Analysis of Railroad-Highway Crossing Active Advance Warning Devices

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The purpose of this study was to determine which one of three candidate active advance warning devices for use on roadway approaches to rail-highway crossings was the most effective. Each of the candidate devices, developed during a previous study, consisted of a primary message sign, a supplementary, WATCH FOR TRAINS message plate, and two 8-in. amber, alternately flashing beacons. The devices differed only in the configuration and message of the primary sign. The study was conducted at four sites where sight restrictions on the approach resulted in an insufficient safe stopping distance. The train detection circuitry at each site was modified to provide train activation of each advance warning device approximately 10 sec before the activation of the at-grade warning system. Each test device was installed at all four sites. The results of the speed profile analysis during the activated state indicated that the alternately flashing beacons produce a significant decrease in vehicle velocity. Similar analysis, during the unactivated state, revealed that there was no significant difference in vehicle velocities resulting from the use of different primary signs. These results indicate that the test configuration that used a 48-in. standard (W10-1) railroad advance warning sign would be effective in providing motorists the required advance warning.

The number of annual rail-highway crossing accidents has decreased since the maintenance of records was required by the Accident Reports Act of 1910 *(1)*. Statistics are currently available on grade crossing accidents beginning in 1920. During that year, 1,791 persons died in accidents occurring at public grade crossings *(2)*. By comparison, there were only 542 fatalities in 1983 *(2, 3)*. This reduction in accidents is primarily the result of improvements to the railroad crossing environment. These improvements include the increased use of active warning devices (flashing lights and gates), improvements in track circuitry and control logic, and the installation of advance warning signs and pavement markings.

Hazardous crossing environments exist, however, where safety could be further enhanced by the installation of active advance warning devices. Crossing environments in need of these devices are those where sight restrictions on the approach prevent motorists from viewing either the at-grade warning system or a queue of vehicles stopped at the crossing until an insufficient safe stopping distance exists. These devices would become active only on the presence of a train with the purpose of providing motorists sufficient advance warning to permit a safe stop or a reduction in speed. The devices would be intended for use only on approaches to crossings that are equipped with train detection circuitry.

Many roadway jurisdictions have devised and implemented their own active advance warning devices. These devices usually consist of flashing hazard identification beacons in conjunction with standard or unique advance warning signs. The use of these specialized advance warning systems demonstrates an awareness that standard, passive advance warning signs do not provide motorists with adequate warning at certain types of crossings.

BACKGROUND

In the interest of highway safety, the Federal Highway Administration sponsored a project to develop and test prototype active advance warning devices (AAWDs) for use with existing train detection circuitry and associated railroad crossing signals. Completed in the project concentrated on the development of a simple, relatively inexpensive device that would meet several criteria. These criteria were that the device have high conspicuity, a readily understandable and unambiguous message (even in the fail-safe mode), and that it conform with current signing practices. The result was the selection of three candidate advance warning devices consisting of three principal components: (a) a primary message sign with optional directional arrows, (b) a supplemental message plate, and (c) a pair of alternately flashing yellow beacons. All devices used alternately flashing beacons positioned one above and below the primary and supplementary signs as shown in Figure 1. The supplementary message plate, common to the three candidate devices, consisted of a 3-ft × 2-ft (90 × 60 cm) sign with the message WATCH FOR TRAINS. The primary signs identified as candidates by Ruden et al. are described next *(4)*.

- Primary Sign A, shown in Figure 2, was a 48-in. (120-cm) version of the standard-passive warning sign (W10-1) specified in the *Manual on Uniform Traffic Control Devices* (MUTCD). Because of its circular shape and the R X R symbol filling a large portion of the surface area, Primary Sign A was not used with directional arrows.
- Primary Sign B, a diamond-shaped sign with a black legend on a yellow background, incorporated a red X, bracketed by two Rs (R X R). The red X was used to increase the sign's target value. Instead of the X being constructed at 90 degrees, as with the standard W10-1, it was flattened to 60 degrees. The resultant asymetric symbol had the advantage of being 5 to 10 percent longer than the 90 degree X of the W10-1. In addition, the flattened X provided sufficient room for insertion of directional arrows. This sign has a straight arrow option and is shown in Figure 3.

Goodell-Grivas, Inc., 17320 West Eight Mile Road, Southfield, Mich. 48075.

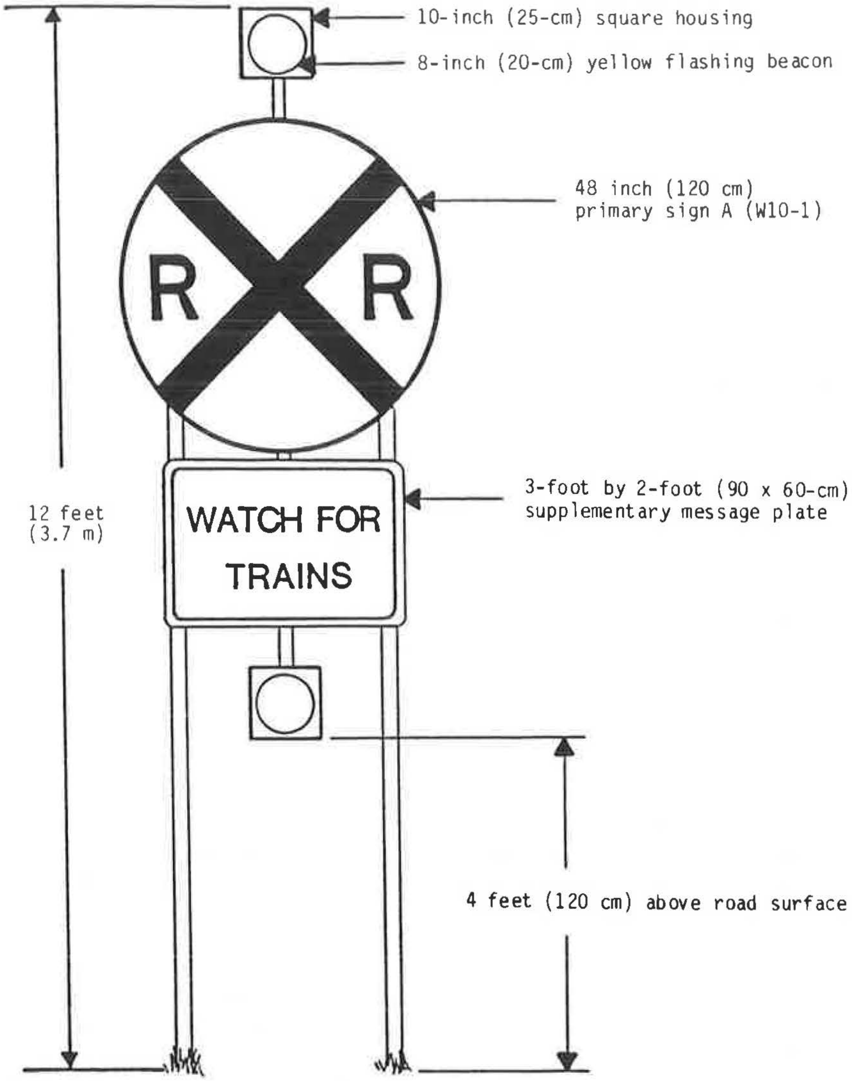


FIGURE 1 Front view of AAWD device.

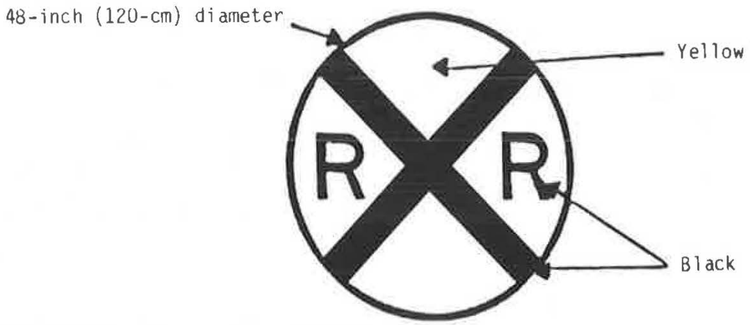


FIGURE 2 Primary Sign A (W10-1).

- Primary Sign C has an arrow option and was intended for use at a horizontal curve (see Figure 4). The sign incorporated a miniature facsimile of the standard W10-1 with red upper and lower quadrants on a yellow background. The miniature W10-1's diameter was one-half the dimensions of the diamond sign.

STUDY SCOPE AND OBJECTIVES

The purpose of this study was to conduct extensive field tests of the three candidate AAWDs to determine the most effective configuration. The effort consisted of three primary tasks: (a) selection of appropriate test sites, (b) modification of the exist-

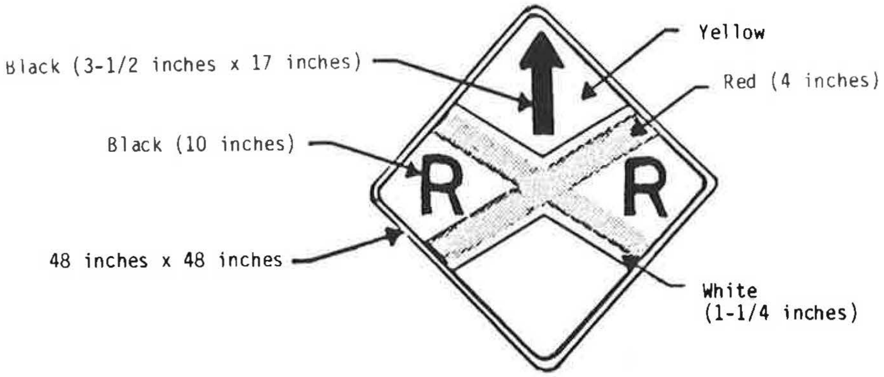


FIGURE 3 Primary Sign B (with vertical curve arrow option).

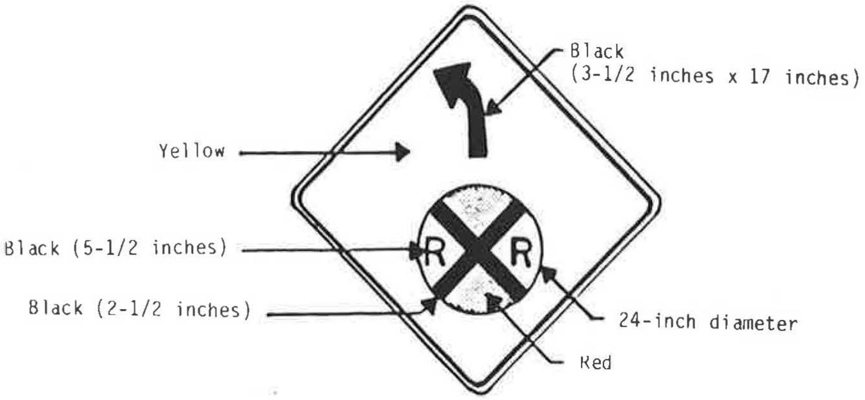


FIGURE 4 Primary Sign C (with left horizontal curve arrow option).

ing train detection circuitry to provide AAWD activation before the start of the crossing signals, and (c) collection of vehicle operational and driver behavior data.

The specific objectives of the study were to

- Perform field demonstration and data collection for each candidate AAWD,
- Analyze the data and evaluate the candidate AAWDs, and
- Determine the most effective AAWD.

METHODOLOGY SUMMARY

Four railroad-highway crossings located in southeastern Michigan were selected as test sites. Each site had (a) sight restrictions that prevented the motorist from observing the crossing on at least one approach, (b) two roadway lanes, (c) a single pair of tracks, and (d) relatively high train and vehicle volumes. The test devices were installed on only one approach to each crossing in the same position as the original advanced warning sign (W10-1). Modifications were made to the train detection circuitry to cause the asynchronous flashing beacons of the test device to activate before the at-grade warning flashers. A summary of selected characteristics for each site is given in Table 1.

Experimental Design

The design used in this project was a modified before-during-after design. It was modified in that the measurements con-

TABLE 1 SUMMARY OF TEST SITE CHARACTERISTICS

Site Designation	ADT	Train Volume	Posted Speed mi/h	Distance from the crossing to AAWD (feet)	Amount of advance activation time (sec).
1	2000	8	45	530	9
2	1100	12	55	560	7
3	6000	10	45	530	9
4	1800	10	45	600	10

1 ft = 0.3 m
1 mi/h = 1.6 km/h

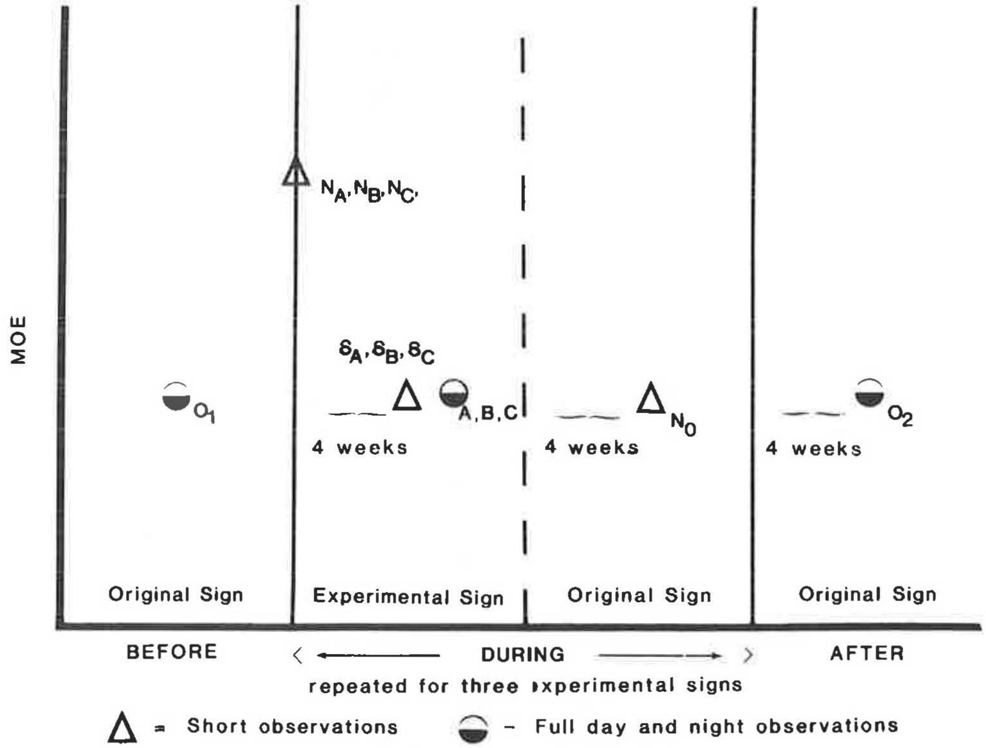


FIGURE 5 Data collection scenario.

tained observations designed to measure the novelty effect of the three different sign installations at each test site. Another deviation from the conventional design is that the during period consisted of three experimental and two intermediate original sign installations. A better understanding of the data collection scenario can be obtained by considering Figure 5 in context with the following paragraphs.

Full day and night observations (O_1) were conducted on the original sign configuration before the installation of any experimental sign. These measures provided the threshold values that were used to gauge the novelty effect and, when analyzed with the after measurements, provided information on long-term trends. On the day that an experimental sign configuration (A, B, or C) was installed, a short observation (denoted by N_i for $i = A, B, C$) was obtained. These observations were interpreted to represent the maximum novelty effect for that particular configuration. The data were statistically analyzed to determine if the measures were significantly different from the appropriate original (O_1) sign observations.

After 4 weeks, another short observation (S_i for $i = A, B, C$) was taken. If the speed observations approached those obtained from the original sign (O_1), then full observations were obtained. If, however, the observations of S_i were similar to N_i, then observation S_i was repeated after 1 week. If the S_i measurements were still similar to N_i then a steady state situation was assumed and full observations were obtained.

After full day and night observations were conducted, the new sign configuration was removed and the original conditions were reestablished. After another 4 weeks had passed, a short reading (N_o) was taken. If this measure was found to be similar to the initial measurements on the original sign configuration (O_1), then the next experimental sign was installed. The same process (denoted by N_B, S_B, B and N_C, S_C, and C) was then repeated for the final sign configuration. After the third experimental sign had been replaced, the original sign was installed and full observations (O_2) were conducted. A flowchart of the data collection procedure is shown in Figure 6.

Evaluation Methodology

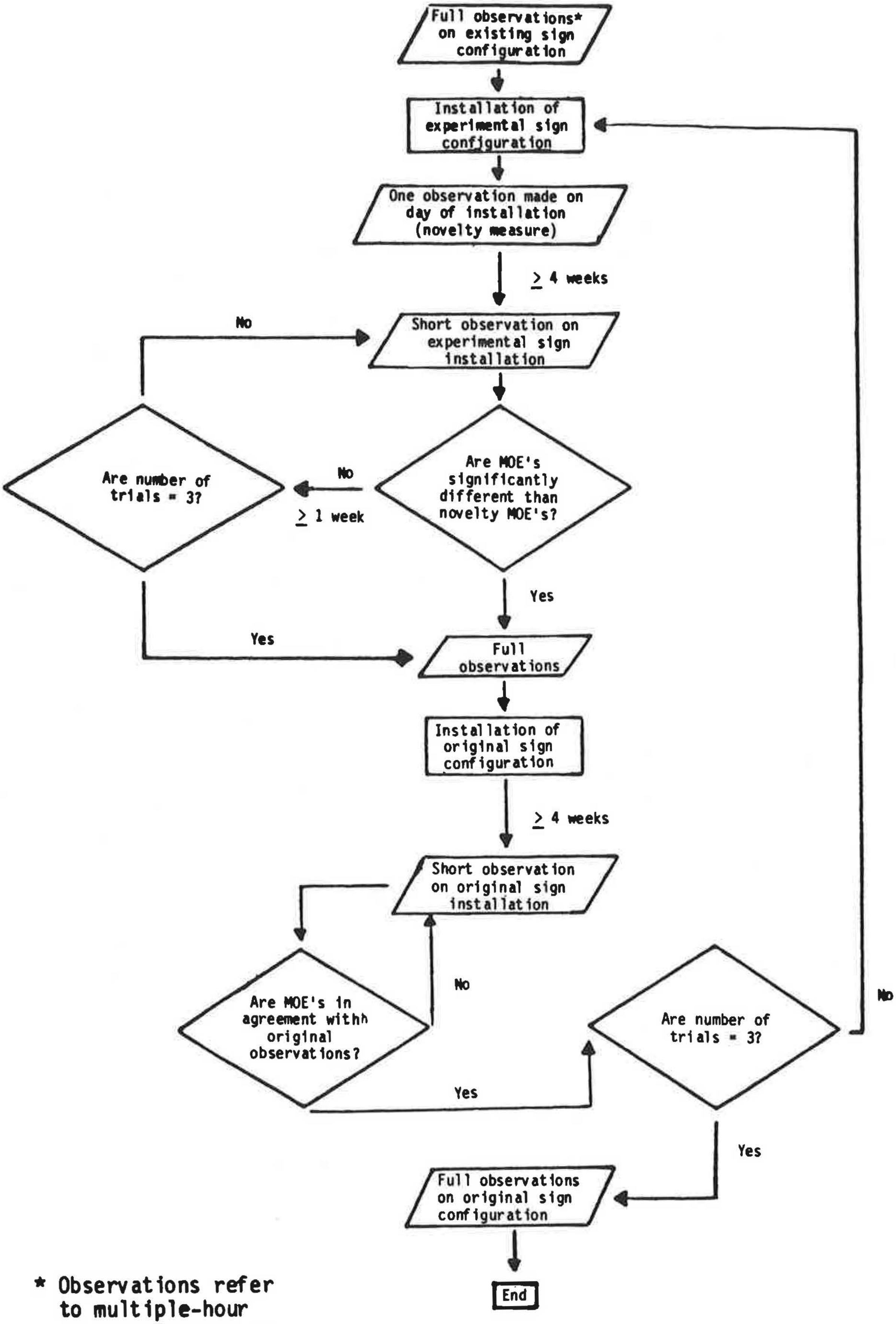
The evaluation methodology consisted of four principal parts: (a) determining the presence of trends over time, (b) ascertaining the presence and dissipation of novelty effects, (c) determining device effectiveness within sites, and (d) determining device effectiveness between sites.

Trends Over Time

The presence of changes resulting from extraneous factors was identified by applying the Scheffe pairwise comparison procedure. This procedure was applied to data that were collected on the original sign in two time periods: before and after the test sign installation procedure. When the Scheffe pairwise comparison procedure resulted in a simultaneous confidence interval that did not include zero, then a significant difference between the before and after data existed. This difference signified a trend, and a pooled mean and variance were calculated. The pooled parameters were then used as the base, or threshold value, for subsequent analysis to determine the effectiveness of the test configurations.

Novelty Effect

An installation and novelty testing procedure was developed that used a 4-week waiting period and statistical tests to ensure



* Observations refer to multiple-hour data collection on each MOE.

FIGURE 6 Flowchart of data collection procedures.

that the novelty effect had dissipated. The statistical tests included plotting a 95 percent confidence interval and performing the Scheffe pairwise comparison procedure to identify significant data differences.

Configuration Effectiveness Within and Between Sites

A two-way analysis of variance (ANOVA) was used to analyze the effects of the different sign configurations on the selected measure of effectiveness (MOE) for each site and between all test sites. ANOVA was used to determine if any exhibited differences were a result of the effect of the devices being tested or a result of the differences exhibited by either the measurement zones or the test sites. If a significant difference was determined as being caused by the test devices, the Scheffe contrast test was used to identify the combination of test devices that caused that difference. When the sample sizes were sufficiently large, separate analyses were performed under the following conditions.

- Daytime/active AAWD
- Nighttime/active AAWD
- Daytime/inactive AAWD
- Nighttime/inactive AAWD

Application of the ANOVA and Scheffe procedures was basically the same for tests of effectiveness both within and between sites. The differences resided in the MOE being analyzed and the structure of the ANOVA matrix. The purpose of the within-site analysis was to determine which test device was the most effective at each particular site. This was performed by testing the mean spot speeds by specific measurement locations at each site against the types of test device.

The purpose of the between-site analysis was to determine the impact of the test configurations irregardless of the test site location. Because this involved testing for the differences between sites, it was necessary to use a MOE that accounted for the various distances of the measurement points from the crossing. The ANOVA for the between-site analysis was performed by testing the average acceleration at every test site against the types of test device.

DATA ANALYSIS RESULTS

Summary of Unactivated Data Analysis

Within-Site Results

The results of the within-site statistical analysis, during the unactivated state, are summarized in Table 2. The data in this table, which result from the site-by-site analysis of the mean spot speeds contained in Tables 3 and 4, indicate that during night conditions at Site 4, Primary Sign A was the only sign that displayed a significant difference from the original sign and every other sign tested. The within-site analysis, therefore, indicated that Primary Sign A was the only sign to display a conclusive impact on vehicle speeds during the unactivated state.

Between-Site Results

The effectiveness of the test devices between sites during the unactivated state was determined by grouping all of the sites together and performing a two-way ANOVA. The purpose of this analysis was to determine if those differences that were identified by analyzing the spot velocities on a site-by-site basis were sufficiently prevalent to result in an overall effect.

Because the magnitude of data variations between the different analysis sites was of interest, it was necessary to provide a measure of effectiveness that was common to all of the sites. Measures based on velocity were not appropriate because the distance from the crossing for the spot speed measurements varied at each site. The larger the distance between the measurement points, the larger the expected velocity change. The overall acceleration was, therefore, used as the measure of effectiveness for comparisons between sites.

The results of the analysis of variance on the overall mean acceleration are given in Tables 5 and 6 for day and night conditions, respectively. The only significant difference revealed by this analysis was that between sites for night conditions, as indicated in Table 6. This result supports those of the within-site analysis, which concluded that the primary signs had similar impacts on vehicle velocities during the unactivated state.

TABLE 2 SUMMARY OF STATISTICAL ANALYSIS OF MEAN SPOT VELOCITIES CONDUCTED WITHIN EACH SITE DURING THE UNACTIVATED STATE

		Site #1				Site #2				Site #3				Site #4			
Condition	Device	0	A	B	C	0	A	B	C	0	A	B	C	0	A	B	C
Day	0	-	-	-	-	-	-	*	-	-	-	-	-	-	-	-	-
	A	-	-	-	-	-	-	*	-	-	-	-	-	-	-	-	-
	B	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	C	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Night	0	-	-	*	-	-	-	-	*	-	-	-	-	-	*	-	-
	A	-	-	-	-	-	-	*	*	-	-	-	-	-	-	-	-
	B	-	-	-	-	-	-	-	-	-	*	-	*	-	*	-	-
	C	-	-	*	-	-	-	-	-	-	-	-	-	-	*	-	-

Asterisk (*) indicates significant difference.

TABLE 3 SUMMARY OF DAY MEAN SPOT SPEED (mph) MEASUREMENTS OBTAINED DURING THE UNACTIVATED STATE

Distance from Crossing[1]	Site Designation	Mean Spot Speed (mi/h) for Test Configurations[2]			
		0	A	B	C
1169	1	41.0	44.5	42.8	43.7
1038	2	53.2	51.4	50.6	51.2
1350	3	48.7	49.0	47.4	49.7
845	4	47.3	46.9	48.7	45.8
715	1	41.6	41.1	37.7	40.6
480	2	51.4	50.2	45.4	48.5
545	3	41.9	39.6	41.4	39.1
550	4	39.1	41.9	36.5	35.2
415	1	39.7	31.7	34.9	36.7
240	2	47.7	47.8	44.7	45.2
311	3	41.3	40.8	39.5	39.8
430	4	39.4	38.3	40.1	37.1
215	1	29.8	30.8	28.4	30.3
30	2	40.0	43.1	39.0	42.2
15	3	33.9	30.1	33.6	27.2
270	4	35.0	34.9	35.8	33.7
15	1	26.0	23.4	23.7	23.5
--	2	---	---	---	---
--	3	---	---	---	---
15	4	30.2	32.0	25.4	23.1

[1] 1 ft = 0.3 m

[2] 1 mi/h = 1.6 km/h

TABLE 4 SUMMARY OF NIGHT MEAN SPOT SPEED (mph) MEASUREMENTS OBTAINED DURING THE UNACTIVATED STATE

Distance from Crossing[1]	Site Designation	Mean Spot Speed (mi/h) for Test Configurations[2]			
		0	A	B	C
1169	1	41.0	42.6	41.6	43.4
1038	2	53.1	54.4	51.3	51.2
1350	3	48.0	48.2	51.8	46.8
845	4	48.1	48.6	49.1	49.4
715	1	41.3	39.4	33.2	39.9
480	2	50.8	51.1	47.3	48.4
545	3	40.5	39.5	46.0	33.7
550	4	36.3	42.9	35.6	35.8
415	1	37.3	34.9	27.9	36.6
240	2	48.9	49.3	46.4	45.3
311	3	40.7	41.4	44.9	36.0
430	4	37.3	39.1	37.2	37.3
215	1	29.9	31.4	28.2	30.9
30	2	44.5	48.4	44.0	41.7
15	3	32.7	30.2	42.0	22.1
270	4	31.4	35.1	29.8	29.8
15	1	25.0	23.5	23.1	23.9
--	2	---	---	---	---
--	3	---	---	---	---
15	4	26.0	30.7	24.2	24.3

[1] 1 ft = 0.3 m

[2] 1 mi/h = 1.6 km/h

TABLE 5 ANOVA ON THE AVERAGE DAYTIME ACCELERATION (ft/sec^2) FOR EACH DEVICE CONFIGURATION AT THE DIFFERENT TEST SITES DURING THE UNACTIVATED STATE

Test Configuration	Site #1	Site #2	Site #3	Site #4
Original	-1.31	-1.67	-1.01	-1.49
A	-1.42	-1.11	-1.14	-1.69
B	-1.31	-1.09	-1.01	-1.55
C	-1.53	-1.11	-1.36	-1.52

Source	df	SS	MS	$F_{3,9}$	95% Critical F Value
Site	3	0.41	0.14	3.61	3.86
Device	3	0.05	0.02	0.50	3.86
Error	9	0.34	0.04		

TABLE 6 ANOVA ON THE AVERAGE NIGHTTIME ACCELERATION (ft/sec^2) FOR EACH DEVICE CONFIGURATION AT THE DIFFERENT TEST SITES DURING THE UNACTIVATED STATE

Test Configuration	Site #1	Site #2	Site #3	Site #4
Original	-1.31	-1.14	-0.94	-1.74
A	-1.39	-0.63	-1.07	-1.98
B	-0.99	-0.66	-0.73	-1.93
C	-1.47	-1.15	-1.15	-1.98

Source	df	SS	MS	$F_{3,9}$	95% Critical F Value
Site	3	2.55	0.85	28.33*	3.86
Device	3	0.27	0.09	3.00	3.86
Error	9	0.25	0.03		

1 mi/h = 1.6 km/h
Asterisk (*) indicates significance.

Summary of Activated Data Analysis

The number of observations obtained while the devices were activated were, with one exception, too small to perform a statistical analysis. The one exception was when the at-grade flashers and the flashing beacons of Device B were operating in the fail-safe mode because of problems with the train detection circuitry. This provided the opportunity to analyze the differences in the spot velocity measurements at the locations that were influenced by the active advance warning device.

The analysis consisted of comparisons between the mean spot velocities obtained for the activated and unactivated states of Device B at measurement locations that were influenced by the active warning device (S_2, S_3, and S_4). The free speed (S_1) was not used; because of the presence of a horizontal curve, the device was not visible until the vehicles had passed point S_1. The spot velocity at the crossing (S_5) was also not used because it would be expected to be lower for the activated state. Velocities at S_5 would, therefore, include the effect of the at-grade flashers in addition to that of the active warning device.

The activated and unactivated data collected on Device B is given in Table 7. A t-test performed on the area of this table, which is designated by hatch marks, revealed that there was a significant difference between the activated and unactivated data of Device B. This indicates that the flashing beacons are effective in reducing spot velocities.

Summary of Study Results

Analysis of data obtained during the activated condition indicated that the flashing beacons were effective in reducing vehicle speeds. This analysis was performed by concentrating on the spot speeds obtained from locations that were directly influenced by the activated advance warning device. Free-running approach speeds and vehicle speeds obtained at the railroad crossing were not, therefore, included in determining the impact of the devices during the activated state.

With one exception, all of the primary signs evaluated during the unactivated state displayed a similar impact on vehicle velocity and acceleration. The exception was Primary Sign A, which was significantly different from the original sign and all of the other test devices during the night at one site.

An active advance warning device, configured as specified

TABLE 7 ACTIVATED AND UNACTIVATED MEAN SPOT VELOCITY (mph) DATA OBTAINED ON DEVICE B AT 22-mi ROAD

Condition	Test Configuration	Number of Observations	Time of Day	S_1	S_2	S_3	S_4	S_5
Unactivated	B	572	Day	42.8	37.7	34.9	28.4	23.7
Activated	B	61	Day	41.7	27.6	23.7	17.6	4.2

1 mi/h = 1.6 km/h
t-test performed on ////// area
t = 6.2
95-percent critical t value = 2.8

by Ruden et al. with a 48-in. (120-cm) standard (W10-1) railroad advance warning sign (Primary Sign A), would be effective in reducing vehicle speeds during the activated state *(4)*.

COST ANALYSIS

Estimates of the total cost associated with installing an active advance warning device were obtained by itemizing incurred project costs and requesting price quotes from traffic departments located in three different states. These costs are site specific and dependent on the following considerations.

- Costs of train detection circuitry changes. The costs of changes to the train detection circuitry are inherently related to three issues: (a) the economic relationship with the operating railroad, (b) the amount of prior warning time needed, and (c) the amount of at-grade warning time being provided. The first issue is more related to who assumes the cost than to the cost magnitude.

The remaining two issues are closely related. For example, suppose that 12 sec is the amount of time that is desired between the activation of the advance warning device and the start of the grade crossing flashers. Suppose further that the crossing is provided with 40 sec of warning until train arrival, but only 20 sec are required by applicable regulations, existing geometrics, and operating conditions. Under these conditions, there exists an excess of 20 sec from which 12 sec can be provided to the advance warning device. This could result in activating the advance warning device 40 sec and the at-grade flashers 28 sec before train arrival.

When these conditions exist, it is possible to provide the necessary timing changes by installing a capacitive timing relay. This is a relatively inexpensive procedure. When these conditions are not present, it often becomes necessary to extend the detection loop further upstream. This can be expensive, especially if the proximity of adjacent streets complicates the task of extending the loop.

- Electrical connection from crossing control box to active advance warning device. The applicability of providing power to the device by underground trenching or an overhead drop depends on the site environment and preferences of the roadway agency. If overhead wire already exists on the side of the roadway on which the sign is to be installed, then providing an overhead drop is less expensive than trenching and laying conduit. If overhead wiring does not exist, providing overhead capabilities necessitates the installation of a support system such as utility poles. This not only decreases the cost benefits of overhead wiring, but can result in additional roadside hazards.

These considerations were used to develop both low and high installation scenarios. The estimate for an overhead power supply was developed by considering only those installations for which overhead power lines already exist. The high and low installation cost scenarios were used in conjunction with the 1984 accident cost estimates provided by the National Safety Council *(5)*. The results given in Table 8 indicate the number of accidents that need to be prevented to return the installation cost. The components used in developing the high and low cost scenarios are given in Table 9.

INSTALLATION GUIDELINES

Identifying Sites in Need of AAWD Installation

The types of railroad-highway crossings that warrant the installation of an AAWD are characterized as those where the warning devices at the crossing are not visible to vehicles on the approach until an insufficient safe stopping distance exists. One method of initially identifying crossings with sight-restricted approaches is through accident analysis.

Identification through accident analysis requires an investigation of the total number of accidents in the vicinity of the crossing. The accident analysis should be conducted in a manner that is similar to that used for roadway intersections. This involves including all accidents occurring within at least 150-ft (45-m) from the crossing. Approaches with total number of accidents exceeding the areawide mean (for railroad crossing approaches) indicate that further analysis is required. A high incidence of rear-end, run-off-the-road, fixed-object, and train-involved accidents are often an indication of approach sight restrictions.

Ascertaining that a sight restriction contributes to accident occurrence requires an on-site inspection and an application of safe stopping sight distance (SSSD) concepts. The on-site inspection should include obtaining the 85th percentile speed for use in determining the perception-reaction time and the total

TABLE 8 REQUIRED ACCIDENT REDUCTION TO RETURN AAWD INVESTMENT COST FOR DEVICE PLACED AT 600 ft (180 m) FROM CROSSING CONTROL BOX FOR BOTH UNDERGROUND AND OVERHEAD INSTALLATION

		AAWD Costs				Required Accident Reduction			
		Underground		Overhead		Underground		Overhead	
Accident Severity	1984 NSC Costs	Low	High	Low	High	Low	High	Low	High
Fatality	220,000	6,000	10,300	2,000	6,300	1	1	1	1
Personal Injury	9,300	6,000	10,300	2,000	6,300	1	2	1	1
Property Damage	1,190	6,000	10,300	2,000	6,300	5	9	1	1

TABLE 9 ESTIMATE OF ACTIVE ADVANCE WARNING DEVICE FABRICATION AND INSTALLATION COSTS

Activity Sign Fabrication	Itemized Unit Cost[1]		Cost Scenarios Low	High
Square Tube (Pre-galvanized)	2 pcs. @ 39 inches 2 1/2 x 2 1/2 inches 2 pcs. @ 12 inches 2 3/16 x 2 3/16 inches 1 pc. @ 108 inches 1 3/4 x 1 3/4 inches 2 pcs. @ 48 inches 1 3/4 x 1 3/4 inches Fastening hardware Telspar Subtotal	115		
Sign Faces	Primary Sign Supplemental Message	75 30		
Beacons	2 - 8 inch lens units @ $80	160		
Pre-assembly	3 man hours @ $25/hour	75		
Flashing Capability	CD4047 free running multivibrator integrated circuit	100		
	Total Sign Fabrication		555	555
Train Detection Modifications	Pre-emptive method track circuit change	1,000 5,300	1,000	5,300
Installation	Underground (Overhead)		4,400 (450)	4,400 (450)
Approximate totals for underground installation			6,000	10,300
Approximate totals for overhead installation			(2,000)	(6,300)

[1] 1 inch = 2.54 cm.

safe stopping distance. The crossing warning system should be visible to drivers throughout the perception-reaction zone.

If it is determined that insufficient perception-reaction or safe stopping distances exist, then the installation of an active advance warning device may be beneficial. However, consideration should be given to other countermeasures such as additional flashing lights on extended masts, removal of foilage, and other measures to increase the visibility of the crossing warning devices.

Placement Distance From the Crossing

The safe stopping sight distance criteria determines the minimum distance that the AAWD should be placed in advance of the crossing. If necessary, this minimum distance should be increased in order to maximize the distance at which approaching drivers can view the device. For vertical and horizontal curves, this may require that the devices be placed further in advance of the crossing.

Timing of AAWD Activation

The AAWD should be activated before the activation of the crossing warning system by an amount of time equal to the travel time between the AAWD location and the crossing location.

Where a queue of vehicles is expected to occur during the presence of a train, it may be necessary to retain AAWD activation beyond deactivation of the crossing warning system. The amount of retention time will be dependent on the characteristics of each site but can be accomplished by the use of a delay timer.

CONCLUSIONS

The following conclusions were drawn from project activities.

1. During the activated state, the flashing beacons were effective in producing large speed reductions. Statistical analysis performed at the 95 percent level of confidence between the activated and unactivated states revealed (Table 7) that a significant reduction in velocity occurred during the activated state of the device. This velocity reduction occurred in the vicinity of the activated advance warning device.
2. The within-site analysis summarized in Table 2 indicated that Primary Sign A was the only test sign to display a conclusive impact on vehicle speeds during the unactivated state. Primary Sign A [a 48-in. (120-cm) standard (W10-1) railroad advance warning sign] displayed a significant difference from the original sign and all of the other primary signs during the night at one site.
3. The active advance warning device, configured as specified by Ruden et al. *(4)* and using the 48-in. (120-cm) standard (W10-1) railroad advance warning sign, is effective in reducing vehicle approach speed.
4. Practically all of the test configurations, when initially installed, had a novelty effect on the mean velocity of individual vehicles. In most cases, this novelty effect had dissipated after the device was in place for approximately 4 weeks.
5. The approximate cost of device assembly and installation can range from $6,000 to $10,300 for underground and from $2,000 to $6,300 for overhead installation. These costs can be expected to vary from site to site depending on the physical and operational characteristics of the crossing.
6. The most expensive installation scenario would require the prevention of either nine property damage, two personal injury, or one fatal accident during the life of the active warning device to return the investment cost. Accident types to be included in this analysis would include vehicle-train, vehicle-vehicle, fixed object, and run-off-the-road.

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