Abridgment

Active Advance Warning Signs at High-Speed Signalized Intersections: A Survey of Practice

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ABSTRACT

A synthesis of current traffic engineering practice relative to accident countermeasures at high-speed signalized intersections is presented. The synthesis was prepared by using two main sources of information: a review of published and unpublished literature, and results of a questionnaire survey sent to practicing traffic engineers. Sixty-five state and local agency traffic engineers from all regions of the United States and Canada responded to the questionnaire. Physical environments known to cause problems at high-speed signalized intersections are described. The three most commonly used types of active advance warning devices are discussed along with quantitative and qualitative assessments of their effectiveness. The three types of devices are flashing RED SIGNAL AHEAD signs, PREPARE TO STOP WHEN FLASHING signs, and flashing strobe lights. Active devices are usually installed only as a last resort where conventional countermeasures have not proved to be effective. Although specific situations in which each type of device has been effective or in which its use should be avoided were identified, there is a need for guidelines to define the use, design, installation, and timing of active warning devices.

Introduction of signalization of high-speed highways (defined as approaches with posted speeds greater than or equal to 45 mph) creates the potential for a significant increase in traffic accidents. Two common problems at such locations are the creation of a decision zone and the existence of geometrics such that the signal is not expected or that the display cannot be seen in time.

The most promising countermeasures for this problem appear to be active advance warning devices. These are traffic control devices, placed at or in advance of high-speed signalized intersections, that alter the information provided to drivers on the basis of whether drivers should stop or proceed. With active devices, accident potential is reduced because drivers have additional information on which they can decide the best course of action.

The two principal types of active devices are the . . . WHEN FLASHING signs and signal head supplements. The . . . WHEN FLASHING signs include devices placed in advance of the intersection, which indicate to drivers whether to stop or proceed. Such devices usually take one of two forms, the flashing RED SIGNAL AHEAD sign and the PREPARE TO STOP WHEN FLASHING (or similar message) sign. The flashing RED SIGNAL AHEAD sign displays two messages: RED SIGNAL AHEAD or SIGNAL AHEAD. The neon RED SIGNAL AHEAD message is activated near the end of the green interval or during the yellow interval and remains on throughout the red interval. The word RED flashes alternatively with the words SIGNAL AHEAD. At all other times during the cycle length, the SIGNAL AHEAD message is displayed (nonflashing).

There are many variations of the PREPARE TO STOP WHEN FLASHING signs. Essentially, the device consists of a sign panel with a word or symbol message and yellow flashers that illuminate a predetermined time before the start of red. The signs are characterized by their variety; messages currently in use include STOP AHEAD WHEN LIGHTS FLASHING, STOP ON SIGNAL WHEN LIGHTS FLASH, and BE PREPARED TO STOP.

The strobe light is a flashing white light that supplements the red indication of a traffic control signal. The flashing strobe is intended to draw motorist attention to the signal in situations in which the signal is unexpected or may be difficult to see because of other lights and signs. The flash rate of strobe lights is usually 90 or more flashes per minute; the pulsating strobe appears only with the normal steady red indication.

Although the availability of these solutions has reduced some of the problems, accidents at high-speed signalized approaches appear to be a persistent concern nationwide. To provide guidance to traffic engineers who face decisions about countermeasures at high-speed signalized intersections, there is a need for comprehensive review and evaluation of such countermeasures, both successes and failures.

A research project was undertaken to provide the review and evaluation of such countermeasures. Objectives of the study were

1. To review current traffic engineering practice relative to accident countermeasures at high-speed signalized intersections through (a) review of published literature and (b) a survey of practicing traffic engineers, and
2. To prepare a synthesis of practice on approaches to the problem.

The countermeasures described were included on the basis of having been identified as specific treatments for high-speed intersections. Therefore, many of the more traditional signalized intersection countermeasures such as improved intersection geometrics, left-turn lanes, advance rumble strips, all-red clearance intervals, and flashing signal operation were not considered.

SURVEY OF PRACTICE

To obtain information not available in the published literature, a survey of practicing traffic engineers was conducted to collect data on the nature of the specified accident problem and on the evaluation of appropriate corrective treatments. The questionnaire was sent to engineers with responsibilities in planning, design, and installation of traffic signals. Of the 211 agencies sent questionnaires, 110 responded, although only 65 actually returned completed questionnaires. Response rates were 62 percent for state agencies, 19 percent for local agencies, and 30 percent overall.

ANALYSIS OF QUESTIONNAIRE RESPONSES

Safety and Operational Problems

The first question on the survey form attempted to define circumstances under which safety and operational problems are experienced at high-speed signalized approaches. Respondents were asked to identify circumstances most relevant to their jurisdiction by ranking them (1 = most pressing problem, 2 = next most serious problem, and so forth) and then listing particular safety and operational problems associated with the given circumstance. For state agencies, rural expressways where signalization was unexpected ranked as the most pressing problem. This was followed, in order, by intersections hidden by horizontal curves, rural expressways with heavy truck traffic, and intersections hidden by crest vertical curves. Steep downgrades and intersections hidden by other features were not noted as serious problems by state agencies.

Responses of local agencies were different from those of the states in that only two circumstances stood out as important: intersections hidden by horizontal curvature and those hidden by vertical curvature. In all other circumstances the number of respondents not indicating that a circumstance was a particular problem exceeded those who indicated a ranking for that circumstance.

The relative importance of safety and operational problems associated with intersection circumstances was tabulated separately for state and local agencies. Because there was little difference between the two responses, it was decided to combine the results. Rear-end accidents were the most frequently mentioned accident type overall. This accident type had the highest frequency in all circumstance categories except one (rural expressways with heavy truck traffic). Second and roughly equal in importance with 26 percent of the citations were right-angle accidents and red violations. Within these overall categories, right-angle accidents had a tendency to be associated with limited sight distance, whereas red violations were most frequently mentioned with rural expressways and steep downgrades.

Countermeasures

Several questions on the survey form inquired about countermeasures implemented to reduce problems at high-speed signalized intersections. Results indicated that traditional approaches to intersection accident problems, detector placement, and yellow time adjustment are by far the most frequently used countermeasures at both the state and local levels. At the state level, the flashing RED SIGNAL AHEAD sign was the most widely used dynamic device, with more than 300 installations nationwide. More than 200 PREPARE TO STOP WHEN FLASHING signs were reported, with more than one-half of these being of the ground-mounted type. Only 12 strobe installations were reported nationally. This is significantly less than the number reported in another recent survey (1).

The basis for installation of various countermeasures used by state and local agencies was also reported. Overall, for both state and local agencies, rear-end and right-angle accidents and red violations were the most frequently cited bases for installation, accounting for almost 60 percent of the responses. In general, all countermeasures revealed a similar pattern for basis for installation. The one exception was the flashing SIGNAL AHEAD sign. Both state and local agencies indicated that one of the main reasons for installing the flashing SIGNAL AHEAD sign was as a response to speed problems.

Although results indicated that truck accidents were not a significant problem, a question on the survey form asked whether trucks were given special consideration in countermeasure selection. Of the 22 state agencies responding to this question, 59 percent indicated that trucks were given special consideration. In contrast, only 36 percent of the 18 responding local agencies answered the question affirmatively.

Agencies were asked to provide information on the interval of the signal cycle in which the dynamic devices are activated. In general, the results agreed with what had been expected. For state agencies, roughly two-thirds of the dynamic devices (excluding flashing strobes) were activated at a predetermined time before the start of red (i.e., during green). This percentage was lower for local agencies for which a higher proportion of devices were activated at the beginning of yellow.

Respondents were asked to provide two types of countermeasure cost information: (a) typical installation cost per intersection approach, and (b) annual maintenance cost per approach. For local and state agencies, yellow time adjustment had both the lowest median installation cost and the lowest median annual maintenance cost of all countermeasures considered. The overhead PREPARE TO STOP WHEN FLASHING sign was the most expensive to install, costing about $5,000 per intersection approach. At the state level, ground-mounted PREPARE TO STOP WHEN FLASHING signs and flashing RED SIGNAL AHEAD signs had approximately the same mean installation costs, around $2,500. These responses differed from those of local agencies for which costs for detector placement and flashing RED SIGNAL AHEAD signs were significantly higher than those reported by state agencies. But because of the very small sample size, little confidence is placed in the cost data for flashing strobe lights.

As just mentioned, yellow time adjustment had the lowest median annual maintenance cost of all countermeasures. Note that local agency data will not be discussed here because of limited sample size. The most costly devices to maintain were the overhead and ground-mounted PREPARE TO STOP WHEN FLASHING signs. In the intermediate cost range were detector placement, the flashing RED SIGNAL AHEAD sign, and the flashing SIGNAL AHEAD sign.

Effectiveness Evaluation

Two forms of countermeasure effectiveness evaluation--a subjective assessment and an objective quantitative evaluation--were sought on the survey form. The first question asked respondents to give an overall assessment of countermeasure effectiveness on a scale of 1 (no effect) to 5 (excellent).

In several instances state and local agencies differed in their assessments of countermeasure effectiveness. At the state level, detector placement was rated most effective followed by the flashing RED SIGNAL AHEAD sign. Both countermeasures had ratings of "good" or better. Ranking somewhat lower in effectiveness was a group of three countermeasures (overhead and ground-mounted PREPARE TO STOP WHEN FLASHING signs and yellow time adjustment). Two other devices (flashing SIGNAL AHEAD sign and flashing strobe lights) rated just better than neutral.

In contrast, local agency engineers thought the overhead PREPARE TO STOP WHEN FLASHING sign was the most effective. Three devices were tied as the second most effective countermeasures (ground-mounted PREPARE TO STOP WHEN FLASHING sign, flashing RED SIGNAL AHEAD sign, and flashing strobe lights). The flashing SIGNAL AHEAD sign, detector placement, and yellow time adjustment received the lowest effectiveness ratings. In general, local agencies rated the dynamic devices more highly than did state agencies.

The second question relative to countermeasure effectiveness evaluation asked agencies to include results of any formal studies conducted to evaluate the effectiveness of the four dynamic countermeasures identified on the form. Relatively few agencies had conducted formal studies to evaluate effectiveness. Six state agencies and one local jurisdiction sent copies of reports documenting results of evaluation studies. The amount of data furnished was not sufficient to permit statistical analysis.

It is interesting to note that more than one-half of the studies involved evaluation of the flashing strobe light (1-3). Overall, based on a relatively small number of intersections, there was no clear consensus on the effectiveness of strobes. Strobes appeared to be effective in reducing right-angle and total accidents, but in most cases there were no statistical differences in the number of accidents before and after installations of strobe lights.

An Ohio Department of Transportation before-and-after study (4) evaluated the PREPARE TO STOP WHEN FLASHING sign at six locations. High-speed approaches revealed a statistically significant accident reduction for total, rear-end, property-damage-only, and truck-at-fault accidents.

Maryland evaluated the flashing RED SIGNAL AHEAD sign through a before-and-after study that involved 22 intersection approaches (5). The RED SIGNAL AHEAD sign was determined to be successful in reducing right-angle accidents at sight-obstructed signalized intersections. The device appeared to be more effective in reducing rear-end and total accidents on horizontal curve approaches than on steep vertical approaches.

CONCLUSIONS AND RECOMMENDATIONS

The research described in this paper involved an assessment of active advance warning devices and other accident countermeasures at high-speed signalized intersections. Output from two of the project activities--a literature review and a survey of current practice--was combined to achieve a synthesis of practice (6) on active warning devices.

Both the literature review and the survey of practice indicated that hidden intersections and rural expressways where signals are unexpected are the two circumstances creating problems at high-speed signalized intersections. At such locations, rear-end accidents are the most pressing problem, following by right-angle accidents and red violations. Only when conventional countermeasures such as detectorization or continuously flashing SIGNAL AHEAD signs fail to solve the problem will agencies turn to dynamic devices. When active devices are used, they are installed selectively so that their effectiveness is not diminished by overuse.

The most popular dynamic devices are the flashing RED SIGNAL AHEAD sign, the PREPARE TO STOP WHEN FLASHING sign (and its variations), and flashing strobe lights. Some agencies tend to favor one dynamic device more than others. This may be due, in part, to topography, past experience with the device, and installation and maintenance costs. Of the three devices, flashing strobes have the lowest costs. It was concluded that, in general, the flashing RED SIGNAL AHEAD sign was the most effective dynamic device; traffic engineers gave it a "good" rating. Flashing strobe lights were the least effective of the three active devices; engineers rated strobes closer to neutral than to good in terms of effectiveness. For dynamic devices in general, it was concluded that activation of flashing near the end of green is more effective than activation at the beginning of yellow.

Although this study has identified certain situations in which each type of dynamic device is effective or in which its use should be avoided, there are no general warrants or guidelines for the use of active warning devices at high-speed signalized intersections. An application standard is needed to define the use, design, installation, and timing of active devices. Additional investigations using a combination of field studies and laboratory experimentation with a driving simulator are recommended.

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