Effect of Nonpermanent Pavement Markings on Driver Performance

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A study was conducted to determine the effect on driver performance of different length pavement markings commonly used in work zones. The study was conducted on a divided multilane facility, and the two nonpermanent, or temporary, marking patterns examined were 0.61-m stripes with 11.59-m gaps (2-ft stripes with 38-ft gaps) and 1.22-m stripes with 10.98-m gaps (4-ft stripes with 36-ft gaps). Both of these patterns were compared with the full complement of markings [i.e., 3.05-m stripes with 9.15-m gaps (10-ft stripes with 30-ft gaps) and edge lines]. The field data collection effort consisted of following randomly selected traffic stream vehicles through a segment of roadway marked with one of the patterns noted. The maneuvers of each of the 436 vehicles followed in this manner were recorded on videotape. The tape was then used to obtain the measures of effectiveness (MOEs) necessary to evaluate driver performance as related to the pavement marking patterns. The MOEs used included lateral placement of the vehicle on the roadway, vehicle speed within the test segment, number of edge line and lane line encroachments, and number of erratic maneuvers. For each operational measure examined, the results of the analysis indicated that drivers performed better with the 3.05-m (10-ft) markings that included edge lines. This result is reasonable and was expected. However, the analysis also indicated that drivers generally performed better with the 1.22-m (4-ft) lane lines than with the 0.61-m (2-ft) lane lines, particularly under adverse weather conditions.

Road construction and maintenance operations, such as pavement overlay projects, often require the use of temporary pavement markings. Such markings must provide a level of guidance for the driver that will ensure safe travel. Using the concepts of positive guidance (i.e., combining traffic engineering and human factors technologies), the markings provided must enable a driver to determine the appropriate path and speed (*1*). If the markings are inadequate, the driver may choose an inappropriate path or speed, which may result in an accident.

Through the conduct of a large number of research and accident studies, it has been determined that the current recommended standard for permanent broken lines, either centerlines or lane lines, meets the needs of drivers in providing the appropriate level of guidance. The *Manual on Uniform Traffic Control Devices* (MUTCD) defines this standard for a broken line as a combination of stripes and gaps, usually in the ratio of 1:3, with the most typical pattern consisting of 3.05-m (10-ft) stripes and 9.15-m (30-ft) gaps (*2*).

Whereas the standards for permanent markings are widely accepted, there are varying opinions regarding temporary, short-term, or nonpermanent markings. (The MUTCD first used the term "temporary" pavement markings. In the 1988 edition of the MUTCD, the term was changed to "short-term." Currently, the term "nonpermanent" is being used in the revision of Part VI of the MUTCD now in the process of proposed rule making for final acceptance.) In a 1986 survey conducted by the Traffic Engineering Section of the Arizona Department of Transportation, it was discovered that 15 different temporary marking patterns were in use in 50 states (*3*).

This lack of consistency among states and the need to improve safety in work zones resulted in the development of the current FHWA policy on nonpermanent pavement markings. This policy was first incorporated into the MUTCD as section 6D-3 with a compliance date of January 1989. The official ruling regarding the incorporation of the new policy indicates the intention of creating uniformity and providing additional guidance with respect to nonpermanent pavement markings.

Nonpermanent pavement markings are defined in the MUTCD as "those that may be used until the earliest date when it is practical and possible to install pavement markings that meet the full MUTCD standards for pavement markings." For nonpermanent broken-line pavement markings, the MUTCD recommends 1.22-m (4-ft) stripes and 10.98-m (36-ft) gaps, with some exceptions. It is this recommended broken-line marking that is presently being questioned. Of those 50 states surveyed, 33 used markings less than 4 ft (1.22 m) or gaps longer than 10.98 m (36 ft). It is the concern in many of these states that the newly recommended standard of 1.22-m (4-ft) stripes and 10.98-m (36-ft) gaps will significantly increase project costs while not providing any additional safety benefits.

The lack of information related to nonpermanent pavement markings and the benefits and costs associated with different marking patterns makes the decisions related to policy development difficult. This study was undertaken to determine the operational effects of different marking patterns on driver behavior so that future decisions regarding nonpermanent pavement markings can be based on sound transportation engineering research.

LITERATURE REVIEW

A number of studies have been conducted examining the retroreflectivity and reliability of permanent markings and raised pavement markers (RPMs). Likewise, a large number of efforts have been undertaken to determine the effectiveness of various work zone traffic control devices, including delin-

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eators, beacons, drums, and so forth. However, few studies have examined the effectiveness of nonpermanent pavement markings. A summary of two recent research efforts in which a number of temporary pavement marking patterns were studied is presented below.

A 1986 study by Dudek et al. (*4*) examined the effectiveness of 10 temporary marking treatments (see Table 1) on various measures of driver performance under dry weather and road conditions only. All 10 treatments were tested during the day, and the 7 most effective were examined at night. Two of the most effective treatments were Treatments 1 and 2, both of which were examined in the current study. The experiment consisted of having test subjects traverse a 9.7-km (6-mi) test track, which included several horizontal curves and simulated a two-lane, two-way roadway with 3.36-m (11-ft) lanes, including a standard centerline and edge lines outside the treatment zones. The treatments studied were placed on four horizontal curves on the track, with the edge lines being dropped 153 m (500 ft) before the beginning of the curve and continuing 153 m (500 ft) after the curve (*4*).

The measures of effectiveness (MOEs) used in evaluating the treatments included

1. Speed and distance measurements, such as maximum entry speed into the curve, minimum speed while in the curve, and magnitude of the speed change;
2. Erratic maneuvers, such as lateral deviations or completely missing the curve; and
3. Subjective comments and ratings of the treatments by the drivers.

Results found by Dudek et al. pertaining to the two nonpermanent treatments examined in the current study were as follows:

- There were no practical differences between the treatments, either daytime or nighttime, in MOEs developed from speed and distance measurements. Practical differences were arbitrarily defined as at least 6.4 km/hr (4 mi/hr) for speed measures and 0.31 m (1 ft) for distance measures. There were also no significant differences in the erratic maneuver data between the two treatments.
- Treatment 2 [0.61-m (2-ft) stripes with 11.59-m (38-ft) gaps] was associated with some drivers missing the curve and with a few wide deviations to the right of the centerline. Subjectively, this treatment was rated as the least effective.
- Treatment 1 [1.22-m (4-ft) stripes with 10.98-m (36-ft) gaps], which was the baseline condition and is the current recommended standard in the MUTCD, was rated average in terms of effectiveness by the drivers during the daytime studies. The erratic maneuver data also showed that this treatment resulted in relatively few complete misses of the curve during the day, but a relatively high frequency of deviations from the centerline.
- Although Treatment 1 [1.22-m (4-ft) stripes with 10.98-m (36-ft) gaps] was not the preferred choice of drivers during the nighttime tests, the performance data did not indicate any differences between that treatment and the preferred treatments, which included the use of RPMs.

The second study related to this topic was an NCHRP research effort in which Dudek et al. compared 0.31-m, 0.61-m, and 1.22-m (1-ft, 2-ft, and 4-ft) temporary broken-line markings in work zones during the night under dry weather conditions. The field studies were conducted at seven pavement overlay projects on two-lane, two-way roadways in four states. The sites selected had 3.66-m (12-ft) lanes, paved shoulders [1.22 to 3.05 m (4 to 10 ft)], lengths ranging from 772 to 2,044 m (2,530 to 6,700 ft), and annual average daily traffic counts ranging from 2,750 vehicles to 9,600 vehicles. Each site contained a tangent section and a horizontal curve of 2.0 degrees, with the exception of one with a 3.0-degree curve. The material used for the temporary centerline markings was yellow retroreflective tape (*5*).

Traffic stream studies conducted included comparisons of operational measures among the three sets of markings. The MOEs evaluated included vehicle speeds, lateral distances from the centerline to the left front tire, centerline encroachments, and erratic maneuvers. Results from the studies showed no practical significant differences [≥6.4 km/hr (4 mi/hr)] between the three striping patterns with respect to vehicle speeds. There were also no statistical or practical differences [≥0.31 m (1 ft)] between the marking patterns in the comparison of lateral distance from the centerline. The remaining

TABLE 1 Temporary Pavement Marking Patterns Evaluated in Proving Ground Studies (*4*)

Treatment	Description
1[a]	1.22 m stripes (10.2 cm wide) with 10.98-m gaps (control condition)
2[a]	0.61-m stripes (10.2 cm wide) with 11.59-m gaps
3[a]	2.44-m stripes (10.2 cm wide) with 9.76-m gaps
4[a]	0.61-m stripes (10.2 cm wide) with 5.49-m gaps
5[a]	Four nonretroreflective RPM's at 1.02-m intervals with 9.15-m gaps and one retroreflective marker centered in alternate gaps at 24.40-m intervals
6[a]	Three nonretroreflective and one retroreflective RPM at 1.02-m intervals with 9.15-m gaps
7	0.61-m stripes (10.2 cm wide) with 14.64-m gaps
8	Treatment 2 plus RPM's at 24.40-m intervals
9[a]	Two nonretroreflective RPM's at 1.22-m intervals with 10.98-m gaps plus one retroreflective RPM centered in each 10.98-m gap
10	0.31-m stripes (10.2 cm wide) with 5.80-m gaps

[a] Treatments evaluated both day and night.
1 m = 3.28 ft; 1 cm = 0.39 in

MOEs, centerline encroachments and erratic maneuvers, were noted as being infrequent or nonexistent.

In addition to the traffic stream studies, paid driver subjects were recruited to drive through the test segments and rate the different marking patterns. The results of this effort showed no significant differences between the ratings for the three marking patterns. However, the general trend indicated that the 0.31-m (1-ft) stripe was ranked slightly poorer and that the drivers preferred the longer 1.22-m (4-ft) stripe.

In summary, these two studies produced no strong evidence to indicate that 1.22-m (4-ft) stripes with 10.98-m (36-ft) gaps were any more effective in providing driver guidance than the 0.31-m (1-ft) stripes with 11.90-m (39-ft) gaps or 0.61-m (2-ft) stripes with 11.59-m (38-ft) gaps. However, as noted by the authors of these efforts, the research conducted was limited in scope, and thus the results obtained could only be applied to those situations tested. Their suggestions for future research related to this issue included determining effectiveness of the different marking patterns under adverse weather conditions.

GENERAL RESEARCH APPROACH

The objective of this study was to determine the effect of nonpermanent pavement markings on driver performance. Three marking patterns were tested:

- 0.61-m stripes with 11.59-m gaps (2-ft stripes with 38-ft gaps),
- 1.22-m stripes with 10.98-m gaps (4-ft stripes with 36-ft gaps), and
- 3.05-m stripes with 9.15-m gaps (10-ft stripes with 30-ft gaps) and edge lines.

The first two patterns are the temporary markings examined, whereas the third scenario is the full complement of markings recommended in the MUTCD. Data were collected for all three marking patterns during day and night and under dry and wet weather conditions. (Collection of data under the full complement of markings provided a baseline performance measure, that is, an indication of how drivers normally perform with all markings present.)

The data analysis consisted of comparing a number of operational measures collected for the three marking patterns, with the principal comparison being between the two temporary marking patterns. The MOEs selected were defined to provide a clear indication of the differences in driver performance associated with the different marking patterns and included the following:

- Lateral placement of the vehicle on the roadway: Typically, drivers will attempt to center their vehicles in the travel lane. The amount of deviation from this position provides an indication of accident potential, either a run-off-road type accident to the right or a sideswipe accident to the left when the vehicle is in the right lane of a multilane facility. The lateral placement measure used in the analysis was the distance from the lane line to the center of the vehicle.
- Vehicle speed within the test segment: The speed at which a vehicle traverses the study site provides a measure directly related to the ability of the driver to determine the appropriate travel path. The inability to perform this task may result in an accident, either into another vehicle in an adjacent lane or into a fixed object off the roadway. A difference in speed between two marking patterns indicates that drivers need to travel slower under one scenario to see the markings and determine the correct path of travel. The speed selected for the analysis was the average running speed over the test segment.
- Number of edge line and lane line encroachments: These operational measures are similar to lateral placement in that they indicate the potential of an accident resulting from inappropriate lateral position. The number of encroachments occurring during each run was the measure used in the analysis.
- Number of erratic maneuvers: Occurrences such as sudden speed or directional changes and brake applications are performance variables that measure the ability of the driver to select the appropriate travel path. Making such maneuvers while driving through the test segment is indicative of a driver's inability to select a proper path on the basis of the information available (i.e., pavement markings).

The results presented in this paper are for operations on divided multilane facilities. The temporary broken-line pavement marking has two specific applications as stated in the MUTCD: to provide (*a*) white lane lines for traffic moving in the same direction on multilane facilities and (*b*) yellow centerlines on two-lane, two-way roadways where it is safe to pass.

In this research, only the lane line application on multilane facilities was examined. Since the objective of this study was to determine the operational effects of different lane line patterns without the effect of other markings, a divided multilane facility was selected as the test segment. On the basis of FHWA policy as documented in the MUTCD, the only marking present on this type of roadway under temporary conditions would be the lane line. On an undivided multilane roadway, the permanent centerline would be marked in addition to the temporary lane lines. This centerline could obviously affect driver performance and, consequently, distort any results obtained regarding the effects of the lane line.

With regard to the application of centerlines on two-lane, two-way roadways, the study by Dudek et al. (*5*) previously examined temporary pavement markings on two-lane roadways. The missing element in that effort was the effect of adverse weather conditions on driver performance. Such conditions were studied in this project and provide insight into the effects associated with different marking patterns and adverse weather conditions.

DATA COLLECTION

Site Selection

With the help of the Virginia Department of Transportation, several divided multilane sites scheduled for pavement overlay were identified. The site finally selected was a 6.4-km (4-mi) segment of southbound Interstate 85 extending from the intersection with Virginia State Route 903 (Exit 1) to the North Carolina state line (see Figure 1). The test segment with the temporary markings began 122 m (400 ft) south of

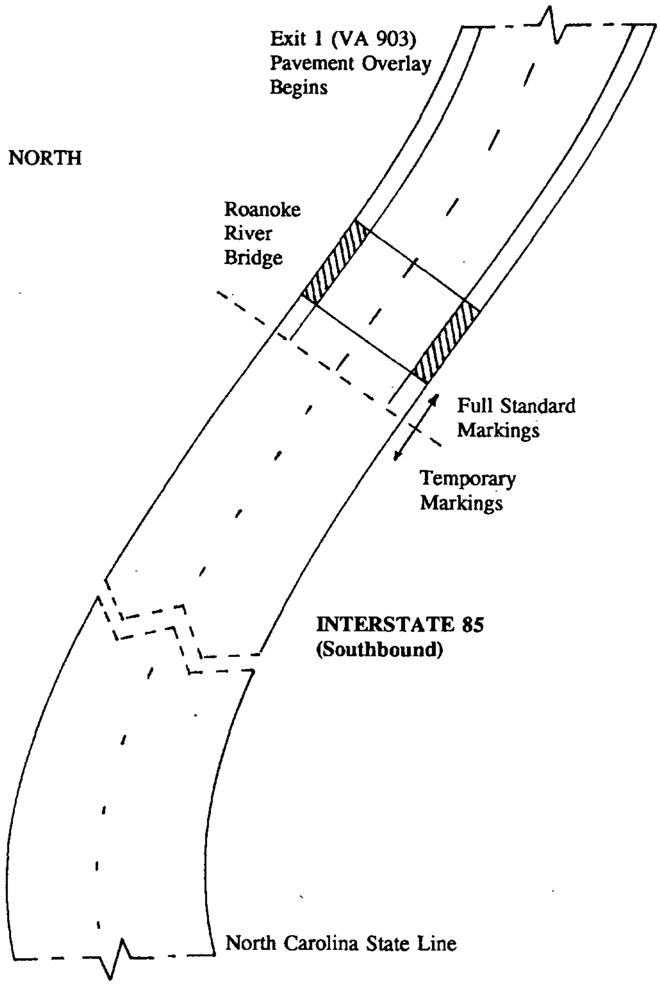


FIGURE 1 Field study site.

the Roanoke River bridge and continued to the state line with a total length of 5.0 km (3.1 mi). The terrain was relatively flat and the curvature was mild. The cross section of the roadway, once the final markings were in place, would consist of a 3.05-m (10-ft) right shoulder, two 3.66-m (12-ft) lanes, and a 1.22-m (4-ft) left shoulder.

Pavement Markings

Once the pavement overlay work was completed, the placement of the markings began. The marking material used for all three patterns tested was retroreflective paint, which was the material to be used for the permanent markings once the data collection for this research study was completed. All markings were 10.2 cm (4 in.) wide and were placed with a typical high-speed pavement marking truck in a rolling lane closure.

The first set of markings placed was the full complement of markings, as recommended in the MUTCD, from the beginning of the overlay segment to a point 122 m (400 ft) past the Roanoke River bridge. This was done as a safety measure to avoid having any temporary markings on the approach to the bridge where the shoulders tapered down to 0.61 m (2 ft) on either side. The first marking pattern [0.61-m (2-ft) stripe with 11.59-m (38-ft) gap] was then placed from the point below the bridge where the full complement of markings stopped to the state line. This pattern was left in place for 2 weeks while data were collected. The second pattern [1.22-m (4-ft) stripe with 10.98-m (36-ft) gap] was then placed over the 0.61-m (2-ft) pattern and left in place for 2 additional weeks while data were collected. The final set of data was then collected on a segment of Interstate 3.5 mi (5.6 km) long, approximately 1.6 km (1 mi) upstream of the original study site. This segment exhibited the same curvature, terrain, and cross section elements as the original study site and had also been resurfaced just before the data collection effort, which resulted in approximately the same contrast between the markings and the pavement surface as exhibited on the original test segment. The traffic characteristics (e.g., average speed, vehicle classification percentages, hourly volumes) were almost identical at the two locations. This was expected since one was immediately downstream of the other.

Field Procedures

The field data collection procedure consisted of a data collection van following and videotaping the operations of random cars in the traffic stream along the selected route. Three restrictions were placed on the vehicles selected from the traffic stream for data collection:

1. To maximize sample size, the only vehicle type selected was a passenger car (i.e., no vans, pickups, or trucks).
2. The vehicle selected had to be isolated for at least 70 percent of the segment to eliminate any influences caused by other traffic.
3. The vehicle selected had to remain in the right lane for at least 70 percent of the segment since data were collected for that lane only.

The first requirement was easily determined in the field before beginning each run. The other requirements were not determined until the data collection run was under way or completed. These requirements resulted in some aborted runs in the field and in the elimination of runs during the data reduction task.

At an on-ramp upstream of the roadway segment being used for the study, the data collection team parked and waited for traffic stream vehicles. When a passenger car of interest passed, the team pulled in behind the vehicle and closed to the necessary following distance before reaching the beginning of the study segment. Preliminary information about the vehicle, such as body style, color, and taillight description, was recorded to help match the vehicles on the videotape with the appropriate run number during data reduction.

When the data collection team reached the beginning of the study segment, the distance measuring instrument (DMI), stopwatch, and videocassette recorder were started, and they continued to run through the entire segment. The videotape provided a continuous real-time record of the operations of each vehicle followed as it traversed the roadway and allowed for the acquisition of all MOEs in the office.

For those runs conducted in wet weather, an additional variable was collected, which subjectively gauged the intensity of the rainfall or the road conditions. The two-member data collection team jointly selected one of the following factors during each run: wet road, splash/spray, light rainfall, medium rainfall, or heavy rainfall.

The total number of passenger cars for which data were collected in the above manner was 436. A breakdown of these runs by weather and light condition is given in Table 2. Whereas the goal was to obtain 45 runs for each of the 12 cells, the amount of time allowed between the deployment of the different marking patterns (2 weeks) and the sporadic rainfall limited the number of runs in the wet weather cells for the 0.61-m (2-ft) and 1.22-m (4-ft) patterns.

DATA REDUCTION

Obtaining the operational measures to be analyzed from the collected data consisted of three basic steps: recording lateral placement from the video images, recording encroachments and erratic maneuvers from the videotape, and determining average running speed.

Lateral Placement

Determining the lateral placement of each followed vehicle began with the determination of vehicle width. During the field data collection effort, several measurement points were selected for this purpose. At each of these points, lane widths, shoulder widths, distances to guardrails, and other points of reference were precisely measured. Video images were produced from two of these points for each vehicle. The widths of the vehicle and the lane (or other reference) in the video image were measured, recorded on the data reduction form, and used to determine the actual vehicle width as follows:

$$C = (W/w) \times c$$

where

C = actual car width,
W = actual reference width,
c = measured car width, and
w = measured reference width.

For each vehicle, video images were then produced for each point at which lateral placement was to be measured. A total of eight points were selected within the segment to be representative of the geometric characteristics of the roadway. From each video image, the car width and distance from the centerline to the outside edge of the left rear tire were measured as shown in Figure 2 and recorded on the data reduction form. The actual distance from the centerline was then computed as follows:

$$D = (C/c) \times d$$

where

D = actual distance from the lane line,
C = actual car width,
c = measured car width, and
d = measured distance from the lane line.

Encroachments and Erratic Maneuvers

A second run through the videotape was conducted to record encroachments and erratic maneuvers. An encroachment was defined as occurring when the outside edge of the rear tire

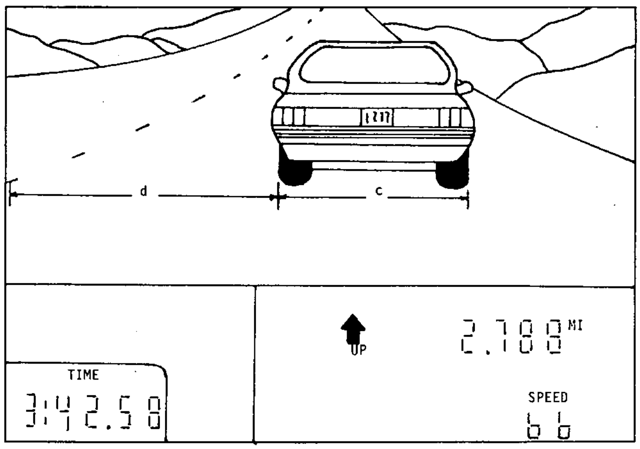


FIGURE 2 Measurements obtained from the video image for computing lateral placement.

TABLE 2 Number of Passenger Cars Followed

Stripe Length	Light Condition	Weather Condition Day	Night
0.61 m	Day	45	15
	Night	45	28
1.22 m	Day	45	20
	Night	37	21
3.05 m	Day	45	45
	Night	45	45

1 m = 3.28 ft

of the vehicle being followed crossed the outside edge of the lane line or edge line. For the temporary marking patterns, there was no edge line present. In those cases, the seam in the pavement served as a surrogate. This seam was consistently 3.66 m (12 ft) from the lane line and would eventually serve as a guide for placing the edge line. For each encroachment observed during a run, beginning and ending mileposts (from the DMI) and times (from the stopwatch) were recorded on the data reduction form along with the type of encroachment (lane line or edge line).

Whereas lateral placement and encroachments serve as objective measures of vehicle performance, erratic maneuvers are more subjective in nature. For purposes of this study, three events were classified as erratic maneuvers: brake applications, sudden speed changes of 8 km/hr (5 mi/hr) or greater, and sudden directional changes. Each event was recorded on a form indicating the type of erratic maneuver and the location where it occurred (DMI reading).

Running Speeds

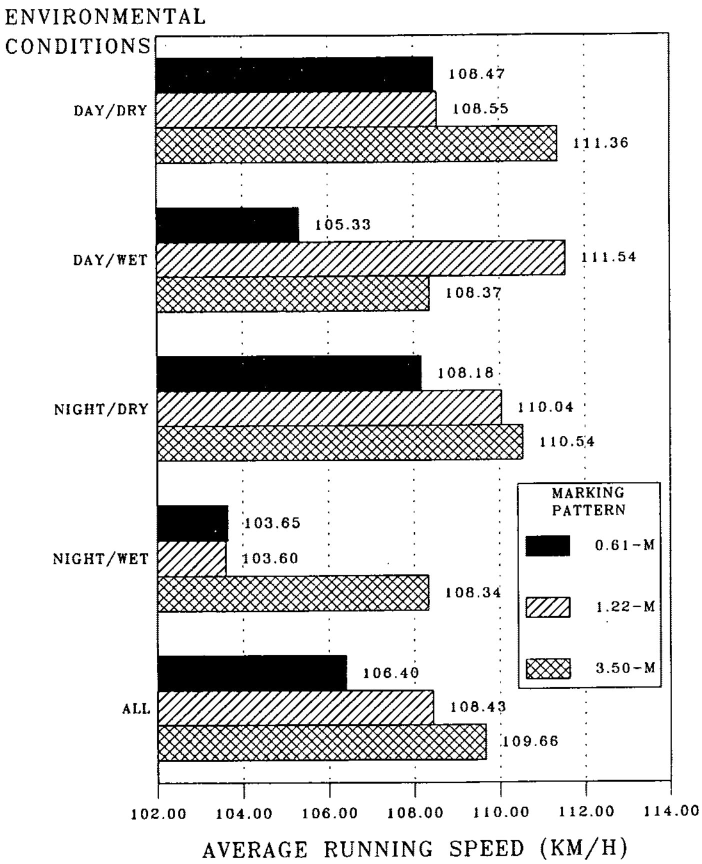
The final MOE obtained from the videotape was the average running speed. At the start of the second run through the tape, the time at which the vehicle entered the test segment (shown on the stopwatch) was recorded. The time at which the vehicle exited the segment was also recorded. Using these values and the known distance between the two points (obtained from the DMI), the average running speed was calculated for each vehicle followed.

DATA ANALYSIS AND RESULTS

The mean values for each of the collected MOEs by pavement marking pattern and environmental condition (time of day/weather) are shown in Figures 3 through 6. The statistical analysis of the data consisted of a number of procedures, including analysis of variance (ANOVA). For all analyses, a 95 percent confidence level was selected to determine whether a class variable (e.g., pavement marking pattern) had a significant effect on an MOE.

The primary issue addressed in this study was, What effect does pavement marking pattern have on driver performance? A summary of the results from the analysis indicated the following:

- There were significant differences between the average running speeds of vehicles when comparing the 3.05-m (10-ft) marking pattern with the 0.61-m (2-ft) pattern. There were no significant differences in speeds when comparing the 1.22-m (4-ft) marking pattern with either the 3.05-m (10-ft) or the



1 km/h = 0.62 mi/h; 1 m = 3.28 ft

FIGURE 3 Average running speeds.

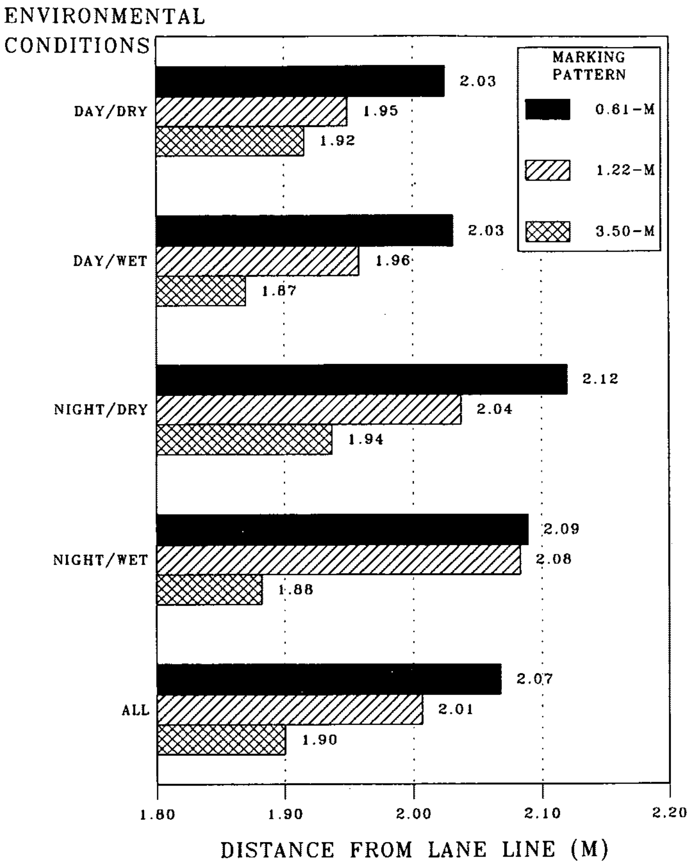


FIGURE 4 Mean distance from the lane line to the center of the vehicle.

0.61-m (2-ft) pattern. Overall, travel speeds were reduced as the length of the marking became shorter (see Figure 3).

- The lateral placement MOE, distance from the lane line to the central axis of the vehicle, proved to be significantly different for the 3.05-m (10-ft) marking pattern compared with either the 0.61-m (2-ft) or 1.22-m (4-ft) pattern. The differences for the 0.61-m versus 1.22-m (2-ft versus 4-ft) patterns, however, were not significantly different. The general trend was for drivers to position their vehicles closer to the center of the lane [i.e., 1.83 m (6 ft) from the lane line] as the length of the marking was increased (see Figure 4).
- Lane placement variance, which served as a measure of a driver's ability to traverse the roadway in a consistent manner, proved to be significantly different for the three marking patterns. The results indicated an increase in lane placement variability as the length of the marking was reduced (see Figure 5).
- The differences between the average number of edge line and lane line encroachments for the three marking patterns were significantly different and revealed that drivers tended to stray out of the travel lane more frequently as the marking was reduced in length (see Figure 6).

In addressing the primary issue above, the data collection and analyses were structured to determine the effects of marking pattern with respect to two secondary issues: day versus night and weather conditions. A summary of the results from the analysis as related to these issues is given below.

What effect does day versus night have on vehicle operations with respect to pavement marking pattern?

- Whereas the data showed speeds to be generally lower at night than during the day, there were no significant differences between the three marking patterns that could be attributed to time of day.
- Drivers positioned their vehicles closer to the center of the lane during the day than at night for all three marking patterns. However, these differences were not statistically significant with respect to the length of the marking.
- The variance in lane placement was significantly greater for night conditions. The results indicated that the difference in variance between day and night for the 3.05-m (10-ft) pattern was relatively small compared with the 0.61-m (2-ft) and 1.22-m (4-ft) patterns. The difference in variance between day and night for the 0.61-m (2-ft) and 1.22-m (4-ft) patterns was relatively the same.
- The number of encroachments per run during the night was significantly different from the number that occurred during the day. The results revealed higher values at night for each marking pattern.

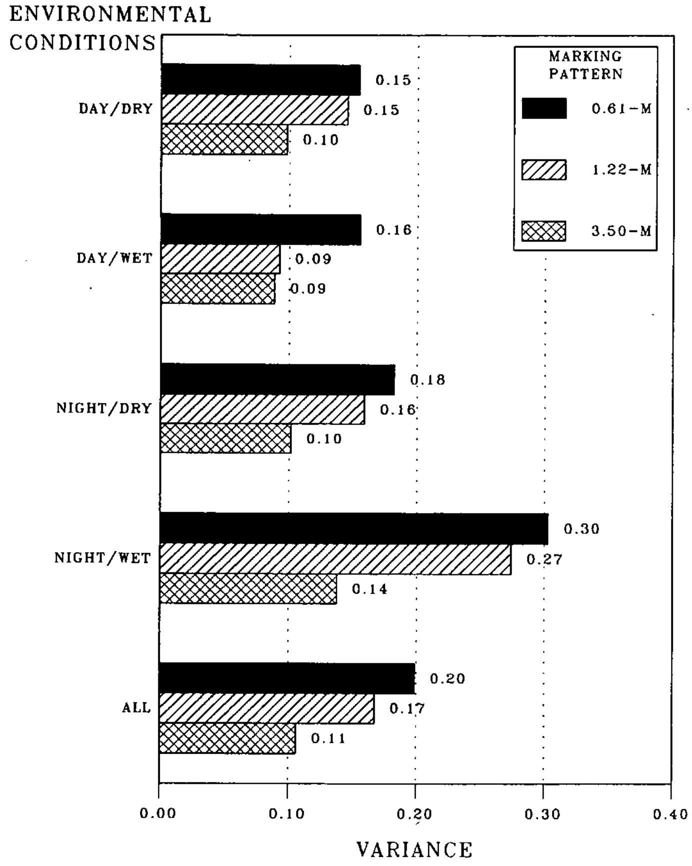


FIGURE 5 Average lateral placement variance.

What effect does adverse weather (i.e., rain and wet road conditions) have on driver performance with respect to pavement marking pattern?

- The effects of weather, specifically rain, on the differences in average running speeds between the three marking patterns were mixed. There were significant differences between the 3.05-m (10-ft) and 0.61-m (2-ft) patterns. There were no significant differences between the 3.05-m (10-ft) and 1.22-m (4-ft) patterns. Finally, the differences in speeds between the 0.61-m (2-ft) and 1.22-m (4-ft) patterns were not significant, but they did reveal some effects that could be attributed to weather conditions. In general, speeds were lower for wet weather conditions than for dry conditions for each marking pattern.
- The effects of weather on differences in lateral placement (i.e., the ability of drivers to center their vehicles in the travel lane) between the three marking patterns were insignificant. There was no consistent pattern for this measure when examining wet and dry conditions, and the actual differences were relatively small.
- The impact of weather on lane placement variance was significant. This confirmed earlier results that showed lane placement variability to increase as the length of the marking decreased and emphasized the impact of rain on this measure.
- The number of encroachments per run was significantly different for dry and wet weather conditions. The data revealed a slight decrease in the number as a result of wet weather conditions.

CONCLUSIONS

For each operational measure examined, the 3.05-m (10-ft) marking pattern generally resulted in better driver performance than either the 0.61-m (2-ft) or 1.22-m (4-ft) pattern. This result is reasonable and was expected, since the 3.05-m (10-ft) pattern consisted not only of longer stripes but also contained edge lines, the standard full complement of markings recommended in the MUTCD.

Comparisons against this scenario provided indications of the differences to be expected when drivers encounter nonstandard markings. For example, on the basis of data in this study, drivers would travel 1.22 km/hr (0.76 mi/hr) slower on a segment with 1.22-m (4-ft) stripes and 3.25 km/hr (2.02 mi/hr) slower on a segment with 0.61-m (2-ft) stripes than they would on the same roadway segment fully marked.

The differences are even more significant when examining encroachments. Drivers are likely to encroach over the lane line or edge line 66 percent more in the presence of a 1.22-

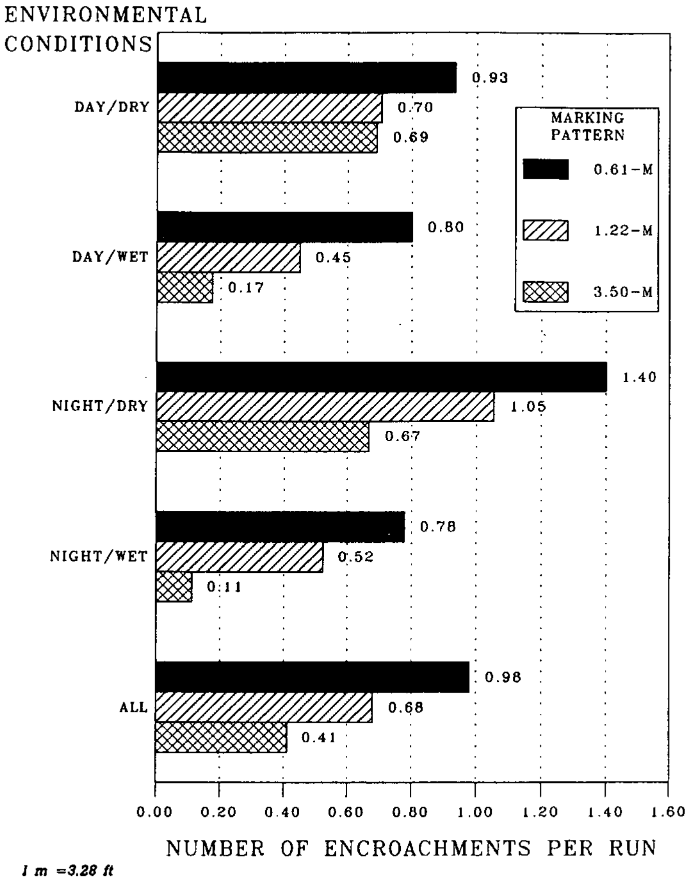


FIGURE 6 Average number of encroachments per run.

m (4-ft) temporary marking and 139 percent more in the presence of a 0.61-m (2-ft) marking than in the presence of the 3.05-m (10-ft) pattern. These values increase dramatically under night and wet weather conditions.

Overall, the results provide evidence of significant decreases in driver performance associated with either of the temporary marking patterns tested. Whereas it may not always be feasible to place full markings on a temporary basis, measures should be taken to prevent reductions in driver performance that result in increased accident potential. Such measures include the use of longer temporary markings and the appropriate use of advance warning signs to indicate a change in the pavement marking pattern.

A comparison of the operational measures for the two temporary marking patterns [0.61-m (2-ft) versus 1.22-m (4-ft)] indicates that there were not a large number of statistical differences, largely because of the small sample size. However, certain trends existed with respect to driver performance:

- The speed at which drivers traveled decreased as the length of the lane line decreased.
- Drivers positioned their vehicles closer to the center of the lane as the length of the lane line increased.
- The variability of vehicle placement within the lane increased as the length of the lane line decreased.
- The number of encroachments increased as the length of the lane line decreased.
- All operational measures were negatively affected by adverse weather conditions.

The cumulative results of these trends indicate that drivers performed better with the 1.22-m (4-ft) stripes than with the 0.61-m (2-ft) stripes. The number of encroachments per run is an operational measure that illustrates the differences in the two marking patterns (see Figure 6). Under dry weather conditions, day and night, the number of encroachments is 33 percent higher for the 0.61-m (2-ft) pattern than for the 1.22-m (4-ft) pattern. This value increases to 50 percent for nighttime/wet weather conditions and 77 percent for daytime/wet weather conditions.

As in any operational study, it is difficult to directly translate differences in operational measures to accident potential, since the link between the two has not been clearly established. However, the operational measures examined in this study provide an indication of a driver's ability to choose and maintain a correct path and speed, thus reducing the risk of being involved in an accident. The differences in operational measures associated with each of the temporary marking patterns show that drivers maintain higher speeds, position their vehicles closer to the center of the lane, have less variance in their lane placement as they traverse the roadway segment, and have fewer encroachments with the 1.22-m (4-ft) stripe than with the the 0.61-m (2-ft) stripe. Combining these results, it becomes apparent that drivers have more confidence with the longer temporary marking, resulting in a safer driving environment.

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