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RAILROAD GRADE CROSSING PASSIVE SIGNING STUDY

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Cambridge MA 02142

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FINAL REPORT

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16. Abstract

This report describes the results of a study to determine the effectiveness of new passive signing configurations in warning drivers of the potential hazards at railroad grade crossings. Experiments were conducted in two phases over a two-year period. The first phase was begun in March 1975 and evaluated seven sign configurations at five test sites in Ohio and one site in Maine. The purpose of Phase I was to determine at a few crossings whether any of the new signs showed promise of being more effective than the existing sign configuration and to evaluate a variety of experimental variables. The results of Phase I were previously reported and indicated improved effectiveness for the new signs tested. The purpose of Phase II was to test and verify and a national level (18 sites in 14 states) the most effective signs as determined from Phase I and to concentrate on and refine, if necessary, the most improtant variables. In each phase, before-and-after data were collected at each site so that relative improvements provided by the new signs could be determined.

The results of Phase II confirmed the findings of Phase I in that drivers showed more awareness (that is, an increased percentage of headmovements or looking for trains) with the new signs at the crossings tested.

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FOREWORD

This report describes Phase II of the Railroad Grade Crossing Passive Signing Study. This study was funded by FHWA, FRA, and 25 participating States. During this phase of the study, three experimental grade crossing signing systems were tested at 18 sites in 14 States. During the field testing when the experimental signs were used, there was an increase in drivers looking for trains.

Based on the study results, the study advisory committee (representing FHWA, FRA, and the 25 participating States) recommended to the Federal Highway Administrator and the National Advisory Committee (NAC) on Uniform Traffic Control Devices that one of the experimental advance warning signs be adopted as a national standard. The request was denied by the NAC with a recommendation to the Federal Highway Administrator that additional field experimentation be undertaken to determine the safety benefits that could be expected if the new sign were used. The FHWA Office of Research is planning additional work to determine both the safety benefits attributable to a change in signing and the costs involved.

Sufficient copies of this report are being sent to provide two copies to each region, division, and State highway agency. The division and State copies are being sent to the division office. Additional copies have already been sent to the State representatives who participated in the study.

Charles F. Scheffey
Director, Office of Research

PREFACE

This report represents the culmination of a two-year two-phase effort involving passive signing at railroad grade crossings. The results of the first phase were reported in an Interim Report DOT-TSC-FHWA-71-1 entitled "Railroad Grade Crossing Passive Signing Study," January 1977. The study was jointly funded by 25 states, the Federal Railroad Administration and the Federal Highway Administration.

The authors gratefully acknowledge the cooperation and understanding of Janet Coleman of the Federal Highway Administration (FHWA) who provided the project guidance since its inception; Maury Lanman also of the FHWA who assisted in the design of the experiments and managed the data collection and data reduction activities at the Maine Facility; Patricia Brown of the Transportation Systems Center who participated in the data analysis; and Gene Jordan and Burt Marter of the Applications Research Corporation who spent nine months in the field collecting the required data.

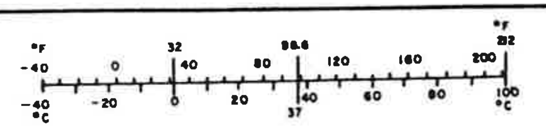
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
	AREA			
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
	MASS (weight)			
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
	VOLUME			
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
	AREA			
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
	MASS (weight)			
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
	VOLUME			
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
	TEMPERATURE (exact)			
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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EXECUTIVE SUMMARY

This report describes the second phase of a two phase study to evaluate the effectiveness of new passive signing configuations (i.e., static signs and markings without signals or gates) in warning drivers of potential hazards of railroad grade crossings. In the interest of greater safety to motorists, this study was undertaken because more than three-fourths of the 219,000 public grade crossings nationwide are protected by passive signs only, the existing signing configuration has not been changed for many years other than the angle of the crossbuck which was changed in the 1971 MUTCD, and it was hypothesized that introducing new signing at railroad grade crossings would be an effective method of improving safety at the crossings.

Phase I of the study evaluated seven new passive signing configurations at five sites in Ohio and one site in Maine. The seven signing configurations were selected by a program advisory committee formed at the initial stages of this project, and are shown in Figure 1 with the base sign configuration. The committee consisted of representatives of 25 participating states(1) who supported this pool-funded effort, the Federal Railroad Administration, the Federal Highway Administration and the Association of American Railroads.

The performance data for evaluating the new signs consisted of driver head movement (i.e., looking for a train) and vehicle speed profiles. In this study, head movement was taken to be the prime indicator of sign effectiveness because it was

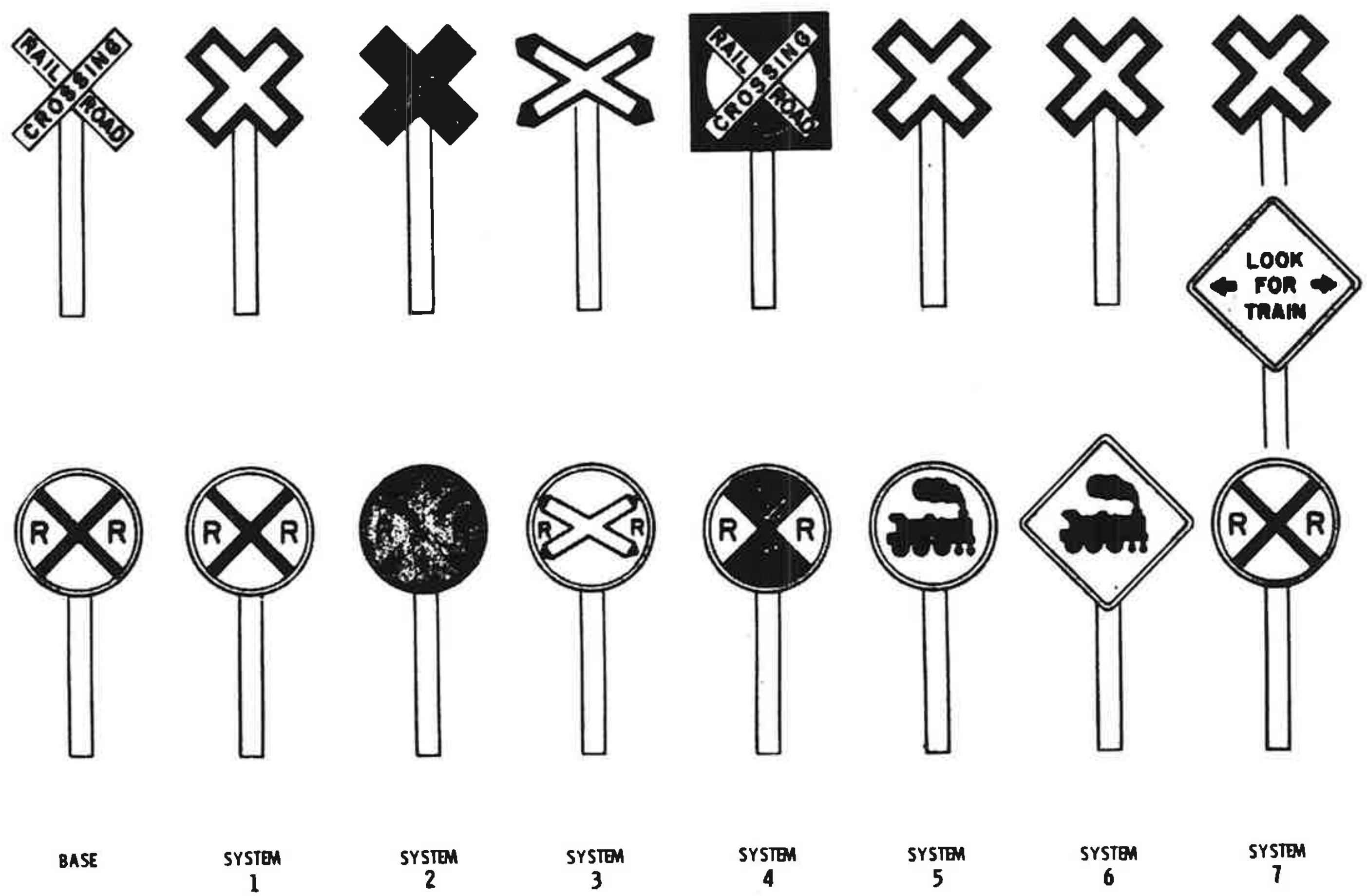

FIGURE 1. PHASE I SIGN CONFIGURATIONS

the most direct indication of driver response to the signs. However, no head movement data were taken at night, due to lack of adequate illumination at the sites.

The major finding of Phase 1 of the study was that the new signs in Ohio averaged an increment of 19 percent more head movement (from 35.5 percent to 54.5 percent) than the base sign (99 percent significant). However, there were no significant differences between the signs, including the base sign, in terms of the speed profiles.

Because of the head movement finding in Phase I the program advisory committee decided to continue testing into Phase II. The "best" sign configuration from Phase I (i.e. sign configuration 4 - Figure 1) was selected for further testing, together with two modifications of this configuration. The resulting three sign configurations shown in Figure 2 were tested at 18 sites in 14 states.

The results from Phase II were found to be consistent with the major findings from Phase I in that the new signs showed significant improvement over the base sign in terms of head movement and no differences in terms of speed profiles. Specifically the major findings from Phase II were:

a. Sign configuration 1 - Figure 2 - showed significant improvement over the base sign configuration averaging an increment of 6.7 percent more head movement (from 34.7 percent to 41.4 percent)

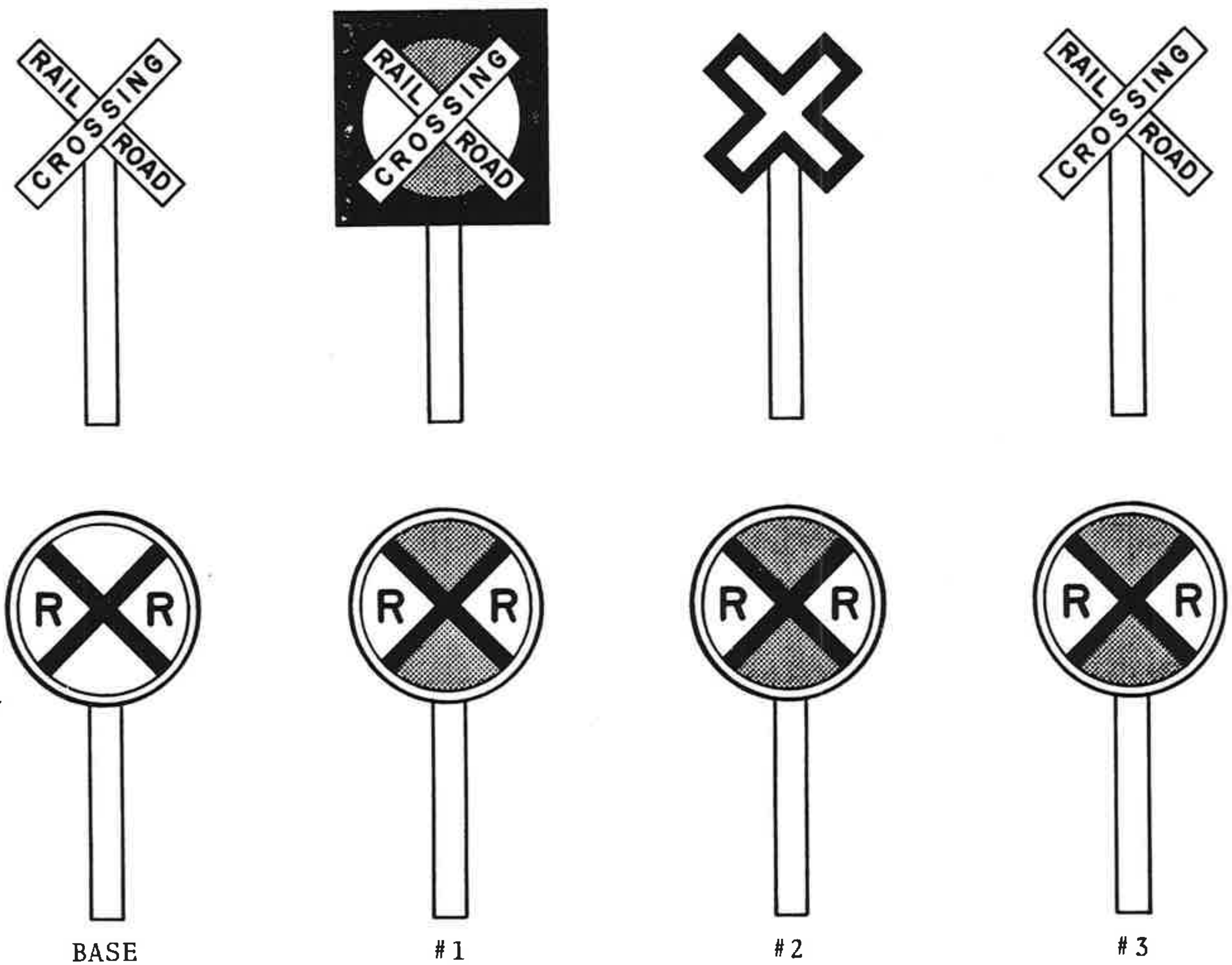

FIGURE 2. PHASE II SIGN CONFIGURATIONS

b. The advance warning sign of sign configuration 1 (also sign configuration 3 - Figure 2) accounted for about half of this improvement

c. Sign configuration 1 showed an increment of 3.9 per cent more head movement (from 37.5 to 41.4 percent) than sign configuration 2 & 3.

d. The new signs showed no significant differences in speed profiles compared to the base sign under day or night conditions.

e. The head movement data were judged to be quite reliable based on several measures that were formulated to evaluate the subjectivity of this data.

Based on the results of the experiments (Phase I and Phase II) the research investigators recommend that the existing signing at all hazardous passive railroad grade crossings be changed in a two-stage implementation process. The first stage consists of changing only the advance warning sign to the new red and yellow advance warning sign. The second stage consists of changing the existing crossbuck sign to the new red, yellow and black sign tested but only if after wide scale and long term application (3-5 years) the new advance warning sign itself is proven successful in terms of accident reduction.

This process allows testing of real benefits through a relatively inexpensive procedure (Stage I implementation). The decision to change the existing crossbuck sign (Stage II

implementation can then be based on whether doubling the accident benefits (predicted by the study) is worth the cost of changing to the new crossbuck sign.

1/ Note to page vii:
The 25 participating States included California, Colorado, Connecticut, Georgia, Iowa, Kansas, Kentucky, Louisiana, Maryland, Michigan, Minnesota, Mississippi, Montana, Nebraska, New Mexico, North Dakota, Ohio, Pennsylvania, Rhode Island, Tennessee, Texas, Utah, Washington, West Virginia, and Wisconsin.

1. INTRODUCTION

There are about 219,000 public railroad grade crossings in the United States with an additional 37,500 grade intersections separated by structures. Of these public railroad grade crossings, 50,370 are protected by "active" devices which provide the driver with a positive indication of the approach of a train (e.g., signals and/or gates). The remaining 168,630 public crossings and an additional 142,000 private crossings have some type of "passive" warning.

Static signs and markings constitute the usual form of passive warning. These inform the motorist of the existence and location of a crossing, but the driver must determine whether a train is approaching and whether it is safe to cross by looking up and down the tracks.

With more than three-fourths of the public grade crossings nation-wide equipped only with passive signs, it is most important that both the approach and at-the-crossing signs be effective. Furthermore, at the 70,000 or more crossings with two or fewer trains per day and 500 or fewer vehicles per day, economic justification for "active" devices does not appear possible. The majority of railroad grade crossings will continue to have only signs and markings which provide passive warning to drivers to proceed with caution.

To determine which signs would most effectively warn drivers of the hazards at railroad grade crossings, a study

was initiated to evaluate the effectiveness of seven new passive sign configurations. The seven sign configurations were selected by a program advisory committee formed at the initial stages of the project. The study was divided into two phases. Phase 1 involved five test sites in Ohio and one test site in Maine and was intended to determine, on a limited scale, if any of the new signs were more effective than the existing signs and to determine the important variables for the study. Phase 1 data collection was completed in October 1975 and the results [(1)] indicated that the new signs increased driver awareness at railroad grade crossings. Phase II was undertaken to test and verify on a nationwide basis (18 sites in 14 states) the most effective signs as determined in Phase 1, to quantify the expected improvement from the new signs, and to recommend what sign or signs should be adopted for driver warning at railroad grade crossings. The results from Phase II and the recommendations of the study are reported herein.

1/ Koziol, Joseph and Mengert, Peter, "Railroad Grade Crossing Passive Signing Study," Interim Report No. DOT-TSC-FHWA-76-1, January 1977.

2. SIGN CONFIGURATIONS

The three new passive sign configurations evaluated in Phase II of this study are shown in Figure 2 together with the existing (base) configuration.

Sign configuration 1 - the so-called Texas sign configuration, consisting of a red and yellow advance warning sign and a white crossbuck with "Railroad Crossing" legend in black lettering superimposed over a circular red and yellow background with black boarder - was the most effective sign tested in Phase I of this study.

Sign configuration 3 - red and yellow advance warning sign and a standard white crossbuck with "Railroad Crossing" legend in black lettering - was not tested in Phase I of this study but was selected for Phase II testing to determine if the colorful advance warning sign alone could explain the expected sign configuration improvement. If should be pointed out here that there were no significant differences between any of the new sign configurations tested in Phase I. But most of these configurations involved two new signs; a crossbuck and an advance warning sign. None of the new sign configurations in Phase I involved just a standard crossbuck with new advance warning sign. If sign configuration 3 were proven just as effective as sign configuration 1 in the Phase II tests then this would mean that only half as many signs (the advance warning sign but not the crossbuck) would be involved in any recommended replacement program.

Sign configuration 2 - red and yellow advance warning sign and a yellow crossbuck with black border - also was not tested in Phase I but was selected for Phase II because (1) the yellow crossbuck is currently being tested by a number of states (2) it was reportedly in wide scale application in Canada and (3) it was part of the sign configuration (#7 in Figure 1) which was second best in Phase I.

Although the "look-for-train" advance warning sign was also part of the sign configuration which was second best in Phase I, it was not included in Phase II because it was viewed as a supplementary sign which could be used at the discretion of the local authorities.

3. SITE CHARACTERISTICS AND TEST CONDITIONS

Experiments were conducted using a single traveling test team at 18 sites in 14 states. The site locations, sequence of testing, and test completion date at each site are shown in Figure 3. The sites were fairly well distributed across the country with a good representation of the participating states in this project. There were two sites in each of California, New Mexico, Texas, and Louisiana. As in Phase I each site was selected based on the following general requirements.

a. Two-lane, two-way rural road with a high speed limit (greater than 45 mph) preceding the crossing.

b. Average Daily Traffic (ADT) between 1000 and 4,000.

c. An average of two-four trains per day.

d. Sight distance restrictions in at least one quadrant.

In actuality, not all requirements were met at every site, but every site did have sight distance restrictions in at least one quadrant. All tests were conducted in one direction only and during good weather conditions only (i.e. no rain, snow, fog or wet roadway). All vehicles crossing the tracks were included in the analysis except, (1) required stop vehicles, (2) vehicles arriving within five minutes of a train crossing, (3) short headway vehicles (less than six seconds between two vehicles approaching the crossing in the same direction.) Only the following vehicles were excluded in these cases, (4) turning vehicles. These vehicles,

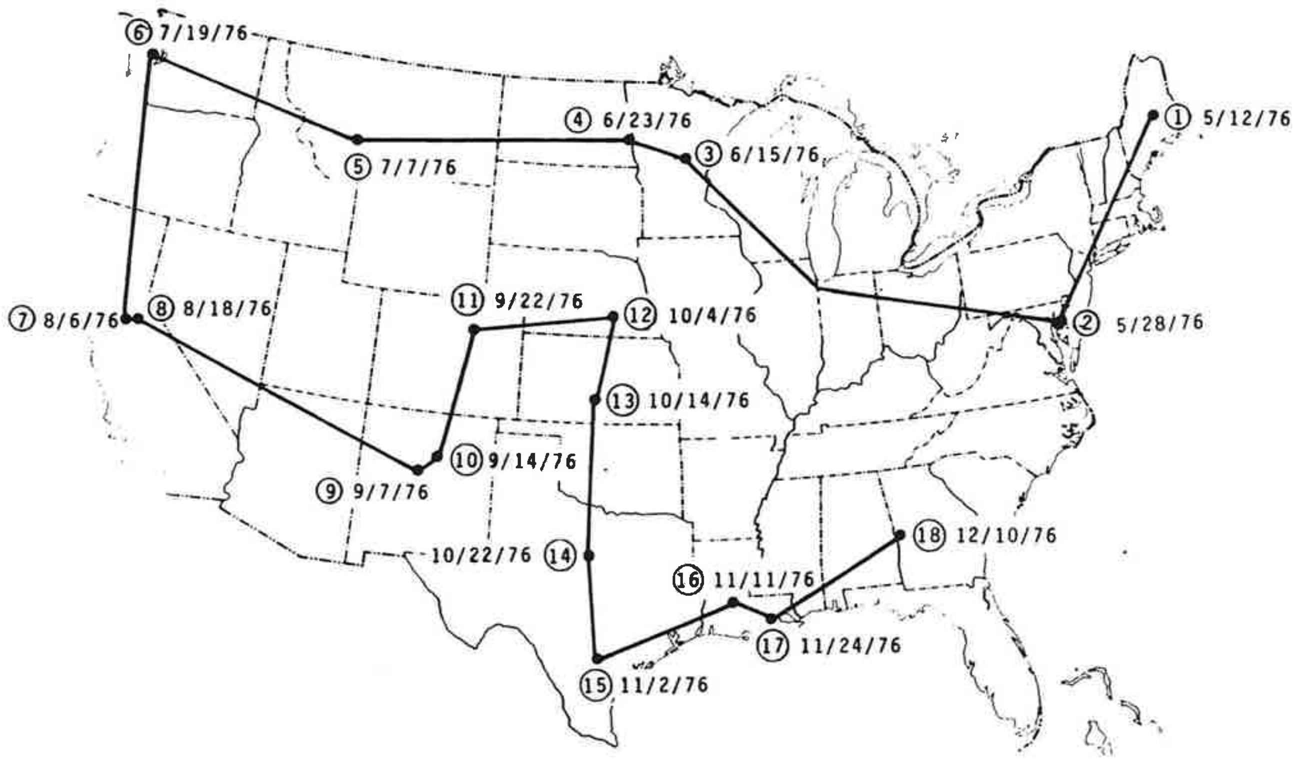

FIGURE 3. SITE LOCATIONS AND TEST SCHEDULE

constituted only a small percentage of the total vehicles crossing the tracks.

4. EXPERIMENT VARIABLES AND MEASURES OF EFFECTIVENESS

During the course of the experiments both dependent and independent variables were measured or recorded manually for each vehicle as it traversed the test area.

4.1 INDEPENDENT VARIABLES

The independent variables, those that remained constant for each sampled vehicle included:

a. site (18 in 14 states)

b. time of day (day-night)

c. observer collecting manual data (2 at each site)

d. observer location (van, car).

The van, which housed the electronic equipment, was parked off the right side of the road about 200 feet from the crossing on the approach side. The car was parked on the opposite side of the road on the opposite side of the crossing and within 100 feet of the crossing. Each observer alternated in collecting the manual data from within each vehicle.

Several other independent variables were studied in Phase I including vehicle type, (car; other) license plate (in-state, out-of-state) driver (male, female) passenger in vehicle (yes, no), required-stop vehicle (yes, no), approach speed >45 mph (yes, no), train expected (yes, no) weather (good, bad) but none of these was found to have an effect on sign configuration improvement and were thus not included in Phase II. Time of

day (day, night) effects were also studied in Phase I, but only in terms of speed profiles since head movement data were not collected at night. The new signs showed no significant differences in speed profile compared to the base sign under day or night conditions. However, time of day was retained as an independent variable in Phase II because the location of the speed sensors was changed (see below) and it was thought that this might have an impact on the speed findings.

4.2 DEPENDENT VARIABLES

The dependent variables were a) head movement and b) speed profile. Head movement data were collected visually and recorded manually, while speed profile data were collected electronically. Vehicle time headway, an additional dependent variable in Phase I, was not retained in Phase II because of the relatively low traffic volume of the sites studied and the inconclusiveness of the data in Phase I.

4.3 MEASURES OF EFFECTIVENESS

Two basic types of measures of effectiveness were formulated from the dependent and independent variables.

4.3.1 Sign Effect Measures

These measures were used for evaluating the effectiveness of the new passive signs and included the following:

a. Head Movement-observer #1

The head movement measure (i.e. percent head movement) was calculated on the basis of the first two states above. That is:

$$\%\text{head movement} = \frac{\#\text{ of definite Head Movements}}{\#\text{ of definite Head Movements} + \#\text{ of definitely no Head Movements.}}$$

Since there were two observer locations (i.e., car and van - see below), the observers were also instructed to distribute as equally as possible the time spent observing driver head movements at each location. Thus, the head movement measure by observer was averaged over the two observer locations.

Head movement was considered the primary measure in this study providing not only an indication of the attentiveness and safety orientation of the driver but also a direct and positive indication of the driver seeing and reacting to a particular sign configuration.

b. Head Movement - Observer #2

This measure was similar to (a) except that data were obtained by observer #2

c. Head Movement - Van Location

This measure was similar to (a) except that data were obtained by and averaged over two observers at the van location. The measurement zone for driver head movement was not restriction to the van region but, was similar to that for measure (a). The van housed the electronic system (described below) and

was located off the right side of the road on the approach side approximately 200 feet from the crossing.

d. Head Movement - Car Location

This measure was similar to (a) except that data were obtained by and averaged over two observers at the car location. The measurement zone for driver head movement was not restricted to the car location. The car was parked on the opposite side of the road and on the opposite side of the crossing from the van, and within 100 feet of the crossing.

e. Agreed Head Movement

This measure considered only those drivers for whom both observers agreed on either "definite head movement" or "definitely no head movement". The measure was calculated similarly to that described in (a). More consideration was given to this measure in the analysis since it reflected the results of one observer reinforced by the other.

f. Speed Reduction

Speed reduction was defined as entrance speed, at a location 800 feet from the crossing on the approach side minus exit speed at a location 200 feet from the crossing on the approach side.

This measure provided an indication of whether or not the driver reacted to the sign configuration by slowing down in the approach to the crossing. This measure together with measure g) - speed near crossing - provided a concise representation of the vehicle's

speed profile. In general, large values of speed reduction implied more effectiveness.

g. Speed Near Crossing

This was the speed at a location 200 feet from the crossing on the approach side. This measure, in addition to providing information on the relative safety aspects between signs and sites directly, together with measure f) - speed reduction - provided information on the vehicle's speed profile near the crossing. Since advance warning signs were located approximately 300-600 feet from the crossing, reaction to the advance warning signs was expected to occur before the driver was "near the crossing." In general, smaller values of this measure implied more effectiveness. However, in the analysis a "speed near crossing" effect was not considered important unless accompanied by a "speed reduction" effect. This was because a "speed near crossing" effect alone could have been accounted for by a different speed driver population rather than a reaction to the sign configurations.

Several other measures for determining sign configuration effectiveness were used in Phase 1 including RMS[1] deceleration, headway reduction ratio, time in hazard zone and number of vehicles stopping at the crossing. These measures were

1/ RMS deceleration is root mean square deceleration.

considered experimental in Phase I and were found to be either inconclusive or uninterpretable due in some cases to small sample sizes. Since the site characteristics in Phase II were similar to those in Phase I, these measures were not retained in Phase II.

4.3.2 Subjectivity Measures

It was recognized at the onset of the study that the primary measure for discriminating sign configuration effectiveness-driver head movement - might be too subjective to provide meaningful results. Phase I of this study showed consistent results in terms of head movement data between observers at different sites but very little data was available for comparing data between observers at the same site. Phase II attempted to surmount these problems by providing for two observers at each of the 18 sites tested. The subjectivity measures formulated and described below, attempted to quantify the subjectivity and variability of the head movement data and assess its reliability.

a. Head Movement Comparison between Observers

This measure was a comparison of the mean head movement data between observers for each sign at each site. A similar comparison is also made between observer locations. The measure provided a gross indication of the consistency and agreement between observers.

b. Head Movement Correlation between observers.

A correlation measure was formulated to provide an

indication of the agreement between observers on a per driver basis. A correlation was determined for each site. The correlation measure was essentially the percent agreements between observers of the "definite head movement" and "definitely no head movement" states. The measure was defined as follows:

YY - the number of times both observers agreed that the driver showed "definite head movement."

NN = the number of times both observers agreed that the driver showed "definitely no head movement."

YN = the number of times the 1st observer indicated "definite head movement" while the second observer indicated "definitely no head movement."

NY = the number of times the 1st observer indicated "definitely no head movement" while the second observer indicated "definite head movement."

Then,

$$\text{correlation measure} = \frac{YY + NN}{YY+NN+YN+NY}$$

c. Head Movement Uncertainty by each Observer

This measure was the percent of time each observer indicated the "not sure" state compared to the "definite head movement" and "definitely no head movement" states. Percent uncertainty was calculated for each observer and for each site. This measure provided an indication of the difficulty of obtaining and degree of subjectivity of the head movement data.

5. DATA COLLECTION AND TEST SCHEDULE

Electronic and manual data were collected on one side of the crossing at each of the 18 sites. The sides were selected based on the criteria described in Section 3. The signs were installed on both sides of the crossing. The electronic data provided speed-profile information and were obtained using a data acquisition system housed in a mobile van. The mobile van, the same used in Phase I, was parked off the side of the road about 200 feet from the crossing on the approach side. A second vehicle (car) was also used in the study primarily as a means of transportation for the data collectors in the vicinity of each site once the data acquisition system was set up. During the experiment, the car was parked on the opposite side of the road and on the opposite side of the crossing from the van, within 100 feet of the crossing. One data collector was stationed in each vehicle when collecting the manual data.

Although the van and car were visible to the passing motorists, they were parked at unobtrusive locations and did not seem to affect the driver's behavior to the various sign configurations. The van was an unmarked recreational vehicle and due to the rural characteristics of the sites, most of the passing motorists paid little or no attention to its presence. Attempting to conceal the van was out of the question because of its size and lack of adequate obstructions.

Speed profile data were measured by sensors laid across the lane of the road on the approach side of the crossing. The sensors were activated by each axle of each vehicle. Sensors were located 200, 400, 600 and 800 feet from the crossing. A pair of sensors was laid at each location - separated by 6 feet - providing spot speed information at each of the four locations.

Manual data were collected on a clipboard by each observer and at each location (van & car). The manual data consisted of vehicle crossing time, head movement state, required stop vehicles, turning vehicles, and train crossing time (whenever it occurred during the data collection period). Only one pass (visit) was made at each site during which data were collected for each of the three new sign configurations. In addition, data were collected for the existing (base) sign configuration before and after the new signs were tested. After the data acquisition system was set up and checked out, then the data collectors obtained data first for the base sign configuration, next for the new sign configurations on the following and succeeding days and finally for the base sign configuration once again.

It was desired to obtain approximately 200 samples per sign per site. At most sites this translated into 1 day of data collection per sign. For those sites with lower traffic volumes a two day limit on data collection was set. This was done in order to keep the total experiment within reasonable

length and cost and to allow a reasonable schedule to be set up for coordinating the data collection progress with the local authorities in whose states the tests were being conducted.

Each sign configuration (except for the base "before") was installed on the morning of testing for that particular sign configuration.

No data were collected over weekends, holidays or during bad weather. Over weekends and holidays, the base sign configuration was reinstalled (if not already set up) until testing was resumed the following week. If weather did not permit testing on a particular day, the last installed sign configuration or base sign configuration was kept up until such time that weather permitted the next sign configuration to be tested. Testing during the day was equally distributed between morning and afternoon periods.

Speed profile data were collected at night at 6 sites. All 18 sites were not utilized because no night effects were found during Phase 1. A limited number of sites was determined sufficient to verify this Phase 1 finding. Testing at night was constrained to a four hour period initiated about one hour after sunset.

The test schedule and sign/site arrangement are shown in Figure 4. The sites are blocked in sets of six. Since there are six possible permutations or arrangements of the three new sign configurations each set of six sites was balanced in terms of the sign arrangements. The six night sites were also balanced in terms of sign arrangements. There

TEST SCHEDULE

Site	Data Collector	Start Date (begin testing)	Sign Arrangement (N-includes night data)					Completion Date (end testing)
1 Bingham ME	1,2	5/03/76	B^N	2^N	1^N	3^N	B^N	5/12/76
2 Chestertown MD	1,2	5/19/76	B*	3	1	2	B	5/28/76
3 Merrifield MN	1,2	6/07/76	**B^N	1^N	2^N	3^N	B^N	6/15/76
4 Warren ND	1,2	6/16/76	B	2	3	1	B	6/23/76
5 Bozeman Hot Springs MT	1,2	6/28/76	B	1	3	2	B	7/07/76
6 Olympia WA	1,2	7/9/76	***B	3	2	1	B	7/19/76
7 Jamestown CA	3,2	7/26/76	B	3	1	2	B	8/06/76
8 Chinese Camp CA	3,2	8/09/76	B	2	1	3	B	8/18/76
9 Belen NM	3,2	8/24/76	B	1	2	3	B	9/07/76
10 Lamy NM	1,2	9/08/76	B	1	3	2	B	9/14/76
11 Plumbs CO	1,2	9/16/76	B^N	3^N	2^N	1^N	B^N	9/22/76
12 Edgar NE	1,2	9/27/76	B^N	2^N	3^N	1^N	B^N	10/04/76
13 Seward KS	3,2	10/08/76	B^N	1^N	3^N	2^N	B^N	10/14/76
14 Mineral Wells TX	3,2	10/18/76	B	2	3	1	B	10/22/76
15 McQueeney TX	3,2	10/25/76	B	3	2	1	B	11/02/76
16 Alexandria LA	1,2	11/04/76	B	2	1	3	B	11/11/76
17 Sun LA	1,2	11/15/76	B^N	3^{N+}	1^N	2^N	B^N	11/24/76
18 Columbus GA	1,2	11/29/76	B	1	2	3‡	B	12/10/76

*Pavement markings painted

**Sign configurations include Look-for-Train sign.

***Sign configurations include 20 MPH plaque on advance sign.

Van moved farther into shoulder to avoid obstructing signs.

2 approach signs stolen

SIGN LEGEND

B - Base (standard) configuration

1 - Texas at-crossing, Texas advance

2 - Yellow crossbuck at-crossing, Texas advance

3 - Standard at-crossing, Texas Advance

FIGURE 4. SIGN/SITE ARRANGEMENT

TABLE 1. SAMPLE SIZES

Site	Signs				
	B	2	1	3	B
1. Bingham ME	189/98*	187/60	180/0	166/76	188/40
	B	3	1	2	B
2. Chestertown MD	210	490	202	440	205
	B	1	2	3	B
3. Merrifield MN	64/0	23/11	10/0	37/38	34/43
	B	2	3	1	B
4. Warren ND	52	51	40	44	46
	B	1	3	2	B
5. Bozeman Hot Springs MT	251	282	245	227	225
	B	3	2	1	B
6. Olympia WA	169	161	137	127	125
	B	3	1	2	B
7. Jamestown CA	184	192	192	175	210
	B	2	1	3	B
8. Chinese Camp CA	175	191	174	198	158
	B	1	2	3	B
9. Belen NM	191	169	146	164	188
	B	1	3	2	B
10. Lamy NM	160	174	95	176	177
	B	3	2	1	B
11. Plumbs CO	282/163	336/254	249/100	290/162	342/164
	B	2	3	1	B
12. Edgar NE	135/38	104/18	122/13	112/7	111/18
	B	1	3	2	B
13. Seward KS	179/37	236/74	209/35	194/70	211/34
	B	2	3	1	B
14. Mineral Wells TX	212	139	187	166	219
	B	3	2	1	B
15. McQueeney TX	152	101	138	133	134
	B	2	1	3	B
16. Alexandria LA	423	202	419	384	253
	B	3	1	2	B
17. Sun LA	89/43	142/66	77/67	129/32	158/54
	B	1	2	3	B
18. Columbus GA	112	88	103	60	40

*DAY/NIGHT

6. RESULTS

The results of Phase II of the railroad grade-crossing passive signing study are presented below in four sections. The first three sections evaluate the effectiveness of the three new passive sign configurations tested in terms of seven measures of effectiveness: head movement - observer #1, head movement - observer #2, head movement - van location, head movement - car location, agreed head movement, speed reduction and speed near crossing. The fourth section evaluates the subjectivity of the head movement data.

Section 6.1 provides a summary of "quick look" data. That is, based on the individual means and standard deviations of the measures for each sign configuration at each site, counts were developed that represented the number of sites (out of a total of 18 for daytime conditions and 6 for night conditions) where particular effects occurred. This technique permitted an evaluation of relative sign configuration improvement for all sites considered without averaging the data over all the sites. Averaging over all sites, although a straight forward approach is not always directly interpretable in terms of expected effects at a particular site.

Section 6.2 averages the measures over all 18 sites and provides a 3-way Analysis of Variance (ANOVA) with sign order, site, and sign configuration as the variables. The 3-way ANOVA was performed for the three new sign configurations each relative to the average of the base "before" and base

"after" sign conditions. This ANOVA permitted a direct evaluation of sign order effects and sign configuration improvement effects.

Section 6.3 also averages the measures over all 18 sites but provides a 2-way ANOVA with site and sign configuration as the variables. The 2-way ANOVA was performed for five sign conditions - the three new sign configurations plus the base "before" and base "after" sign conditions. This ANOVA permitted a direct evaluation of each of the three new sign configurations with respect to each of the two base conditions.

Section 6.4 evaluates the subjectivity of the head movement data in terms of three measures: head movement comparisons between observers and location of observers, head movement correlation between observers, and head movement uncertainty by each observer. These measures provided quantitative information for assessing the reliability of the head movement data.

6.1 SUMMARY OF "QUICK LOOK" DATA

The data presented in this section were based on a convention that was adopted for determining different ranges of improvement (or impairment) when comparing the sign configurations in terms of their measures of effectiveness. The convention can be explained with the aid of Figure 5, which shows three different ranges (cases) of improvement when comparing two individual means or averages. The dots represented the mean values of a particular measure for each sample and the

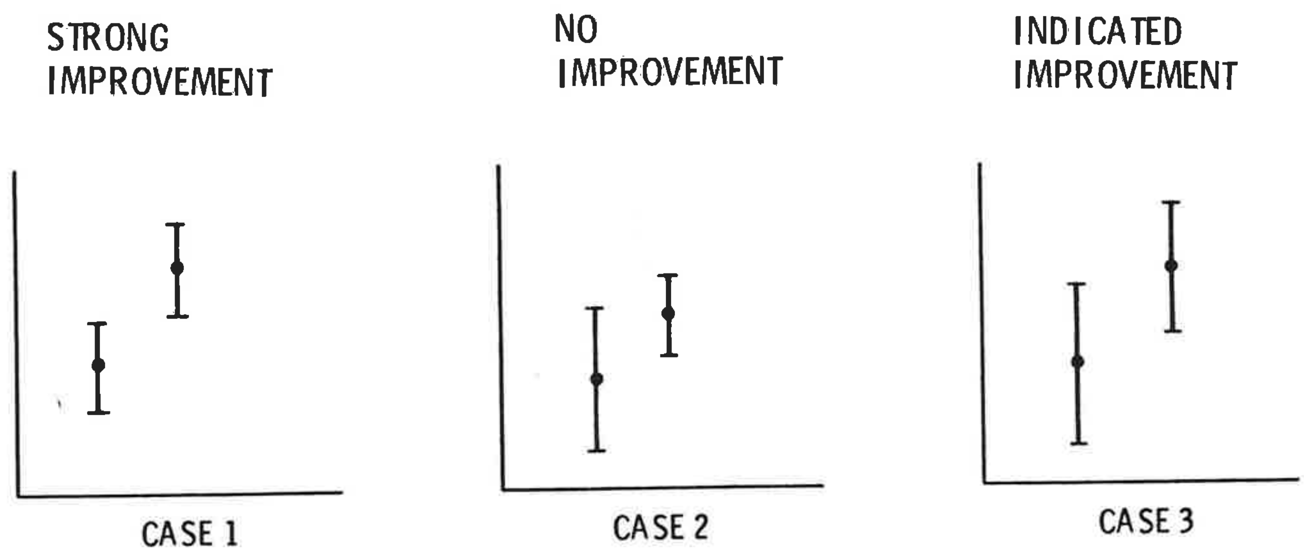

FIGURE 5. RANGES OF IMPROVEMENT

bars represented the 95 percent confidence intervals for the individual means.

By the convention adopted in this study, case 1 represented a "strong" improvement of one mean, (i.e., measure of effectiveness mean) over the other mean, since there was no overlap of the end points of the error bars between the samples. When the end point of an error bar of one sample overlapped the center point (mean) of the other sample (case 2), no improvement between the means was declared. When the end point of an error bar of one sample overlapped the end point of an error bar of the other sample but not the center point of the other sample (case 3), the difference between the means was declared an "indicated" improvement.

The defined ranges of improvement should be viewed primarily as aid for making relative comparisons. The actual levels of significance (two-sample comparison) for the three cases as shown were .01, .15 and .05. Thus, for 2-sample comparisons, case 1 had a level of significance of .01 or better, case 3 a level of significance between .01 and .15, and case 2 a level of significance of .15 or worse.

The common level of significance for declaring a difference (whether 1-sample, 2-samples or multiple samples) is generally .05.

The 2-sample level of significance ranges were felt to be reasonable for defining the particular ranges of improvement (according to Figure 5) and for making multiple comparisons.

Table 2 summarizes the "quick look" data for daytime conditions. The data in the Table represented counts on the number of sites (out of 18) where particular sign configuration effects occurred. The counts were determined for each measure of effectiveness and for each new sign configuration. Two basic types of effects were examined:

a. STR - This effect represented a strong improvement (by the convention adopted in this study and explained above) for the particular new sign configuration compared to the base "before" <u>and</u> base "after" sign conditions.

b. IND - This effect represented an indicated improvement (by the convention adopted and explained above) for the particular new sign configuration compared to three base sign conditions.

1. base "before" or base "after"
2. base "before" <u>only</u>
3. base "before" <u>and</u> base "after"

Thus, for the STR effect a single count was determined for each measure and each new sign configuration; for the IND effect, three counts were determined for each measure and each new sign configuration.

For each of the above effects, a sign control count was also determined. The sign control counts represented strong or indicated impairments for the particular new sign configuration. Finally, a base control was also determined for each measure. The base control counts represented the number of sites where

the base "after" sign condition showed an indicated "improvement" over the base "before" sign condition. The controls were established to provide a relative basis for interpreting the sign configuration effect.

Two additional measures, shown in the table, were introduced for purposes of the "quick look" summary data only. The first measure was "Observer 1 & 2 head movement." The counts indicated for this measure represented the number of sites where both observers agreed on a particular effect. "Observer 1 & 2 head movement" thus represented agreement between the observers on a per site basis whereas "Agreed head Movement" represented agreement between observers on a per driver basis. The "Observer 1 & 2 head movement" counts were believed to provide more meaningful information than the "Observer 1 head movement" counts and "Observer 2 head movement" counts separately.

The second measure was "speed reduction and speed near crossing." The counts indicated for this measure represented the number of sites where there was both a speed reduction effect and a speed near crossing effect. Since the "speed reduction" measure and the "speed near crossing" measure by themselves did not provide a clear picture of the speed profile effects (see Section 4.3.1), the "speed reduction and speed near crossing" measure was considered the only important speed measure in the analysis.

The results in Table 2 showed that there were very few strong improvements for any measure and any sign configurations. But, on the other hand, there were even fewer strong impairments. This put a bound on the range of effects. In terms of indicated improvement and their controls there was a pattern of effects especially for the head movement data. Sign configuration (SC) 1 showed higher counts than the other two S.C.'s for all three base sign conditions. For example, observer 1 found indicated improvements for S.C. 1 at 15 of the 18 sites when compared to the base "before" <u>or</u> base "after" but only 12 for S.C. 2 and 9 for S.C. 3. S.C.'s 2 & 3 showed about the same indicated improvement in terms of the count data with S.C. 2 having a slight edge. The improvement counts for the speed measures were much less. The important speed measure, namely "speed reduction and speed near crossings," rated S.C. 2 the highest. However, overall the speed results appeared to be minimal: there were indicated improvements for S.C. 2 in speed profiles at only 4 of the 18 sites.

The very low sign control counts reinforced the improvement results for both the head movement data and the speed data. However the head movement effect was clearly more substantial than the speed effect.

The fact that the counts for the effect - indicated improvement compared to base "before" <u>and</u> base "after" - were relatively low compared to the other sign improvement counts and the counts for the base control relatively high compared to the sign con-

trol counts, seemed to imply that there was some influence on the drivers due to the testing itself. However, this did not diminish the relative findings because (1) the sign control counts were all low compared to the improvement counts, and (2) the base control counts were about half the corresponding sign improvement counts (i.e., compared to base before only).

In summary, the "quick look" data showed that

1. S.C. 1 was best in terms of head movement.

2. S.C.'s 2 & 3 were rated about equal in terms of head movement with S.C. 2 having a slight advantage and both showed indicated improvements compared to the base conditions.

3. S.C. 2 was rated highest in terms of speed profile but showed only minimum improvement compared to the base conditions.

Table 3 summarizes the "quick look" data for night conditions. The results showed that once again as for the daytime conditions, there were very few speed profile effects. (No head movement data were collected at night.)

Only S.C. 1 showed indicated improvement in terms of "speed reduction and speed near crossing." But this occurred at only 1 of the six sites studied at night. On this basis it was concluded that the new sign configurations were not having an effect on the drivers at night in terms of speed profiles and no further analysis of the night data was performed.

TABLE 3. QUICK LOOK SUMMARY DATA - NIGHT

	SIGN CONFIGURATIONS	1		2		3		B*
MEASURE	EFFECT TYPE	EFFECT	CONTROL	EFFECT	CONTROL	EFFECT	CONTROL	
SPEED REDUCTION	STR IND	0 1-1-1	0 1-0-0	0 1-1-1	1 2-2-1	0 0-0-0	1 2-1-1	1
SPEED NEAR CROSSING	STR IND	0 1-1-1	0 0-0-0	0 0-0-0	0 0-0-0	1 1-1-1	0 1-1-1	0
SPEED REDUCTION AND SPEED NEAR CROSSING	STR IND	0 1-1-1	0 0-0-0	0 0-0-0	0 0-0-0	0 0-0-0	0 0-0-0	0

STR - STRONG IMPROVEMENT COMPARED TO BASE "BEFORE" AND BASE "AFTER"

IND - INDICATED IMPROVEMENT COMPARED TO BASE "BEFORE" OR BASE "AFTER"; BASE "BEFORE" ONLY; BASE "BEFORE" AND BASE "AFTER"

*BASE CONTROL

NOTE: Illustration of interpretation - In terms of speed reduction, S.C.2 showed a strong improvement compared to the base "before" and base "after" sign conditions at none of the 6 sites and a strong impairment compared to the base "before" and base "after" sign conditions at 1 of the 6 sites. Furthermore the base "after" sign condition showed an indicated "improvement" over the base "before" sign condition at 1 of the 6 sites.

6.2 3-WAY ANOVA

A 3-way analysis of variance was performed for the three new sign configurations each relative to the average of the base "before" and base "after" sign conditions. The three variables were sign order, site, and sign configuration. Table 4 summarizes the levels of significance for each variable and for each measure of effectiveness. The dashes in the table indicated that the level of significance for that condition was greater than .1.

Using .05 as the level of significance for declaring an effect, Table 4 showed that there was no sign order effect, (i.e., no effect due to when a sign was tested in the sign configuration arrangement). For this variable, all new sign configurations tested in the first position in the arrangement were averaged together over 18 sites as were all sign configurations tested in the second position and lastly all sign configurations tested in the third position. Since there was a balance in the total sign/site arrangement, this meant that for each position, the averages included six of each of the three new sign configurations. The significance test was then a comparison between the three positions in the sign configuration arrangement. The no significant difference finding meant that results were not dependent on when a sign was tested in an arrangement. This implied no day-to-day novelty effect and gave additional credence to the daily sequential method of testing.

TABLE 4. 3-WAY ANOVA SUMMARY

	OBS 1 HEAD MOVEMENT	OBS 2 HEAD MOVEMENT	AGREED HEAD MOVEMENT	VAN HEAD MOVEMENT	CAR HEAD MOVEMENT	SPEED REDUCTION	SPEED NEAR CROSSING
ORDER (3)	-	-	-	-	-	.1	-
SITE (18)	.01*	.01	.01	.01	.1	-	.1
SIGN CONFIGURATION (3)	.01	.1	.025	.05	-	-	-

* Significance Level

Table 4 also showed there were significant site-to-site effects in terms of head movement improvement (the measures were relative to the average of the base "before" and base "after" sign conditions), but no site-to-site effects in terms of speed profile changes. This meant that different amounts of head movement improvement were found from site-to-site for the new sign configurations, but the speed profile changes due to the new sign configurations were not found to be significantly different from site-to-site.

Finally, Table 4 showed that there were significant differences amongst the three new sign configurations themselves in terms of the head movement data (car head movement being a minor exception), but no significant difference amongst the three new sign configurations in terms of the speed profile data. The next table examined the relative mean effects and where the significant differences occurred.

Table 5 shows the relative mean effects for the three new sign configurations each relative to the average of the base "before" and base "after" sign conditions. The 95 percent confidence ranges for multiple comparisons (Bonferroni method) are also shown. For determining significance the difference between any two sign configurations was compared to the 95 percent confidence range.

In terms of the head movement measures S.C. 1 was clearly superior to S.C.'s 2 & 3 as well as the average of the base "before" and base "after" sign conditions. (The latter was

TABLE 5. RELATIVE MEAN SIGN CONFIGURATION EFFECTS - 3 NEW SIGN CONFIGURATIONS, EACH RELATIVE TO AVERAGE OF BASE "BEFORE" AND BASE "AFTER"

SIGN CONFIGURATION	1	2	3	95% CONFIDENCE RANGE 3.73 σ
OBS 1 HEAD MOVEMENT (%)	8.0	5.4	4.0	2.2
OBS 2 HEAD MOVEMENT (%)	6.3	2.3	2.5	5.0
AGREED HEAD MOVEMENT (%)	10.7	5.9	6.2	4.3
VAN HEAD MOVEMENT (%)	9.1	4.6	4.8	4.7
CAR HEAD MOVEMENT (%)	5.7	3.5	2.1	4.3
AVERAGE HEAD MOVEMENT (%)	8.0	4.3	3.9	4.2
SPEED REDUCTION (mph)	.13	.13	.07	.43
SPEED NEAR CROSSING (mph)	-1.11	-.69	-.35	.97

determined by comparing the relative mean effect for S.C. 1 to zero.) Based on the average head movement (i.e. the average over the five head movement measures) S.C. 1 was significantly better than the average of the two base conditions and almost significantly better than S.C.'s 2 & 3. It is also interesting to note that the new advance warning sign (i.e. sign configuration 3) accounted for about half the total improvement due to sign configuration.

There were no significant differences between S.C.'s 2 & 3. Furthermore, S.C. 2 was significantly better, and S.C. 3 almost significantly better than the average of the two base conditions. Because of the conservative nature of the Bonferroni test (i.e., 3.73 σ for 95 percent confidence intervals) "almost significant" in this section can be considered for all practical purposes "significant."

In terms of the speed reduction measures, there were no significant differences amongst the sign configurations including the average of the two base conditions. For the speed near crossing measure, the only significant difference was between S.C. 1 and the average of the two base conditions. Since the speed changes were all relatively low (on the order of 1 mph or less) and since there were no combined speed reduction and speed near crossing effects (see section 4.3.1), it was concluded that there were no significant and substantial changes in speed profiles due to the new sign configurations.

In summary, S.C. 1 was significantly better than the average of the two base conditions in terms of the head movement data averaging (over the five head movement measures) an increment

almost significantly better than the other two new sign configurations averaging an increment of 3.9 percent more head movement. S.C.'s 2 & 3 appeared to be equally effective. S.C. 2 was significantly better and S.C. 3 almost significantly better than the average of the two base conditions by an increment of 4.3 percent and 3.9 percent more head movement respectively. There were no significant differences in terms of the speed measures for any of the new sign configurations.

6.3 2-WAY ANOVA

A 2-way analysis of variance was performed for five sign conditions - the three new sign configurations plus the base "before" and base "after" sign conditions. The two variables were site and sign condition. Table 6 summarizes the levels of significance for each variable and for each measure of effectiveness. The results showed that there were significant differences from site-to-site in terms of all the measures. This was expected and was not an interesting finding. It meant simply that the nominal behavior of drivers approaching crossings (i.e. head movement and speed) differed from site to site. The more interesting finding was that there were sign condition effects for all the head movement measures, the speed near crossing measure but not the speed reduction measure.

Table 7 shows the mean sign condition effects for the five sign conditions including the base "before" and base "after." The 95 percent confidence ranges for multiple comparisons (Bonferroni

TABLE 6. 2-WAY ANOVA SUMMARY

	OBS 1 HEAD MOVEMENT	OBS 2 HEAD MOVEMENT	AGREED HEAD MOVEMENT	VAN HEAD MOVEMENT	CAR HEAD MOVEMENT	SPEED REDUCTION	SPEED NEAR CROSSING
SITE (18)	.01 *	.01	.01	.01	.01	.01	.01
SIGN CONDITION (5)	.01	.05	.01	.01	.01	-	.01

* Significance Level

TABLE 7. MEAN SIGN CONDITION EFFECTS - 5 SIGN CONDITIONS INCLUDING BASE "BEFORE" AND BASE "AFTER"

SIGN CONDITIONS	B	1	2	3	B	95% CONFIDENCE RANGE 3.93 σ
OBS 1 HEAD MOVEMENT (%)	30.6	40.5	37.7	36.6	34.4	4.5
OBS 2 HEAD MOVEMENT (%)	35.7	43.1	38.9	39.4	37.9	6.5
AGREED HEAD MOVEMENT (%)	28.2	39.5	34.3	35.0	29.4	5.5
VAN HEAD MOVEMENT (%)	34.2	43.6	38.7	39.3	34.8	5.7
CAR HEAD MOVEMENT (%)	32.1	40.3	38.1	36.8	37.2	5.1
AVERAGE HEAD MOVEMENT (%)	32.2	41.4	37.5	37.4	34.7	5.5
SPEED REDUCTION (mph)	5.50	5.58	5.60	5.51	5.45	.59
SPEED NEAR CROSSING (mph)	39.50	38.21	38.62	38.96	39.13	1.00

method) are also shown. The interesting additional finding that was not evident in Table 5 was that S.C. 1 was superior to both the base "before" and the base "after" sign conditions for all head movement measures plus the average of the five head movement measures. In terms of the average head movement measure and most of the other head movement measures, S.C. 1 was significantly better than both base condition. S.C. 1 was superior to, but not significantly better than, the S.C. 2 & 3. Finally, S.C.'s 2 & 3 were found to be equally effective and superior to, but not significantly better than, the base "before" and base "after" conditions. The fact that the base "after" sign condition showed more head movement than the base "before" sign condition was probably due to the sign testing effect itself. The true relative effect of the new sign configurations was therefore probably more closer reflected by the change from the base "after" only while the true value for the base head movement was probably more reflected by the base "before" only. With respect to the base "before" only sign condition, Table 7 showed that S.C. 1 was significantly better averaging (over the five head movement measures) an increment of 9.2 percent more head movement (from 32.2 percent to 41.4 percent). With respect to the base "after" only sign condition, S.C. 1 was significantly better averaging an increment of 6.7 percent more head movement (from 34.7 percent to 41.4 percent). S.C.'s 2 & 3 averaged an increment of 5.3 percent more

head movement (from 32.2 percent to 37.5 percent) over the base "before" and 2.8 percent more head movement (from 34.7 percent to 37.5 percent over the base "after." Finally, S.C. 1 was superior to, but not significantly bett er than, S.C.'s 2 & 3 averaging an increment of 3.9 percent more head movement (from 37.5 percent to 41.4 percent).

The only major finding for the speed measures was for the "speed near crossing" measure where S.C. 1 was significantly better than the base "before" and almost significantly better than the base "after" sign conditions. However, the change in speed was small (about 1 mph) and was not accompanied by a speed reduction effect. Hence, no significant speed profile effect was declared for any of the new sign configurations.

6.4 RELIABILITY OF HEAD MOVEMENT DATA

Three types of measures were used to evaluate the subjectivity of the head movement data and to assess its reliability. The first type was a comparison of head movement data on a per site and per sign condition basis, between observers and between location of observers. The comparison between observers is shown in Figure 6. (For each observer, head movement data were averaged over the two locations - car and van - where the data were collected.)

Overall the two observers showed strong consistency and fair agreement in the percent head movement data. At a few sites (e.g., site #3, 10, 11 and 12), the relative differences were quite large. At site #3, the differences may have been due to sample size effects. Sample sizes per site and per

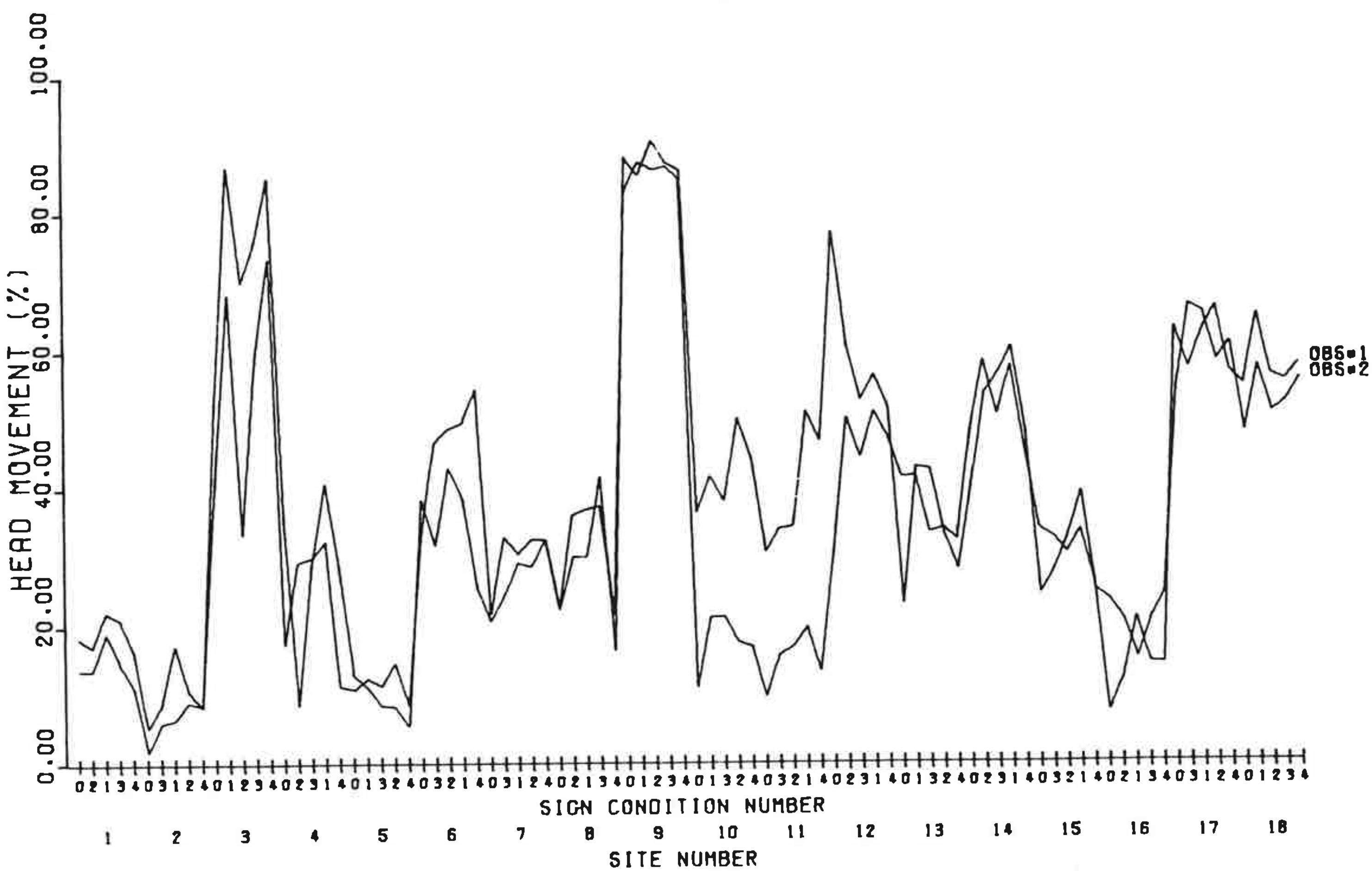

FIGURE 6. HEAD MOVEMENT VS. SIGN AND SITE FOR EACH OBSERVER

sign configuration were generally above 150 but at site #3 were between 10 and 64. At sites #10, 11,and 12,the differences may have been partly due to a change in observers which occurred after site #9.

Figure 6 also showed a relatively high percent of head movement at sites #3 and 9. At site #3, this may have been due once again to sample size effects. In addition, site #3 had relatively severe sight restrictions, a sharp contrasting background for all the signs and an additional look-for-train sign located about midway between the crossbuck and the advance warning sign. All or some of these factors may have contributed to the high percentage of head movement.

There were no obvious factors to account for the high percentage of head movement at site #9. The behavior of drivers at railroad crossings was apparently affected by other factors that were not controlled or studied in the experiment. The variation of the head movement data from site to site as shown in Figure 6 provided a visual representation of the site-significant effects as found from the 2-way ANOVA (Table 6 .)

Figure 7 compared the head movement data as a function of observer location. (For each observer location, head movement data were averaged over the two observers.)

Again, as in Figure 6, a strong consistency between the two curves was found. Furthermore, the variation due to the location of the observers was substantially less than the

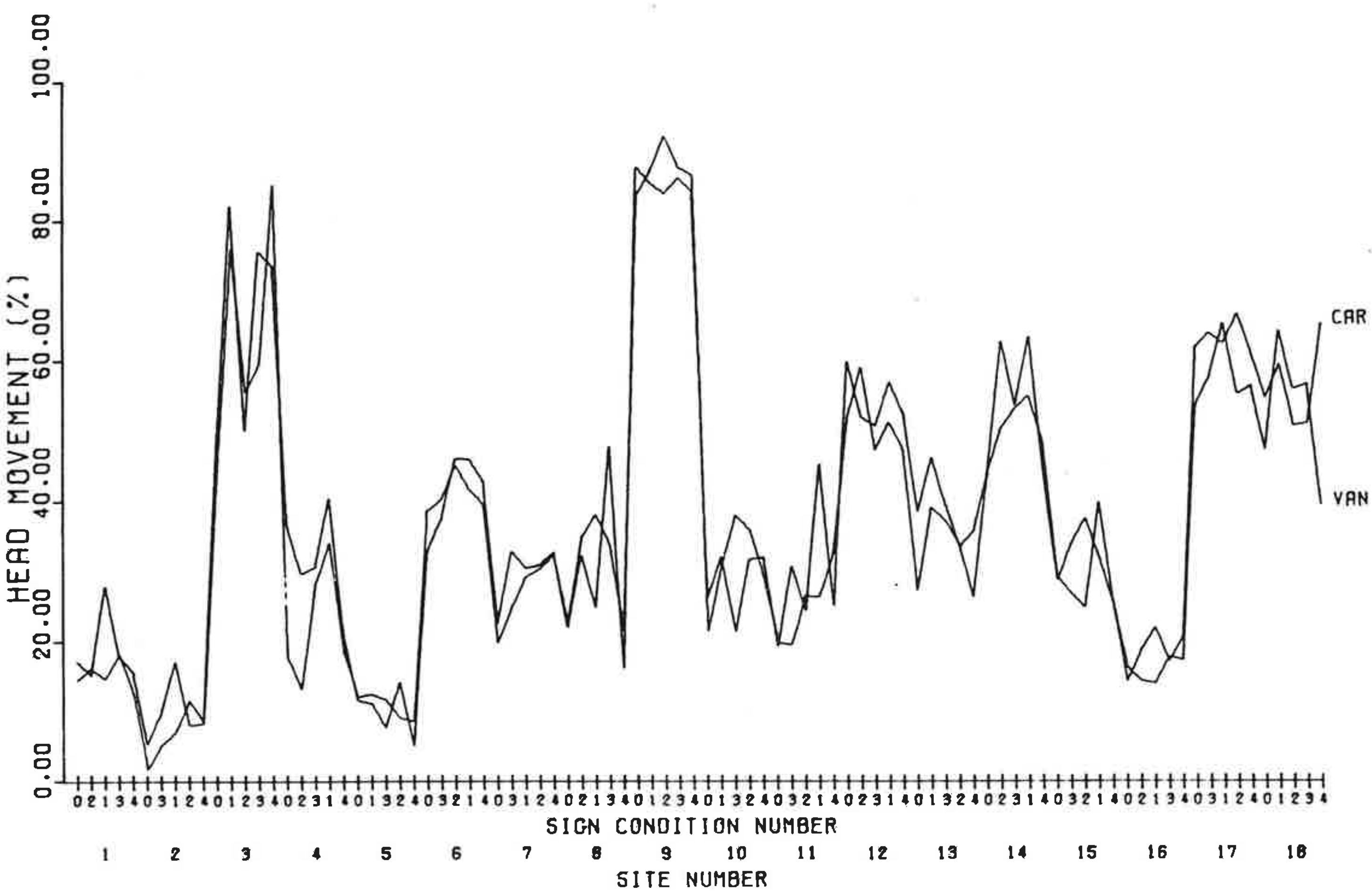

FIGURE 7. HEAD MOVEMENT VS. SIGN AND SITE FOR EACH OBSERVER LOCATION

variations due to the observers themselves. The location of the observer therefore had little influence on the results compared to the variation between observers.

The second type of measure used to evaluate the subjectivity of the head movement data was head movement correlation between observers. The correlation, essentially the percent agreement between observers on the driver head movement states was defined in Section 4.3.2 and is shown in Figure 8 as a function of site. The correlations were all relatively high and uniform over the 18 sites. The average correlation over the 18 sites was .76. The small variations can be explained by the change in nominal percent head movement from site to site. But, in general, the observers tended to agree on the driver head movement states.

The third type of measure used to evaluate the subjectivity of the head movement data was head movement uncertainty by each observer (see Section 4.3.2).

Figure 9 shows percent uncertainty for each site and for each observer. The percent uncertainties for both observers were rather low and consistent over the 18 sites. The average percent uncertainties over the 18 sites for observer 1 and observer 2 were .13 and .15 respectively. This meant that the observers were confident on the driver head movement states over 85 percent of the time.

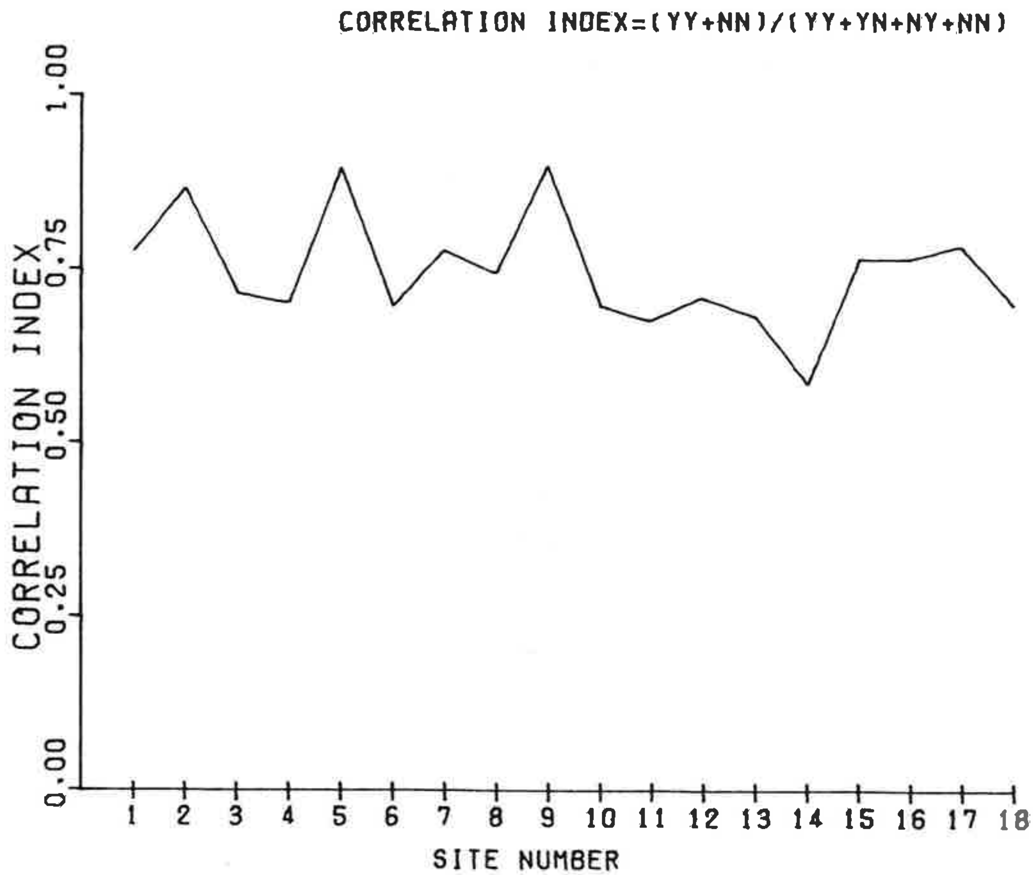

FIGURE 8. CORRELATION OF HEAD MOVEMENT DATA BETWEEN OBSERVERS

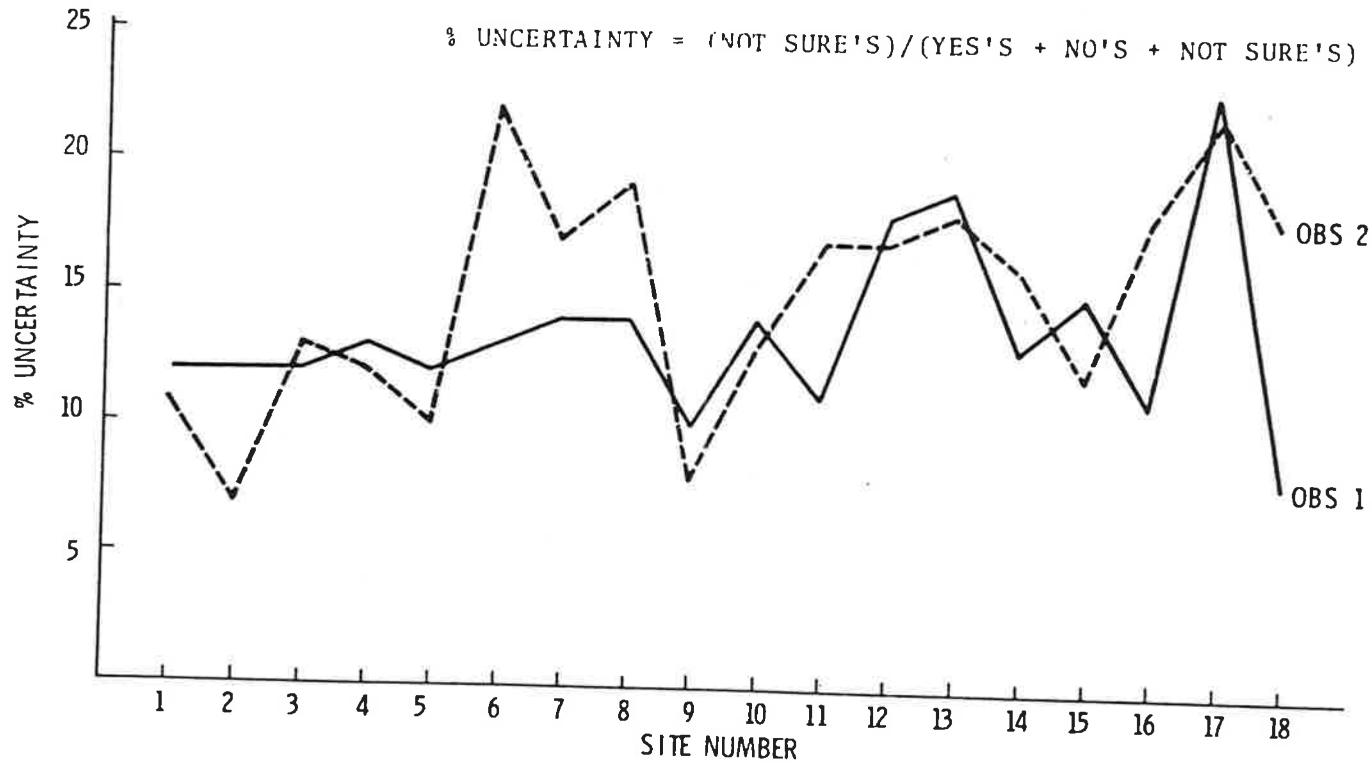

FIGURE 9. PERCENT UNCERTAINTY OF HEAD MOVEMENT DATA

In summary the subjectivity measures showed that:

a. The variability due to location of observer was less than the variability due to the observers themselves.

b. The observers agreed over 76 percent of the time on driver head movement state.

c. The observers expressed uncertainty of head movement for less than 15 percent of the drivers. (These data were not included in the analysis.)

The results of the subjectivity measures and the fact that the major sign configuration effectiveness findings were reached by each observer separately seemed to indicate that the variability and subjectivity of the head movement data were adequately controlled and minimized in the experiment making the data reliable and the major findings on relative sign configuration improvement valid.

7. Conclusions And Recommendations

The major findings of Phase II of the Railroad Crossing Passive Signing Study were:

a. Sign configuration 1 showed significant improvement over the base sign configuration in terms of head movement averaging (over all sites and all measures) an increment of 6.7 percent more head movement (from 34.7 to 41.4 percent).

b. The advance warning sign of sign configuration 1 (also sign configuration 3) accounted for about half of this improvement.

c. Sign configuration 2 and sign configuration 3 were equally effective in terms of head movement and showed an increment of 2.8 percent more head movement (from 34.7 to 37.5 percent) than the base sign configuration.

d. Sign configuration 1 showed an increment of 3.9 percent more head movement (from 37.5 to 41.4 percent) than sign configurations 2 and 3.

e. The new signs showed no significant differences in speed profiles compared to the base sign configuration under day or night conditions.

f. There were significant differences in head movement improvement from site to site.

g. There was no effect due to the order in which the new sign configurations were tested.

These results were consistent with the Phase I findings. Furthermore, even though the Phase II Study was limited to short term effects (i.e., most tests of the new sign configurations were conducted on the same day that the new signs were installed), when combined with the Phase II study where longer term effects were considered (the new sign configurations were tested 3-6 weeks after the new signs were installed), the net effect was that the sign configuration improvement findings applied over both short (less than 1 week) and longer term (up to six weeks) periods. Extropolating beyond a six week period would be conjecture but it would not be unexpected if after wide-scale and long term application, the initial benefits of the new signs diminished.

Thus, based on the findings from the Phase I and Phase II experiments, and considering the cost as well as possible diminishing benefits of the new sign configurations, it is recommended that the existing signs at all hazardous passive railroad grade crossings only be changed in a two stage implementation process. The first stage consists of changing only the advance warning sign to the new red and yellow advance warning sign (a change in effect to sign configuration 3 studied in this report). The second stage consists of changing additionally the existing crossbuck sign to the new red, yellow, and black sign studied in this report (a net

change to sign configuration 1). However, the second stage should be contingent on the new advance warning sign itself first proving successful in terms of accident reduction after wide scale and long term application.

This two-stage process allows testing of real benefits through a relatively inexpensive procedure (Stage 1 implementation) before proceeding to the more expensive step (Stage 11 implementation). The cost of changing from the present to the new advance warning sign is expected to be negligible while the cost of changing from the present to the new crossbuck is estimated to be between $20 and $50. The decision to change the existing crossbuck sign (stage II implementation) can then be based on whether doubling the accident benefits (assuming that the relative head movement findings of this study are translatable to proportional accident reductions-the increase in head movements with the new crossbuck and the new advanced warning sign was more than double that with the new advance warning sign above) is worth the cost of changing to the new crossbuck.

The recommendation to change signs at hazardous passive railroad grade crossing only was made for the following reasons.

a. The study was conducted at passive crossings only.

b. The more wide-spread the application of the new signs the more the improvements found in this study would be expected to diminish.

c. With an effective publicity campaign there would appear to be an advantage to indicating hazardous

passive crossings as opposed to other crossings: a driver unfamiliar with the roadway he was traveling on would be provided with additional and relatively important information on an approaching crossing.

The determination of hazardous crossings would be left to the local authorities involved in highway safety and should be based on the following factors which were used in the present study.

1. traffic-volume
2. traffic-speed
3. train volume
4. train crossing condition (e.g., stopped or slowed for vehicle traffic, flagman present, warning whistle only)
5. sight distance restrictions from roadway.