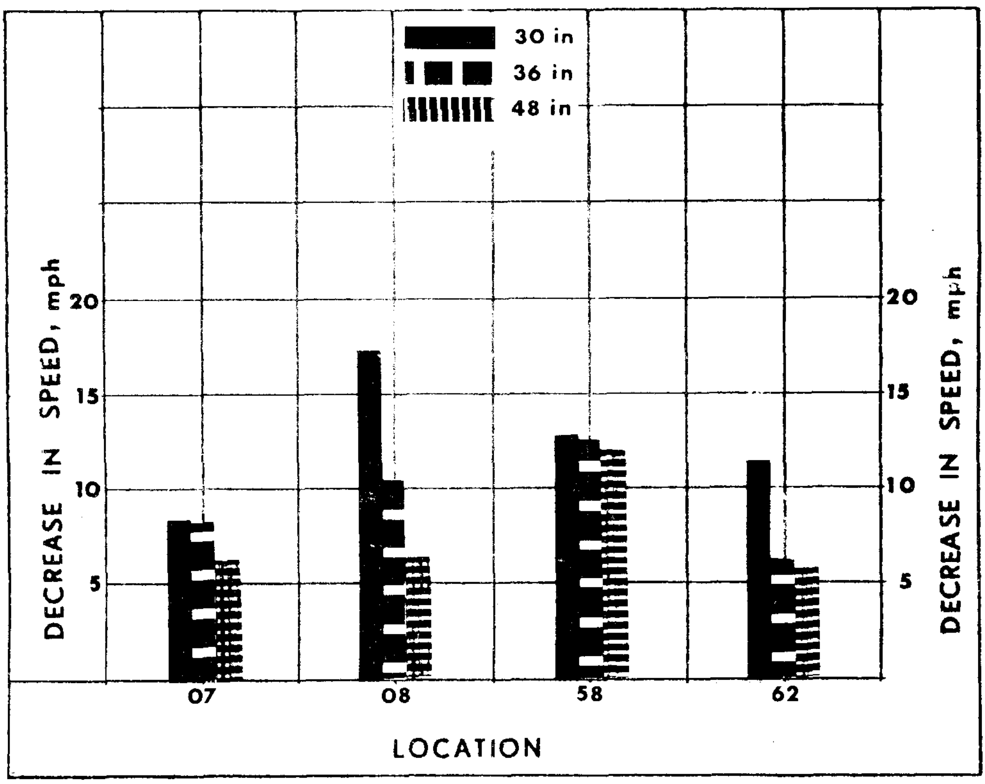


FIGURE 4.2: MEAN SPEED DECREASE AT TWO-LANE LOCATIONS ACCORDING TO SIZE AND HEIGHT (TOP)

the critical zone was far below the posted speed of 55 miles per hour (88 km/hour). This also may be due to habitual or local user of the facility.

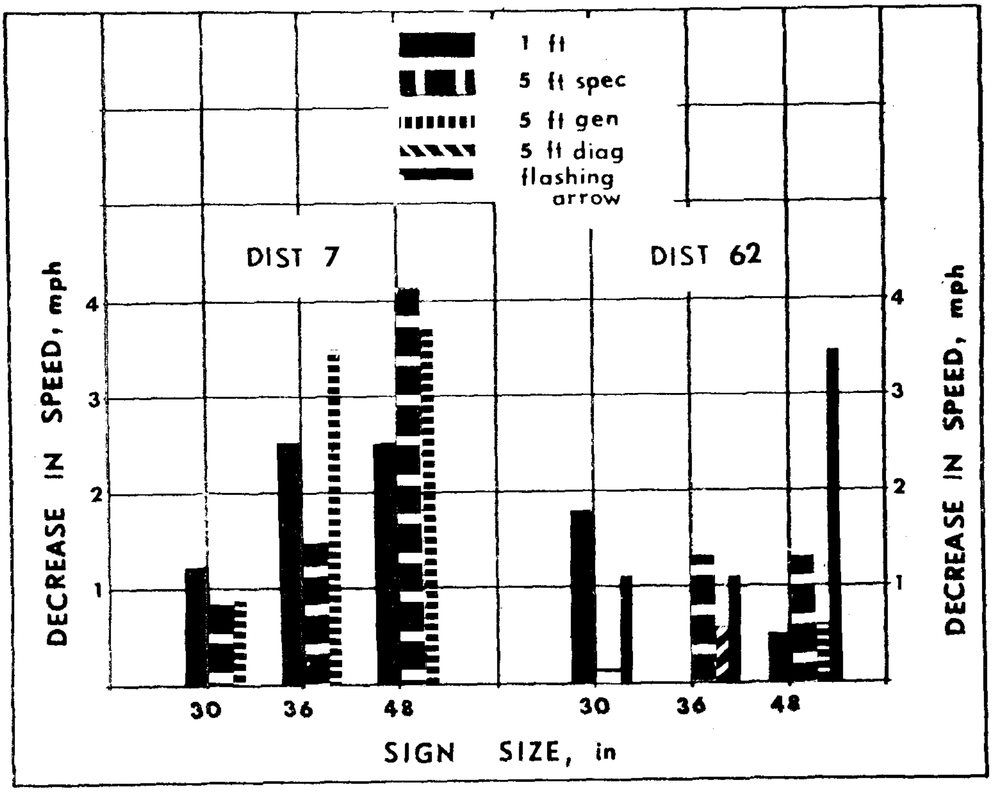
In summary, then, on two-lane rural roads the increase in sign size or sign height does not improve the response of the driver to the impending roadway maintenance operation.

B. Interstate System

1. Speed Decrease

Table 4.2 is a listing of data with respect to the speed parameter for each sign configuration at different locations. Graphical representations of these data appear as bar charts in Figure 4.3. Figure 4.4 represents a comparison of data, pooled according to size and height, for each location.

The reduction in speed in the critical zone is statistically significant for all locations except District 62. Likewise, the size factor was also shown to be significant at the five percent probability level. However, the trend is inconsistent and is location dependent. This means that the driver attitude may be confounding the effectiveness of the independent variables. Only one location (District 07) indicated the expected trend as is seen in Figure 4.3. In District 62 an increase in speed in the critical zone was observed. (This increase is shown as zero decrease in the figure.) Overall, the 36-inch (0.914 m) sign provided better or increased awareness than either of the other two. The difference in response variables due to the height factor was statistically insignificant.



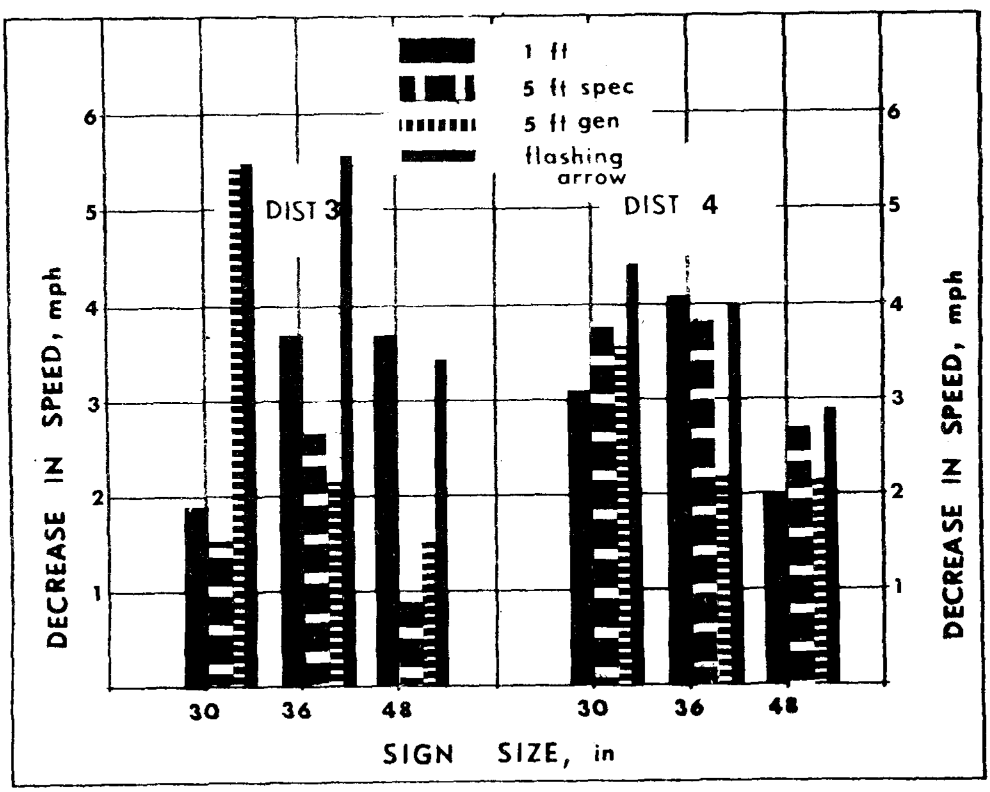
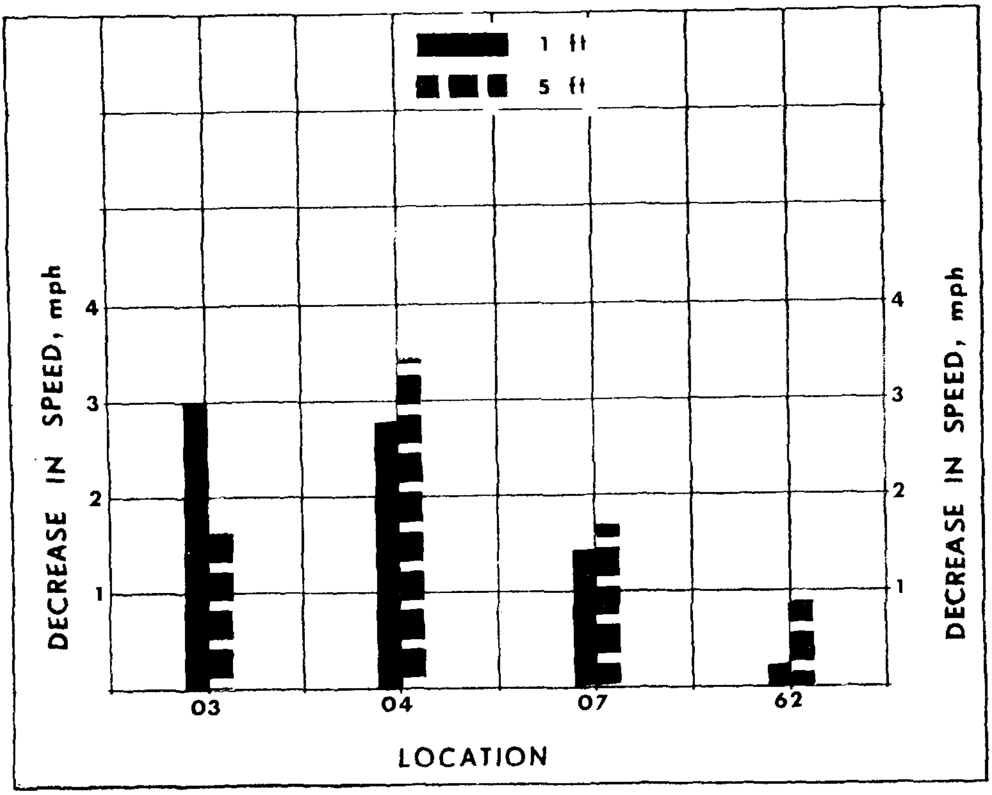


FIGURE 4.3: MEAN SPEED DECREASE AT INTERSTATE LOCATIONS



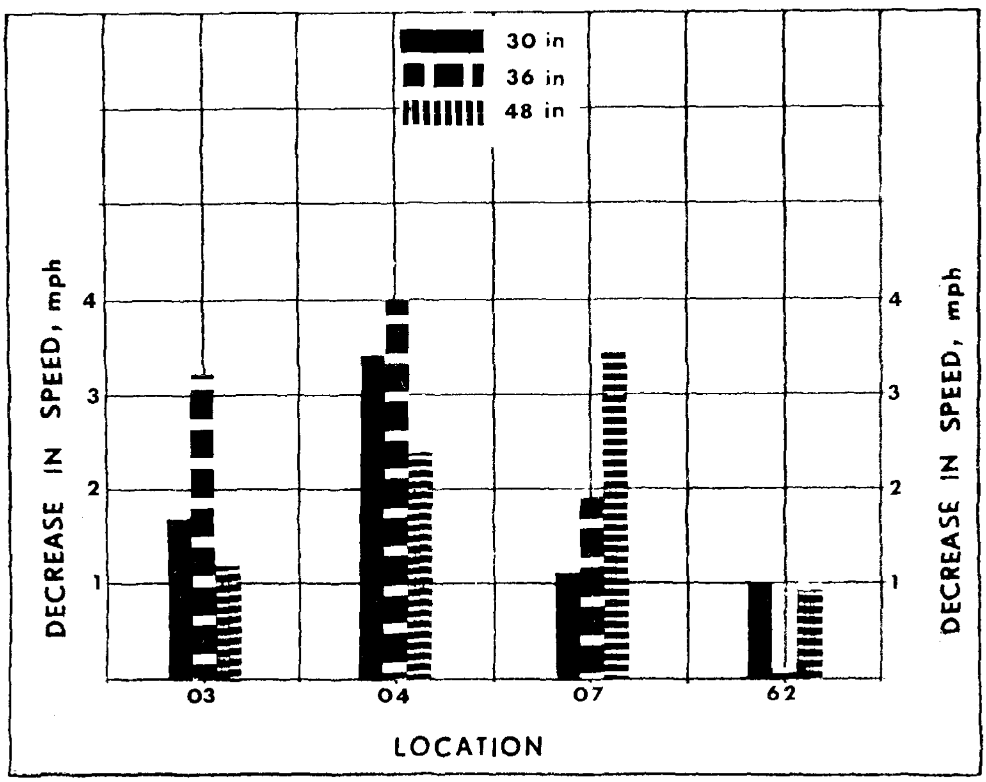


FIGURE 4.4: MEAN SPEED DECREASE AT INTERSTATE LOCATIONS ACCORDING TO SIZE AND HEIGHT (TOP)

The mean decrease in speed for each sign scheme can not be considered to be of any recognizable magnitude. The small magnitude which does exist can be attributed to the present legal, posted speed of 55 miles per hour (88 km/hour) which is considerably lower than the 70-miles-per-hour (112 km/hour) speed limit of three years ago. At such latter speeds Kentucky (2) had reported a mean decrease in speeds of about 15 miles per hour (24 km/hour) during their evaluation of sign color schemes on the Interstate system.

2. Queuing and Conflict

These response variables are two of the primary indicators of effective signing on the Interstate system requiring single lane closures. Table 4.3 represents comparative queuing data for various sign configurations for all locations. The corresponding graphical evaluation is presented in Figures 4.5 and 4.6. The queue data were arrived at after application of the split factor prevalent at the time the particular sign configuration was evaluated. In other words, the data account for vehicles already in the travel, or open, lane before arrival at the last sign.

Two locations, 03 and 07, yielded generally consistent results, namely, increasing obedience to signing with increasing size and height. Results at location 62 contradicted the expected norm although the 5-foot (1.52 m) height did show better response than the corresponding 1-foot (0.305 m) height within each size.

TABLE 4.3
QUEUE AND CONFLICT MEASUREMENTS FOR INTERSTATE SYSTEM

SIZE (IN)	HEIGHT (FT)	LEGEND	TOTAL VEHICLES	TOTAL CARS	TOTAL TRUCKS	QUEUED TOTAL	QUEUED PERCENT	CONFLICTS TOTAL	CONFLICTS PERCENT
DISTRICT 03									
30	1	SPECIFIC	85	68	17	12	14.1	12	14.1
30	5	SPECIFIC	103	85	18	28	27.2	10	9.7
30	5	FLASHER	112	80	32	37	33.0	5	4.5
30	5	GENERAL	100	78	22	26	26.0	9	9.0
36	1	SPECIFIC	128	97	31	40	31.3	12	9.4
36	5	SPECIFIC	121	101	20	46	38.0	6	5.0
36	5	FLASHER	155	110	45	77	49.7	4	2.6
36	5	GENERAL	162	130	32	82	50.6	12	7.4
48	1	SPECIFIC	76	61	15	34	44.7	5	6.6
48	5	SPECIFIC	119	82	37	63	52.9	8	6.7
48	5	FLASHER	92	67	25	42	45.7	5	5.4
48	5	GENERAL	90	75	15	36	40.0	3	3.3
DISTRICT 04									
30	1	SPECIFIC	162	121	41	91	56.2	3	1.9
30	5	SPECIFIC	158	124	34	66	41.8	7	4.4
30	5	FLASHER	132	92	40	72	54.5	2	1.5
30	5	GENERAL	155	126	29	91	58.7	2	1.3
36	1	SPECIFIC	168	138	30	101	60.1	1	0.6
36	5	SPECIFIC	188	151	37	106	56.4	3	1.6
36	5	FLASHER	189	150	39	105	55.6	4	2.1
36	5	GENERAL	198	171	27	68	34.3	2	1.0
48	1	SPECIFIC	177	130	47	93	52.5	0	0.0
48	5	SPECIFIC	141	116	25	54	38.3	1	0.7
48	5	FLASHER	164	121	43	98	59.8	2	1.2
48	5	GENERAL	175	131	44	80	45.7	3	1.7
DISTRICT 07									
30	1	SPECIFIC	138	114	24	58	42.0	19	13.8
30	5	SPECIFIC	120	98	22	53	44.2	9	7.5
30	5	GENERAL	97	80	17	39	40.2	14	14.4
36	1	SPECIFIC	141	126	15	66	46.8	15	10.6
36	5	SPECIFIC	101	84	17	53	52.5	7	6.9
36	5	GENERAL	183	167	16	72	39.3	29	15.8
48	1	SPECIFIC	132	115	17	72	54.5	4	3.0
48	5	SPECIFIC	224	196	28	101	45.1	39	17.4
DISTRICT 62									
30	1	SPECIFIC	159	133	26	76	47.8	0	0.0
30	5	SPECIFIC	163	127	36	92	56.4	0	0.0
30	5	FLASHER	111	90	21	92	82.9	0	0.0
30	5	GENERAL	125	107	18	68	54.4	0	0.0
30	5	DIAGR.	115	91	24	72	62.6	0	0.0
36	1	SPECIFIC	76	62	14	33	43.4	0	0.0
36	5	SPECIFIC	163	123	40	80	49.1	0	0.0
36	5	FLASHER	118	95	23	72	61.0	0	0.0
36	5	GENERAL	110	92	18	68	61.8	0	0.0
36	5	DIAGR.	137	112	25	69	50.4	0	0.0
48	1	SPECIFIC	100	77	23	41	41.0	0	0.0
48	5	SPECIFIC	96	69	27	46	47.9	0	0.0
48	5	FLASHER	78	59	19	57	73.1	0	0.0
48	5	GENERAL	133	102	31	101	75.9	0	0.0
48	5	DIAGR.	78	68	10	43	55.1	0	0.0

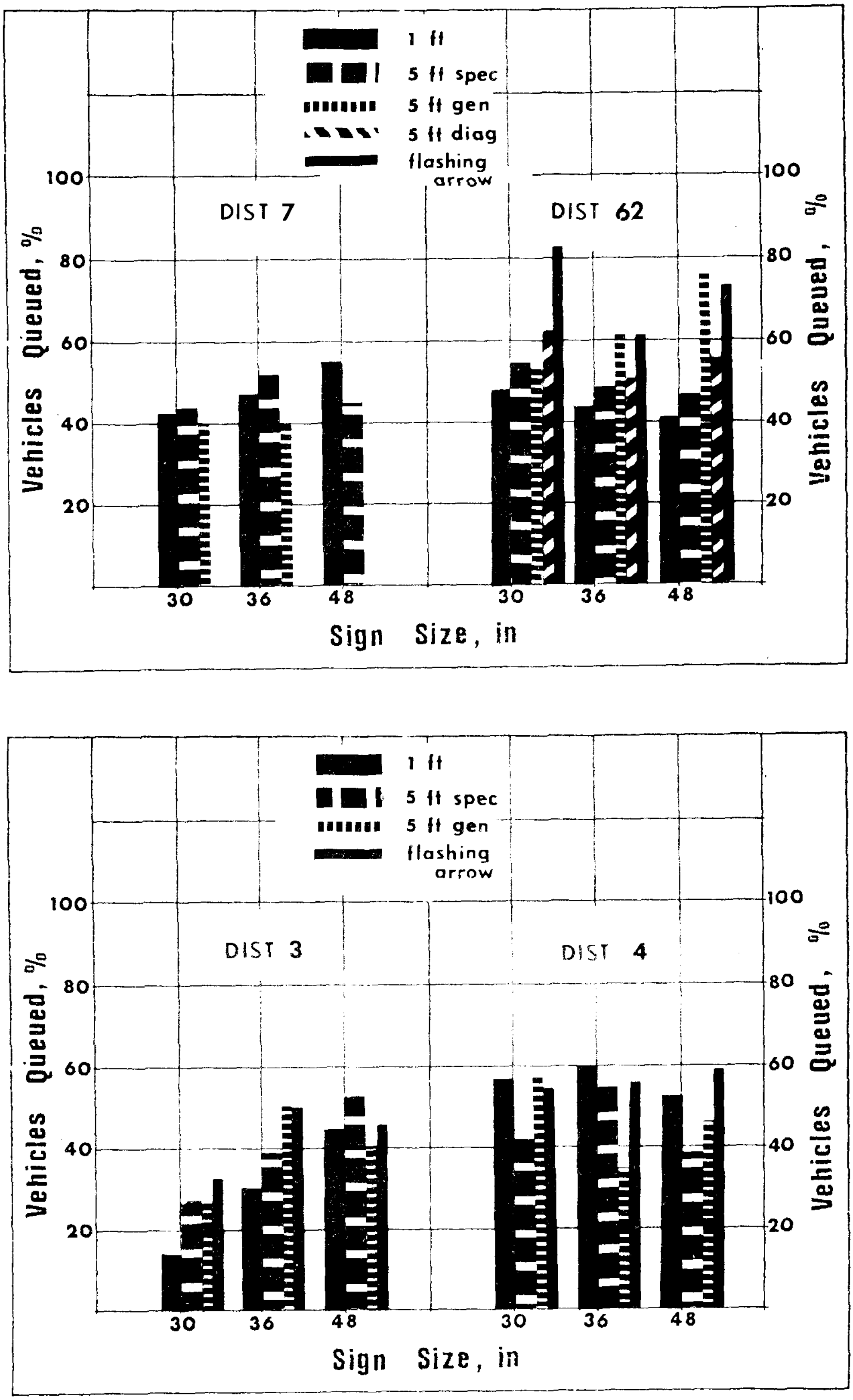
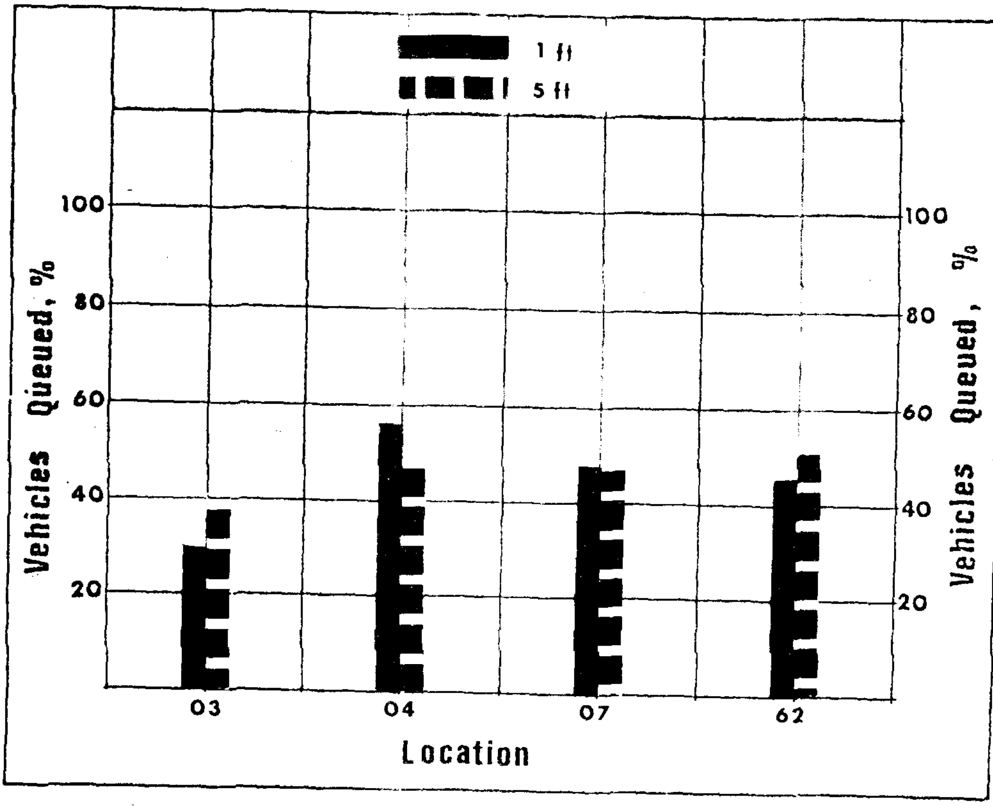


FIGURE 4.5: QUEUED VEHICLES AT LOCATIONS



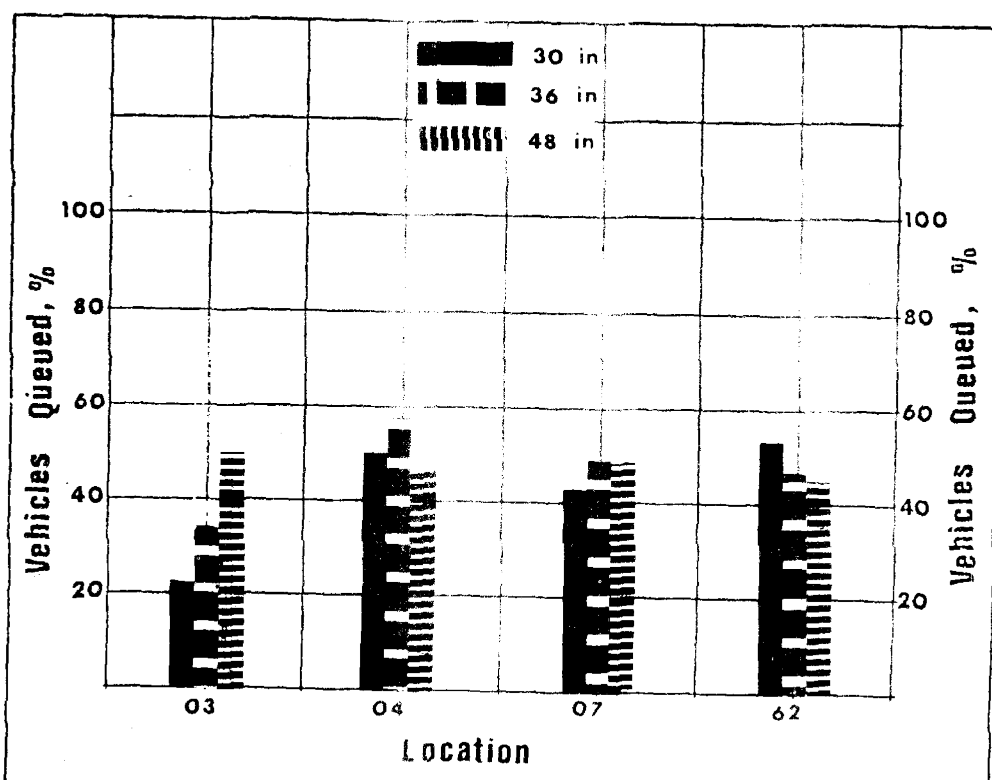


FIGURE 4.6: QUEUED VEHICLES BY SIZE AND HEIGHT (TOP)

No significant difference in queuing was indicated by the analysis for any of the factors except size and location. Ideally, adequate advance warning signs of a lane closure should result in increased queuing in the open lane between the last sign and the beginning of cone taper. However, with increasing traffic volume the available gap for merging becomes more difficult with the result that drivers become trapped in the closed lane. This ultimately increases the occurrence of conflict which is generally created by forced merging. This fact is emphasized by data for locations 03 and 04 in Figure 4.6. The former had a smaller proportion of queuing and a correspondingly larger occurrence of conflict (Figure 4.8). Likewise, the latter location had a high percentage of queued vehicles and correspondingly few conflicts. The large magnitude of conflict at location 07 can be attributed to increased traffic volume.

Detailed conflict data are presented in Table 4.3 with the corresponding bar charts in Figures 4.7 and 4.8. The differences in this parameter was significant with respect to size variable at the 0.05 probability level. This is readily seen in Figure 4.8. The total absence of conflicts at location 62 can be attributed to the high proportion of queuing (although not as high as at 04).

II. Effect of Legend on Response Variables

Specific legend as used in this evaluation (RIGHT LANE CLOSED 1000 FEET) provides a warning message as to what the motorist will run into some distance further up the road. It does not specifically tell him what he should do; and the action he should take, once he encounters this warning sign, is strictly left to his discretion. Diagrammatic signs also

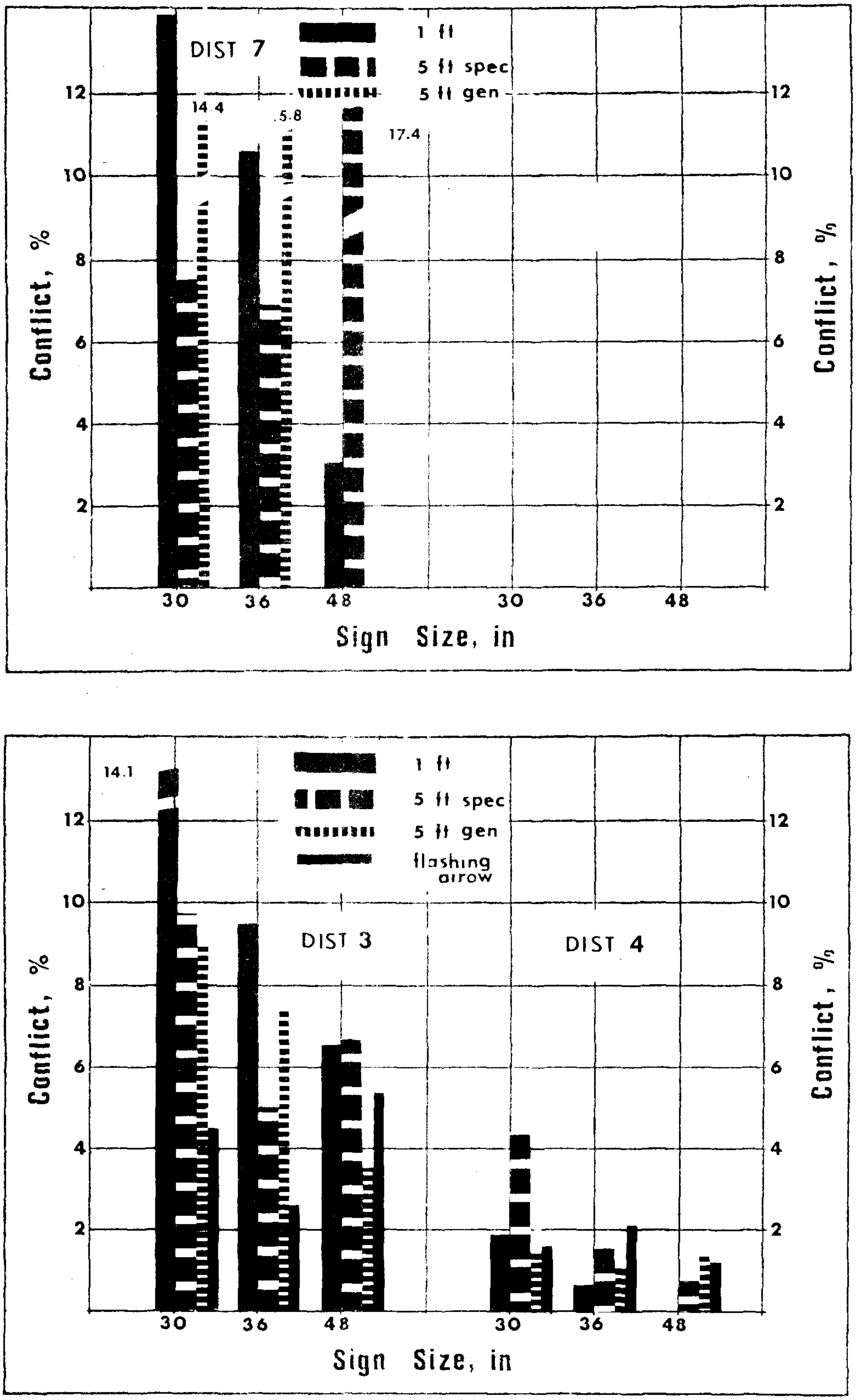


FIGURE 4.7: CONFLICT AT LOCATIONS

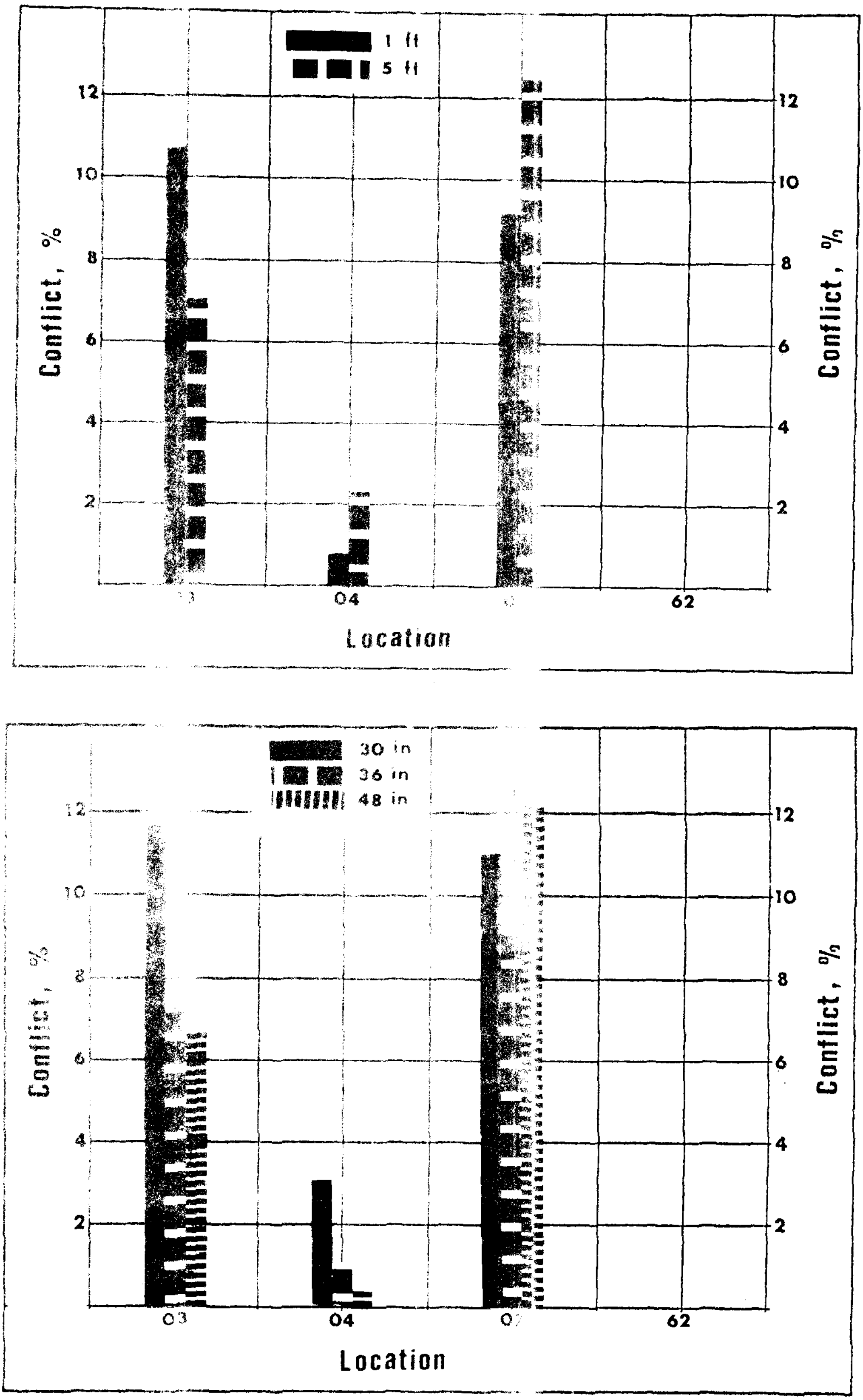


FIGURE 4.8: CONFLICT BY SIZE AND HEIGHT (TOP)

fall in this category. General legend as employed here (MERGE LEFT) is in a way more specific in that it orders him to take specific action.

The figures discussed in the preceding sections (4.3, 4.5 and 4.7) also include comparative data on the effect of messages on different response variables. As was mentioned before, data on diagrammatic signs were limited to one location only. Data in these figures indicate inconsistency within the location and no significant difference in any of the response variables due to this factor. Location 62, however, showed a more pronounced effect on the queuing with general and diagrammatic messages than with the specific message.

III. <u>Sequencing Flashing Chevrons</u>

These are attention getting devices and can be categorized in the legend variable group. The equipment, shown in Figure 4.12, consists of a 3.5-ft. x 6.5-ft. (1.07 m x 1.98 m) trailer mounted panel of amber lamps marketed by the Casell Company of California. The lamps are activated to achieve a series of sequential bidirectional arrows. Passing left operational mode with sequencing accumulative chevrons was utilized in the evaluation.

Figures 4.3, 4.5 and 4.7 compare data for this independent variable against other variables. The differences in mean speeds and queuing were significant at the 0.05 probability. The measured conflict was slightly less for flashing conditions than nonflashing but not to any statistical extent. The greatest difference in queuing was observed at Location 62: 72 percent with sequencing chevrons against 51 percent without.

IV. General Discussion - Pooled Interstate Data

Figures 4.9, 4.10 and 4.11 represent comparative data for the study variables pooled according to size, over all locations, for speed, queue, and conflict, respectively. The data represent weighted averages and are presented to reflect the overall trend of the effects of sign size, legend and attention-getting devices on the driver responses as measured by speed, queuing and conflict in the critical zone. Although the effect of location on the measured responses was predominant, an assumption had to be made in this analysis that such variations between locations represent variations due to psychological factors (and therefore random variations) associated with the population.

There is a significant variation in driver awareness toward sign size. The 30-inch (0.762 m) signs yielded a greater number of conflicts than the other two sizes. Likewise, the queuing for this size was the least of the three. The effect of sign legend is insignificant. The most significant difference in driver obedience is toward the electronically actuated, directional flashing signs used as reinforcement to the normal sign installations. The presence of such an attention-getting warning system amplifies, to the motorist, the fact that some activity is going on as specified by standard sign messages. Disrespect for standard maintenance sign installations has some validity since it is not uncommon for motorists to encounter such warning signs while at the specified distance away there is total lack of maintenance activity. Directional electronic flashing signs provide these motorists with a genuine warning of the situation ahead.

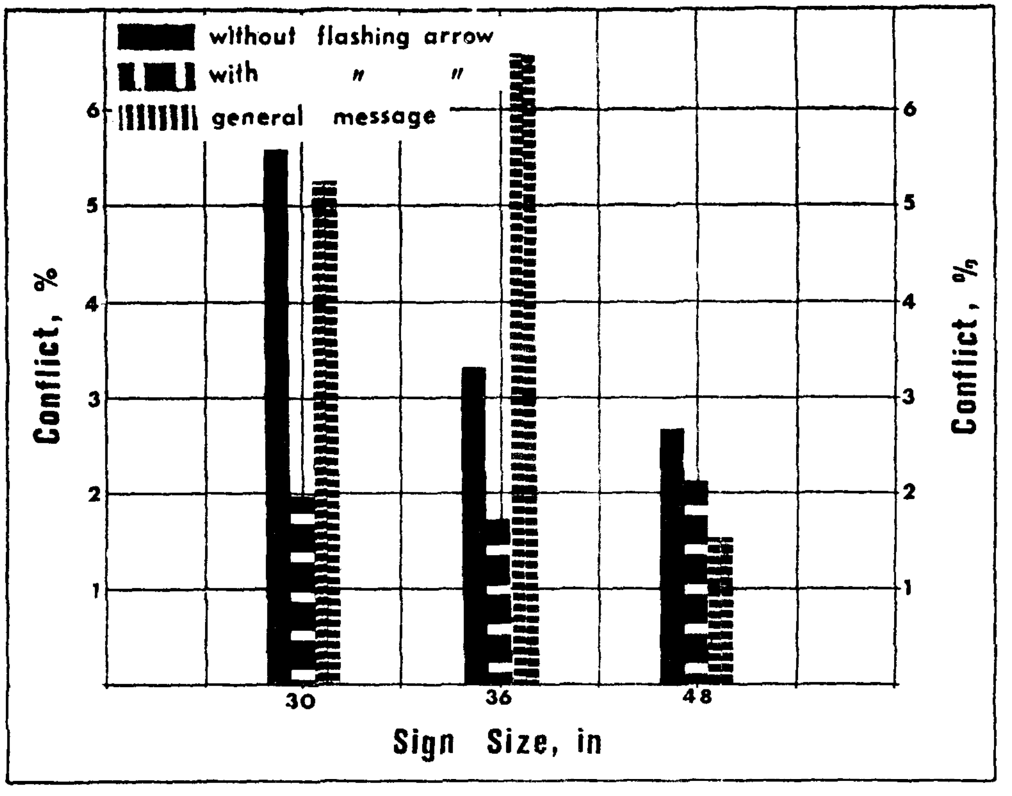


FIGURE 4.11: CONFLICT DUE TO SIZE, LEGEND AND SEQUENCING CHEVRONS

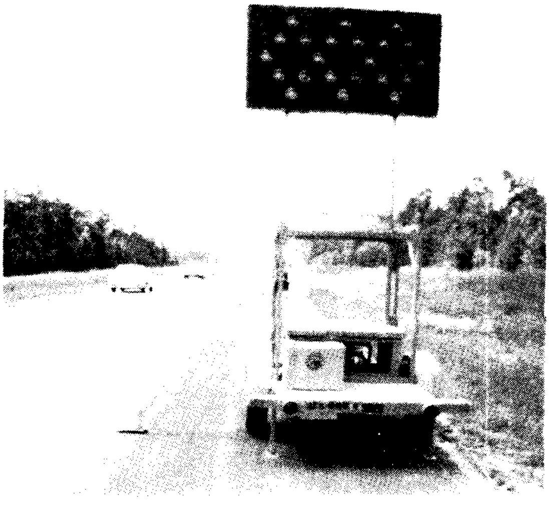


Figure 4.12: Trailer Mounted Flashing Sign

5. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary:

In the preceding sections an attempt was made to evaluate, quantitatively, the effects of certain variables defined by sign size, installation and legend on the driver responses as measured by speed, conflict and queuing parameters. Effects of electronically actuated, directional flashing signs were also evaluated in terms of the above defined responses. The experiment was conducted at four locations within the State on two-lane and Interstate systems requiring single lane closures during maintenance. The conclusions that follow are based on the analysis and evaluation of the various responses using the analysis-of-variance procedure.

Conclusions:

1) Motorists do respond to advance warning signs as was indicated by reduction in speed in the critical zone. However, this reduction is much more pronounced for the two-lane system than the Interstate system.

2) The height of sign installation does not indicate any statistical difference in any of the measured responses for either the two-lane or the Interstate system.

3) For the two-lane system there was a recognizable difference in speed reduction for the three sign sizes. However, the 30-inch (0.762 m) sign yielded better response, through greater speed reduction, than either the 36-inch (0.914 m) or the 48-inch (1.22 m) sign.

An added advantage of such devices was realized during the actual setup of the barricade and zone taper for the work area. Although flashing beacons on work vehicles and flagmen have proven effective during this initial setup, the safety provided by the use of these directional flashing signs, coupled with the reduction in total time required for such installation, was significantly better.

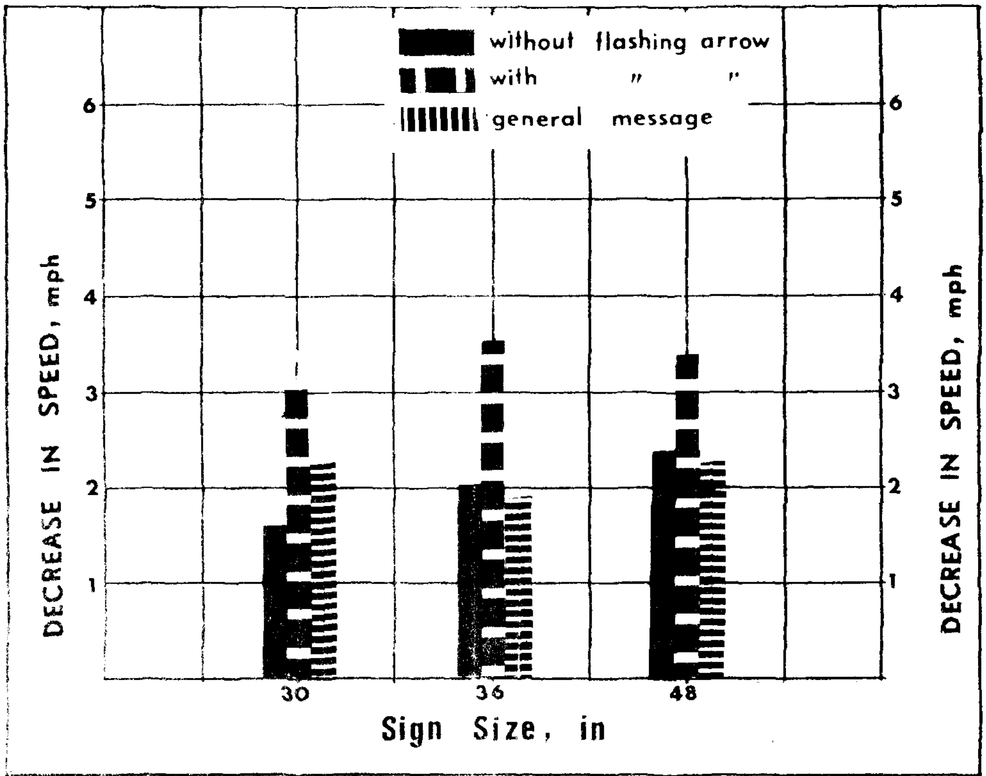


FIGURE 4.9: MEAN SPEED DECREASE OVER ALL INTERSTATE LOCATIONS DUE TO SIZE, LEGEND AND SEQUENCING CHEVRONS

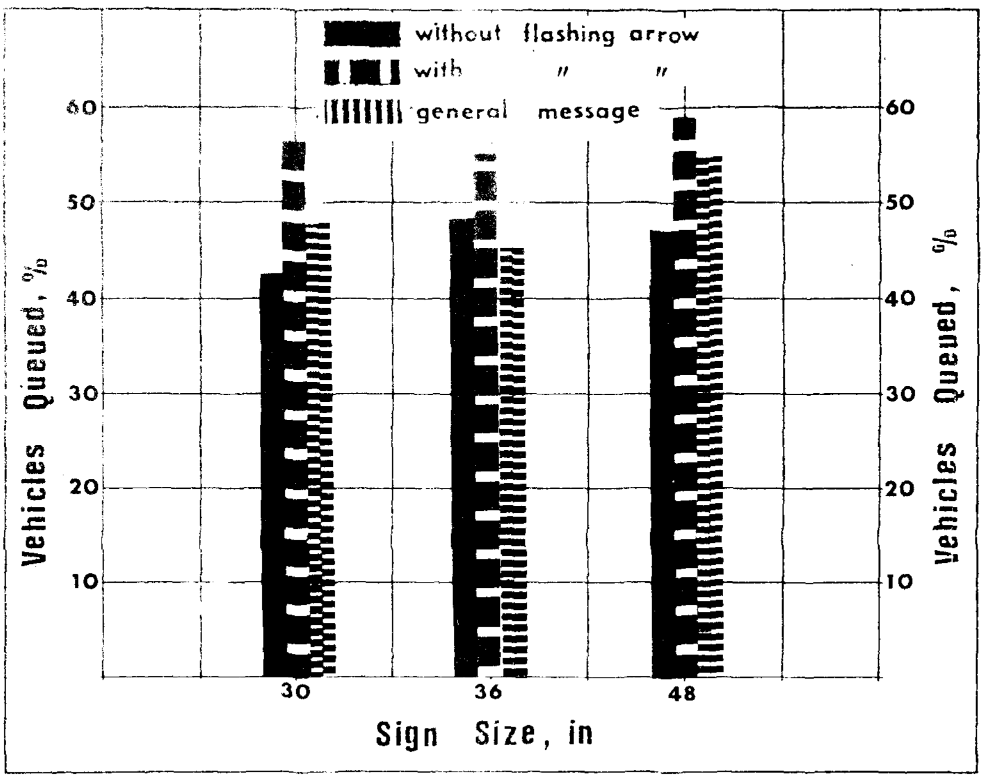


FIGURE 4.10: QUEUED VEHICLES DUE TO SIZE, LEGEND AND SEQUENCING CHEVRONS

4) The observed difference in the dependent variables between locations was highly significant and therefore indicative of the drivers' attitude (psychological) towards signing in general.

5) At Interstate locations the 36-inch (0.914 m) signs yielded better results than the corresponding 30-inch (0.762 m) signs. The difference between the 36-inch (0.914 m) size and the 48-inch size (1.22 m) was negligible.

6) Driver responses to sign legend were statistically insignificant.

7) Sequencing accumulative bidirectional chevrons greatly enhance the obedience of the driver to warning signs, and also provide greater safety to the work force and the motorists during initial sign scheme installation and subsequent maintenance activity.

Recommendations:

Based on the above conclusions the following recommendations are made with respect to the study variables:

1) The presently used 30-inch (0.762 m) signs at one foot height (0.305 m) seem adequate for two-lane systems.

2) On Interstate systems, the sign size should be 36-inch installed at either one-foot (0.305 m) or five-foot (1.52 m) height.

3) The present standard signing schemes requiring lane closures should be reinforced with some type of directional flashing signs.

6. REFERENCES CITED

(1) Manual on Uniform Traffic Control Devices for Streets and Highways, Federal Highway Administration, U. S. Department of Transportation, 1971.

(2) Seymore, William M., et al, Traffic Control for Maintenance on High-Speed Highways, Transportation Research Record 484, Transportation Research Board, Washington, D. C., 1974.

(3) Maintenance Traffic Control Handbook, Louisiana Department of Highways, 1973