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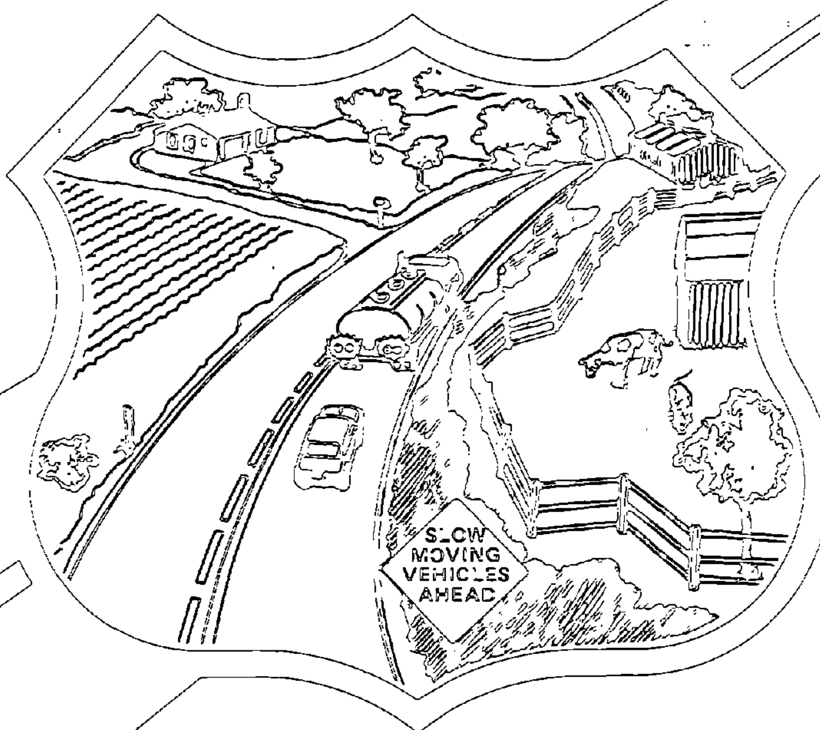
EVALUATION OF TECHNIQUES FOR WARNING OF SLOW-MOVING VEHICLES AHEAD

May 1979
Final Report



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FEDERAL HIGHWAY ADMINISTRATION
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FOREWORD

This report provides a detailed evaluation of an experiment conducted at the Federal Highway Administration's (FHWA) Maine Facility to test the effectiveness of different combinations of roadside signs and devices mounted on a slow-moving vehicle to alert motorists that they are approaching a slow-moving vehicle on a grade. The report will be of particular interest to traffic research and development audiences. An executive summary of this report is now being prepared and will be distributed later to traffic safety personnel, motor-carrier operators and engineers who are responsible for traffic accident prevention.

In the experiment, a staged slow-moving vehicle was introduced into the traffic stream and data were taken on motorists' reactions who overtook it. The results indicated that the use of standard four-way flashers on the back of trucks was an effective way of causing following motorists to modify their reaction distance, speed reduction, and vehicle following characteristics. The effects of roadside signs were positive in the vicinity of the roadside signs in that motorists reduced their speed slightly. However, they quickly resumed their initial speed once past the sign, but before they sighted the slow-moving vehicle.

Sufficient copies of the research report are being distributed by FHWA to provide one copy to each Regional Office, one copy to each Division Office, and one copy to each State Highway Agency. The State and Division Office copies are being sent directly to each Division Office.

Charles F. Scheffey
Director, Office of Research
Federal Highway Administration

NOTICE

NOTICE

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16. Abstract

This report reviews an experiment undertaken to examine the relative effectiveness of roadside signs and vehicle markings for warning motorists of the presence of a slow moving vehicle on the road ahead in a rural two lane situation. In the experiment a staged slow moving vehicle was introduced into the traffic stream, and data were taken on the reactions of motorists who overtook it. Samples of motorists were exposed to different combinations of roadside signs, vehicle markings and types of slow moving vehicles. The principal finding was that the use of standard four way flashers is an effective device for reducing the hazardousness of the overtaking situation relative to reaction distance, speed reduction and following characteristics. While the effects of the roadside signs were positive in the vicinity of the sign placement (out of sight of the slow vehicle), there were no lasting effects relative to the actual overtaking maneuver. The experiment was undertaken at the Federal Highway Administration's Maine Facility with cooperation from the Maine Department of Transportation and the University of Maine at Orono.

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standard four-way flashers, roadside warning signs, slow-moving vehicles, U.S. Slow Moving Vehicle Emblem, New Zealand Slow Moving Vehicle Emblem	No restrictions. This document is available to the public through the National Technical Information Service, Springfield, VA 22161

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1.0 INTRODUCTION

The National Safety Council (1976) recently reported that twenty-six percent (26%) of all rural non-intersection accidents involving two vehicles occurred when both vehicles were traveling in the same direction. One of the principal factors in these types of accidents is the speed differential between the two vehicles. Thus, vehicles moving considerably more slowly than the mean speed on a particular roadway constitute a significant traffic hazard.

The hazard potential of slow moving vehicles is probably at its greatest when heavily laden trucks are expected to negotiate a reasonably steep grade. Since trucks travel 8 km/h (5 mph) to 11 km/h (7 mph) slower on the average than passenger vehicles on level terrain, grades tend to widen this differential. While trucks' hill-climbing abilities vary with the weight-horsepower ratio, a typical truck whose pounds/horsepower is 136 kg/horse power (300) would slow from 80 km/h (50 mph) to 48 km/h (30 mph) over 610 m (2,000 feet) of a 4% grade (Glennon and Joyner, 1969); a dramatic, and sometimes unexpected, decrease. On the other hand, grades have little effect on the speed of passenger vehicles. Thus, the probability of faster vehicles overtaking slower ones increases on upgrades as does the potential for rear end collisions.

There is, however, a lack of consensus relative to the method(s) to be used for warning motorists of the possibility of encountering slow-moving vehicles on the road ahead. The principal objective of this study was to evaluate the relative effectiveness of two approaches to providing motorists with such a warning. Specifically, the two approaches studied were:

- roadside signs warning of the potential of slow-moving vehicles ahead, and
- vehicle markings on the slow-moving vehicles.

The study was limited to a rural two-lane situation where slow-moving vehicles were likely to be encountered (i.e., an upgrade). The study was undertaken at the Federal Highway Administration's (FHWA) Maine Facility (the Facility) during the summer of 1977 and winter of 1977/1978.

Considerable research has been done relative to the type of vehicle markings appropriate for slow-moving vehicles when such vehicles have been identified as tractors (or other farm equipment), horse drawn wagons and carriages, or construction equipment, but results vary (see King, et. al., 1977 for a review, or Harkness and Stuckey, undated; National Safety Council, 1966; and Francis, 1971).

As to the use of four-way flashers as a warning device on slow moving vehicles, Knoblauch, et. al. (1978) reported that opinions among the States are divided as to their effectiveness and legality. Pennsylvania, for example, posts signs on the Turnpike stating "Trucks Under 64 km/h (40 MPH)

Use Flashers" at specific locations. On the other hand, California and Virginia prohibit the use of four-way flashers unless a vehicle is stopped.

2.0 EXPERIMENT IMPLEMENTATION

The project was principally concerned with the evaluation of roadside warning signs and vehicle markings/devices. In general, the approach taken was to insert a staged slow-moving vehicle into the normal traffic stream on a specific experimental segment of U.S. Route 2 in Central Maine (under a specific set of conditions - e.g., dry pavement, daylight) and observe and record the reactions of motorists as they entered an experimental area; passed a roadside warning sign; and sighted, overtook and followed, or passed the slow vehicle. Through the use of a system of induction loops embedded in the road at 61 m (200 feet) intervals the motorist was tracked over an approximate 1524 m (5,000 feet) grade varying between three and seven percent. The loops are connected to a Raytheon 500 computer. The capabilities of the Maine Facility for experimentation of this sort in general and the arrangement for this particular project were discussed in detail by Lanman (1978).

The instrumentation allowed the computer to identify a "subject vehicle" at Point A (Figure 1) and "track" it over the instrumented section as it overtook, and possibly passed, a slow-moving vehicle. To ensure that encounters with slow-moving vehicles were consistent with one another, a staged vehicle was inserted at Point C and traveled upgrade at a fixed speed. The procedure is best illustrated by the sequence of events for a "run" outlined as follows:

1. the staged vehicle was "at the ready" on the side road at Point C;

2. the computer identified the next vehicle (subject vehicle) entering the experimental section at Point A which satisfied the following criteria -

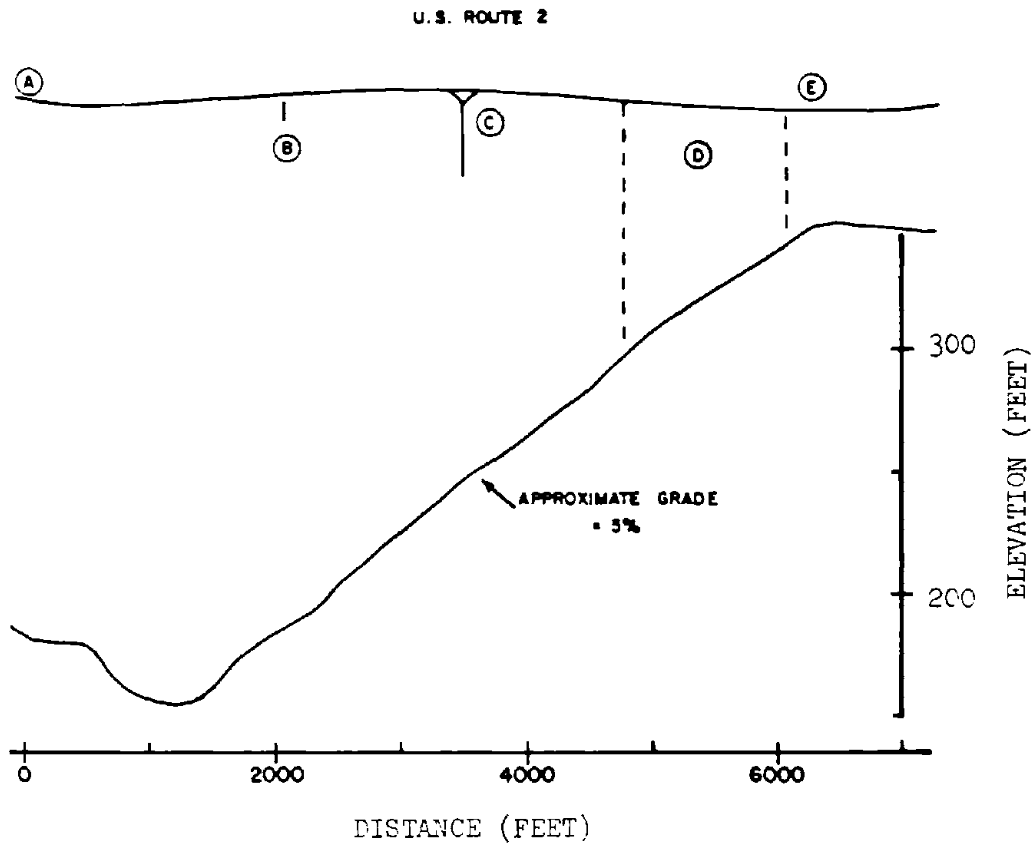
   a. there were no other vehicles between the subject vehicle and Point C, and

   b. the subject vehicle was moving at least 24 km/h (15 mph) faster than the staged vehicle's assigned running speed (this was to ensure that the actual overtaking occurred in Zone D);

3. the computer gave the driver of the staged vehicle a "go" signal;

4. the driver pulled out onto the road, accelerated to the assigned running speed, and maintained that speed through the remainder of the instrumented section;

5. the computer tracked both the subject and staged vehicles relative to their positions on the grade and speeds; and



Metric Conversion:
1 foot = 0.3 meters

FIGURE 1 PLAN AND PROFILE OF EXPERIMENT SITE

6. after the staged vehicle reached Point E, the driver pulled off, returned to Point C and signaled the computer that he was ready to go again.

During the course of a "run" the driver of the subject vehicle saw a specific sign condition at the roadside (relative to slow moving vehicles), and then encountered a specific staged vehicle with specific markings. All data relative to the subject vehicle driver's responses were recorded automatically on magnetic tape for later processing. Raw data were in the form of time intercepts of the embedded loops. They were later processed to reflect a vehicle's speed profile from which the different measures of effectiveness were calculated (see the following sections for details.)

3.0 VARIABLES AND MEASURES

3.1 INDEPENDENT VARIABLES

The principal variables examined in this experiment involved various roadside signs and vehicle markings. These, along with the type of slow moving vehicle, were the principal independent variables. All of the independent variables considered in this experiment are discussed in the following paragraphs.

3.1.1 Slow Moving Vehicle Type

Two different vehicle types were used for the experiment. A large two-axle truck with a box body was chosen to represent a vehicle which is often slow moving. For the experiment, the truck was operated empty and the box was closed to the view of overtaking motorists. The truck was operated at two different speeds, 32 km/h and 48 km/h (20 and 30 mph).

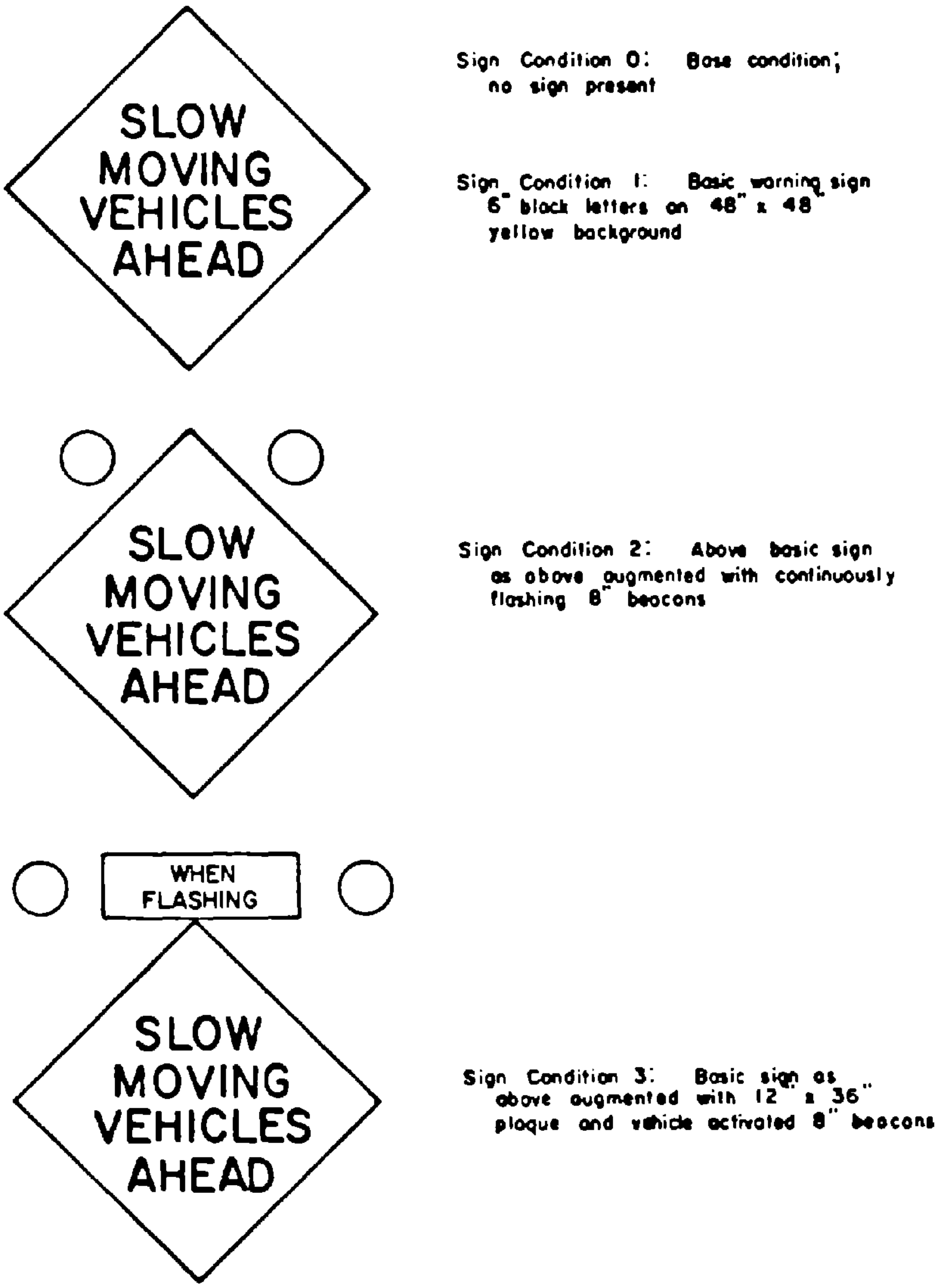
The other vehicle type, one that is always slow-moving, was a small to medium size utility tractor with an enclosed cab. The tractor phase of the experiment was curtailed due to the extreme vibration and jostling the driver had to endure when the vehicle was continuously driven on the hard-surfaced road at 24 km/h (15 mph).

3.1.2 Roadside Signs

One of the variables of primary interest was the roadside signs. The basic hypothesis was: provision of a warning sign that conveyed information to the motorist relative to the possibility of encountering a slow-moving vehicle ahead would result in a less hazardous situation when such a slow-moving vehicle was actually sighted and overtaken.

The roadside signs that were actually deployed are illustrated in Figure 2. Briefly, the first condition was a base which yielded information regarding what motorists' reactions were when no sign was present. The second was a warning sign for "SLOW MOVING VEHICLES AHEAD." While the message was non-standard, it was straightforward and non-ambiguous. The urgency of the information conveyed to motorists is typical of other warning signs.

The next sign condition had the same message but was made more emphatic by the addition of continuously flashing beacons mounted above the sign. It was hypothesized that the motorist seeing this sign was conveyed more positive (and urgent) information. The last sign condition conveyed the most positive information since the addition of the "WHEN FLASHING" plaque to the basic sign informed the motorist, with virtual certainty, that he or she would encounter a slow-moving vehicle. The beacons in the last conditions were activated by the subject vehicle crossing an embedded loop so that the driver of the subject vehicle actually saw the beacons begin to flash.



Metric Conversion:
1 inch = 2.5 centimeters

FIGURE 2 ROADSIDE SIGN CONDITIONS

Thus, the four sign conditions represented a base and successively more positive information relative to the conditions to be encountered on the road ahead. The signs were sighted well before the slow-moving vehicle was in view.

The reasons for selecting the wording on the signs were twofold - first, the wording should be relatively familiar to most drivers, and the second was in response to the requirement that the basic message should make sense when combined with the "when flashing" plaque.

The rationale for including a vehicle activated sign in the series had two aspects. First, there has been relative success in providing motorists with definitive information. (This was a reasonably successful approach in slowing vehicles as they passed through a rural village where the message indicated that they were exceeding the posted speed.) Second, the vehicle actuated device had a particular value as an attention getting device.

3.1.3 Vehicle Markings

The other key variable concerned the warning conveyed by on-board vehicle markings. The markings differed according to the type of vehicle that was used as the staged slow vehicle. When the single unit truck was used, the marking conditions were simply whether or not the truck's standard four-way flashers were activated. The consideration of using standard flashers as a warning device on slow moving trucks should help to resolve some of the disagreement among the States (and regulatory agencies) relative to whether or not such use of flashers should be recommended (see e.g., King, et al., 1977 or Knoblauch, 1978 for a summary of the opposing viewpoints.)

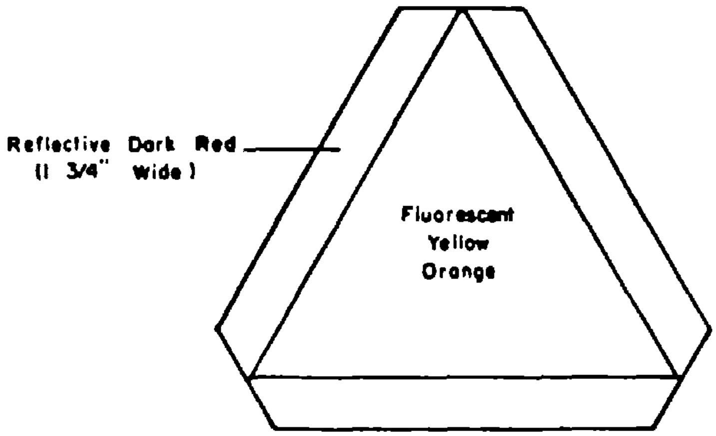
Three conditions were defined when the tractor was the staged vehicle: no symbol, U.S. Standard Slow Moving Vehicle (SMV) emblem, and a modified New Zealand Standard (SMV) emblem (see figure 3). This was similar to the truck marking sequence since the modified New Zealand Standard differed primarily in the addition of flashers.

3.1.4 Other Variables

In addition to the independent variables specified above, there were others which were accounted for in the experiment. The other specified conditions are summarized below:

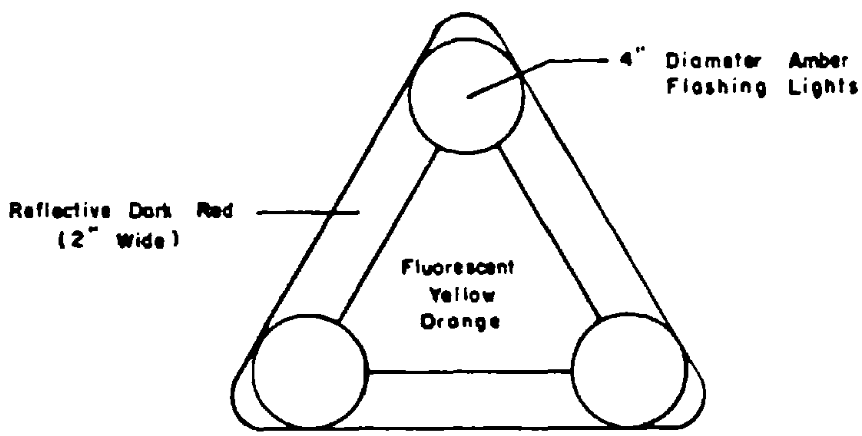
- Ambient light - truck data were collected during the day and night, tractor data were collected during the day only, and no data were collected during dawn and dusk periods;

- weather and pavement conditions - data were collected during periods with good visibility (e.g., no fog) and dry pavement; and



Actual Base = 12"

U.S. Standard Symbol
Vehicle Condition # 1



Actual Base = 16"

Modified New Zealand Symbol
Vehicle Condition # 2

Metric Conversion:
1 inch = 2.5 centimeters

FIGURE 3 VEHICLE MARKING CONDITIONS (TRACTOR)

. passing vehicles - for the truck phase, analysis was restricted to considering those vehicles which did not pass the slow-moving vehicle, and only limited analysis was undertaken on those vehicles which passed the tractor.

A summary of the independent variables is provided in Table 1.

3.2 DEPENDENT VARIABLES AND MEASURES OF EFFECTIVENESS

As discussed previously, each acceptable subject vehicle was tracked, unbeknownst to the motorist, by the computer. As the vehicle crossed over a loop detector buried in the roadway, the detector sent an on-off pulse to the computer which, in turn, calculated the speed of the vehicle over that portion of the road. That series of "speed" points over the test section yielded a composite speed profile which formed the basic data set for analysis. Of the several variables calculated, definitions of the seven on which the majority of the conclusions are based are provided below.

The variables were chosen as being indicative of the "safety" of an overtaking maneuver or of the "awareness" of the driver performing the maneuver. The degree of effectiveness of any sign or marking was determined relative to base conditions by the presence or absence of significant "positive" changes in the values of these variables. A "positive" change was one presumed to increase the general level of safety of the maneuver.

The dependent variables that were of interest can be separated into two groups: the early grade variables, which were those calculated for each subject vehicle prior to sighting the slow-moving vehicle; and the overtaking variables which were calculated after the slow vehicle was in view.

3.2.1 Early Grade Variables (Before slow vehicle is sighted)

The entry speed was calculated as the subject vehicles entered the test section. In addition to providing a criterion for acceptance as a subject vehicle, comparison of entry speeds for each set of vehicles was a measure of whether or not the sets of vehicles were behaving similarly as they entered the experiment area.

The early grade speed is the average speed over the first 48 m (1,600 feet) of the experiment area. While the staged slow-moving vehicle was generally not visible, the roadside sign condition was. Lower values (relative to the base condition - no sign) would indicate that the signs had a positive effect in slowing the subject vehicles as they began the upgrade.

Initial speed reduction is the difference between the entry speed and the early grade speed. A larger value indicated that there was a reduction in the mean vehicle speed, presumably due to the sighting of the roadside signs.

TABLE 1 SUMMARY OF INDEPENDENT VARIABLES BY VEHICLE TYPE

TEST VEHICLE	INDEPENDENT VARIABLES	LEVELS OR CONDITIONS ENCOUNTERED
Tractor	Ambient Lighting	1. Day Only
	Roadside Signs	0. Base 1. SC#1 (See Fig. 2) 2. SC#2 (See Fig. 2) 3. SC#3 (See Fig. 2)
	Speed of Test Vehicle	1. 24 km/h (15 MPH)
	Vehicle Warning Device	0. None 1. U.S. Standard (See Fig. 3) 2. N.Z. Standard (See Fig. 3)
Truck	Ambient Lighting	1. Day 2. Night
	Roadside Signs	0. Base 1. SC#1 (See Fig. 2) 2. SC#2 (See Fig. 2) 3. SC#3 (See Fig. 2)
	Vehicle Warning Device	0. None Activated 1. Standard Four-Way Flashers Activated
	Speed of Test Vehicle	1. 32 km/h (20 MPH) 2. 48 km/h (30 MPH)

3.2.2 Overtaking Variables (Subject vehicle actually overtaking slow vehicle)

The maximum speed reduction is the maximum speed change in any 30m (100 feet) interval. A larger reduction was indicative of a more abrupt change in the velocity profile of the overtaking vehicle. An effective warning device (either on the vehicle or the roadside) should result in a more uniform reduction in speed and, hence, a lower value.

Minimum space headway is the minimum spatial separation of the overtaking and slow vehicles (for non-passing vehicles). Larger values indicate that the overtaking vehicles did not follow the slow vehicle as closely. More effective devices would lead to higher values. Values can be compared to "standards" (e.g., 1 car length per 16 km/h (10 mph)) as an indication of effectiveness.

Minimum time to collision is a type of time headway. As the subject vehicle overtook the slow vehicle, a continuing record was kept so that at any point in time, given the speeds of both vehicles and their spatial separation, a time to interception (collision) could be calculated which assumed that both vehicles maintained their current speeds. The minimum of these values was the value of the variable in question. Larger relative values were indicative of a safer situation. (Note that this value is not directly comparable to the so-called "two second rule.")

The reaction distance is the space headway between the two vehicles when the overtaking vehicle had reduced its speed by ten percent (10%), or about 8 km/h (5 mph), from the early grade speed. Larger values of this variable indicated that the overtaking vehicle was beginning to slow down further back from the slow vehicle.

3.2.3 Other Variables

Several other variables were also computed, but were subsequently deleted from the analysis for one or more reason: (1) they were essentially redundant forms of those above; or (2) they were untested, "experimental" forms which proved either inconsistent or insensitive to the effects under investigation.

4.0 DATA COLLECTION AND ANALYSIS TECHNIQUES

4.1 DATA COLLECTION

Data collection, in general, consisted of tracking subject vehicles over the experiment section under a given combination of the independent variables. For example, one of the combinations consisted of slow moving vehicle type truck; slow vehicle speed: 32 km/h (20 mph); light condition: daytime; roadside sign: SC#3 (vehicle activated); and vehicle warning device: standard four-way flashers activated. All subject vehicles exposed to this set of conditions were grouped together, and their average value on a dependent variable (e.g., entry speed) was calculated and compared to that of another group of vehicles exposed to other combinations of conditions (e.g., an identical set of conditions with the exception of roadside sign condition).

4.2 ANALYSIS TECHNIQUES

The first of the three levels of analysis undertaken primarily consisted of a graphical comparison of the mean values and variances of a dependent variable attained under each possible combination of roadside sign and vehicle marking conditions with other variables held constant. The effects being compared are shown in Table 2. The initial analysis also provided a check for erroneous input entries, e.g. impossible vehicle speed. The results of the first level of analysis (and those described below) are discussed in a later section and presented in detail in Appendix A.

TABLE 2. SUMMARY OF VARIABLE COMBINATIONS

Vehicle Marking Conditions	Roadside Sign Conditions: SC#0	SC#1	SC#2	SC#3
VSC#0				
VSC#2				
*VSC#2				

Conditions held constant: Vehicle type, vehicle speed, ambient light.

*Note that when the truck is the slow vehicle there are only two (SC#0 and SC#1) vehicle marking conditions.

The next level of analysis consisted of a statistical comparison of the mean values. A one-way analysis of variance with multiple comparisons (contrasts) was undertaken for each set of graphical results.

The last level of analysis consisted of multiple-way ANOVAs structured to examine the data for interactive effects - that is, were there elements of driver behavior which were not explained by either the use of flashers or deployment of signs alone but by a combination (interaction) of the two. For example, it seemed logical that if the activated sign was effective as an advance warning device alone (which it was to some degree) and if the flashers were effective once the slow-moving vehicle was in sight (which they were), there would have been some additional (interaction) effect if a motorist saw a vehicle with flashers after seeing the activated warning sign.

5.0 DETAILED RESULTS OF THE EXPERIMENT

In the preceding sections the principal variables were introduced and discussed, and a summary of findings is presented in section 6. In this section the specific results of the experiment are presented.

5.1 EARLY GRADE VARIABLES

Three variables were identified as early grade variables. These were basically concerned with the motorists' reactions prior to seeing the slow moving vehicle.

Entry speed was calculated at the point where the vehicle was initially picked up by the computer - the motorist could not see either the slow moving vehicle or the roadside sign. The importance of entry speed was basically to ascertain whether or not the samples of motorists that saw each sign condition were similar. (Note that some absolute differences in entry speed were expected - e.g., the differences between vehicles observed during the day and the night). An examination of the entry speed values for all groups showed the similarity among the samples, a result which was consistent with expectations.

In all instances there were differences in early grade speed. The multiple comparisons that were made basically supported the contention that the signs, and especially lighted ones, were effective. Explicit comparisons were made relative to the overall effectiveness of any sign versus the base condition (no sign) and the basic sign versus one equipped with continuously flashing beacons.

For the daytime data (with the truck traveling at 32 km/h (20 mph)), the results were somewhat mixed although the clear tendency was for signs of any type to have some slowing effect and for the addition of continuously flashing beacons to increase the effectiveness. The results when the slow truck was traveling at 48 km/h (30 mph) were less clear-cut (especially relative to the superiority of flashing signs).

For the night-time data, the results were less ambiguous: the signs lighted with flashing beacons were superior; and signing, in general, was more effective than having none present. It is important to note that although the differences are statistically significant at no less than the .975 level for the night data, the actual differences in "real" terms are on the order of one or two mph which was of small practical importance.

Basically, the results were similar regardless of whether the truck or the tractor was the slow vehicle.

As with early grade speed, initial speed reduction increased in effectiveness was noted with the increasing urgency of the information that the sign conveyed to the motorist. Again, as above, while statistical significance was achieved in several instances, the absolute differences which were under consideration were not more than 5 km/h (3 mph) (which as a practical matter is a slight difference). This comment notwithstanding, the trend was reasonably clear and, at night, unambiguous.

5.2 OVERTAKING VARIABLES

It was expected that the roadside signs would have some lasting effect on the values of the variables measured once the slow-moving vehicle was in sight and the actual overtaking was imminent. In general, this was not the case - that is, the signs appeared to have no lasting effect on the motorists as they actually caught up with the slow moving vehicle. The following discussion pertains only to instances when the slow vehicle was the truck. Tractor results are reported separately.

In all but one instance the use of four-way flashers on the slow vehicle resulted in less maximum speed reduction by motorists closing on the slow vehicle (in an absolute sense). However, some of the differences were not statistically significant. For example, when the truck was traveling at 32 km/h (20 mph), all differences except one were significant.

Several comparisons were made for night data alone, and using day and night data. The first result was that the use of flashers at night had an advantage over non-use. The second, and perhaps more interesting, result was that flashers were as effective during the day as they were at night. A third result was that a comparison of day and night data when the four-way flashers were not in use showed that the night drivers were more likely to have less abrupt velocity changes than their daytime counterparts. This is possibly explained by either 1) that the running lights of the truck provided a better visual cue as to the truck's presence and speed, and, thus overtaking drivers were more cautious, or 2) that drivers at night tended to be more cautious in general.

Thus, relative to maximum speed reduction when the use vs. non-use of flashers was examined there was a clear, if not always statistically significant, trend. A trend attributable to the effects of the roadside signs (for the overtaking variables) was not apparent. For example, considering the results when the slow moving vehicle was the truck going 32 km/h (20 mph), it appeared that sign condition 3 alone was roughly as effective as the use of flashers. However, when the truck was going 48 km/h (30 mph) the opposite was true (i.e., SC#3 was the least effective). Thus, although some of the results relative to the effectiveness of roadside signs were positive if taken individually, a consideration of the overall results yielded the conclusion that the use of signs was inconsequential relative to changes in motorist behavior during actual overtaking.

In all instances the use of flashers by the truck resulted in the overtaking vehicles following at a safer distance (i.e., a greater minimum headway). However, not all of the differences were statistically significant.

The comparison of day and night use of flashers showed that the flashers were generally as effective during the day as at night. Using the "rule of thumb" that safe following distance is equivalent to one car length per 16 km/h (10 mph) of speed, the safe following distance was attained for only one treatment combination when the slow vehicle was not using flashers. Conversely, when flashers were in use, the safe following distance was attained in several instances.

Although it generally appeared that the roadside signs had an inconsequential effect, there was some graphical evidence that there was an interactive effect between the lighted signs and use of flashers on the slow moving vehicle. This latter result was not consistent across the three basic comparisons that were made.

Relative to daytime data, the use of four-way flashers by the slow-moving vehicle resulted in significantly higher time to collision values, regardless of its speed for all treatment combinations, but one. Night results were similar.

A comparison of day and night data with flashers in use again showed that use of flashers tended to be as effective during the day as during the night.

Relative to the effects of the roadside signs, the results were inconsistent. In one or two instances there was evidence of a trend in the effectiveness of the lighted signs (or for some interaction effect). However, examination of all results led to the conclusion that the roadside signs had little continuing effect.

The results relative to reaction distance were similar to the others reported above - that is, in most instances the use of four-way flashers resulted in significantly higher values. Comparison of day and night data showed that while the results were analogous, the tendency was for flashers to be more effective during the night than during the day.

This last result may be explained by the fact that the variable (reaction distance), while being classed as an "overtaking variable," was measured some distance from the slow-moving vehicle although visual contact had been made. Thus, the flashers, which were more noticeable at a distance at night, were more effective at night than during the day.

An examination of the data showed some weak indication in a statistical sense that lighted signs may have been somewhat more effective than non-lighted ones. Therefore, no strong conclusion can be made in favor of sign effectiveness. However the need for possible additional research is suggested.

Several other variables were examined including "space headway at the point of maximum speed reduction" and a "confusion measure." The results relative to these variables were inconsistent, in either a positive or negative sense, relative to the effectiveness of roadside signs or vehicle markings.

5.3 ADDITIONAL OBSERVATIONS

There were two aspects of the experiment relative to the tractor which are of interest. The first was that the results of the straightforward analysis of the variables were similar to those obtained when the truck was the slow vehicle. The second concerned the comparison of passing vs. non-passing drivers. Both of these aspects are discussed below.

5.3.1 Tractor as the Slow-Moving Vehicle

It should be noted that the experiment was incomplete for the tractor. The original intention was to test the four roadside sign conditions with each of the three vehicle markings (base, standard U.S. Symbol, modified New Zealand). There was, however, a curtailment of the tractor phase, and only the first two roadside sign conditions (SC #0, SC #1) were tested with all three vehicle markings. The third sign condition (SC 32) was tested with only two vehicle markings (VSC #0; VDS #1) and the fourth sign condition was not tested when the tractor was the slow vehicle.

In considering the effects of vehicle markings for tractors, the results were somewhat more ambiguous than the results for the truck. The following points are made:

1. There were no significant differences among the groups of motorists who saw the tractor. The markings had no consistent (or statistically significant) positive or negative effects on the values of the variables measured. A possible explanation is that the motorists expects the tractor to be slow moving regardless of any vehicle marking. It should be noted that the modified New Zealand symbol generally resulted in slightly better values than the standard U.S. Symbol - the difference was not, however, statistically significant.

2. When truck and tractor data were compared, it appeared that the magnitudes of the result achieved when the tractor was the slow moving vehicle were similar to the magnitudes achieved when flashers were activated on the truck. The interpretation here is that the motorists' expectancy in both situations is the same - the vehicles were slow moving.

5.3.2 Comparison of Passing and Non-Passing Drivers

The behavior of drivers who pass was interesting insofar as it appeared to be quite different from drivers who did not pass, not only in their passing maneuvers but also relative to their reactions to the signs and the slow vehicle

The passing drivers generally entered the instrumented area faster and maintained their higher speed throughout the test site exhibiting less reaction to either the warning signs or to the slow vehicle itself. Unfortunately, the sample size for passing vehicles was inadequate for statistical testing.

6.0 SUMMARY AND CONCLUSIONS

The purpose of the experiment was to evaluate the effectiveness of three roadside signs and two vehicle mounted warning devices to reduce the potential for accidents between slow moving vehicles and vehicles overtaking them.

The experimental situation can be summarized as introducing a staged slow moving vehicle into the traffic stream on a grade so that an unsuspecting motorist overtook it within an instrumented zone. The motorist had passed one of four roadside sign conditions (including the absence of a sign) and encountered a slow vehicle displaying one of several vehicle marking conditions (which is, in part, dependent on which of two types of slow moving vehicles was encountered). Data were collected on the behavior of the motorists (as manifested in vehicle speeds and positions) as they moved through the instrumented zone during the day and at night when clear/dry road conditions prevailed. The experiment was undertaken and data were collected at the FHWA's Maine Facility near Pittsfield, Maine.

6.1 PRINCIPAL FINDINGS AND CONCLUSIONS

A reiteration of the findings and conclusions discussed in the several sections of this report is presented below:

1. Activation of four-way flashers on slow-moving trucks was an effective device for reducing the accident potential when such vehicles were overtaken by faster moving vehicles. Measures of effectiveness included variables descriptive of the overtaking maneuver (e.g., minimum headway).

2. The four-way flashers were as effective during the day as they were at night.

3. The roadside signs were relatively ineffective as warning devices in this situation. Although there was a measureable positive effect in the vicinity of the signs themselves, the effect was not lasting. That is, motorists who saw the signs that caused the immediate reaction did not generally exhibit any different behavior at the point of overtaking than did those who saw no sign.

4. Where the roadside signs were effective, those that conveyed more emphatic information (i.e., those that were lighted) were generally more effective.

5. There was some evidence of an interactive effect between the more effective signs and the use of flashers, but it was not statistically significant.

6. Reactions to the different warning devices on the tractor were inconclusive. The modified New Zealand Symbol was often slightly more effective than the standard U.S. symbol although the differences were not statistically significant.

7. Drivers that tend to pass the slow moving vehicle (when it is the tractor) also tend to enter the instrumented area at a higher speed, maintain a higher speed through the area, and be less responsive to any of the warning devices.

6.2 FOUR-WAY FLASHER EFFECTS

Table 3 summarizes the results discussed in Section 5 and documented in Appendix A relative to "four-way flasher effects." The table essentially illustrates that flashing beacons, four-way flashers in use on the slow moving truck and the New Zealand Modified slow moving emblem on the tractor had a positive effect on lessening the degree of the conflict situation when the overtaking was actually occurring (i.e., the slow moving vehicle was in sight). Conversely, the table also showed that the use of flashers had no effect on motorist behavior before the vehicle was actually sighted.

6.3 ROADSIDE SIGN EFFECTS

Table 4 shows a summary of the "roadside sign effects" for the same variables as were shown in the previous summary. Whereas in the prior discussion only the variables where the slow moving vehicle was in sight were of practical interest, in this instance all variables are of interest.

Examination of typical vehicle speed profiles as they passed through the experimental area showed that there was generally a "dip" in speed in the vicinity of the roadside signs, and then a tendency to return to the original speed. The results summarized in Table 4 on a variable by variable basis indicate that, in general, there was an initial effect attributable to sighting the roadside sign. This effect did not appear to be of any duration, nor make a difference in driver behavior when the slow vehicle was actually sighted and overtaken.

6.4 GENERAL RESULTS

The major finding of this research was that the most effective device of those tested for decreasing the potential of a dangerous conflict, when a faster moving vehicle overtakes a slow one on an upgrade, was the use of standard four-way flashers by the slow moving vehicle. Specific positive effects were relative to the initial reaction distance, closing rate, and minimum following headway. A second finding was that the effectiveness of advanced warning roadside signs seemed limited to the motorist's immediate reaction in the vicinity of the sign itself - that is, the roadside signs did not seem to make any difference in overt driver behavior as the slow-moving vehicle was actually overtaken. However, it was not known if the driver's anticipation of the slower moving vehicle was any higher for having seen the sign.

It can be hypothesized that drivers who saw one of the roadside signs had a higher degree of anticipation of the slow moving vehicle and, hence, would have been less surprised by the encounter even though such drivers

TABLE 3 FOUR-WAY FLASHER EFFECTS FOR NON-PASSING VEHICLES*

	Experimental Condition			
	Truck-20mph** Day	Truck-30mph Day	Truck-20mph Night	Tractor-15mph Day*
Early Grade Variables				
Entry Speed (ESPD)	No	No	No	No
Early Grade Speed (SEG)	No	No	No	No
Initial Speed Reduction (DSEG)	No	No	No	No
Overtaking Variables				
Max-Speed Reduction (DVMX)	Yes	No	Yes	No
Minimum Headway (HMIN)	Yes	No	0	0
Time to Collision (TCOL)	Yes	Yes	0	0
Reaction Distance (RDST)	Yes	0	Yes	No

Explanation of Table:

Comparisons were made (for all four sign conditions) between flasher and non-flasher effects, and

Yes indicates that flashers, in general, had a statistically significant positive effect

0 indicates that flashers, in general, had a marginally significant positive effect

No indicates that flashers, in general, had no effect

* Tractor equipped with the New Zealand Modified slow-moving emblem instead of four-way flasher

** 1 mph = 1.6 km/h

TABLE 4 ROADSIDE SIGN EFFECTS FOR NON-PASSING VEHICLES

	Experimental Condition			
	Truck-20mph** Day	Truck-30mph Day	Truck-20mph Night	Tractor-15mph Day*
Early Grade Variables				
Entry Speed (ESPD)	No	No	No	No
Early Grade Speed (SEG)	Yes	Yes	Yes	Yes
Initial Speed Reduction (DSEG)	Yes	Yes	Yes	Yes
Overtaking Variables				
Max-Speed Reduction (DVMX)	No	No	No	0
Minimum Headway (HMIN)	No	0	No	No
Time to Collision (TCOL)	No	No	No	0
Reaction Distance (RDST)	0	No	0	No

Explanation of Table:

Each variable was reviewed for the range of signs, and general trends were noted:

Yes indicates that the signs, in general, had a statistically significant positive effect on driver behavior

0 indicates that the sign effect was mixed - no effect in some instances and positive in others

No indicates that the sign effects appear to be, in general, negligible

* Tractor equipped with the New Zealand Modified slow-moving emblem instead of four-way flasher

** 1 mph = 1.6 km/h

did not overtly behave much differently from those that saw no warning sign. Nonetheless, it must be re-emphasized that, given the variables measured, the roadside signs did not have any overt effect during the actual overtaking.

7.0 REFERENCES

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APPENDIX A

DETAILED GRAPHIC AND TABULAR RESULTS

Presented on the following pages are graphic and analytical representations of the results of the analyses done on the principal dependent variables. As a guide to understanding this information the following comments are made:

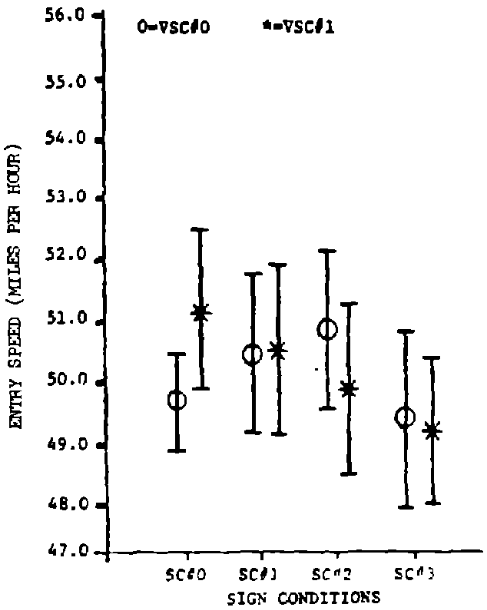
The graphical presentations show a co-ordinate system with the vertical axis showing the appropriate units for the dependent variable in question (e.g., miles/hour for ESPD). The horizontal axis shows the four roadside sign conditions used in the experiment. For each roadside sign condition (e.g., SC#0), there are generally two or three (depending on slow moving vehicle type) "means and error bars" for the appropriate vehicle marking configurations (e.g., VSC#0)

The caption of the figure shows the slow moving vehicle type, speed of slow moving vehicle, light condition and whether or not the subject vehicles passed the slow-moving vehicle (e.g., truck 32 km/h (20 mph); day; no pass).

The table to the right of each figure shows (in tabular form), the mean (X), standard deviation (s) and cell site (n) for each cell which is plotted, as well as the summary for the variable over all roadside sign and vehicle marking conditions. Also shown is the overall F statistic which is from a one-way ANOVA performed on the data summarized in the figure. The symbol (s) indicates significance at the five percent level while (n) indicates non-significance

There are several abbreviations used for the variables on the following pages. These abbreviations are listed below:

Entry Speed	ESPD
Early Grade Speed	SEG
Initial Speed Reduction	DSEG
Maximum Speed Reduction	DVMX
Minimum Space Headway	HMIN
Minimum Time to Collision	TCOL
Reaction Distance	RDST



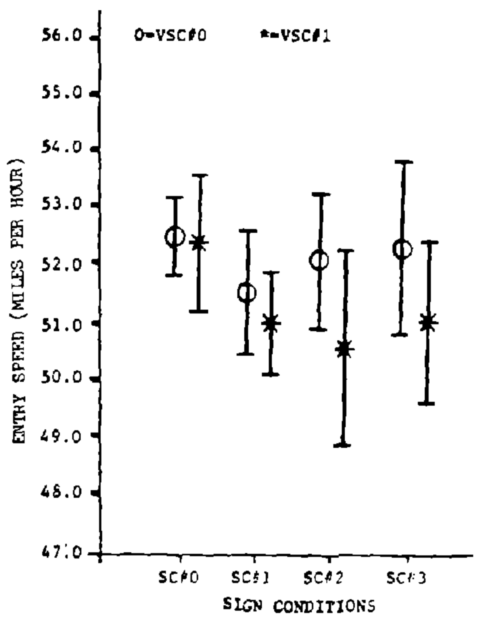
ROADSIDE SIGN CONDITIONS		VEHICLE MARKINGS		
		NONE	FLASHERS	--
SIGN CONDITION 0	$\bar{x}$	49.7	51.2	--
	s	5.1	5.4	--
	n	153	66	--
SIGN CONDITION 1	$\bar{x}$	50.3	50.4	--
	s	4.7	5.7	--
	n	52	66	--
SIGN CONDITION 2	$\bar{x}$	50.7	49.9	
	s	5.7	5.9	
	n	68	64	
SIGN CONDITION 3	$\bar{x}$	49.4	49.2	
	s	5.7	4.9	
	n	61	62	

SUMMARY
Overall $\bar{x}$ = 50.1
Pooled s = 5.4
Total n = 592
F = 1.078(n)

Metric Conversion:

1 mph = 1.609 km/hr

FIGURE 4. ESPD (MPH) VS. ROADSIDE SIGN CONDITIONS TRUCK 20, DAY, NO PASS.



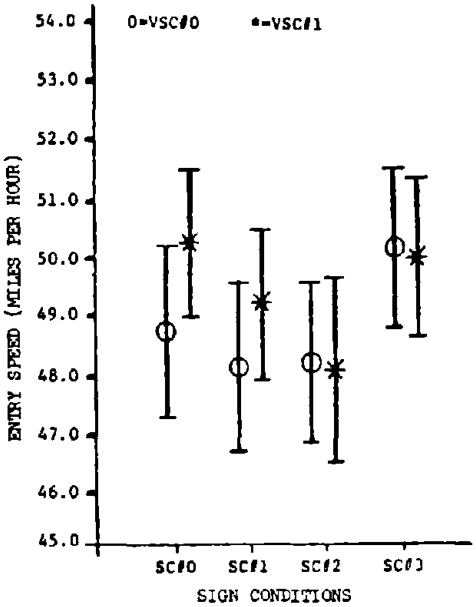
ROADSIDE SIGN CONDITIONS		VEHICLE MARKINGS		
		NONE	FLASHERS	--
SIGN CONDITION 0	$\bar{x}$	52.4	52.3	--
	s	4.7	5.2	--
	n	197	90	--
SIGN CONDITION 1	$\bar{x}$	51.4	50.9	--
	s	4.2	3.5	--
	n	66	66	--
SIGN CONDITION 2	$\bar{x}$	51.9	50.5	
	s	4.7	4.9	
	n	65	38	
SIGN CONDITION 3	$\bar{x}$	52.2	50.5	
	s	5.1	5.0	
	n	52	53	

SUMMARY
Overall $\bar{x}$ = 51.6
Pooled s = 4.7
Total n = 627
F = 1.839(r)

Metric Conversion:

1 mph = 1.609 km/hr

FIGURE 5. ESPD (MPH) VS. ROADSIDE SIGN CONDITIONS TRUCK 30, DAY, NO PASS.

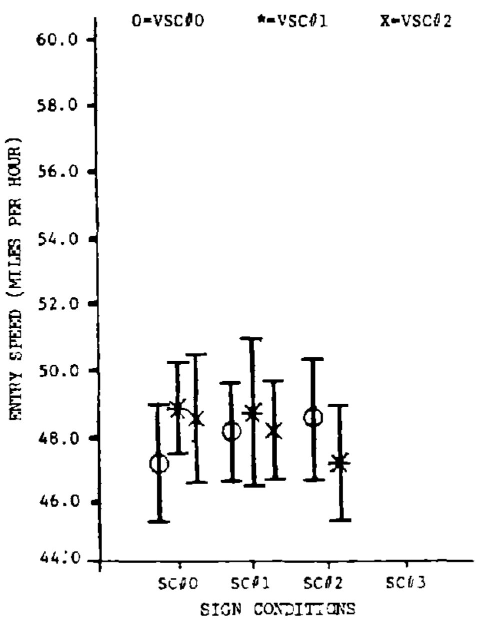


ROADSIDE SIGN CONDITIONS		VEHICLE MARKINGS		
		NONE	FLASHERS	
SIGN CONDITION Ø	$\bar{x}$	48.7	50.2	--
	s	5.8	5.3	--
	n	66	74	--
SIGN CONDITION 1	$\bar{x}$	48.1	49.2	--
	s	5.9	5.5	--
	n	72	82	--
SIGN CONDITION 2	$\bar{x}$	48.2	48.1	
	s	5.6	5.8	
	n	69	56	
SIGN CONDITION 3	$\bar{x}$	50.1	49.9	
	s	5.9	5.5	
	n	74	70	

SUMMARY	
Overall	$\bar{x}$ = 49.1
Pooled	s = 5.7
Total	n = 563
	F = 1.603(n)

Metric Conversion:
1 mph = 1.609 km/hr

FIGURE 6. ESPD (MPH) VS. ROADSIDE SIGN CONDITIONS TRUCK 20, NIGHT, NO PASS.

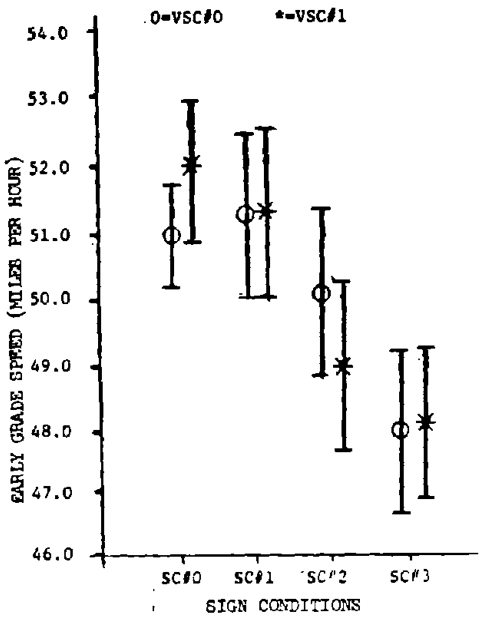


ROADSIDE SIGN CONDITIONS		VEHICLE MARKINGS		
		NONE	US STND	NZ STND
SIGN CONDITION Ø	$\bar{x}$	47.2	48.9	48.6
	s	5.2	4.9	6.1
	n	30	42	32
SIGN CONDITION 1	$\bar{x}$	48.1	48.7	48.1
	s	4.0	5.9	4.7
	n	26	24	35
SIGN CONDITION 2	$\bar{x}$	48.5	47.2	
	s	5.8	5.7	
	n	33	35	
SIGN CONDITION 3	$\bar{x}$	---	---	
	s	---	---	
	n	---	---	

SUMMARY	
Overall	$\bar{x}$ = 46.2
Pooled	s = 5.3
Total	n = 257
	F = 0.511(n)

Metric Conversion:
1 mph = 1.609 km/hr

FIGURE 7. ESPD (MPH) VS. ROADSIDE SIGN CONDITIONS TRACTOR, DAY, NO PASS.

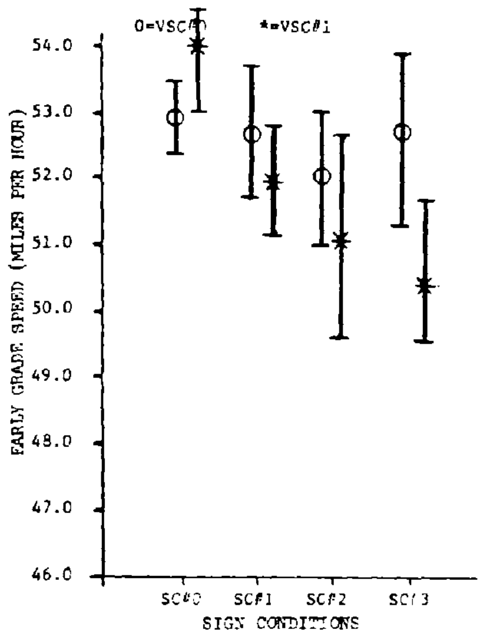


ROADSIDE SIGN CONDITIONS		VEHICLE MARKINGS		
		NONE	FLASHERS	--
SIGN CONDITION 0	$\bar{x}$	51.0	52.0	--
	s	5.2	4.7	--
	n	153	66	--
SIGN CONDITION 1	$\bar{x}$	51.3	51.4	--
	s	4.8	5.7	--
	n	52	66	--
SIGN CONDITION 2	$\bar{x}$	50.1	49.0	
	s	6.1	5.9	
	n	68	64	
SIGN CONDITION 3	$\bar{x}$	47.9	48.1	
	s	5.3	5.0	
	n	61	62	

SUMMARY	
Overall	$\bar{x}$ = 50.2
Pooled	s = 5.4
Total	n = 592
	F = 5.770(s)

Metric Conversion:
1 mph = 1.609 km/hr

FIGURE 8. SEG (MPH) VS. ROADSIDE SIGN CONDITIONS TRUCK 20, DAY, NO PASS.

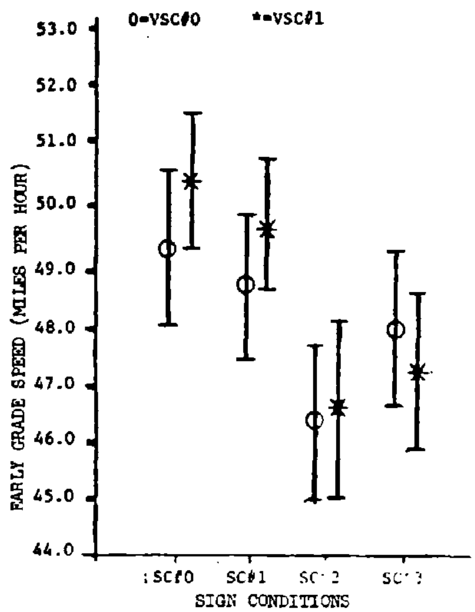


ROADSIDE SIGN CONDITIONS		VEHICLE MARKINGS		
		NONE	FLASHERS	--
SIGN CONDITION 0	$\bar{x}$	52.9	54.0	--
	s	4.6	5.0	--
	n	197	90	--
SIGN CONDITION 1	$\bar{x}$	52.7	51.9	--
	s	4.5	3.7	--
	n	66	66	--
SIGN CONDITION 2	$\bar{x}$	52.0	51.0	
	s	4.4	5.3	
	n	65	38	
SIGN CONDITION 3	$\bar{x}$	52.6	50.4	
	s	5.3	4.5	
	n	52	53	

SUMMARY	
Overall	$\bar{x}$ = 52.5
Pooled	s = 4.6
Total	n = 627
	F = 3.943(s)

Metric Conversion:
1 mph = 1.609 km/hr

FIGURE 9. SEG (MPH) VS. ROADSIDE SIGN CONDITIONS TRUCK 30, DAY, NO PASS.

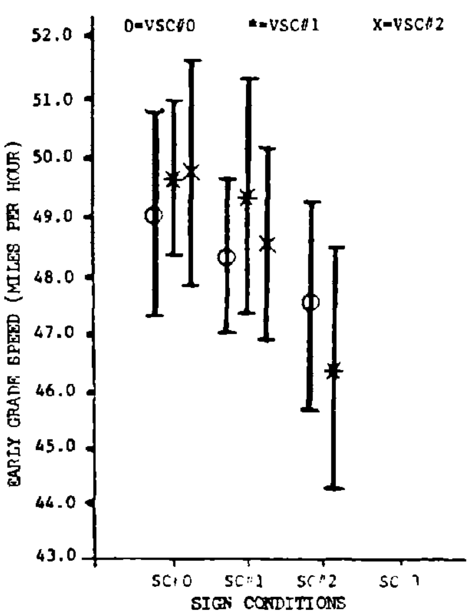


ROADSIDE SIGN CONDITIONS		VEHICLE MARKINGS: NONE	FLASHERS	—
SIGN CONDITION Ø	$\bar{x}$	49.4	50.4	--
	s	5.3	4.9	--
	n	66	74	--
SIGN CONDITION 1	$\bar{x}$	48.7	49.7	--
	s	5.1	5.1	--
	n	72	82	--
SIGN CONDITION 2	$\bar{x}$	46.4	46.6	
	s	5.4	5.9	
	n	69	56	
SIGN CONDITION 3	$\bar{x}$	48.0	47.3	
	s	5.8	5.4	
	n	74	70	

SUMMARY
Overall $\bar{x}$ = 48.4
Pooled s = 5.4
Total n = 563
F = 5.297(s)

Metric Conversion:
1 mph = 1.609 km/hr

FIGURE 10. SEG (MPH) VS. ROADSIDE SIGN CONDITIONS TRUCK 20, NIGHT, NO PASS

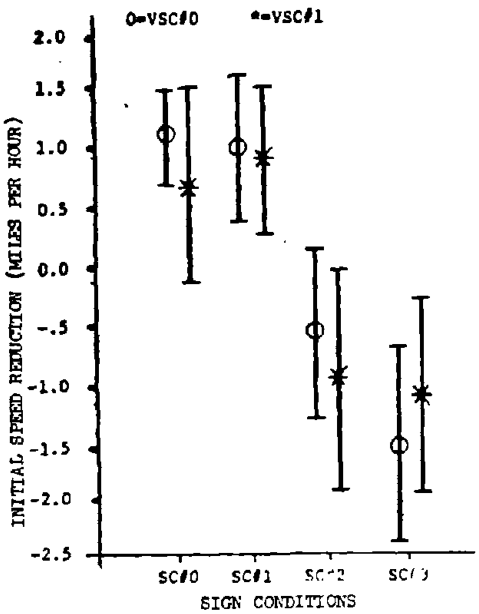


ROADSIDE SIGN CONDITIONS		VEHICLE MARKINGS: NONE	US STND	NZ STND
SIGN CONDITION Ø	$\bar{x}$	49.0	49.6	49.7
	s	4.7	4.3	4.7
	n	30	42	32
SIGN CONDITION 1	$\bar{x}$	48.3	49.3	48.5
	s	3.4	4.9	4.7
	n	26	24	35
SIGN CONDITION 2	$\bar{x}$	47.5	46.3	
	s	5.4	5.9	
	n	33	35	
SIGN CONDITION 3	$\bar{x}$	--	--	
	s	--	--	
	n	--	--	

SUMMARY
Overall $\bar{x}$ = 48.5
Pooled s = 4.9
Total n = 257
F = 1.96(n)

Metric Conversion:
1 mph = 1.609 km/hr

FIGURE 11. SEG (MPH) VS. ROADSIDE SIGN CONDITIONS TRACTOR, DAY, NO PASS.

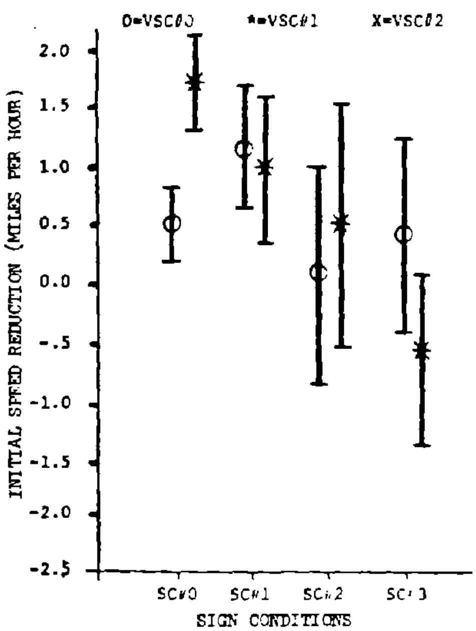


ROADSIDE SIGN CONDITIONS		VEHICLE MARKINGS: NONE	FLASHERS	--
SIGN CONDITION Ø	$\bar{x}$	1.2	0.8	
	s	2.5	3.2	--
	n	153	66	--
SIGN CONDITION 1	$\bar{x}$	1.0	0.9	--
	s	2.2	2.5	--
	n	52	66	--
SIGN CONDITION 2	$\bar{x}$	-0.6	-0.9	
	s	3.0	3.8	
	n	68	64	
SIGN CONDITION 3	$\bar{x}$	-1.5	-1.1	
	s	3.4	3.2	
	n	61	62	

SUMMARY
Overall $\bar{x}$ = 0.2
Pooled s = 3.0
Total n = 592
F = 10.52(s)

Metric Conversion:
1 mph = 1.609 km/hr

FIGURE 12. DSEG (MPH) VS. ROADSIDE SIGN CONDITIONS TRUCK 20, DAY, NO PASS.

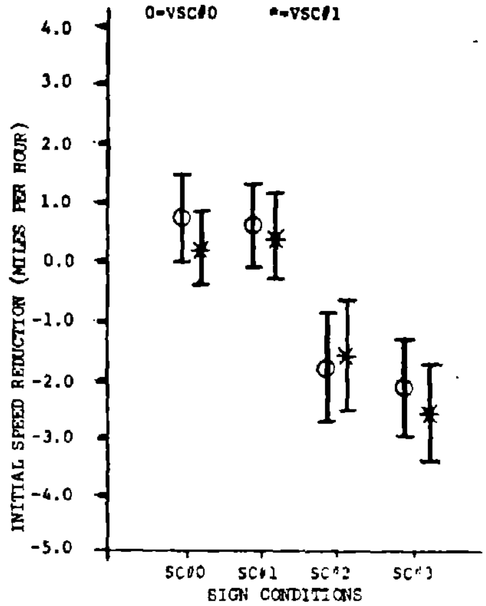


ROADSIDE SIGN CONDITIONS		VEHICLE MARKINGS: NONE	FLASHERS	--
SIGN CONDITION Ø	$\bar{x}$	0.5	1.7	--
	s	2.5	2.5	--
	n	197	90	--
SIGN CONDITION 1	$\bar{x}$	1.2	1.0	--
	s	2.0	2.5	--
	n	66	66	--
SIGN CONDITION 2	$\bar{x}$	0.1	0.5	
	s	3.7	3.3	
	n	65	38	
SIGN CONDITION 3	$\bar{x}$	0.4	-0.6	
	s	3.1	2.6	
	n	52	53	

SUMMARY
Overall $\bar{x}$ = 0.6
Pooled s = 2.7
Total n = 627
F = 2.927(s)

Metric Conversion:
1 mph = 1.609 km/hr

FIGURE 13. DSEG (MPH) VS. ROADSIDE SIGN CONDITIONS TRUCK 30, DAY, NO PASS.

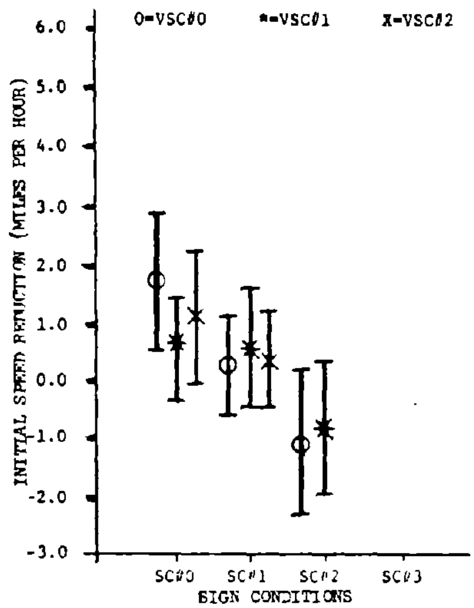


ROADSIDE SIGN CONDITIONS		VEHICLE MARKINGS		
		NONE	FLASHERS	—
SIGN CONDITION Ø	$\bar{x}$	0.7	0.2	—
	s	2.9	2.7	—
	n	66	74	—
SIGN CONDITION 1	$\bar{x}$	0.6	0.4	—
	s	3.0	3.3	—
	n	72	82	—
SIGN CONDITION 2	$\bar{x}$	-1.8	-1.6	
	s	4.0	3.5	
	n	69	56	
SIGN CONDITION 3	$\bar{x}$	-2.2	-2.6	
	s	3.6	3.5	
	n	74	70	

SUMMARY
Overall $\bar{x}$ = -0.7
Pooled s = 3.3
Total n = 563
F = 12.33(s)

Metric Conversion:
1 mph = 1.609 km/hr

FIGURE 14. DSEG (MPH) VS. ROADSIDE SIGN CONDITIONS TRUCK 20, NIGHT, NO PASS.

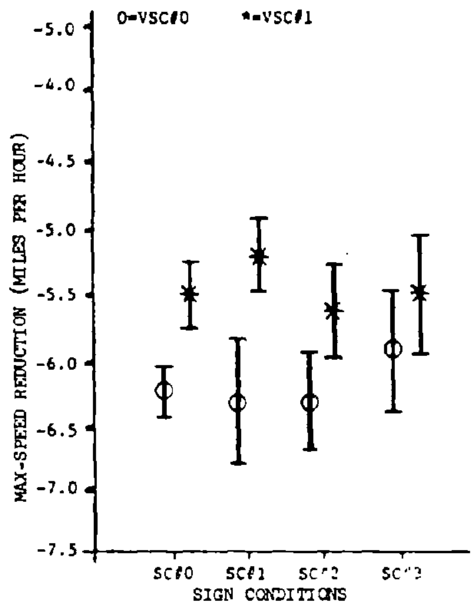


ROADSIDE SIGN CONDITIONS		VEHICLE MARKINGS		
		NONE	US STND	NZ STND
SIGN CONDITION Ø	$\bar{x}$	1.7	0.6	1.1
	s	3.0	2.6	3.3
	n	30	42	32
SIGN CONDITION 1	$\bar{x}$	0.2	0.5	0.3
	s	2.2	2.5	2.5
	n	26	24	35
SIGN CONDITION 2	$\bar{x}$	-1.1	-0.9	
	s	3.5	3.2	
	n	33	35	
SIGN CONDITION 3	$\bar{x}$	--	--	
	s	--	--	
	n	--	--	

SUMMARY
Overall $\bar{x}$ = 0.3
Pooled s = 2.9
Total n = 257
F = 3.40(s)

Metric Conversion:
1 mph = 1.609 km/hr

FIGURE 15. DSEG (MPH) VS. ROADSIDE SIGN CONDITIONS TRACTOR, DAY, NO PASS.

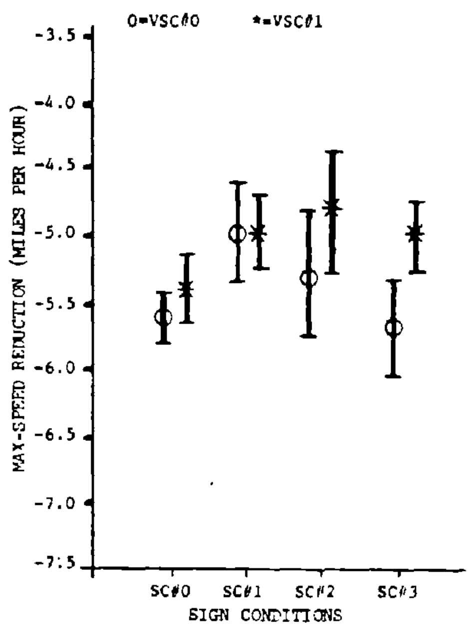


ROADSIDE SIGN CONDITIONS		VEHICLE MARKINGS NONE	FLASHERS	--
SIGN CONDITION 0	$\bar{x}$	-6.2	-5.5	--
	s	1.8	1.5	--
	n	153	66	--
SIGN CONDITION 1	$\bar{x}$	-6.3	-5.2	--
	s	1.9	1.5	--
	n	52	66	--
SIGN CONDITION 2	$\bar{x}$	-6.3	-5.6	
	s	1.9	1.6	
	n	68	64	
SIGN CONDITION 3	$\bar{x}$	-5.4	-5.5	
	s	2.3	2.1	
	n	61	62	

SUMMARY	
Overall	$\bar{x}$ = -5.9
Pooled	s = 1.8
Total	n = 592
	F = 3.862(s)

Metric Conversion:
1 mph = 1.609 km/hr

FIGURE 16. DVMX (MPH) VS. ROADSIDE SIGN CONDITIONS TRUCK 20, DAY, NO PASS.

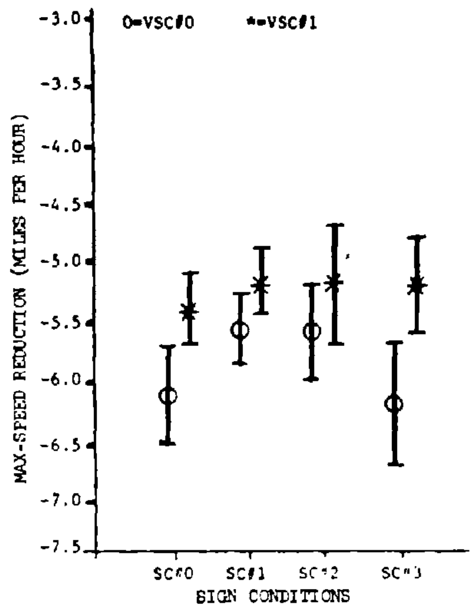


ROADSIDE SIGN CONDITIONS		VEHICLE MARKINGS NONE	FLASHERS	--
SIGN CONDITION 0	$\bar{x}$	-5.6	-5.4	--
	s	1.9	1.7	--
	n	197	90	--
SIGN CONDITION 1	$\bar{x}$	-5.0	-5.0	--
	s	1.6	1.3	--
	n	66	66	--
SIGN CONDITION 2	$\bar{x}$	-5.3	-4.8	
	s	2.1	1.7	
	n	65	38	
SIGN CONDITION 3	$\bar{x}$	-5.7	-5.0	
	s	1.5	1.4	
	n	52	53	

SUMMARY	
Overall	$\bar{x}$ = -5.3
Pooled	s = 1.7
Total	n = 627
	F = 2.526(s)

Metric Conversion:
1 mph = 1.609 km/hr

FIGURE 17. DVMX (MPH) VS. ROADSIDE SIGN CONDITIONS TRUCK 30, DAY, NO PASS.

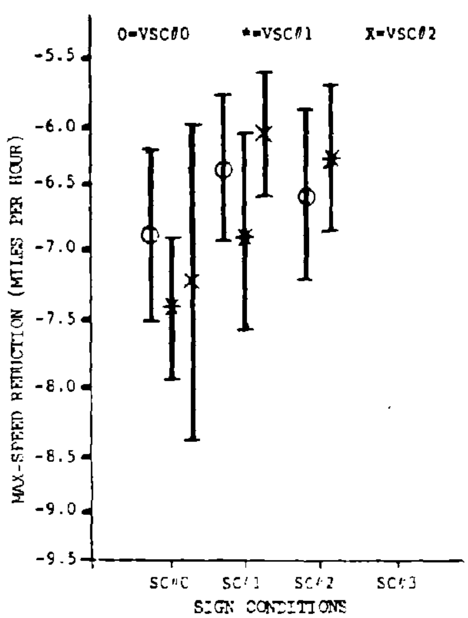


ROADSIDE SIGN CONDITIONS		VEHICLE MARKINGS		
		NONE	FLASHERS	--
SIGN CONDITION Ø	x̄	-6.1	-5.4	--
	s	1.8	1.6	--
	n	66	74	--
SIGN CONDITION 1	x̄	-5.6	-5.2	--
	s	1.6	1.4	--
	n	72	82	--
SIGN CONDITION 2	x̄	-5.6	-5.2	
	s	1.8	1.9	
	n	69	56	
SIGN CONDITION 3	x̄	-6.2	-5.2	
	s	2.4	1.9	
	n	74	70	

SUMMARY
Overall x̄ = -5.6
Pooled s = 1.8
Total n = 5.63
F = 3.413(s)

Metric Conversion:
1 mph = 1.609 km/hr

FIGURE 18. DVMX (MPH) VS. ROADSIDE SIGN CONDITIONS TRUCK 20, NIGHT, NO PASS.

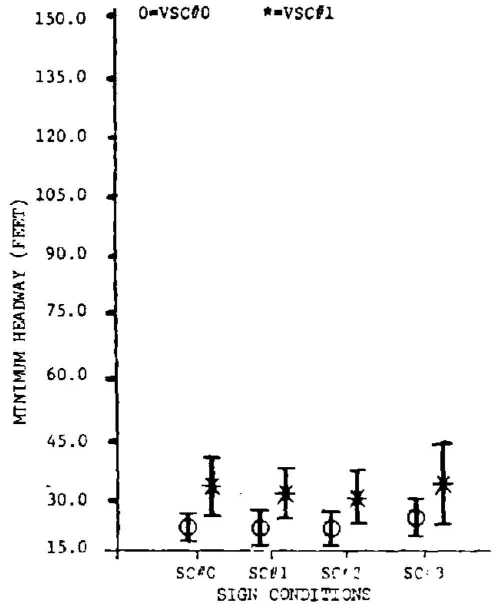


ROADSIDE SIGN CONDITIONS		VEHICLE MARKINGS		
		NONE	US STND	NZ STND
SIGN CONDITION Ø	x̄	-6.9	-7.4	-7.2
	s	1.9	2.0	3.7
	n	30	43	32
SIGN CONDITION 1	x̄	-6.4	-6.9	-6.1
	s	1.7	2.1	1.7
	n	26	24	35
SIGN CONDITION 2	x̄	-6.6	-6.3	
	s	2.2	2.0	
	n	33	35	
SIGN CONDITION 3	x̄	--	--	
	s	--	--	
	n	--	--	

SUMMARY
Overall x̄ = -6.7
Pooled s = 2.4
Total n = 257
F = 1.451(n)

Metric Conversion:
1 mph = 1.609 km/hr

FIGURE 19. DVMX (MPH) VS. ROADSIDE SIGN CONDITIONS TRACTOR, DAY, NO PASS.

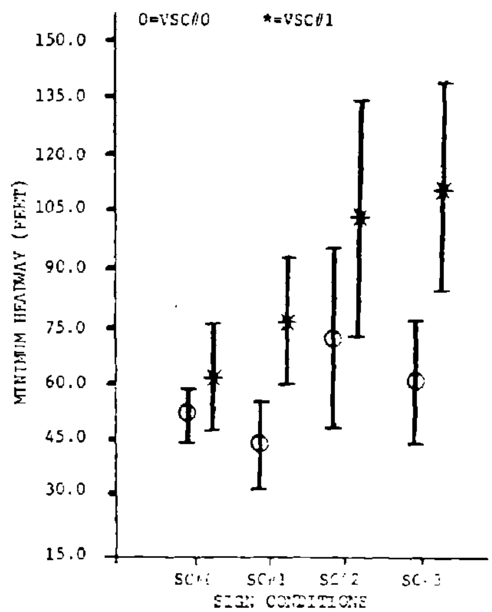


ROADSIDE SIGN CONDITIONS		VEHICLE MARKINGS NONE	FLASHERS	--
SIGN CONDITION Ø	$\bar{x}$	23.3	36.1	--
	s	19.6	28.9	--
	n	153	66	--
SIGN CONDITION 1	$\bar{x}$	22.4	33.9	--
	s	17.1	25.9	--
	n	52	66	--
SIGN CONDITION 2	$\bar{x}$	24.0	32.1	
	s	16.5	26.3	
	n	68	64	
SIGN CONDITION 3	$\bar{x}$	27.7	39.5	
	s	18.5	40.1	
	n	61	62	

SUMMARY	
Overall	$\bar{x}$ = 29.0
Pooled	s = 24.5
Total	n = 592
	F = 5.078(s)

Metric Conversion:
1 mph = 1.609 km/hr

FIGURE 20. HMIN (FT) VS. ROADSIDE SIGN CONDITIONS TRUCK 20, DAY, NO PASS.

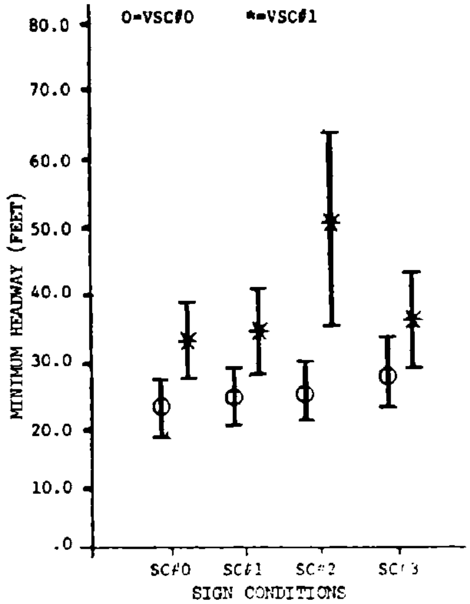


ROADSIDE SIGN CONDITIONS		VEHICLE MARKINGS NONE	FLASHERS	--
SIGN CONDITION Ø	$\bar{x}$	52.9	65.9	--
	s	45.7	64.2	--
	n	197	90	--
SIGN CONDITION 1	$\bar{x}$	44.9	76.5	--
	s	42.7	62.2	--
	n	66	66	--
SIGN CONDITION 2	$\bar{x}$	72.4	104.4	
	s	89.2	89.3	
	n	65	38	
SIGN CONDITION 3	$\bar{x}$	61.1	112.7	
	s	55.6	93.1	
	n	52	53	

SUMMARY	
Overall	$\bar{x}$ = 67.3
Pooled	s = 64.3
Total	n = 627
	F = 8.465(s)

Metric Conversion:
1 mph = 1.609 km/hr

FIGURE 21. HMIN (FT) VS. ROADSIDE SIGN CONDITIONS TRUCK 30, DAY, NO PASS.

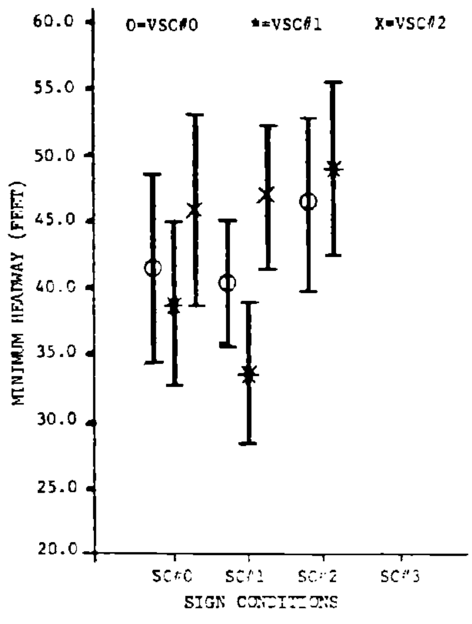


ROADSIDE SIGN CONDITIONS		VEHICLE MARKINGS		
		NONE	FLASHERS	--
SIGN CONDITION Ø	$\bar{x}$	24.1	33.7	--
	s	18.9	27.1	--
	n	66	74	--
SIGN CONDITION 1	$\bar{x}$	25.4	35.4	--
	s	20.7	32.3	--
	n	72	82	--
SIGN CONDITION 2	$\bar{x}$	25.9	51.1	
	s	20.8	58.8	
	n	69	56	
SIGN CONDITION 3	$\bar{x}$	29.1	37.6	
	s	27.3	32.0	
	n	74	70	

SUMMARY	
Overall	$\bar{x}$ = 32.4
Pooled	s = 31.1
Total	n = 563
	F = 5.045(s)

Metric Conversion:
1 mph = 1.609 km/hr

FIGURE 22. HMIN (FT) VS. ROADSIDE SIGN CONDITIONS TRUCK 20, NIGHT, NO PASS.

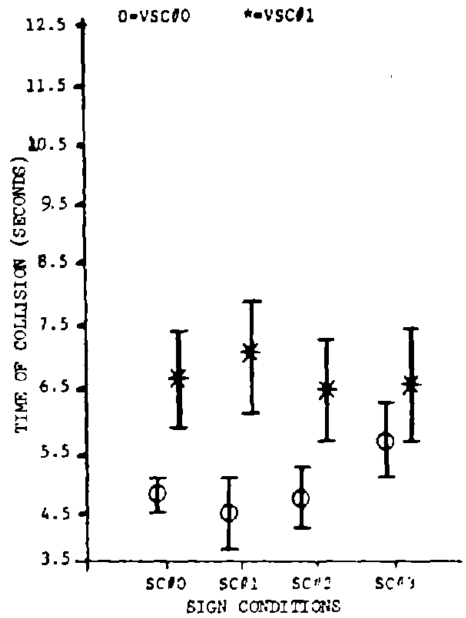


ROADSIDE SIGN CONDITIONS		VEHICLE MARKINGS		
		NONE	US STND	NZ STND
SIGN CONDITION Ø	$\bar{x}$	41.7	38.8	45.9
	s	21.1	21.9	22.3
	n	30	43	32
SIGN CONDITION 1	$\bar{x}$	40.2	33.8	46.9
	s	13.3	14.6	17.8
	n	26	24	35
SIGN CONDITION 2	$\bar{x}$	46.3	49.1	
	s	20.6	20.7	
	n	33	35	
SIGN CONDITION 3	$\bar{x}$	--	--	
	s	--	--	
	n	--	--	

SUMMARY	
Overall	$\bar{x}$ = 43.2
Pooled	s = 19.7
Total	n = 257
	F = 2.027(n)

Metric Conversion:
1 mph = 1.609 km/hr

FIGURE 23. HMIN (FT) VS. ROADSIDE SIGN CONDITIONS TRACTOR, DAY, NO PASS.

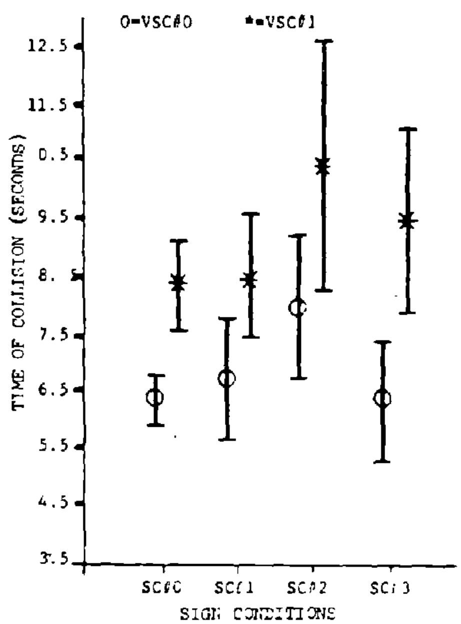


ROADSIDE SIGN CONDITIONS		VEHICLE MARKINGS		
		NONE	FLASHERS	--
SIGN CONDITION Ø	$\bar{x}$	4.8	6.7	--
	s	2.3	3.2	--
	n	153	66	--
SIGN CONDITION 1	$\bar{x}$	4.5	7.1	--
	s	2.3	3.6	--
	n	52	66	--
SIGN CONDITION 2	$\bar{x}$	4.7	6.5	
	s	2.1	3.5	
	n	68	64	
SIGN CONDITION 3	$\bar{x}$	5.7	6.6	
	s	2.5	3.7	
	n	61	62	

SUMMARY
Overall $\bar{x}$ = 5.7
Pooled s = 2.9
Total n = 592
F = 9.54(s)

Metric Conversion:
1 mph = 1.609 km/hr

FIGURE 24. TCOL (S) VS. ROADSIDE SIGN CONDITIONS TRUCK 20, DAY, NO PASS.

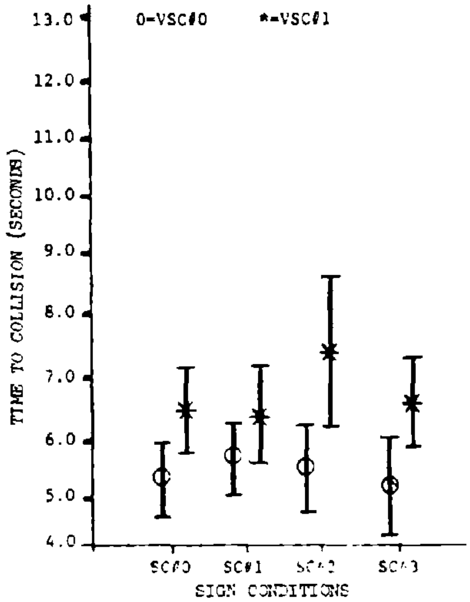


ROADSIDE SIGN CONDITIONS		VEHICLE MARKINGS		
		NONE	FLASHERS	--
SIGN CONDITION Ø	$\bar{x}$	6.3	8.4	--
	s	3.3	3.5	--
	n	197	90	--
SIGN CONDITION 1	$\bar{x}$	6.7	8.4	--
	s	4.1	4.0	--
	n	66	66	--
SIGN CONDITION 2	$\bar{x}$	7.9	10.4	
	s	5.1	6.2	
	n	65	38	
SIGN CONDITION 3	$\bar{x}$	6.3	9.4	
	s	3.6	5.5	
	n	52	53	

SUMMARY
Overall $\bar{x}$ = 7.5
Pooled s = 4.2
Total n = [illegible]
F = 8.674(s)

Metric Conversion:
1 mph = 1.609 km/hr

FIGURE 25. TCOL (S) VS. ROADSIDE SIGN CONDITIONS TRUCK 30, DAY, NO PASS.

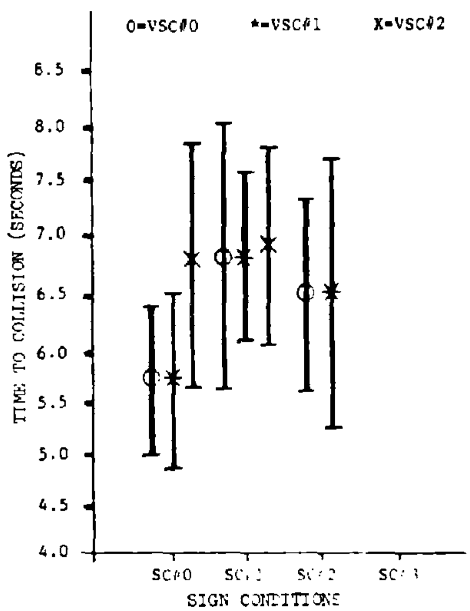


ROADSIDE SIGN CONDITIONS		VEHICLE MARKINGS: NONE	FLASHERS	--
SIGN CONDITION Ø	$\bar{x}$	5.3	6.5	--
	s	2.5	3.2	--
	n	66	74	--
SIGN CONDITION 1	$\bar{x}$	5.7	6.4	--
	s	2.9	3.9	--
	n	72	82	--
SIGN CONDITION 2	$\bar{x}$	5.5	7.4	
	s	2.9	4.5	
	n	69	56	
SIGN CONDITION 3	$\bar{x}$	5.2	6.6	
	s	3.6	3.2	
	n	74	70	

SUMMARY
Overall $\bar{x}$ = 6.1
Pooled s = 3.4
Total n = 563
F = 3.368(s)

Metric Conversion:
1 mph = 1.609 km/hr

FIGURE 26. TCOL (S) VS. ROADSIDE SIGN CONDITIONS TRUCK 20, NIGHT, NO PASS.

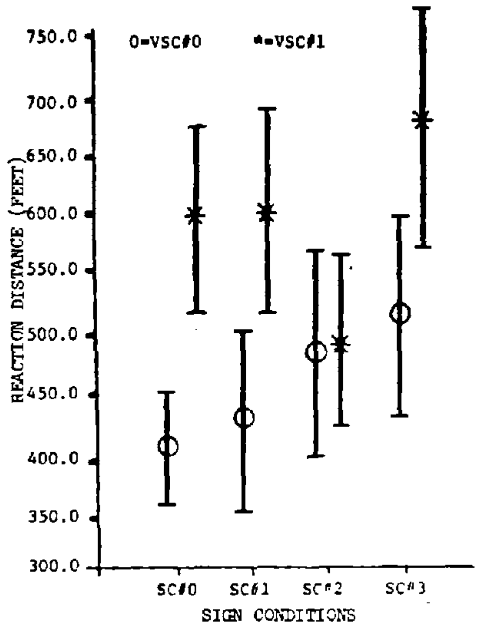


ROADSIDE SIGN CONDITIONS		VEHICLE MARKINGS: NONE	US STND	NZ STND
SIGN CONDITION Ø	$\bar{x}$	5.7	5.7	6.8
	s	1.8	2.5	2.9
	n	30	43	32
SIGN CONDITION 1	$\bar{x}$	6.8	6.1	6.9
	s	2.8	3.6	2.6
	n	26	24	35
SIGN CONDITION 2	$\bar{x}$	6.5	6.5	
	s	2.5	3.3	
	n	33	35	
SIGN CONDITION 3	$\bar{x}$	--	--	
	s	--	--	
	n	--	--	

SUMMARY
Overall $\bar{x}$ = 6.4
Pooled s = 2.6
Total n = 257
F = 1.041(n)

Metric Conversion:
1 mph = 1.609 km/hr

FIGURE 27. TCOL (S) VS. ROADSIDE SIGN CONDITIONS TRACTOR, DAY, NO PASS

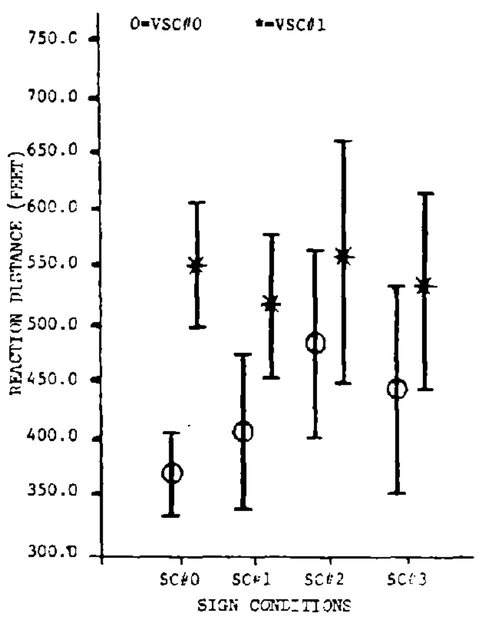


ROADSIDE SIGN CONDITIONS		VEHICLE MARKINGS NONE	FLASHERS	--
SIGN CONDITION Ø	$\bar{x}$	413.8	597.7	--
	s	291.4	311.1	--
	n	153	66	--
SIGN CONDITION 1	$\bar{x}$	437.0	603.0	--
	s	269.4	335.0	--
	n	52	66	--
SIGN CONDITION 2	$\bar{x}$	484.6	494.2	
	s	350.7	283.3	
	n	68	64	
SIGN CONDITION 3	$\bar{x}$	510.8	681.4	
	s	318.6	396.2	
	n	61	62	

SUMMARY	
Overall	$\bar{x}$ = 512.3
Pooled	s = 328.6
Total	n = 592.
	F = 6.566(s)

Metric Conversion:
1 mph = 1.609 km/hr

FIGURE 28. RDST (FT) VS. ROADSIDE SIGN CONDITIONS TRUCK 20, DAY, NO PASS.

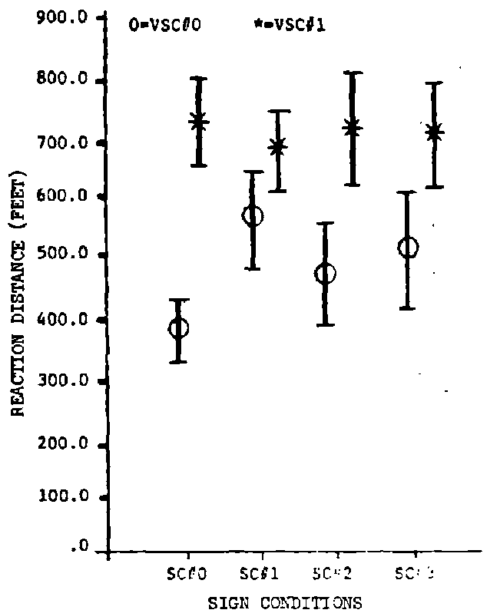


ROADSIDE SIGN CONDITIONS		VEHICLE MARKINGS NONE	FLASHERS	--
SIGN CONDITION Ø	$\bar{x}$	369.9	547.7	--
	s	236.9	245.8	--
	n	197	90	--
SIGN CONDITION 1	$\bar{x}$	406.6	514.2	--
	s	248.7	237.0	--
	n	66	66	--
SIGN CONDITION 2	$\bar{x}$	480.3	554.3	
	s	308.2	305.4	
	n	65	38	
SIGN CONDITION 3	$\bar{x}$	440.9	534.1	
	s	301.1	297.3	
	n	52	53	

SUMMARY	
Overall	$\bar{x}$ = 456.8
Pooled	s = 262.9
Total	n = 627
	F = 6.906(s)

Metric Conversion:
1 mph = 1.609 km/hr

FIGURE 29. RDST (FT) VS. ROADSIDE SIGN CONDITIONS TRUCK 30, DAY, NO PASS.

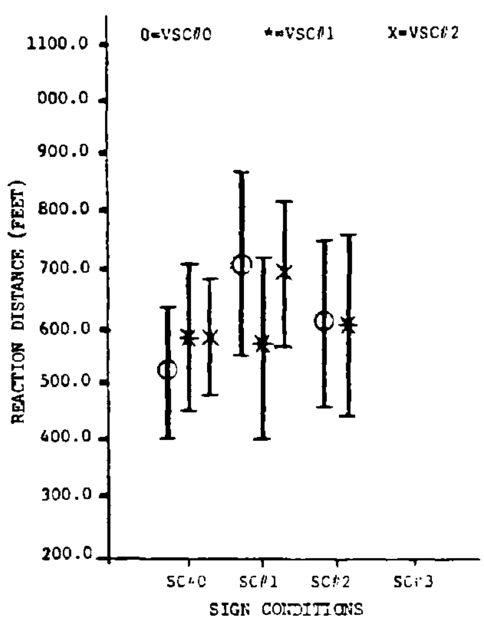


ROADSIDE SIGN CONDITIONS		VEHICLE MARKINGS		
		NONE	FLASHERS	--
SIGN CONDITION Ø	$\bar{x}$	382.0	743.4	--
	s	195.8	305.2	--
	n	66	74	
SIGN CONDITION 1	$\bar{x}$	563.2	684.1	--
	s	333.1	308.5	--
	n	72	82	--
SIGN CONDITION 2	$\bar{x}$	475.7	723.5	
	s	336.5	345.3	
	n	69	56	
SIGN CONDITION 3	$\bar{x}$	509.8	717.2	
	s	397.0	358.1	
	n	74	70	

Summary
Overall $\bar{x}$ = 600.6
Pooled s = 327.4
Total n = 563
F = 11.754(s)

Metric Conversion:
1 mph = 1.609 km/hr

FIGURE 30. RDST (FT) VS. ROADSIDE SIGN CONDITIONS TRUCK 20, NIGHT, NO PASS.

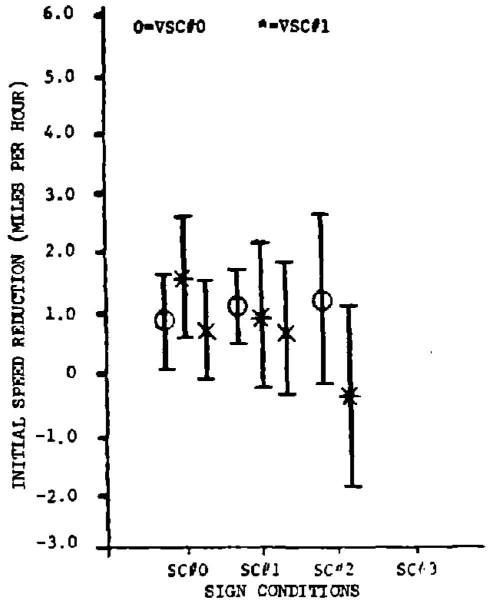


ROADSIDE SIGN CONDITIONS		VEHICLE MARKINGS		
		NONE	US STND	NZ STND
SIGN CONDITION Ø	$\bar{x}$	516.3	583.3	582.4
	s	296.2	398.4	270.7
	n	30	43	32
SIGN CONDITION 1	$\bar{x}$	701.8	560.0	690.0
	s	388.5	366.3	340.0
	n	26	24	35
SIGN CONDITION 2	$\bar{x}$	606.5	603.7	
	s	389.0	432.0	
	n	33	35	
SIGN CONDITION 3	$\bar{x}$	--	--	
	s	--	--	
	n	--	--	

Summary
Overall $\bar{x}$ = 605.6
Pooled s = 365.7
Total n = 257
F = 0.879

Metric Conversion:
1 mph = 1.609 km/hr

FIGURE 31. RDST (FT) VS. ROADSIDE SIGN CONDITIONS TRACTOR, DAY, NO PASS.

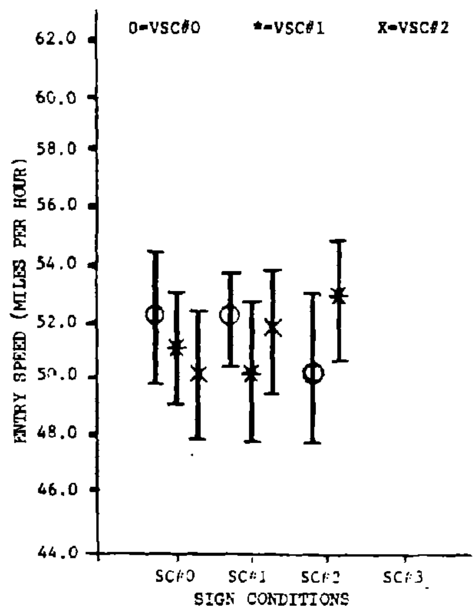


ROADSIDE SIGN CONDITIONS		VEHICLE MARKINGS		
		NONE	US STND	NZ STND
SIGN CONDITION Ø	x̄	0.9	1.6	0.7
	s	2.2	3.5	2.3
	n	26	46	29
SIGN CONDITION 1	x̄	1.1	0.9	0.7
	s	2.2	3.6	3.5
	n	44	34	36
SIGN CONDITION 2	x̄	1.2	-0.4	
	s	3.2	3.3	
	n	21	18	
SIGN CONDITION 3	x̄	--	--	
	s	--	--	
	n	--	--	

SUMMARY	
Overall	x̄ = 0.9
Pooled	s = 3.0
Total	n = 254
	F = 0.908(n)

Metric Conversion:
1 mph = 1.609 km/hr

FIGURE 32. DSEG (MPH) VS. ROADSIDE SIGN CONDITIONS TRACTOR, DAY, PASS.

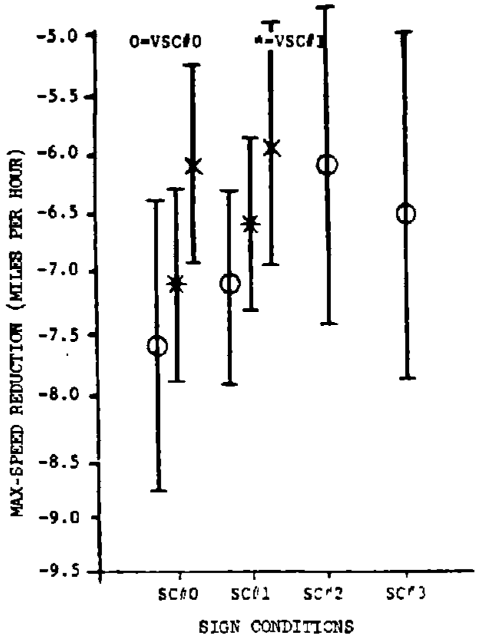


ROADSIDE SIGN CONDITIONS		VEHICLE MARKINGS		
		NONE	US STND	NZ STND
SIGN CONDITION Ø	x̄	52.6	51.0	50.6
	s	5.7	6.1	5.6
	n	26	46	29
SIGN CONDITION 1	x̄	52.2	50.5	51.8
	s	5.1	6.8	5.9
	n	44	34	36
SIGN CONDITION 2	x̄	50.6	52.9	
	s	5.8	4.3	
	n	21	18	
SIGN CONDITION 3	x̄	--	--	
	s	--	--	
	n	--	--	

SUMMARY	
Overall	x̄ = 51.5
Pooled	s = 5.8
Total	n = 254
	F = 0.764(n)

Metric Conversion:
1 mph = 1.609 km/hr

FIGURE 33. ESPD (MPH) VS. ROADSIDE SIGN CONDITIONS TRACTOR, DAY, PASS.

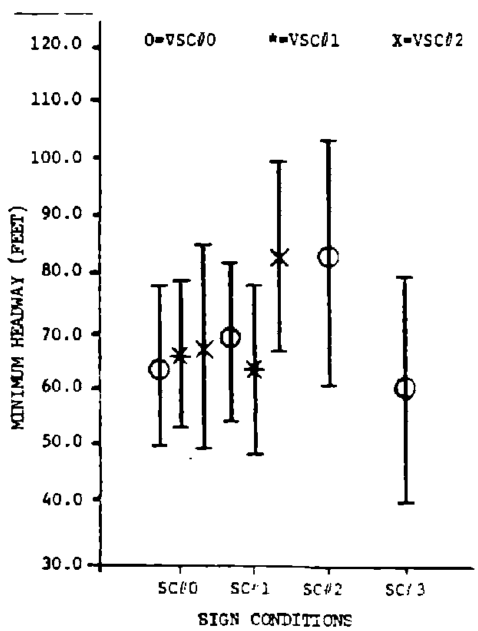


ROADSIDE SIGN CONDITIONS		VEHICLE MARKINGS		
		NONE	US STND	NZ STND
SIGN CONDITION Ø	$\bar{x}$	-7.6	-7.1	-6.1
	s	3.0	2.8	2.3
	n	26	46	29
SIGN CONDITION 1	$\bar{x}$	-7.1	-6.4	-5.9
	s	2.9	2.3	3.1
	n	44	34	36
SIGN CONDITION 2	$\bar{x}$	-6.1	-6.5	
	s	3.0	3.0	
	n	21	18	
SIGN CONDITION 3	$\bar{x}$	--	--	
	s	--	--	
	n	--	--	

SUMMARY	
Overall	$\bar{x}$ = -6.5
Pooled	s = 2.8
Total	n = 254
	F = 1.448(n)

Metric Conversion:
1 mph = 1.609 km/hr

FIGURE 34. DVMX (MPH) VS. ROADSIDE SIGN CONDITIONS TRACTOR, DAY, PASS.

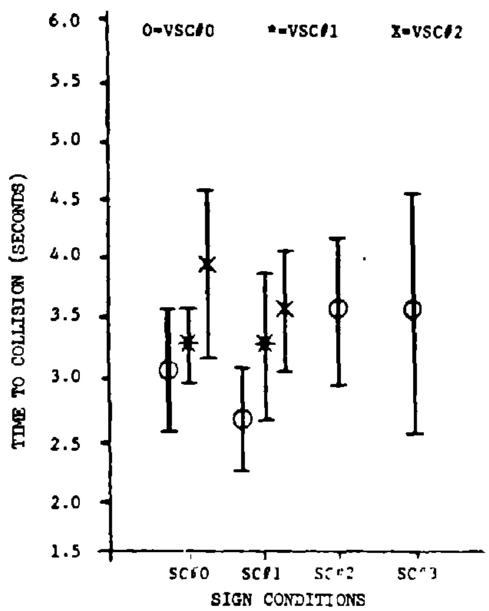


ROADSIDE SIGN CONDITIONS		VEHICLE MARKINGS		
		NONE	US STND	NZ STND
SIGN CONDITION Ø	$\bar{x}$	62.9	66.6	67.5
	s	32.8	41.6	46.0
	n	26	46	29
SIGN CONDITION 1	$\bar{x}$	68.0	63.3	82.0
	s	42.3	40.7	46.4
	n	44	34	36
SIGN CONDITION 2	$\bar{x}$	81.7	59.1	
	s	44.9	38.7	
	n	21	18	
SIGN CONDITION 3	$\bar{x}$	--	--	
	s	--	--	
	n	--	--	

SUMMARY	
Overall	$\bar{x}$ = 69.0
Pooled	s = 42.1
Total	n = 254
	F = 1.101(n)

Metric Conversion:
1 mph = 1.609 km/hr

FIGURE 35. HMIN (FT) VS. ROADSIDE SIGN CONDITIONS TRACTOR, DAY, PASS.

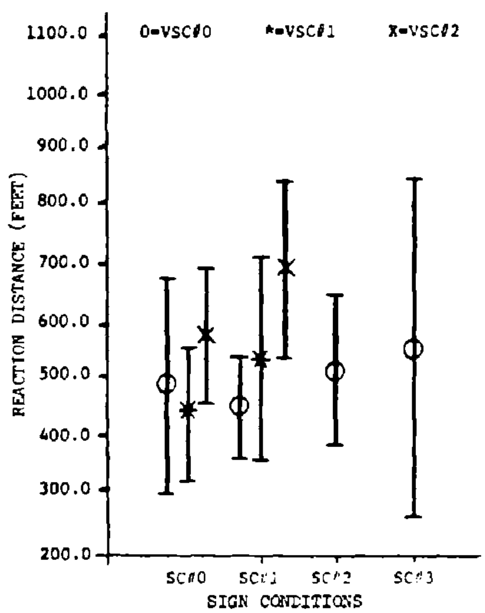


ROADSIDE SIGN CONDITIONS		VEHICLE MARKINGS		
		NONE	US STND	NZ STND
SIGN CONDITION Ø	x̄	3.1	3.3	3.9
	s	1.3	1.3	2.1
	n	26	46	29
SIGN CONDITION 1	x̄	2.7	3.3	3.6
	s	1.3	1.8	1.7
	n	44	34	36
SIGN CONDITION 2	x̄	3.6	3.6	
	s	1.4	2.1	
	n	21	18	
SIGN CONDITION 3	x̄	--	--	
	s	--	--	
	n	--	--	

SUMMARY	
Overall	x̄ = 3.3
Pooled	s = 1.6
Total	n = 254
	F = 1.866(n)

Metric Conversion:
1 mph = 1.609 km/hr

FIGURE 36. TCOL (S) VS. ROADSIDE SIGN CONDITIONS TRACTOR, DAY, PASS.



ROADSIDE SIGN CONDITIONS		VEHICLE MARKINGS		
		NONE	US STND	NZ STND
SIGN CONDITION Ø	x̄	489.8	441.4	566.9
	s	434.1	370.4	285.7
	n	26	46	29
SIGN CONDITION 1	x̄	442.0	523.2	692.2
	s	261.2	472.8	416.5
	n	44	34	36
SIGN CONDITION 2	x̄	501.6	534.2	
	s	272.3	590.4	
	n	21	18	
SIGN CONDITION 3	x̄	--	--	
	s	--	--	
	n	--	--	

SUMMARY	
Overall	x̄ = 525.9
Pooled	s = 387.6
Total	n = 254
	F = 1.845(n)

Metric Conversion:
1 mph = 1.609 km/hr

FIGURE 37. RDST (FT) VS. ROADSIDE SIGN CONDITIONS TRACTOR, DAY, PASS.

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