DETECTION OF WORK ZONE TRAFFIC CONTROL DEVICES

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Before discussing any data, there had best be some definition of the topic at hand. The work zones studied and the data reported herein are of the long-term (over 24 hours), high-speed (45+ mph) variety usually found in freeway or four-lane highway settings.

Detection has several definitions, but for this presentation will have two meanings: (1) when do drivers see that a device is present, and (2) when and how do drivers react to devices?

Particular emphasis will be placed on channelizing devices, with less consideration of advance signing and delineation.

BACKGROUND CONCEPTS

Traffic control devices (TCDs) are part of an information system that is supposed to meet those driver information needs required to traverse a work zone (1). Therefore, major concerns about TCDs are what behavior is elicited from drivers at what point in the work zone.

While behavior can be observed and measured, current information needs statements leave several unanswered questions (2). Does optimal (in terms of safety and throughput) work zone operation require speed reduction; should merging at lane closures be spread out as much as possible; and should channelizing devices provide advance hazard warning and lane closure information, in addition to delineating a clear path through the work zone? For purposes of this paper, the assumption was made that channelizing devices serve both roles. The rationale behind this is that people seem reluctant to change lanes until they see the need. In other words, past experience has led many drivers to disbelieve advance warning signs; they are not always correct.

Given the assumption, at what distance should channelizing devices provide warning and lane closure guidance information? The decision sight distance concept (3, 4, 5) encompasses the time, expressed in distance at different speeds, taken by drivers to detect, recognize, select speed and path, perform a maneuver safely. The times given in Table 1 were derived from experiments with subjects driving an instrumented car through a variety of city, arterial, and freeway situations. These distances provide one performance standard to use in assessing detection distance results.

ADVANCE SIGNING

Relatively little research has been conducted on advance signing. The major research effort has been on color coding, with the result that orange is the standard construction zone sign color (e.g., 6). Like other types of signs, work zone signing is equally in need of nighttime illumination or reflectivity. Advance signing legibility has not been overly studied, and there is little evidence that legibility of black on orange is sufficient on current signs. The greatest problem with advance signing has little to do with detection. Drivers often read the advance signing message and act accordingly, only to find the work zone situation is different. Signing quickly loses credibility and, subsequently, effectiveness in eliciting the desired driver behavior.

ARROW BOARDS

Extensive study of arrow boards (7) indicates they can be initially detected anywhere from 2500 to 5000 feet away. Identification of the arrow and direction occurs between 1500 and 2500 feet. These values are well in excess of the recommended recognition distance of 725-1175 feet, depending on speed. Field evaluations indicate arrow boards are most useful for lane closures, where they promote earlier merging. Only in specific situations were they helpful in lane diversion (crossover) operations. Placing the board on the shoulder at the start of the taper was more effective than placing it in the closed lane farther back in the taper. A second arrow board in advance of the taper was also effective. Human factors studies (8) indicates that the flashing arrow, then chevron, configurations are more effective than the sequential arrow. Hooded lights and automatic dimmers are necessary design features.

CHANNELIZING DEVICES

Concrete Barriers

A study of concrete barrier visibility (9) focused heavily on the durability, over a two-year period, of six reflective products. Both photometric readings and observer ratings of visibility were

TABLE 1: Decision Sight Distances (Adapted from McGee and Knapp (5))

Speed	Detection Through Maneuver Time (sec)	Distance (ft)
30	10.2 - 11.7	450 - 525
40	10.2 - 11.7	600 - 675
50	10.2 - 11.7	750 - 850
60	10.2 - 11.7	900 - 1025

used to assess performance in a median setting. Recommendations for mounting materials, installation cost, etc., are given in the report. From a visibility perspective, reflectors were superior to reflectorized tape. The specific reflectors recommended in the report represent something of a compromise in that no one product was rated high at the beginning and end of the two-year time; there was switching of visibility rankings over time. Other findings include: spacing - 80 feet on tangent, 40 feet on curves; position - mounted on top, horizontal surface, reflectors weathered best; glare is a problem at night; and reflector visibility enhanced under wet night conditions, when barriers are usually least visible.

Other Channelizing Devices

A study of cones, tubes, barricades, panels, drums, and steady burn lights was recently reported and is summarized here in (2). (Research reported was supported through NCHRP Project 17-4.)

A comprehensive literature review was conducted to identify: (1) the safety problem at highway work zones as it relates to channelization devices; (2) the use and effectiveness of traffic control devices in work zones; and (3) measures which can be used to evaluate the performance of channelization devices. The findings of the literature review supported the original contentions that there are many types and designs of channelization devices being used. Furthermore, the data are lacking that would support current design of these devices or their arrangement on the job. The products of the literature review include an extensive bibliography, a literature synthesis, and a chart highlighting current standards and usage guidelines for the various devices.

The next task prior to actual experimentation was to develop performance measures that would reflect drivers' response and the relative effectiveness of particular devices. Using the inputs of the literature review, an Information-Decision-Action (IDA) task analysis procedure was utilized to derive candidate performance measures. By analyzing the driving task, it was possible to identify the desired driver and vehicle responses and, in turn, translate these into performance measures for evaluation. Most of these measures were incorporated into the design of the various experiments which followed.

The experimental program consisted of three types of studies. The first of these was a laboratory study which was aimed at optimizing the design characteristics of barricades and panels. The design features studied were: stripe configuration (horizontal, vertical, diagonal, and chevron), width, and meaning; white-to-orange color ratio; and height-to-width ratio. Subjects saw small bar or panel-shaped stimuli with different design features against a visually noisy background. The background was divided into quadrants, and subjects had to search to find and then detect the stimulus. After seeing the stimulus for 0.4 second, subjects indicated where the target was located, the target shape, and its configuration.

Using the results of the laboratory experiments to define additional problems, another series of experiments were conducted on a closed highway using an instrumented vehicle (the DPMAs on loan from NHTSA) driven by test subjects. The various devices, with varying sizes, spacings, reflectivity, auxiliary lighting (steady burn lights), and configurations were compared to determine their relative effectiveness in eliciting desired driver responses. This study provided additional findings related to the effectiveness of alternate devices and device designs when placed in a channelizing array.

A factorial design was used in which 10 subjects, stratified by age and sex, were exposed to each treatment. Separate groups saw devices day and night. A total of 300 subjects participated.

The dependent measures were speed, speed variance, lateral position, displacement from the centerline (weaving), array detection distance, point of lane change, steering wheel movement, and accelerator and brake pedal movement. The only measures which differentiated between devices were detection distance, point of lane change, and speed.

Only the detection distance results for single devices and device arrays, day and night, are summarized below:

Day: Seven of the devices have mean detection distances of 2000 feet or better. The remaining devices vary from 550- to 1750-foot mean distances.

Night: There was no significant difference between day and night mean detection distances for single devices in general, i.e., all devices pooled together. However, there are changes for specific devices between day and night.

Cones and the 42" post, while detected from 2400-2500 feet in the day and equivalent in detection performance to drums and Type I barricades, became statistically significantly less detectable at night. However, only one amount and type of reflective collar (6") was studied and there is no evidence to suggest this represents an optimum nighttime configuration for cones or tubes. Note that another NCHRP-sponsored project is currently conducting a more thorough test of cone and tube performance.

Arrays: Array detection distance was significantly longer in the daytime than single device detection.

Array detection distance at night was significantly higher than single device detection only for certain devices (3' x 12" barricades, 12" x 24" panel, 28" post and cone, steady burn light, 2' x 8" Type I barricade with chevron stripe).

Array detection in the day was at significantly greater distance than at night.

Single device detection scores were not necessarily predictive of array detection distances.

Variability in Detection: Considerable variability around the mean detection scores was evident.

Using a 1000-foot decision sight distance as a minimum, the 12" x 36" panel, drum, steady burn light, and 8" x 24" panel with chevron could meet the criterion of 97% (2 SDs) of drivers at night. In the day, only the 42" post, 36" cone, and 28" cone met the criterion for 97% of drivers.

The final experiments were conducted in real world situation wherein three types of devices (cones, barricades, and vertical panels) with design and layout variations were tested at three work zone types--a traffic diversion site, a left-lane closure site, and a right-lane closure. Measures of mean speed, speed variance, lane changing, and traffic conflicts were compared to determine relative effectiveness.

Collectively, these experiments provided sufficient data to support several recommendations concerning the use of the alternative devices and their design and layout parameters. In general, it was found that most of the channelization devices studied were equally effective in providing a path for the motorist. However, not all devices were equally effective in their alerting function, as it was shown that several types had longer detection distances associated with them.

In conclusion, the findings indicate relatively successful detection and path guidance performance by most devices. One of the major deterrents to effectiveness is not the device, but the position, dirty, or overturned devices destroy the visual line or path created by channelizing devices. Therefore, use of appropriate devices is important but diligent set-up and care of the work zone is equally important.

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