AN EVALUATION OF THE 10:30 CENTERLINE MARKING PATTERN

by

William E. Oliver
Research Assistant

(The opinions, findings, and conclusions expressed in this report are those of the author and not necessarily those of the sponsoring agencies.)

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ABSTRACT

In response to Value Engineering Proposal #M-26, a study of the feasibility of adopting a 10 ft. mark - 30 ft. gap centerline pattern for use on 2- and 4-lane rural roads was conducted. The study included a literature review, field studies of traffic speed and lateral placement on rural highways, a motorist opinion survey, an estimation of expected monetary savings, and a discussion of operational problems and implementation strategies. In terms of traffic performance and public reaction, it was found that no significant differences exist between the 10:30 pattern and the currently used 15:25 pattern, and that annual savings of from $50,500 to $89,500 are possible if the 10:30 pattern is used. It was recommended that the Department of Highways and Transportation adopt the 10:30 centerline marking pattern on all rural highways.

SUMMARY OF FINDINGS

Literature Survey

The literature search revealed that the recommendations regarding the centerline pattern in the Manual on Uniform Traffic Control Devices are permissive and do not constitute standards. California, Minnesota, Montana, Texas, and Pennsylvania have adopted patterns other than the 15:25 ratio. The 10:30 pattern is in use in Texas and Pennsylvania, while Minnesota uses a more economical 10:40 pattern. To date, no adverse reaction to these patterns has been encountered.

Field Studies

At the data collection sites, it was found that speeds on roads with the 10:30 pattern were from two to four miles per hour greater than on those with the 15:25 pattern. These differences were statistically significant. A tendency for the standard deviations of speeds to be less on the 10:30 pattern than on the 15:25 pattern was found during the day, but no difference between the patterns was found at night.

Placement data indicated that during the day there was a tendency for motorists to drive closer to the centerline with the 10:30 pattern than with the 15:25 pattern. At night, no consistent difference between the two patterns was recorded.

Motorist Opinion Survey

The following results are based on data collected during roadside motorist interviews

1. Over 96% of the motorists who were driving on the 10:30 pattern did not notice that the pattern had been changed from 15:25.

2. Of the respondents who were aware of the different pattern, the 10:30 pattern was preferred by a 7 to 1 margin. The percentage of motorists approving the pattern for daytime use was larger than the percentage approving it for nighttime use.

Economic Evaluation

Based on the assumptions used in the analysis, possible savings of from $50,500 to $89,500 per year can be realized by changing to the 10:30 pattern. This estimate is based on 1976 prices and road mileages.

Operational Evaluation

Most of the paint trucks in Virginia can be adjusted to paint the 10:30 pattern. One problem that would have to be dealt with is that the trucks which can be adjusted are too wide for use in painting narrow secondary roads. These roads are marked by older trucks that cannot be easily modified. Replacement of these older trucks with small trucks that can paint the 10:30 pattern on narrow roads will be necessary.

There is no apparent reason why the 10:30 pattern cannot be used to retrace existing 15:25 centerlines, or be used to centerline unmarked highways.

CONCLUSIONS AND RECOMMENDATIONS

From the results of the field studies and motorist interviews, it was concluded that there is no major difference between the 10:30 centerline pattern and the 15:25 pattern. On the basis of the literature survey and operational evaluation, no foreseeable problems will arise if the 10:30 pattern is adopted. An annual savings of from $50,500 to $89,500 is possible if the 10:30 pattern is used.

It is recommended that Virginia implement the 10:30 centerline pattern on rural highways. In order to realize the monetary savings as soon as possible, marking and retracing operations should be immediately changed to the 10:30 pattern. In the case of narrow pavements, the 15:25 pattern should be continued until the unmodifiable equipment has been replaced.

It is also recommended that further study be conducted to evaluate the 10:30 pattern in urban areas, with consideration being given to use of the 1:3 ratio in different module lengths.

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INTRODUCTION

Reflectorized pavement markings are used to delineate traffic lanes, provide a guidance system for motorists, outline safe passing zones, and convey other information to aid the driver in controlling his vehicle. National emphasis was placed on the importance of pavement markings by Congress in Section 205 of the Highway Safety Act of 1973, which established a pavement marking demonstration program "to enable the several states to improve the pavement marking to all highways to provide for greater vehicle and pedestrian safety."(1) Nearly $5 million were appropriated in the federal program for Virginia.

The importance of pavement markings to vehicle control was emphasized by D. A. Gordon, who found that "the essential information required by the driver is provided by the edge and center lane markings. It was found that 98.2% of (driver's eye) fixations made using a small (4^{o}) aperture, and 100% of those made with a larger ($9\text{-}3/4^{o}$) aperture included at least one of these road features."(2)

The current centerline marking practice, as outlined in the Manual on Uniform Traffic Control Devices, is to paint a 15-ft. line followed by a 25-ft. gap.(3) The 15:25 centerline pattern appears to have originated from early marking practices and does not seem to be founded on any scientific principle.(1)

During the energy crisis of 1973-74, the cost of traffic paint doubled and suppliers were unable to furnish most states with enough paint to accomplish normal pavement marking operations. Because of the materials shortage and the need to provide an adequate delineation system for highway safety, several states experimented with alternative painting patterns. One of the techniques suggested for conserving traffic paint was to change the mark-to-gap ratio for centerlines where passing maneuvers are permitted in rural areas.

One of the findings of a National Cooperative Highway Research Program study of roadway delineation systems was that the mark-to-gap ratio for centerlines should be decreased from the present standards. "This would result in a savings in paint material costs."(1) The study also recommended "that more extensive field studies be conducted in the United States to determine the optimum mark and gap lengths."

In the interest of conserving paint and providing a delineation system that would convey the same meaning as the current 15:25 marking pattern, W. A. Carpenter, research engineer, submitted value engineering proposal #M-26 to the Management Services Division of the Virginia Department of Highways and Transportation. The proposal, shown in Appendix A, suggested an evaluation of a test section of highways marked with the 10:30 centerline pattern. Potential benefits of the new pattern would be an estimated annual savings of $117,000 in painting costs for highway systems under the jurisdiction of the Department.

As a result of Proposal #M-26, the Research Council was requested to evaluate the effectiveness of the 10:30 marking pattern. This report presents the results of the evaluation.

PURPOSE AND SCOPE

The purpose of the study was to examine the feasibility of using the 10:30 centerline marking pattern on rural highways in Virginia. The emphasis of the research was a comparison of traffic characteristics, viz., speed and lateral placement, observed for the standard 15:25 pattern and those associated with the 10:30 ratio.

The specific objectives of the study were to—

1. determine if significant differences exist between driver performance on the standard 15:25 marking pattern and the 10:30 pattern;
2. examine public reaction to the 10:30 ratio;
3. provide an economic analysis of the 10:30 ratio in terms of tangible savings; and
4. outline operational problems associated with a change in centerline marking patterns.

The scope of the study included:

1. A literature review,

2. field studies at three sites designed to collect traffic variables for the standard and the new test pattern on 2- and 4-lane facilities,

3. a motorist opinion survey at the test sites,

4. an economic analysis, and

5. an analysis of the operational problems expected to be encountered in adopting the 10:30 paint pattern.

It is recognized that the 10:30 pattern may not be the optimum mark-to-gap ratio when costs are compared to driver performance measures. However, the 10:30 pattern offers a 33% reduction in centerline paint cost when compared to the standard 15:25 ratio. The study was limited to an evaluation of the 10:30 ratio due to constraints on manpower. Also due to manpower constraints, the study did not encompass an evaluation of the 10:30 pattern in urban areas; data collection was limited to only three rural sites.

An accident analysis of the test sections was not conducted because it was the intent of the Council to complete this feasibility study prior to the 1977 maintenance resurfacing season. Before and after accident analyses usually require a year or more of data in each phase before an evaluation can be conducted. A supplemental report will include an accident analysis of the 10:30 pattern.

METHODOLOGY

The study was conducted in accordance with the major activities described below.

Literature Survey

A survey of current practices in centerline marking was initiated through the Highway Research Information Service. In addition, information from states known to be using modified patterns was solicited.

Field Studies

Before and after measurements of traffic performance, viz., speed and lateral placement, were made. Three sections of road, two 4-lane divided highways and one 2-lane highway, scheduled to be resurfaced were chosen. On the 4-lane divided highways, speed and lateral placement measurements were taken with the 15:25 pattern on the road. The roads were then resurfaced and marked with the 10:30 pattern. Speeds and lateral placements were then measured again at the same locations.

Traffic performance data were collected on the 2-lane highway by William Stimpson of Alan M. Voorhees and Assoc., who is conducting an investigation of roadway delineation treatments for the Federal Highway Administration. All data were collected on the resurfaced road. The 10:30 pattern was marked and the data were collected, then the road was retraced with the usual 15:25 pattern and data were again collected.

The three sites chosen cannot accurately represent all of the geometric and traffic situations of roads in Virginia. They can provide only an indication of how the 10:30 pattern compares to the usual 15:25 at the specific test sites. The sites were chosen, following the guidelines below, so that as few confounding variables as possible would enter into the comparisons.

Site Selection

The following criteria were used to select test sites for the evaluation.

1. The sites included 2- and 4-lane rural highways scheduled for resurfacing in 1976. The lengths of the resurfaced sections were in excess of 4 miles.

2. The 15:25 marking pattern was clearly discernible to motorists before resurfacing.

3. The test sites had tangent sections 1,500 ft. or greater in length.

4. The pavement width was between 20 ft. and 24 ft.

5. Standard 4-inch continuous edgelines were provided for both the standard and test patterns.

6. Traffic volumes were sufficient to permit an adequate sampling in a reasonable period of time.

Four-Lane Divided Sites

Route 29, northbound lanes, 18 miles north of Danville. A 6.15-mile segment from Route 719 (MP 13.00) to one mile north of Route 718 (MP 19.15) in mildly rolling terrain was resurfaced. The point of data collection was located on a 1-mile tangent at MP 18.80, about 500 ft. beyond the entrance to an automobile dealership, and 80 ft. before a median crossover. The pavement width was 24 ft. and the posted speed limit was 55 mph.

Route 58, westbound lanes, 2.65 miles east of Danville ECL. A 4.12-mile segment from Route 734 (MP 5.75) to the ECL of Danville (MP 9.87) in rolling terrain was resurfaced. The point of data collection was at the crest of a vertical curve at MP 7.22, 1.47 miles into the resurfaced section. The posted speed limit was 55 mph and the pavement width was 24 ft.

Two-Lane Highway Site

Route 3, 0.66 mile east of Culpeper ECL. A 5.83-mile section of 21-ft. wide pavement from Route 522 (MP 12.61) to Route 739 (MP 6.78) in gently rolling terrain was resurfaced. The points of data collection were located in the eastbound lane at MP 8.83 (site A) and MP 10.03 (site B). The posted speed limit was 55 mph.

Data Collection

To examine the effects of centerline marking patterns on vehicle speeds and lateral placement, traffic data were collected using tapeswitches and recording devices.

On the 4-lane highways, two speed switches were placed in the traffic lane and in the passing lane as shown in Figure 1. As a vehicle hit the switches, the event was recorded on a moving paper tape. The speed of each vehicle was calculated as follows:

$$\text{Speed}_{\text{mph}} = \frac{3600}{5280}\left(\frac{dv}{m}\right)$$

where,

d = distance between speed switches (ft.),

v = speed of paper tape (mm/sec.), and

m = distance between recorded marks on paper tape (mm).

The lateral placement of each vehicle was measured from the inside of the edgeline in increments of 1 foot. If a vehicle hit the placement switch between 1 and 2 ft. from the edgeline, the placement was recorded as 1.5 ft. for purposes of calculation. The placement switch was located between the two speed switches. The switches were not conspicuous to the motorists and the data collection equipment and crew were concealed in order not to influence motorist behavior.

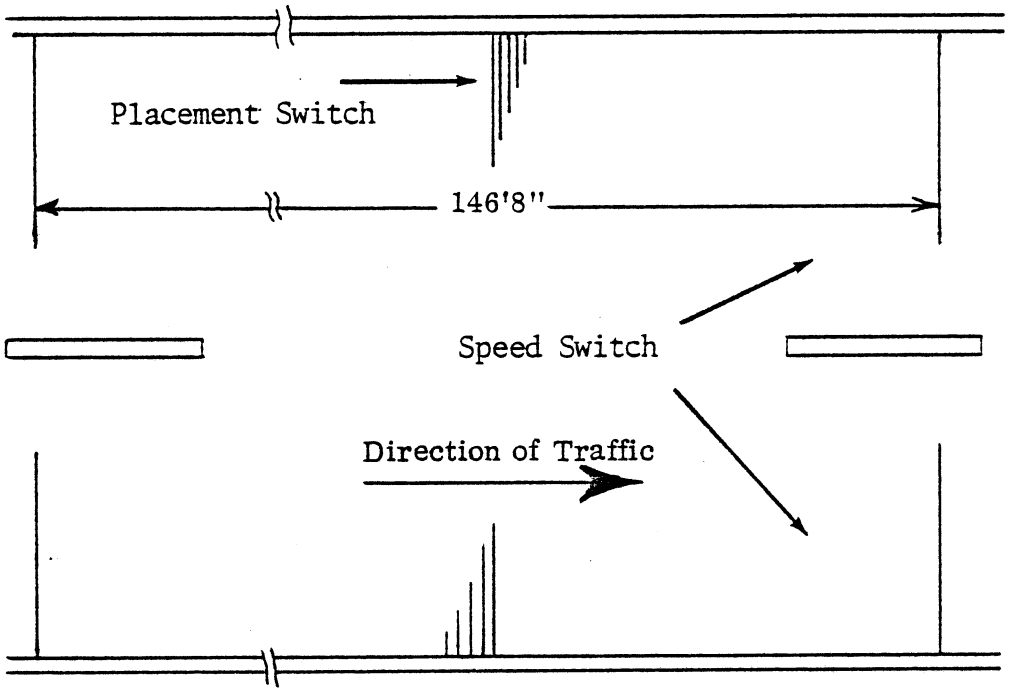

Figure 1. Schematic diagram of speed and placement trap.

The data collection apparatus used on the 2-lane highway utilized pairs of resistance-based tapeswitches. At each site, two speed and placement traps were installed about 600 ft. apart. A vehicle placement and event monitor contained high precision digital clocks to collect data for speed calculations and D'Arsonval meters for lateral placement measurement. The expected error in speed measurement was $\pm$ 2 mph; that for lateral placement was 0.25 to 0.50 ft.

Motorist Opinion Survey

The purpose of the questionnaire was to determine if the motorists interviewed had noticed any changes in the road after it was resurfaced and marked with the 10:30 pattern. An

open-ended question allowed the respondent to indicate what changes he noticed. A direct question as to whether or not the motorist noticed the different centerline marking pattern was also asked. Finally, the opinions of those motorists who noticed the 10:30 pattern were solicited concerning their preference for either pattern.

The questionnaire, shown in Appendix B, was administered at least two months after the roads had been resurfaced, and no less than 300 responses were gathered on each road at the same locations that the speed and placement data were collected.

Economic Analysis

An estimation of the possible annual savings from adopting the 10:30 pattern was made. An investigation of paint and glass bead costs was made with the assistance of the Purchasing Division of the Department. Estimates of the volume of paint used for the 15:25 pattern were obtained from district traffic engineers to determine the volume of paint which would be conserved with the 10:30 pattern.

Operational Evaluation

District traffic engineers were contacted to determine problems that would be encountered in a changeover in centerline marking patterns. The evaluation included aesthetic concerns, equipment adjustment requirements, and several schemes that could be used to convert to the 10:30 pattern.

ANALYSIS

Literature Survey

The Highway Research Information Service search of published reports indicated that there was very little information on the topic of centerline marking patterns.

Paragraph 4 of section 3A-6 of the Manual on Uniform Traffic Control Devices provides recommendations for centerlining patterns.(3) It states:

4. A broken line is formed by segments and gaps, usually in the ratio of 3:5. On rural highways, a commonly used standard is 15 ft. segments and 25 ft. gaps. Other dimensions in this ratio may be used as best suit traffic speeds and need for delineation.

Comment: The language used in paragraph 4 is permissive and is intended as a recommendation, not a requirement. This standpoint is reflected in the decision of the National Advisory Committee on Uniform Traffic Control Devices regarding the request of the state of Montana to be allowed to use a different pattern (see below).

National Cooperative Highway Research Program Report #130 recommends that "the gap to mark ratio for centerlines should be increased from present standards."(1) Conclusions reported for the study included: (1) no significant changes in lateral placement, regardless of centerline treatment, were evident, and (2) although statistically significant changes in mean speeds occurred, no discernible pattern was evident. The report recommended that tests be run on longer road sections, as the 3,000 ft. section "was too short to provide conclusive results."

The report also asserted that the number of mark ends observed is of more significance than the lengths of the lines themselves in determining the effectiveness of a pattern. Although the amount of solid line per mile is decreased, the same number of mark ends per mile maintains the strength of the pattern to communicate information to the driver.

Comment: The test sections chosen in the present study were all greater than 4 miles in length. In one case, the data collection point was only 1.4 miles (7,400 ft.) into the section, but significantly more acclimatization time was allowed for the driver to familiarize himself with the new pattern prior to data collection. The number of mark ends in the 10:30 pattern is the same as that of the 15:25 pattern. According to Report #130, the shorter mark lengths should not reduce the effectiveness of the 10:30 pattern.

Miller stated that marks less than 7 ft. long should not be used because of their dot-like appearance at higher speeds. He recommended use of a 12:36 pattern as it provided adequate continuity at speeds greater than 45 mph, but that at lower speeds the 48 ft. module was too long to be effective.(4)

Comment: The 12:36 pattern is a 1:3 ratio, as is the 10:30 pattern. The 40 ft. module length used in Virginia will provide the same flicker rate at a lower speed as the 48 ft. module will at a higher speed, and provide continuity in a range of speeds less than 45 mph while avoiding the suggested minimum length of 7 ft.

As a result of the petroleum shortage of 1973, several states have adopted centerline patterns that are more economical than the 15:25 ratio. Table 1 summarizes the results of contact with states known to be using modified centerline patterns. Correspondence revealed that while none of them had conducted formal studies to evaluate their patterns before adopting them they have received no adverse public reaction to the changes. Pattern changes in these states were based on subjective visual observations, with the general consensus that a paint stripe shorter than 10 ft. long looked too much like a dot and was therefore undesirable.

Table 1

States Known to Be Using Modified Centerline Patterns

State	Pattern	Date of Initiation	Comments
California	9:15	1942	No comments or questions.
Minnesota	10:40	Spring of 1974	No future change foreseen.
Montana	12:28	Spring of 1974	Approval of 12:28 granted by the National Advisory Committee on Uniform Traffic Control Devices.
Pennsylvania	10:30	Spring of 1976	Motorists have not been adversely affected by the change.
Texas	10:30	Spring of 1974	No adverse comments have been received.

California has been using a 9:15 pattern since 1942, and a review of correspondence of the California Department of Transportation since 1970 revealed that no queries regarding the pattern have been received. In 1976, use of a 12:36 pattern on roads with a design speed greater than 45 mph and a 7:17 pattern on lower speed roads were implemented. Montana asked for a ruling from the National Advisory Committee on Uniform Traffic Control Devices (NAC) to allow usage of a 12:28 pattern. The reasons cited for allowing the pattern included a 100% increase in paint costs, which prevented the state from purchasing the volume of paint required for normal maintenance. In the interest of traffic safety, conservation of paint normally used in centerlining allowed continued painting of other delineation requirements. The NAC's decision allowed the use of the proposed pattern.(5)

Field Studies

The purpose of the field studies was to determine if there was any difference between the 15:25 and the 10:30 centerline patterns as measured by vehicle speed and lateral placement.

Day data were collected from 8:30 a.m. until 11:00 a.m., and night data from about 30 minutes after sunset until about 11:00 p.m. The night data collection times varied from season to season, depending on when motorists began using their headlights and how soon after sunset it became dark. On Routes 29 and 58, data on the 15:25 pattern were gathered in July 1976, and those on the 10:30 pattern from mid to late August 1976. On Route 3, data on the 10:30 pattern were collected first in November 1976, while on the 15:25 pattern collection did not occur until March 1977. The delay was caused by an unusually cold winter which prevented retracing Route 3 with the 15:25 pattern.

For analysis purposes, vehicles were categorized as (1) being influenced by the presence of another vehicle within a 6-second headway either behind or ahead of them, or (2) not being so influenced, or in "free-flow". The presence of a second vehicle will affect the behavior of a given vehicle.(6) To isolate the effect of the centerline patterns, the performance of free-flow vehicles was separated from that of influenced vehicles. Measures describing both categories of vehicles are presented in the Analysis section for Routes 29 and 58. The data on Route 3 did not differentiate between influenced and uninfluenced vehicles.

An accident analysis of the three test sections was not conducted for this report. As mentioned in the objectives, at least a year of accident data, and preferably more, is required to obtain a statistical base. The length and small number of test sections will not produce a large enough number of accidents to derive any meaningful trends in accident occurrence which could be generalized to Virginia's entire highway system. If, upon adoption of the 10:30 pattern an increase in accident rate can be traced to the centerline marking pattern, the original 15:25 pattern can be quickly retraced over the 10:30 pattern.

Speed

As a driver proceeds down a road at a constant speed, he becomes accustomed to the "flicker" of the centerline pattern. In effect, he anticipates the occurrence of the next painted line after a regular time interval. It is hypothesized that if any change in the regular pattern occurs, the driver will adjust his speed to maintain the original time interval between lines. By changing the pattern from 15:25 to 10:30, the interval between lines is increased, and, if the hypothesis holds, an increase in speed will result. The average speed will give a measure of any change in mean speed between the two centerline patterns.

It is a well accepted concept that roads on which speeds are uniform are safer than roads with a high variation of speed in terms of accident occurrence.(7) The standard deviation of the speeds was used to measure how speeds varied about the mean speed, and allowed comparisons of speed variation on each marking pattern.

Table 2 compares speed measures on the 4-lane divided highways. Statistical tests showed that on both roads the average speeds of the vehicles on the 10:30 pattern were significantly higher than those on the 15:25 pattern in both day and night. The stratified data showed that both influenced and uninfluenced vehicle speeds were significantly greater on the 10:30 pattern than on the 15:25, except in one case. No consistent trends were found in the standard deviations of speed, and only two statistically significant changes occurred.

It should be noted here that at the test section on Route 29 several vehicles left the auto dealership, drove fairly slowly (less than 35 mph) to the crossover, and crossed the median there. All speeds on Route 29 less than 35 mph were eliminated from calculations. Also at the site on Route 29, two feet of paved shoulder were added to the existing shoulder, which increased the paved shoulder width from 1.5 ft. to 3.5 ft. The added pavement width could have affected vehicle speeds on the 10:30 pattern.

Table 2

Speed Measure on 4-Lane Divided Highways

		Route	Sample Size		Average Speed (mph)		t Value	Significant @ α = .05	Standard Deviation (mph)		F Value	Significant @ α = .05
			Pattern		Pattern				Pattern			
			15:25	10:30	15:25	10:30			15:25	10:30		
COMPOSITE	Day	29	587	611	54.5	56.4	5.52	Yes	6.0	6.0	1.02	No
		58	907	728	52.6	53.6	2.97	Yes	6.4	6.2	1.07	No
	Night	29	218	237	56.2	58.2	3.77	Yes	5.8	5.5	1.10	No
		58	390	355	50.8	52.8	4.29	Yes	6.1	6.1	1.02	No
FREE-FLOW	Day	29	162	243	54.1	56.2	3.43	Yes	6.2	5.8	1.12	No
		58	238	228	52.5	53.5	1.74	No	6.7	5.6	1.43	Yes
	Night	29	113	123	56.4	58.5	3.24	Yes	4.7	5.3	1.25	No
		58	159	179	50.9	53.1	3.52	Yes	5.4	6.1	1.28	No
INFLUENCED	Day	29	425	368	54.7	56.6	4.46	Yes	5.9	6.0	1.03	No
		58	669	500	52.7	53.6	2.39	Yes	6.3	6.4	1.05	No
	Night	29	105	114	56.0	57.9	2.24	Yes	6.7	5.7	1.37	Yes
		58	231	176	50.8	52.4	2.52	Yes	6.5	6.2	1.11	No

$t_{.05} = 1.96$ $F_{.05} = 1.35$

On the 2-lane highway studied, average speeds tended to be higher on the 10:30 pattern than on the 15:25 pattern also, as shown in Table 3. However, these differences were not consistent at all data collection points. The standard deviations of speeds were consistently lower during the day on the 10:30 pattern, but at night speeds varied less on the 15:25 pattern. These trends were not statistically significant. No other trends were apparent.

The tendency exhibited on the three roads studied for the average speed to be higher on the 10:30 pattern than on the 15:25 pattern could be attributed to seasonal speed variations. A Virginia study of seasonal speed trends[8] indicated that speeds on 2-lane highways tend to be from 1/2 to 1 mph higher in the fall than in other seasons. Although the data collected here is consistent with that finding, one cannot draw a meaningful conclusion from the limited data base.

A tendency for speed to vary less on the 10:30 pattern than on the 15:25 pattern was apparent over all three study roads during the day. The stratification of traffic into influenced and uninfluenced vehicles produced no meaningful insight.

The yellow paint used for centerlining on the 2-lane highway is not as reflective as the white paint used on the 4-lane divided highways. However, the difference in reflectivity of the markings did not seem to produce any trends.

Table 3

Speed Measures on Route 3

		Sample Size		Average Speed (mph)				Standard Deviation of Speed(mph)			
				Pattern		t	Significant	Pattern		F	Significant
	Site	15:25	10:30	15:25	10:30	Value	@ α = .05	15:25	10:30	Value	@ α = .05
Day	A-1	120	156	53.1	56.8	4.45	Yes	7.1	6.5	1.19	No
	A-2	120	156	51.8	55.8	4.39	Yes	8.0	6.3	1.61	Yes
	B-1	127	156	51.5	55.2	4.74	Yes	7.0	5.9	1.41	Yes
	B-2	127	156	53.7	54.8	1.31	No	7.2	6.8	1.12	No
Night	A-1	128	149	53.9	55.0	1.51	No	6.3	5.9	1.14	No
	A-2	129	149	52.9	54.3	1.95	No	5.9	6.2	1.10	No
	B-1	125	150	55.6	57.3	2.21	Yes	6.2	6.5	1.10	No
	B-2	127	150	56.1	55.6	0.59	No	6.8	7.2	1.12	No

$t_{.05} = 1.96$ $F_{.05} = 1.35$

Placement

The hypothesis under test with respect to lateral placement is that a continuous, unbroken lane marking will provide the strongest, most constraining guidance and will minimize the amount of variation within the lane. As the amount of line decreases (i.e., the mark-to-gap ratio decreases) the variation will increase. The standard deviation about the mean placement was used as a measure of variation; a greater value indicating more variation, and a lesser value, less variation. Average placements for each pattern were also compared.

Lateral placement measures obtained for the 4-lane divided highways are given in Tables 4 and 5. Table 4 summarizes placement measures from the traffic lane, while Table 5 deals with the passing lane. The average displacements from the edgelines at the two test sites increased significantly in three of four day situations, which indicated a shift of vehicles closer to the centerline on the 10:30 pattern than on the 15:25 pattern. Stratification of the data showed that the shift occurred primarily with influenced vehicles. No trends were noted at night.

There were no consistent changes in the standard deviations of placements on the 4-lane divided highways.

Again, it is important to note that the paved shoulder was wider on Route 29 after the road was resurfaced. This additional width did not seem to affect any placement measures.

At night, the variation in placement on Route 58 was greater on the 10:30 pattern than on the 15:25. As the data collection site was at the crest of a vertical curve, it is reasonable that a driver would have to rely on the pavement markings in the immediate vicinity for guidance. Because of the dark, he would not have the benefit of other visual cues to show him where the road is, and because of the crest, he could not see pavement markings further ahead. In the situation where the driver was forced to rely on the pavement markings, the variation in placement increased.

On the 2-lane highway, Table 6, a tendency for the average placement to be greater on the 10:30 pattern than on the 15:25 pattern appeared during both day and night. Variation in placement decreased significantly at three of the four data traps during the day, but tended to increase at night.

The data for the 4-lane and 2-lane highways seem to be consistent in showing that drivers on the 10:30 pattern drove closer to the centerline than those on the 15:25 pattern during the day. No overall trend was apparent for the standard deviations of placements.

Table 4

Placement Measures in Traffic Lane on 4-Lane Divided Highways

		Route	Sample Size		Average Placement (ft.) Pattern		t Value	Significant @ $\alpha = .05$	Standard Deviation of Placement (ft.) Pattern		F Value	Significant @ $\alpha = .05$
			15:25	10:30	15:25	10:30			15:25	10:30		
Composite	Day	29	412	511	2.7	2.8	2.24	Yes	1.2	1.1	1.09	No
		58	733	623	2.4	2.8	7.16	Yes	1.2	1.1	1.05	No
	Night	29	178	210	3.9	3.7	1.84	No	1.2	1.2	1.02	No
		58	335	307	2.8	3.0	1.23	No	1.2	1.3	1.14	No
Free-Flow	Day	29	143	227	2.8	2.8	0.24	No	1.2	1.1	1.13	No
		58	226	214	2.6	2.9	2.81	Yes	1.1	1.1	1.04	No
	Night	29	107	119	3.9	3.8	1.05	No	1.3	1.3	1.05	No
		58	150	170	3.1	3.1	0.31	No	1.1	1.2	1.19	No
Influenced	Day	29	269	284	2.6	2.9	2.94	Yes	1.1	1.1	1.07	No
		58	507	409	2.3	2.8	6.60	Yes	1.2	1.1	1.09	No
	Night	29	71	91	3.8	3.5	1.49	No	1.1	1.1	1.02	No
		58	185	137	2.6	2.8	1.37	No	1.2	1.3	1.22	No

$t_{.05} = 1.96$

$F_{.05} = 1.35$

Table 5

Placement Measures in Passing Lane on 4-Lane Divided Highways

		Route	Sample Size		Average Placement (ft.)				Standard Deviation of Placement (ft.)			
					Pattern		t Value	Significant @ α = .05	Pattern		F Value	Significant @ α = .05
			15:25	10:30	15:25	10:30			15:25	10:30		
Composite	Day	29	180	102	2.9	3.3	2.60	Yes	1.3	1.4	1.16	No
		58	177	107	3.1	3.0	1.09	No	1.1	1.2	1.18	No
	Night	29	20	23	2.8	2.7	0.21	No	1.4	1.0	1.77	Yes
		58	57	48	3.4	3.4	0.16	No	1.2	1.3	1.07	No
Free-Flow	Day	29	21	16	3.5	3.5	0.12	No	1.3	1.2	1.32	No
		58	12	14	3.3	3.4	0.07	No	1.0	1.3	1.57	Yes
	Night	29	3	4	3.8	2.8	1.18	No	1.5	0.5	9.36	Yes
		58	10	9	3.8	4.1	0.61	No	0.8	1.0	1.52	Yes
Influenced	Day	29	159	86	2.8	3.3	2.76	Yes	1.2	1.4	1.29	No
		58	165	93	3.1	2.9	1.28	No	1.2	1.2	1.14	No
	Night	29	17	19	2.6	2.7	0.25	No	1.3	1.1	1.35	Yes
		58	47	39	3.3	3.2	0.11	No	1.3	1.3	1.00	No

$t_{.05} = 1.96$

$F_{.05} = 1.35$

Table 6

Placement Measures on Route 3

	Route	Sample Size		Average Placement (ft.)				Standard Deviation of Placement (ft.)			
				Pattern		t	Significant	Pattern		F	Significant
		15:25	10:30	15:25	10:30	Value	@ $\alpha = .05$	15:25	10:30	Value	@ $\alpha = .05$
Day	A-1	120	156	1.1	1.5	3.90	Yes	0.9	0.8	1.33	No
	A-2	120	156	1.4	1.5	0.97	No	0.9	0.7	1.80	Yes
	B-1	127	156	2.4	2.2	1.54	No	1.2	0.9	1.88	Yes
	B-2	127	156	2.5	2.7	1.58	No	1.1	0.9	1.44	Yes
Night	A-1	128	149	1.4	1.9	5.39	Yes	0.7	0.8	1.40	Yes
	A-2	129	149	1.1	1.6	5.37	Yes	0.8	0.8	1.00	No
	B-1	125	150	2.6	2.4	1.86	No	0.8	0.9	1.29	No
	B-2	127	150	2.8	2.9	0.88	No	0.9	1.0	1.25	No

$t_{.05} = 1.96$

$F_{.05} = 1.35$

A factor which could have affected the vehicle placements at night was that the 15:25 pavement markings on the 4-lane divided highways were more worn than the 10:30 markings, and the former would not be as reflective. On the 2-lane highway, data for both patterns were collected on newly marked surfaces.

The effects of the reduced visibility of the yellow centerline cannot be isolated in the experimental design.

Motorist Opinion Survey

A summary of the questionnaire responses is shown in Appendix C, and the responses pertinent to the performance of the striping pattern in Table 7. Under item 3 in Table 7, it can be seen that over 96% of the respondents did not notice the new centerline pattern without prompting from the interviewer. Drivers were not oblivious to all changes, however, as from 41% to 57% cited resurfacing as a noticeable change. The point of change in pattern was coincident in all cases with the beginning of the resurfaced road, so the change in the pavement surface could have dominated the driver's perception of changes. Since 38% to 45% of the respondents stated that they did use the centerline as a form of guidance, it is difficult to conclude that the pattern change was highly noticeable on the basis of motorist opinion.

Upon being asked directly about the change in pattern, a larger proportion of respondents indicated that they had, indeed, noticed the change. Of these, the majority felt that the pattern was adequate. It is assumed that those who did not notice the change also felt the 10:30 pattern was adequate. Since the survey was made during the day, the responses to the question concerning nighttime adequacy were subjective. A cross tabulation was run on the responses to the question on nighttime adequacy to find how many of the respondents had actually driven the marked sections at night, and were likely to have a judgment based on experience with the pattern. About one-half of those who responded did have nighttime driving experience on the road.

About 66% of the drivers who were aware of the changed pattern preferred it over the 15:25, while about 10% preferred the 15:25. Twenty-four percent expressed no preference.

Table 7

Summary of Questionnaire Results

	Route 29	Route 58	Route 3
1. Number of Respondents	443	333	352
2. How often do you travel this road at night?			
Nightly	8.0%	18.0%	9.2%
2-3 times weekly	13.9%	20.7%	18.3%
2-3 times monthly	35.8%	8.7%	15.5%
Rarely	10.9%	34.5%	29.8%
Never	31.4%	18.0%	27.2%
3. Have you noticed any changes in this section of road recently?			
Resurfacing	55.2%	41.1%	57.0%
Different center-line spacing	0.7%	3.6%	3.4%
Other	7.7%	3.9%	1.7%
No change	36.4%	51.4%	37.8%
4. Is there any particular point of reference you use to guide your vehicle down the road?			
Centerline	13.3%	23.1%	12.9%
Edgelines	12.4%	10.6%	15.8%
Centerline & Edgelines	25.1%	21.6%	28.7%
Other	3.7%	5.2%	4.0%
None	45.5%	39.2%	38.5%
5. Did you notice any change in the centerline spacing?			
Yes	16.4%	16.6%	22.3%
No	83.6%	83.4%	77.7%
Of the respondents who were aware of the change in pattern:			
6. Approval of 10:30 pattern			
Day	95.7%	94.5%	98.7%
Night	85.5%	83.6%	85.7%

Table 7, continued.....

	Route 29	Route 58	Route 3
7.. Disapproval of 10:30 pattern			
Day	4.3%	5.5%	1.3%
Night	13.0%	16.4%	14.3%
8. Preference of pattern:			
15:25	5.7%	13.0%	10.7%
10:30	62.9%	70.4%	66.7%
No preference	31.4%	16.7%	22.7%

Economic Analysis

The purpose of the economic evaluation was to estimate the annual savings adoption of the 10:30 centerline marking pattern would allow. The 10:30 pattern consumes less paint and reflective beads per mile than the 15:25 pattern. An estimation of the monetary savings of the 10:30 pattern on Virginia's highways can be made using the following equation:

Savings = (material cost)(number of miles of broken line)(material saved/mile)

In 1976, the Purchasing Division of the Department purchased white paint for pavement marking at $2.54 per gallon and yellow paint for $2.66 per gallon. Beads, which cost $0.1384 per pound, were purchased at an average rate of 5.64 pounds per gallon of paint purchased from 1971 to 1976.

The miles of centerline markings in Virginia were estimated based on the following assumptions:[9]

1. All interstate and 4-lane divided highways carry two centerlines, separating two lanes of unidirectional traffic in two directions.

2. Three-lane roads carry one centerline, separating two lanes of unidirectional traffic flow in one direction.

3. Two-lane road mileage was analyzed by district. Only paved roads 18 ft. wide and wider are eligible for centerlines, and only a percentage of those miles can be marked to allow passing. Two estimates of the percentage of centerlined mileage were made for each district based on the topography. The values, which are strictly estimates, are presented in Table 8.

4. All centerlines separating unidirectional flow are white and all centerlines separating opposing flow are yellow. All centerlines on 2-lane roads are yellow, while those on divided, 4- or 3-lane roads are white.

5. All centerlines are repainted an average of once each year. Some heavily travelled roads require repainting every 3 months, whereas other roads can go 2 years without repainting.

Based on these assumptions, there are 5,685 miles of white and from 1,200 to 2,400 miles of yellow broken centerlined highway in Virginia.

Table 8

Estimates of Percentage of Broken Lines On 2-Lane Highways in Virginia

District	Percentage	District	Percentage
Bristol	10-30	Richmond	30-60
Culpeper	25-50	Salem	10-30
Fredericksburg	40-60	Staunton	10-30
Lynchburg	25-50	Suffolk	40-60

Current practice is to use 1 gallon of paint every 200-300 ft. while marking pavements with an unbroken line, based on estimates of several district traffic engineers. At that rate, the 15:25 pattern will consume from 6.6 to 9.9 gallons per mile, as compared to 4.4 to 6.6 gallons per mile for the 10:30 pattern. Paint volume savings from 2.2 to 3.3 gallons per mile are possible using the latter pattern in place of the former.

Using these figures, the minimum paint savings possible is

$$(\$2.54)(5,685)(2.2) + (\$2.66)(1,200)(2.2) = \$38,790.$$

The maximum paint savings is

$$(\$2.54)(5,685)(3.3) + (\$2.66)(2,400)(3.3) = \$68,719.$$

Use of the same equation gives bead savings of from

$$(0.1384)(5,685 + 1,200)(2.2)(5.64) = \$11,823$$

to

$$(0.1384)(5,685 + 2,400)(3.3)(5.64) = \$20,826$$

Adding these savings yields an annual possible savings of from $50,613 to $89,545 if the 10:30 pattern is used in place of the 15:25 pattern.

Operational Evaluation

Equipment Modification

A survey of the eight highway districts in Virginia revealed that 18 of 22 paint trucks can be adjusted or easily modified to paint the 10:30 pattern. Of the 4 unmodifiable trucks, 2 are scheduled for replacement in the near future and 1 is used only for edgelining.

Centerlines marked on new surfaces are spaced automatically by a cam-activated mechanism on the marking trucks. On Virginia's newer paint trucks, particularly the Kelly-Cresswell machines, the cam is adjustable, making it possible to alter the interval in which paint is applied. No modification of these trucks is necessary. Older paint trucks, usually Wald machines, operate with a fixed cam which requires replacement in order to alter patterns. When the centerlines are retraced, the marks are cued visually by an operator who controls the sprayer manually. Thus, retracing the markings is not dependent on the automatic switching mechanism.

A problem which has been encountered by paint crews is that the newer trucks are too wide to paint narrow secondary roads. The centerline sprayer carriage protrudes about a foot beyond the tire, forcing the opposite side tire onto the shoulder. Some districts prefer to use the dolly-type Wald markers which cannot change from the 15:25 pattern on these narrow roads. Since these older units will have to be replaced in the future, consideration should be given to replacing them with ones able to negotiate the narrow pavements.

Implementation Strategies

If the 10:30 pattern is adopted, the changeover can be made as roads are resurfaced or it can be implemented on all highways.

If the 10:30 pattern is applied only when marking new surfaces, the transition period would extend as long as it takes to resurface all the affected roads in Virginia, possibly as long as seven or eight years. The full amount of savings will not be realized immediately.

If the changeover is implemented by marking new surfaces with the 10:30 pattern and retracing existing 15:25 markings with the new pattern, the transition period would last from two to three years, depending on road usage. Although a ragged mark will result while the old marks wear away, contact with other states which have converted to the 10:30 pattern indicates that this does not seem to pose any problems. The immediate changeover to the 10:30 pattern will allow the Department to reduce paint usage and realize savings immediately.

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APPENDIX A

Report on Value Engineering Proposal #M-26

Present Method – Currently the painting of skip lines is done in accordance with Section 3A-6 (4) of the MUTCD quoted below:

> A broken line is formed by segments and gaps, usually in the ratio of 3:5. On rural highways, a commonly used standard is 15-foot segments and 25-foot gaps. Other dimensions in this ratio may be used as best suit traffic speeds and need for delineation. p. 179.

Value Engineering Proposal – The proposal as written advocated a 10-foot stripe and 20-foot gap. Preliminary analysis indicated that a more advantageous change would be the consideration of a 10-foot stripe with a 30-foot gap. Therefore, this report is in reference to the 10:30 stripe-gap.

Reason for Current Procedure – Compliance with Manual on Uniform Traffic Control Devices.

Cost of Current Procedure – Based on estimated mileage supplied by the Maintenance Division and current contract prices for paint and beads, the estimated cost of painting skip lines is $352,142 annually. This includes only the cost of paint and beads as labor will remain constant.

Methodology of Study – In conducting this study, particular emphasis was placed on NCHRP reports to determine current research findings as to the effect of different skip line spacing on driver performance both in terms of speed and lateral placement of vehicles.

Information was provided by the Maintenance Division regarding the number of miles of skip line and the frequency of painting. Telephone surveys were taken to determine the opinions of the District Traffic Engineers regarding the change and to ascertain from the District Equipment Superintendents if the currently owned centerline equipment could be set to accommodate the 10-foot stripe and 30-foot gap.

Contact was established with Mr. Robert McCarty for an interpretation of MUTCD Section 3A-6(4).

Results – NCHRP report 130 Roadway Delineation Systems and NCHRP synthesis of Research Practice 17, Pavement Traffic Marking "indicate that the 3:5 ratio may not be necessary and that adoption of a lower ratio would reduce material costs."

The phone survey of the District Traffic Engineers indicates all eight districts either support or are willing to consider the 10:30 marking for most roadways. The District Equipment Engineers contacted stated that changing the machine settings would not be a major problem on either the new or older models of centerline equipment. Contact with Mr. Robert McCarty of FHWA revealed that while the 10:30 stripe-gap was not in accordance with the MUTCD, the state of Pennsylvania had recently been given permission to use this pattern. McCarty further stated that if Virginia decided to adopt this new pattern, he felt certain there would be no difficulty in obtaining federal concurrence.

Conclusions and Recommendations – Calculations based on data supplied by the Maintenance and Purchasing Divisions indicate the savings potential of this proposal, when fully implemented, to be $117,000 annually.

Prior to a final decision on this pattern, it is recommended that a trial segment of pavement be striped with the 10:30 pattern and evaluated in terms of appearance by the District Traffic Engineers.

In view of the practical difficulties involved with attempting to paint the center 10 feet of an existing 15 foot stripe, it is recommended that a phase-in program for the 10:30 pattern be adopted by the Department. This would involve the use of the recommended pattern on new construction and resurfacing projects as well as initial striping of previously unmarked pavement.

The recommended adoption of this proposal is not intended to affect those areas where traffic, weather, or other conditions warrant different delineation patterns.

APPENDIX B

MOTORIST OPINION QUESTIONNAIRE

SKIPLINE EVALUATION

ROUTE_____

DATE_____

(1) Approximate age of driver: (a) under 25 (b) 26-40 (c) 41-55 (d) 56+

(2) Sex: (a) Male (b) Female

(3) Vehicle Type: (a) PV (b) Truck (c) Tractor-trailer

(4) How often do you travel this road?

(a) Daily (b) 2-3 times per week (c) 2-3 times per month (d) Rarely (e) First time

(5) How often do you travel this road at night?

(a) Nightly (b) 2-3 times per week (c) 2-3 times per month (d) Rarely (e) Never

(6) Have you noticed any changes in this section of road recently?

(a) Resurfacing (b) Different centerline spacing
(c) New shoulders (d) Other(specify)_____

_____

(7) Is there any particular point of reference you use to guide your vehicle down the road?

(a) None (b) Centerline marking (c) Edgelines
(d) Centerline and edgelines (e) Other (specify)

_____

Note: If the subject did not notice the new skipline spacing in question 6, ask question 8. If he did, skip to question 9.

(8) Did you notice any change in the centerline spacing?

(a) Yes (b) No

Note: If response is no, terminate the interview.

(9) Do you feel that the new centerline spacing is adequate to guide your vehicle during the day?

(a) Yes (b) No

Appendix B, continued

(10) How about at night?

(a) Yes (b) No

(11) Do you prefer the new centerline pattern or the old one?

(a) Old pattern (b) New pattern (c) No preference

(12) Do you have any other comments you would like to make?

_____

_____

APPENDIX C

SUMMARY OF QUESTIONNAIRE RESULTS

	Route 29	Route 58	Route 3
1. Number of Respondents	443	333	352
2. Age			
less than 25	19.0%	17.1%	17.6%
26-40	43.1%	42.0%	48.9%
41-55	25.5%	28.2%	25.3%
56 or older	8.4%	6.6%	6.8%
No Response	4.1%	6.0%	1.4%
3. Sex			
Male	77.0%	74.2%	67.6%
Female	22.6%	24.6%	31.3%
No Response	0.4%	1.2%	1.1%
4. Vehicle Type			
Private Vehicle	79.2%	69.4%	78.7%
Truck	12.2%	15.3%	12.5%
Tractor-Trailer	3.8%	8.7%	3.4%
No Response	4.7%	6.6%	5.4%
5. How often do you travel this road?			
Daily	28.1%	52.7%	40.9%
2-3 times weekly	17.0%	20.2%	27.1%
2-3 times monthly	21.3%	15.1%	14.0%
Rarely	29.2%	11.7%	16.6%
First time	4.3%	0.3%	1.4%
6. How often to you travel this road at night?			
Nightly	8.0%	18.0%	9.2%
2-3 times weekly	13.9%	20.7%	18.3%
2-3 times monthly	35.8%	8.7%	15.5%
Rarely	10.9%	34.5%	29.8%
Never	31.4%	18.0%	27.2%
7. Have you noticed any changes in this section of road recently?			
Resurfacing	55.2%	41.1%	57.0%
Different centerline spacing	0.7%	3.6%	3.4%
Other	7.7%	3.9%	1.7%
No change	36.4%	51.4%	37.8%

Appendix C, continued

	Route 29	Route 58	Route 3
8. Is there any particular point of reference you use to guide your vehicle down the road?			
Centerline	13.3%	23.1%	12.9%
Edgelines	12.4%	10.6%	15.8%
Centerline & Edgelines	25.1%	21.6%	28.7%
Other	3.7%	5.2%	4.0%
None	45.5%	39.2%	38.5%
9. Did you notice any change in the centerline spacing?			
Yes	16.4%	16.6%	22.3%
No	83.6%	83.4%	77.7%
Of the Respondents who were aware of the change in pattern:			
10. Approval of 10:30 pattern			
Day	94.7%	94.5%	98.7%
Night	85.5%	83.6%	85.7%
11. Disapproval of 10:30 pattern			
Day	4.3%	5.5%	1.3%
Night	13.0%	16.4%	14.3%
12. Of the night approvals or disapprovals the following percentage had "never" or "rarely" driven the road:			
Approvals	52.6%	54.3%	51.7%
Disapprovals	77.8%	44.4%	50.0%
13. Preference of pattern:			
15:25	5.7%	13.0%	10.7%
10:30	62.9%	70.4%	66.7%
No preference	31.4%	16.7%	22.7%
14. What percent of noticers are daily users of road?	29.6%	69.1%	55.8%