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Supplemental Signing for Stop Signs

J. L. Gattis

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SUPPLEMENTAL SIGNING FOR STOP SIGNS

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Arkansas State Highway and Transportation Department
and
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Federal Highway Administration

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Abstract

Signs warning motorists that "traffic on the cross street does not stop" can be found at some intersections that are not all-way stop-controlled. These *CROSS TRAFFIC* signs have been installed to furnish a special warning where some motorists on the minor approaches may incorrectly assume that the major crossing street also has *STOP* signs. Some of the signs have been installed only for a short duration, in conjunction with the change of an all-way to a two-way stop; other installations have been permanent. The variety of *CROSS TRAFFIC* signs that have arisen lack uniformity of message, color, shape, and placement location.

A literature review and two surveys were conducted to examine:

1. the present usage of *CROSS TRAFFIC* signs;
2. the circumstances under which these signs have been installed;
3. studies of the effectiveness of the signs; and
4. the issue of "where do we go from here?"

The accident data reviewed offered mixed results about the sign's effectiveness: at some locations the signs seemed to reduce accident frequencies, while at others, accidents continued in spite of the presence of the signs. Expanded use of the signs could cause drivers to come to expect them at all two-way stop-control situations. It is suggested that the signs be used only on a very limited basis, and at locations where statements from those violating the signs suggest repeated incidents of driver misperception. This policy is recommended until more information on the long term impact of the signs and a study of alternative approaches have been completed.

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SUPPLEMENTAL SIGNING FOR STOP SIGNS

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CHAPTER 1
INTRODUCTION

It is not uncommon for a *STOP* sign to be accompanied by other signs on the same pole. *STOP* signs can be found sharing poles with street name, turn prohibition, one-way, and *ALL-WAY* (R1-4), *3-WAY*, or *4-WAY* (R1-3) signs. Of these examples, the *ALL-WAY*, *3-WAY*, and *4-WAY* fall into a special class of "supplemental signs," signs intended to supply additional definition or meaning to the primary sign.

Various forms of supplemental signs, warning motorists that "traffic on the cross street does not stop," can be found at a number of 2-way stop intersections in Canadian provinces and various states, including Arkansas. The presence of these signs indicates that both state/provincial and local traffic engineers have felt the need to furnish a special warning at certain 2-way stop-controlled intersections, where some motorists on the minor approaches may incorrectly assume that the major crossing street also has *STOP* signs. The *Manual on Uniform Traffic Control Devices (MUTCD)(10)* currently does not include any such sign warning minor road motorists that major road traffic is not required to stop.

Even though some national research on this subject has been published, the use of various signs and other traffic control devices (TCDs) warning minor road drivers that major road traffic is not required to stop (hereafter referred to as *CROSS TRAFFIC* signs) has arisen out of perceived needs in various locales, without any effective national control or coordination. With the absence of coordination, it is not surprising that *CROSS TRAFFIC* signs now in use lack uniformity of message, color, shape, and placement location. Given the nature of traffic engineering practice in an environment of relatively independent local and state/provincial governments, information and experiences from the "grass roots" level may not be shared among professionals in other parts of the country unless a formal, coordinated effort is undertaken. There exists a need to

1. identify the extent of use and variations of *CROSS TRAFFIC* signs;
2. evaluate the effectiveness of current *CROSS TRAFFIC* signs;

3. determine the proper applications of and limitations on the usage of the sign; and
4. share information about *CROSS TRAFFIC DOES NOT STOP* and similar-purpose traffic control devices with other transportation professionals.

By evaluating and summarizing the collective experiences of agencies using the *CROSS TRAFFIC* signs, federal, state, and local traffic engineers will be in a better position to evaluate the status of traffic control devices warning motorists that cross traffic does not stop.

The objectives of this research were to investigate and report

1. the present usage of *CROSS TRAFFIC DOES NOT STOP* and other similar supplemental traffic control devices;
2. the circumstances under which these signs/TCDs have been installed, and the situational needs warranting such TCDs, as perceived by traffic officials;
3. any studies or reports of experiences with such TCDs, and the effectiveness of such TCDs.

An additional objective was to address the broader issue of "where do we go from here?" Does the current state of affairs suggest alternative solutions, new warning methods, a change in the *MUTCD*, or new research directions?

If transportation engineering professionals conclude that one or more of the *CROSS TRAFFIC* TCDs merits nationwide use, then studies such as this one hopefully will facilitate the future development of guidelines for the uniform appearance and application of TCDs to warn motorists that cross street traffic does not stop. If transportation engineers want additional controlled research to validate the impact of the *CROSS TRAFFIC* TCDs and define the best future course of action, this project will serve to help direct those efforts.

CHAPTER 2
BACKGROUND

Motorists at stop-controlled intersections may sometimes encounter real or imagined factors that challenge the drivers' ability to correctly analyze and react to intersection traffic patterns. At locations where the driving task is more complicated, increased numbers of accidents may result. For instance, drivers may find it more difficult to safely negotiate a five-leg intersection with a given intersection volume as compared to a T-intersection with the same intersection volume. Traffic engineers may find it difficult if not impossible to correct some intersection problems with traditional traffic control countermeasures. The *CROSS TRAFFIC* signs have been used, in part, in attempts to remedy stubborn intersection accident problems.

THE MOTORIST'S DILEMMA

Motorists approaching intersections may encounter various levels of control, including signal, multi-way stop-, 2-way stop-, yield-, or no-traffic-control-device present. Drivers who pass through these types of controls must exercise differing levels of judgement and skill in order to determine whether they may proceed safely without creating a conflict with traffic on the intersecting street. For instance, a traffic signal tells the motorist to stop or to proceed, and demands from the driver a relatively low level of judgement and skill to determine the proper right-of-way assignment. At the other end of the spectrum, the operation of an intersection with no traffic control devices requires a higher degree of correct judgement and skill from the driver.

At stop-controlled intersections, expectations based on previous experience may affect judgement as a driver determines the advisability of proceeding. Through accumulated driving experience, a driver may have come to associate multiway stop control with certain types of roadway situations, or intersections having a certain "look." In particular, a driver may have subconsciously concluded that intersections will have stop control on all approaches when the entering roadways have similar volumes, widths, number of lanes, pavement quality, or amount and type of roadside development. The driver may associate 2-way control with intersections where one pair of legs has an obviously greater volume or pavement quality than the other pair. However, the motorist cannot always correctly perceive whether one roadway at an intersection is or is not "equal" to the other. Even approximately equal roadways do not always deserve multi-way stop control. Such presuppositions may result in driver misperception about what type of right-of-way control is in effect at a given intersection. When a driver acts on such a false perception, a traffic accident may result.

Another factor may contribute to a driver's incorrect assumption: there may have been a change in the *STOP* sign arrangement. A 4-way stop may have been converted to a 2-way, or the approach directions required to stop at a 2-way may have been "switched" or changed. Motorists may be relying on past experiences at the intersection instead of present realities.

Unusual roadway "situations" can compound the complexity of intersection control or confound the driver. At some intersections, the major traffic movements do not proceed straight through, but rather make a turn onto the intersecting, perpendicular road. For one direction of travel, this means the major flow makes a right turn, but for the return- or reverse-direction major flow it means making a left turn. If the major flow left turn is assigned the right-of-way and does not have to yield or stop, then traffic from the opposing "straight" direction will encounter what may seem to be an unnatural driving situation -- straight-ahead traffic yielding right-of-way to an oncoming left turn. Figure 2.1 offers an example.

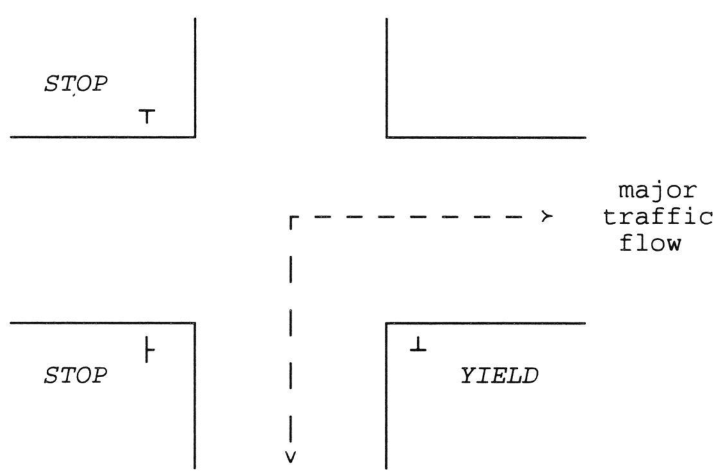


FIGURE 2.1 -- Non-standard Right-of-way Assignment

The driver may also suffer a mental "malfunction" and for no apparent reason assume cross traffic is required to stop; perhaps driver distraction or fatigue are contributing factors. When motorists who encounter a *STOP* sign at an intersection incorrectly assume that the crossing street also has stop control, accident potential greatly increases. This is because the motorists making the incorrect assumption may proceed after stopping, expecting the approaching vehicles on the cross street to slow and stop, when in fact the cross street vehicles may drive on through.

Although up to this point the discussion has been couched in terms of a 4-leg intersection, similar right-of-way assignment confusion can also occur at 3-leg or "T"-intersections.

THE TRAFFIC ENGINEER'S RESPONSE

When confronted with intersection safety problems assumed to result from faulty driver conclusions, traffic engineers responsible for roadway operations may respond by installing additional TCDs. The engineer may direct the installation of an overhead flashing beacon, which by displaying red to one street will emphasize the stop control, and by displaying yellow to the other will offer a warning. Attempting to get the attention of drivers assumed to be inattentive, engineers may add warning signs with messages such as *STOP AHEAD* or install rumble strips in advance of the intersection. Geometric modifications to the intersection may be made to change the appearance of the roadway.

At some locations, traffic engineers have installed a sign warning motorists on the stop-controlled approach that traffic on the crossing street has no *STOP* sign. The need for and use of supplemental signs to warn motorists that crossing traffic does not stop seems to have arisen and been implemented at the "grass roots" level, not due to any centralized coordination.

There is currently no standard or uniform sign in the 1988 *Manual on Uniform Traffic Control Devices (MUTCD)* for notifying motorists at a 2-way stop that the crossing street is not stop-controlled. The ability of traffic engineers to innovate is restricted by the 1988 *MUTCD*: Sec. 2B-4 prohibits the use of secondary messages on *STOP* sign faces. The presence of *CROSS TRAFFIC* signs, on both state and local roadways in many states, strongly indicates that some traffic engineers think a need exists which the *MUTCD* does not currently address.

RELATED ISSUES

As previously alluded to, the installation of *CROSS TRAFFIC DOES NOT STOP* signs as a response to operational problems at 2-way stop-controlled intersections is related to other traffic engineering countermeasures. Other traffic engineering responses to compliance or accident problems at stop-controlled intersections include

1. installing *ALL-WAY STOP* signs;
2. installing overhead flashing beacons;
3. installing flashing beacons on the *STOP* sign post;
4. installing *STOP AHEAD*, oversize *STOP*, multiple or redundant *STOP*, or other signs to get drivers' attention;

5. installing rumble strips to get drivers' attention.

The issue of drivers not fully complying with a *STOP* sign and proceeding into conflicts with cross street traffic is part of a larger issue of *STOP* sign violation.

The use of all-way stop control is guided by the *MUTCD*. The 1988 *MUTCD* states "Any of the following conditions may warrant a multiway *STOP* sign installation," and proceeds to list warrants, including the familiar "Minimum traffic volumes" warrant. Engineers confronted with an elevated accident frequency at an intersection with volumes well below those warranting a multiway *STOP* find themselves on the horns of a dilemma: they either install a multiway *STOP* and not conform with the warrant, or do nothing and appear inactive in the face of the accident problem. Beacons or other alternatives may not be employed because of budgetary constraints or the belief they would be ineffective.

Some traffic control agencies install supplemental *ALL-WAY* plaques at all applicable intersections. Others eschew the plaque under the belief that the plaque contributes to driver "overconfidence;" i.e., if driver "A" approaches an intersection with an *ALL-WAY* plaque, and the intersecting-roadway *STOP* sign is missing, then driver "A" is presumed to be more likely to stop and then proceed in front of an oncoming vehicle on the cross road with the missing *STOP* sign, not waiting for the crossing street vehicle to come to a stop before proceeding.

BACKGROUND SUMMARY

Given the multiplicity of factors and perspectives coming into play, it is not surprising that traffic engineers pursue varying responses to accident problems at *STOP*-controlled intersections. If intersection accidents occur for a variety of reasons, then one given countermeasure may not be effective at every location. The variety of traffic control devices employed at *STOP*-controlled intersections does not contribute to uniformity and subsequent learning through repetition among drivers. Research may lead to a better knowledge of driver understanding and response to various intersection TCDs.

CHAPTER 3
PROJECT METHODOLOGY

In order to investigate the status of attempts to warn motorists that traffic on the crossing roadway is not required to stop, the following tasks were performed. On February 17, 1994, the Federal Highway Administration (FHWA) engineer with the revision file to the current *MUTCD* inspected his records and stated that he "does not know of any pending requests" about this type of sign.

LITERATURE REVIEW

Two sources were employed to identify relevant literature. Various FHWA and state traffic engineers were asked if they were aware of technical papers on this topic, and the TRIS/HRIS database was queried.

INITIAL INTENSIVE EXTENT-OF-USAGE SURVEY

Because these *CROSS TRAFFIC* signs apparently have come into use not as a result of a centrally-coordinated effort, but rather as a result of localized actions in many jurisdictions, a survey was prepared to gather information from disparate sources. The survey forms were mailed to:

1. FHWA regional offices (9);
2. state, District of Columbia, Puerto Rico departments of transportation--DOT (52);
3. Canadian provincial agencies (10); and
4. U. S. and Canadian local traffic engineering agencies (400).

The main purpose of the survey was to identify those agencies across the nation currently using these signs. The survey also asked questions about related types of intersection traffic control. A copy of the survey form is in Appendix B. Contact was also made with the author of *Supplemental Advance Warning Devices*, NCHRP Synthesis 186 *(2)*.

In addition to the direct-mail survey, additional requests were made through news-release notices sent to

state municipal leagues (49),
technology transfer (T^2) centers (51),
Institute of Transportation Engineers (ITE) district chapters (65), and
the National Association of County Engineers (NACE).

These organizations were asked to insert notices requesting information in the publications they distribute. Some of these organizations did choose to "run the story," and furnished complimentary copies of the issue containing the request for information. An issue of the *Urban Transportation Monitor (16)*, a newspaper targeted at transportation professionals, also printed the request.

SUBSEQUENT DETAILED SURVEY

Through responses to the initial survey, a number of transportation agencies using *CROSS TRAFFIC* signs were identified. The researchers made a more detailed request for information from a sample of jurisdictions using these signs.

The aims of the detailed survey were to determine current practices, so the researchers could document and evaluate user agency experiences with *CROSS TRAFFIC DOES NOT STOP* signs. This survey asked:

1. the location and number of devices in use;
2. what amelioration methods had been previously tried;
3. why and when the signs were initially installed;
4. for a description of device configuration, legend, placement, and presence of any additional passive or active devices (such as flashers) used in conjunction with the signs;
5. what has been the experience with the sign;
6. had there been any opposition to or problems with the use of the sign;
7. had any local warrants for use of the sign been proposed or used?

A copy of the survey form is in Appendix B.

CHAPTER 4
FINDINGS

The findings can be divided into three general categories. First, insight was gained from related studies. Second, general information was compiled from the initial extent-of-usage survey responses. Third, specific information was obtained during the intensive follow-up surveys.

LITERATURE REVIEW

The literature identified during the search can be grouped into two classes. Some falls into an overall category of attempts to address violation of the stop control. A second category is the more specific issue of altering the "direction" of stop, either due to changing a multiway stop to a 2-way stop, or changing the direction required to stop at a 2-way stop.

The TRIS computerized database search did yield an abstract from a 1984 South African research report *(14)* stating that a crossroads priority sign to warn side street traffic that cross traffic has priority was tested. From opinion surveys and an experiment, it was concluded that the sign was not effective and that a different system for converting 4-way to 2-way stop should be sought. Since the report was listed as being written in Afrikaans, it was not obtained.

Fundamental Safety Issues

Persaud *(12)* examined the safety effect of converting intersections from one-street-stopped to multiway stop-control. Five issues were considered.

1. Are safety measures more effective at locations where many accidents have occurred?
2. Does safety migrate (i.e., do accidents "go" somewhere else)?
3. Do traffic volumes play a role?
4. Does an acquaintance period help?
5. Does effectiveness decline as more sites are converted?

The data for this study was provided by Ebbecke in a thesis which contained data about the effects of converting 222 intersections of one-way streets from one-street-stopped control to multiway stop-control. These conversions were implemented in Philadelphia, Pennsylvania, from 1970 to 1973. In examining the following issues, the percentage reduction in accidents was estimated for intersections grouped in various ways according to the issue being addressed.

Issue 1: Are safety measures more effective where many accidents occur?

The belief that a safety measure is more effective at locations where many accidents occur than at locations where few accidents occur is often reflected in warrants. For instance, one of the conditions listed in the *MUTCD* as warranting a multiway stop sign is "An accident problem, as indicated by five or more reported accidents of a type susceptible of correction by a multiway stop installation in a 12-month period..." It has been suggested by researchers such as Hauer and Persaud that laws of chance alone can cause accidents to decrease at sites where unusually large numbers of accidents have occurred before a treatment or countermeasure was implemented. Conversely, numbers of accidents may increase at sites with few or no "before" accidents; this phenomenon is known as regression-to-the-mean. It is possible, therefore, to wrongly conclude on the basis of simple before-and-after comparisons that a measure has been effective.

Analysis of the 222 converted intersections showed that the more accidents were expected to occur at a site, the larger the safety effect of a measure is likely to be. This finding is also supported by results obtained in a similar San Francisco study by Hauer, Lovell, and Persaud. An important implication of this finding is that effectiveness should be specified by its relationship to expected number of accidents rather than as a single accident reduction factor, as is currently the practice.

Issue 2: Does Safety Migrate?

This issue arises from a belief by some that an improvement in safety at a treated site leads to a degradation in safety elsewhere in the neighborhood of that site. This phenomenon has been called migration of safety (or "accident migration"). This study found that most of the accidents prevented at the converted intersections had apparently migrated to the unconverted intersections. Persaud offers three explanations for this result. First, drivers may have been compensating for the reduced accident risk at the converted intersections by being less cautious elsewhere. Second, it may be that the accident increases at unconverted intersections were due to confused drivers who were uncertain as to whether those intersections were converted as well. Finally, the apparent migration of safety might have resulted from a redistribution of traffic as drivers sought to avoid the increased delay at the multiway stops.

Issue 3: Do Traffic Volumes Play a Role?

A literature review indicated that a belief exists that the multiway stop conversion measure is more effective when implemented on intersecting roads where the traffic volumes are nearly equal and the total of these volumes is between 6,000 and 12,000 vehicles per day (vpd). This belief is in part reflected by the *MUTCD*. However, this study found no evidence that conversion of intersections to multiway stop control was effective only for certain ranges of total entering volumes; neither was it apparent that effectiveness depended on how this volume was split among the approaches.

Issue 4: Does an Acquaintance Period Help?

It is often claimed that it takes time for drivers to become acquainted with a change in traffic control and therefore the initial period following conversion should be omitted from analysis of the safety effect of the change. Effectiveness based upon an "after" period beginning six months after conversion was compared with effectiveness estimates based on an "after" period commencing immediately after conversion. It was concluded that even if it does take time for drivers to get used to multiway stop conversions, safety is not reduced during this learning period.

Issue 5: Does Effectiveness Decline As More Sites Are Converted?

Ebbecke claimed that the safety effect decreased as more intersections were converted. However, the regression-to-the-mean effects were not eliminated from Ebbecke's study. Persaud asserted that his analysis of the 222 intersections did not support the claim that effectiveness decreased as multiway stop control proliferated in the area.

STOP Compliance and Accidents

Traffic engineers are aware that motorists do not always fully obey traffic control devices. A study *(13)* to investigate why drivers violate stop controls found over a third of both "typical" drivers and chronic violators stated they did so because cross-street volumes were low. Field studies of 31,212 vehicles over 528 hours of observations made at 142 sites found a 67.6% violation rate, with 1.3% resulting in a traffic conflict. Accident and compliance data were collected for 75 stop controlled intersections, and the 75 were divided into low, medium, and high accident categories. The higher accident group was found to have higher approach volumes and speeds than the lower accident group. An analysis of "study" or approach street speed limits, volumes, and accidents found the relationships shown in Table 4.1 to be statistically significant.

An analysis on intersection control was conducted with data from 71 intersections in four large metropolitan areas *(6)*. For accidents involving vehicles on the stop-controlled (2-way) or the lower volume approach (4-way), the average daily traffic on the cross street and on the approach showed a significant direct effect on accidents at intersections under 2-way and 4-way stop control. Sight distance and speed of vehicles on the approach also had a significant effect on accident experience.

TABLE 4.1 -- Approach Speeds, Volumes, and Accidents

Accident Levels	Mean Speed on "Through" Approach km/hr	(mph)	Mean Volume on "Through" Approach veh/hr
Low (0 accidents)	40	(25.0)	16
Medium (2-6 accidents)	45	(28.2)	69
High (7-13 accidents)	50	(31.0)	123

A study *(11)* of *STOP* sign violation rates over a range of major roadway volumes under 6000 found that as major road volume increased, violation rates decreased. One explanation of this is that the higher volume roadways offer an obvious reason for side road vehicles to stop: through road traffic is more often present near the intersection.

Effects of Other Control Device Options

In a study of 61 rural intersections in Indiana, Van Maren *(15)* concluded that the accident rate decreased as the size of the minor road *STOP* sign increased.

Traffic signals operating in the flashing mode act similar to 2-way or all-way stop-controlled intersections. At some intersections controlled by *STOP* signs, flashing beacons are used to supplement the signs. A Texas A&M research project *(4)* both reviewed others' research and performed their own analysis of accidents at intersections with signals operated in the flashing mode. The analysis supported what others had previously concluded: in urban situations, flashing operations are associated with an increase in angle accidents and in the severity of accidents.

Soloman *(15)* studied a number of intersections where red/amber flashers and traffic control signals had been installed. He found that intersection accident rates (accidents per million vehicles) generally went down when flashers were installed. The effects of flashers were more pronounced at low volume intersections. Accident rates increased when traffic control signals were installed at low volume, uncomplicated intersections, but decreased at higher volume or complex intersections.

Agent *(1)* examined 65 rural high-speed, at-grade intersections in Kentucky. Intersection type and geometric, speed limit, right-of-way control, lighting, raised channelization, pavement markings, number of lanes, sight distance, signing, and traffic signal information were obtained through site visits. The information from the site visit and the accident history for each intersection were tabulated. Several intersections were on bypasses. The speed limit on the major intersecting roadway was 89 km/hr (55 mph) at 49 locations and 72 km/hr (45 mph) at 16 locations.

A summary of the types of *STOP* signing used was compiled. Of the several sign combinations that were used, the most prevalent was a single 1.2 m (48 in) sign. In addition to the usual groundmounted location, some *STOP* signs were placed overhead, and some in barrels placed on the pavement. Two intersections that had 2-way stop control used a *CROSS TRAFFIC DOES NOT STOP* plate in conjunction with the *STOP* sign.

Intersection beacons had been added to *STOP* sign control at 11 locations. There were decreases in accidents at seven of the locations and increases at four locations. The overall accident rate decreased from 1.1 to 1.0 accidents per million vehicles (acc/mv) where an intersection beacon was added.

Of the 16 locations where a traffic signal had replaced a *STOP* sign, an equal number of locations experienced decreases and increases in accidents. Four intersections experienced a statistically significant increase, compared to three with a statistically significant decrease.

Among the 20 locations at which a *STOP* sign with an intersection beacon was replaced with a traffic signal, accidents decreased at 12 locations, increased at 7 locations, and remained the same at 1 location. The overall accident rate decreased from 1.4 to 1.1 acc/mv when a traffic signal replaced a *STOP* sign with an intersection beacon.

At locations not controlled by a traffic signal, accidents often involved the side-street vehicle pulling into the path of a through vehicle. The most common explanation given was that the side-street driver, after stopping, did not observe the approaching through vehicle (although sight distance was good in the majority of accidents). The second most common occurrence was that the side-street vehicle failed to stop. Other statements given by the drivers of side-street vehicles included the following: thought the intersection was a 4-way stop, thought the through vehicle was going to turn, or saw the through vehicle but misjudged the time available.

Alternative Warrants for All-Way Stop-Control

A discussion of intersection control problems is not complete without questioning the existing *MUTCD* warrants for conversion to all-way stop control. Intersection control warrants are heavily influenced by traffic delay associated with the particular control strategy. Although the topic of intersection delay falls outside the scope of this report, one such study was reviewed to provide an illustrative example of alternative warrants that could be considered.

Lee and Vodrazka *(5)* evaluated the traffic delay at seven stop-controlled intersections. It was observed that delays began to increase very rapidly at 2-way stop-controlled intersections when 15-minute total volumes on all approaches began to approach 200 to 250 vehicles. At 4-way stops, delays began to increase at total volumes of 300 vehicles per 15 minutes on all approaches. For a given intersection, 2-way stop control produced higher average delay per stopped vehicle, but total delay per vehicle was greater at 4-way stop intersections. The model for total vehicle seconds of delay per 15 minute interval at 4-way stop intersections,

$$\text{total delay} = y = [\ 18.95 + 0.00044\ x^2\ ]^2$$

where x is the total vehicle volume per 15 minute interval, was very consistent with an R^2 of 0.984. This model was developed with input from five intersections, two with four lanes verses two lanes and three with all approaches having four lanes.

Since the total delay at 4-way stops is greater than at 2-way stops for a range of volumes, it was recommended that warrants for 4-way stops should limit the average delay per stopped vehicle rather than total delay. An average delay of 30 seconds per stopped vehicle was suggested, along with a maximum average intersection volume for 2-way operation of 750 to 800 vehicles per hour (vph), and a 30% reduction of table values when major street 85th percentile speeds exceed 40 mph. Depending upon how much delay is considered tolerable and degree of intersection peaking, the authors stated 4-way stop control was warranted with intersection volumes of from 400 to 1000 vehicles per hour (see Table 4.2).

Using *CROSS TRAFFIC* Signs

Literature does contain a few references to the use of *CROSS TRAFFIC* signs. An ITE-section newsletter *(3)* briefly mentions the use of *CROSS TRAFFIC DOES NOT STOP* signing as part of an evaluation of changing stop control patterns at 14 Kansas state highway intersections. A three-year before-and-after comparison of accidents was made. The five intersections changed from 2-way to 4-way control had accidents drop from 45 to three. Changes from 4-way to 2-way at two intersections resulted in going from ten accidents to four accidents. Reversal of stop control resulted in little change in the number of accidents.

NCHRP Synthesis 186, *Supplemental Advance Warning Devices (2),* presented responses from a nationwide survey of many supplemental sign types. Published in 1993, the report listed seven variations of signs attempting to warn motorists at a *STOP* sign that traffic from one or more conflicting directions does not stop. Four states, three counties, and three cities (16% of the survey) responded that they used a variant of this control device. Documentation of the background or effectiveness of *CROSS TRAFFIC* signs was outside the scope of the report.

TABLE 4.2 -- Volume Warrants for 4-way *Stop*-Sign Installation

Peak-Period Factor	Minimum Four-Hour Average Intersection Volumes for Average Delay per Stopped Vehicle of 20 sec	30 sec	35 sec
	Peak-Hour Factor = 0.75-0.80		
0.60	400	525	600
0.70	475	625	700
0.80	550	700	800
0.90	625	800	900
	Peak-Hour Factor = 0.80-0.85		
0.60	425	550	625
0.70	500	650	750
0.80	575	750	850
0.90	650	850	950
	Peak-Hour Factor = 0.85-0.90		
0.60	450	600	675
0.70	550	700	800
0.80	625	800	900
0.90	700	900	1000

Notes:

(1) An average delay of 30 seconds per stopped vehicle is recommended for general use.

(2) Intersection volumes are all-approach totals.

(3) Major-minor flow ratios from 80/20 to 60/40 are included.

(4) Maximum hourly volume for 2-way operation is 800 vehicles per hour (four-hour average).

(5) The peak period factor is analogous to the peak hour factor: the peak period factor relates the maximum hourly intersection flow to the average hourly flow over the four hour period. Peak-period factor equals the average hourly volume for four hours divided by the maximum-hour volume.
PPF = Σ hourly volume for 4 peak hrs / (4 * max. hourly volume)

The *CAUTION, CROSS TRAFFIC DOES NOT STOP* signs were the focus of a study *(7, 8, 9)* for the conversion of unwarranted multiway stop-controlled intersections to less restrictive forms of control. The objectives of this study were to develop and test procedures for converting multiway stop-controlled intersections to 2-way stop-controlled intersections, and to document the safety effects of converting multiway stop-controls to 2-way controls. Recommended procedures reflect empirical data collected from 170 intersections in over 30 jurisdictions throughout the U.S.

The resulting reports stressed the importance of using supplemental plates at all-way stop intersections, to fix in the driver's mind that all directions are supposed to stop; the absence of these plates could lead to driver confusion or uncertainty. If a supplemental *ALL-WAY* plaque has not been used, it was recommended that one be installed at least 30 days prior to conversion. The idea of adding *2-WAY* plaque after conversion was rejected, because the absence of a plaque should imply 2-way stop control.

The authors stated, "The first month immediately after the conversion is the most critical period for accident increase. Drivers who had traveled through the intersection frequently when under a multiway control expect the opposing traffic to stop. Even after the conversion, this expectation can linger. If accidents do increase, there is a concentration of accidents within the first month.

"The use of supplemental signs is intended to overcome this expectation. By advising motorists that in the future the conversion will take place at a certain time, and after the conversion has taken place warning motorists on the stop-controlled approaches that the other approaches do not require a stop, it is hoped that motorists will quickly adapt to the new system.

"In regard to the effect of supplementary signs, the results of the analysis were conflicting. On the one hand, where signs were used, there was a greater percentage of sites where accidents decreased, and, overall, there was a smaller percentage increase in accidents compared with sites without signs. However, what cannot be determined is what further increase in accidents might have occurred if the signs had not been used."

To test warning and information signs and advance notice signs, several alternative warning signs were considered. Seven different sign messages were formulated for a preliminary study on a test group of 30 participants from the University of Maryland. As a result of this preliminary preference test, four more signs were fabricated by the Baltimore Department of Transit and Traffic. These signs formed the basis for a study which included a test to determine the subject's interpretation of sign meaning, a ranking of the signs based on preference, and an opportunity for the subjects to provide comments and suggestions. The test group, consisting of 225 subjects, was reviewed based on age and sex to determine that there was a representative sample.

Results of the sign meaning test were almost identical with the results of the preference test. Of the 11 signs, the black *CAUTION* sign on yellow background separated from the black message on white background (*CROSS TRAFFIC DOES NOT STOP*) was the top candidate as a supplementary sign for safe removal of multiway *STOP* signs. The same top portion reading *CAUTION* with the bottom message *NO LONGER 4-WAY STOP* was a close second preference.

There are three phases to the removal of multiway *STOP* signs *(8)*: the preconversion phase, the actual conversion phase, and the postconversion phase. It was recommended that during the preconversion phase, traffic authorities should conduct traffic engineering studies to determine what type of intersection control is desirable; secure approval for *STOP* sign removals; publicize planned multiway stop intersection conversions; post notice signs with the conversion date mounted adjacent to the *STOP* signs (two supplementary warning signs were recommended); install a *STOP AHEAD* on the remaining stopped-approach; and install necessary pavement markings (including stop lines).

Conversion phase tasks included removing obsolete pavement markings, removing any intersection sight obstructions, and then changing the signs. Prior to the morning rush, authorities should remove the signs with the notification date on the side street and replace them with *CAUTION-CROSS TRAFFIC DOES NOT STOP* signs, and install large *STOP* signs. It was suggested that the supplementary plates used for preconversion notice be replaced by a specific supplementary sign consisting of a top band (610 mm x 152 mm, or 24 in x 6 in) reading *CAUTION* in black letters on yellow background and a bottom portion reading *CROSS TRAFFIC DOES NOT STOP* in black letters on white background. The overall sign dimensions are 610 mm x 457 mm (24 in x 18 in) and the lettering height is 102 mm (4 in). It was also recommended that the surface be reflective sheeting.

In the postconversion phase, authorities should conduct traffic engineering studies, request police enforcement, and eventually remove the *CROSS TRAFFIC* signs. It was recommended that the National Committee on Uniform Traffic Control Devices consider the two notice signs and the warning sign for inclusion in the *MUTCD*.

RESPONSES TO INITIAL INTENSIVE EXTENT-OF-USAGE SURVEY

Transportation professionals expressed a wide range of opinions about the use of TCDs warning minor road drivers that major road traffic is not required to stop (referred to as *CROSS TRAFFIC* signs). Some were for them and some were against them.

With any mail-response survey, there is a possibility that some self-selection takes place in forming the pool of responses; those traffic agencies that are more aggressive or progressive, or those that had experienced problems with the issues being addressed by the survey may be more likely to respond than others.

Table 4.3 presents the mail-response totals from the initial extent-of-use survey. Since the survey included some questions not a part of this study, parts of the survey are not included in the table. Most of the over 300 respondents did use supplemental *ALL-WAY* or *4-WAY* plaques. About half used intersection beacons, while about 1/3 used *STOP* sign beacons.

It is supposed that intersections where one approach had a *YIELD* sign while another approach had the right-of-way to make a 90° movement are less likely to conform to patterns expected by drivers at intersections, and therefore drivers would need to be more alert to determine which movements had right-of-way priority over theirs. Over 1/4 responded they did have this type of intersection.

About 40% indicated they did use supplemental *STOP* sign control devices at or in advance of the intersection to warn motorists they were at a 2-way stop, not an all-way stop. Among those responding, states in the upper midwest and in the far west more often reported using the signs.

Comments from Those Opposing the Sign

Some opposed the use of *CROSS TRAFFIC* signs. Objections expressed included the following.

1. Currently-standard signing methods were adequate.
2. It was the driver's responsibility to observe combinations of *STOP* signs and the presence or absence of any supplementary *ALL-WAY* plaques, and consequences will fall upon those who fail to do this.
3. Driver misinterpretations arising from incorrect assumptions were the fault of the driver.
4. The *CROSS TRAFFIC* signs are not a *MUTCD*-standard sign.

TABLE 4.3 -- Summary of Responses to Initial Survey

	# of responses	Do you have... plaques	int. beacons	*STOP* sign beacons	Do you have right angle control Yes	No	Do you have supplemental *CROSS TRAFFIC* signs or TCDs Yes	No
Alabama	4	4	4	2	1	1	0	4
Alaska	0	0	0	0	0	0	0	0
Arizona	8	8	2	1	3	5	5	3
Arkansas	8	8	3	0	7	1	3	5
California	51	42	12	11	11	40	23	28
Colorado	6	6	1	3	2	4	0	6
Connecticut	4	4	4	0	1	3	2	2
Delaware	1	1	0	0	0	1	0	1
D.C.	1	1	0	0	0	1	0	1
Florida	24	24	18	10	4	20	10	14
Georgia	6	6	6	6	0	6	1	5
Hawaii	2	2	1	0	0	2	0	2
Idaho	1	1	1	1	1	0	0	1
Illinois	7	7	2	0	0	7	7	0
Indiana	1	1	0	0	0	1	0	1
Iowa	4	4	2	2	2	2	4	0
Kansas	4	4	1	2	3	1	2	2
Kentucky	1	1	1	0	1	0	1	0
Louisiana	3	3	3	1	2	1	1	2
Maine	1	1	1	1	0	1	0	1
Maryland	4	4	3	1	3	1	3	1
Massachusetts	1	0	1	0	0	1	0	1
Michigan	5	5	3	1	0	5	3	2
Minnesota	13	13	8	6	4	8	12	1
Mississippi	2	2	1	1	1	1	1	1
Missouri	1	1	0	1	0	1	1	0
Montana	2	2	2	0	0	2	1	1
Nebraska	1	1	0	1	0	1	1	0
Nevada	1	1	1	1	0	1	1	0
New Hampshire	1	1	1	0	1	0	0	1
New Jersey	3	2	2	1	1	2	0	3
New Mexico	3	3	2	1	1	2	0	3
New York	9	9	5	3	3	6	1	8
N. Carolina	7	7	6	4	2	5	3	4
North Dakota	1	1	1	1	0	1	0	1
Ohio	10	10	5	1	3	7	7	3
Oklahoma	3	3	3	1	2	1	2	1
Oregon	6	5	5	3	1	5	4	2
Pennsylvania	2	2	1	0	0	2	0	2
Rhode Island	1	1	1	0	1	0	0	1
S. Carolina	2	2	2	1	1	1	0	2
South Dakota	1	1	1	1	0	1	1	0
Tennessee	6	6	6	1	4	1	5	1
Texas	30	29	25	22	5	24	13	17
Utah	1	1	1	1	1	0	0	1
Vermont	2	2	1	1	0	2	0	2
Virginia	3	3	3	1	3	0	0	3
Washington	11	11	14	5	5	6	4	7
W. Virginia	0	0	0	0	0	0	0	0
Wisconsin	6	6	4	4	1	5	4	1
Wyoming	1	1	1	1	0	1	1	0
Canada	27	25	16	19	6	20	5	20
SUM	303	288	187	124	87	210	132	168

NOTE: Some respondents did not respond to all questions.

One state rejected a request to install such a sign because so doing would create an undesirable set of driver assumptions. Currently, the presence of *ALL-WAY* supplemental signs implies that cross traffic is supposed to stop; therefore, a driver should infer the absence of such a sign to mean that cross traffic does not stop. Introducing a *CROSS TRAFFIC DOES NOT STOP* sign would reverse the situation. In the absence of a *CROSS TRAFFIC* sign, the driver could logically assume the cross street was supposed to stop; this could be a dangerous assumption. Another state agency also opposed using the signs, stating "using other unconventional and non-standard signs...could lead to liability problems..."

A Canadian city responded "...At all-way stop-controlled intersections a red *3-WAY* or *4-WAY* tab is installed under each *STOP* sign...[it] is unambiguous to motorists and cost-effective... If some locations have a *CROSS TRAFFIC DOES NOT STOP* sign and others do not, then motorists would be confused..."

It was reported from three disparate sources (midwest, south, and northwest U.S.) that there had been instances of drivers misunderstanding the *CROSS TRAFFIC DOES NOT STOP* sign, thinking it meant that traffic crossing (i.e, the driver reading the sign) **did not need to stop**. It is not known whether these misunderstandings actually happened, or if these reports are of the same nature as what sociologists refer to as "urban myths." One of the three persons reporting this misunderstanding doubted that it actually happened.

Comments from Those Using the Signs

The comments made by those who have experiences with *CROSS TRAFFIC* signs range from enthusiastic to reserved. The following respondents include both state and local transportation professionals.

ARIZONA

"Some motorists facing a flashing yellow do a rolling stop, are not sure what is expected of them."

CALIFORNIA

"...We use the signs sparingly..."

ILLINOIS

"We do use such a sign...in one certain location...concern started about 10 years ago when a north bound grain truck ran the *STOP* sign and was struck...she was killed. The driver of the grain truck was a local resident and familiar with the intersection. He made a rolling stop..."

"The accident rates have gone down, however, where the sign is used; rumble strips were also installed with other improvements..."

"The general judgement on when to install the sign is when the accident pattern at an intersection suggests that drivers are confused that cross traffic does not stop..."

IOWA

"People...[were] not even reading the *CROSS TRAFFIC*...[this issue] is a concern I've had for some time... Would not have as much a problem using them [*CROSS TRAFFIC* signs] if they were standardized... Perhaps make the supplemental *3-WAY* or *4-WAY* panels a different color or shape - perhaps smaller octagon. I think *CROSS TRAFFIC* signs have not been too effective..."

KANSAS

"Changes in stop control were not the only modifications made... Other measures...included adding sign mounted beacons, *CROSS TRAFFIC DOES NOT STOP* signs, changing lenses in existing overhead beacons and installing *STOP AHEAD* signs..." *(3)*.

LOUISIANA

The problem of drivers incorrectly assuming an all-way stop is "perhaps due to overuse of multiway stops, and not using supplemental plates at all-way stops... [this] has contributed to driver de-education."

MICHIGAN

"...Intersections...tend to be one mile apart... It was our theory that the eastbound driver made the assumption that because the two previous intersections were 4-way stops, this intersection was also a 4-way stop..."

"When [we] first started using the signs, installed them in advance; later changed to installing them on the same post... [It] is more effective to have sign on the *STOP* sign post..." [Note: this is based on subjective experience and comments from police who investigated accidents, not an analysis of data.]

"Some people totally miss the *STOP* sign, even with *STOP AHEAD*"

NEBRASKA

"...In my district...the signs worked well..."

NEW MEXICO

"*TRAFFIC FROM WEST DOES NOT STOP* bothers me, since many drivers can't distinguish up from down, let alone west from east..."

OHIO

"One reason the sign is erected is to address a failure to yield situation..."

WISCONSIN

"Our practice has been to add them at locations where we have experienced an unusual number of right-angle accidents, especially at locations with good visibility and where it appears that the 4-way stop halo effect was a contributing factor. Another practice...is...to relocate all signs on the cross street... perhaps drivers see sign posts on the cross street, assume they are stop signs and pull out in front of oncoming traffic..."

Examples of Sign Use

A number of photographs and drawings of *CROSS TRAFFIC* variations were submitted. Those included in this report were selected to show the wide range of legends that exist.

A few variations of the sign included arrows along with a word legend. Some versions used a single left-right line with arrowheads on both ends; others employed two separate arrows, one in each (i.e., left and right) direction. Some of the *CROSS TRAFFIC* sign legend variations reported are listed below.

CAUTION - CROSS TRAFFIC DOES NOT STOP (used by Ligon et al. in FHWA report)
NOTICE: CROSS ST. TRAFFIC WILL NOT STOP _effective date_ (for 4-WAY removal)
CROSS ROAD (or STREET) TRAFFIC DOES NOT STOP
CROSS TRAFFIC DOES NOT STOP
WATCH FOR CROSS TRAFFIC
WATCH FOR THRU TRAFFIC
WATCH OPPOSING TRAFFIC
ALL TRAFFIC DOES NOT STOP
SIDE STREET TRAFFIC DOES NOT STOP
THRU TRAFFIC DOES NOT STOP
YOU STOP, THEY DO NOT....on other street THEY STOP, YOU DO NOT
name of road *NO LONGER STOPS*
name of road *TRAFFIC DOES NOT STOP*
name of road *DOES NOT STOP*
TRAFFIC ON _name of road_ *DOES NOT STOP*
TRAFFIC FROM _N, S, E, W direction_ *DOES NOT STOP*
TRAFFIC FROM _left or right_ *DOES NOT STOP*
ONCOMING TRAFFIC DOES NOT STOP
YIELD TO ALL ONCOMING TRAFFIC
OPPOSING LEFT TURN TRAFFIC DOES NOT STOP

ACCESS ROAD TRAFFIC DOES NOT STOP
UPHILL TRAFFIC DOES NOT STOP
TWO WAY, THREE WAY
CAUTION 3-WAY
NOT A 4-WAY STOP
STOP AHEAD

Photographs representative of those submitted are shown in Figure 4.1. The signs found in Arkansas are in Figure 4.2. The photos are grouped into

1. *CROSS TRAFFIC DOES NOT STOP* variations,
2. variations notifying that traffic from one direction does not stop, and
3. "others."

They are from Arkansas, California, Colorado, Indiana, Illinois, Minnesota, New Mexico, Oklahoma, Texas, and Washington. One submitter had dated his photo "1978".

Warrants for Use of Sign

A respondent from one state sent a copy of a *CROSS TRAFFIC* sign warrant from the state traffic manual.

ILLINOIS WARRANT:

> *CROSS TRAFFIC DOES NOT STOP* sign (R1-I100). This sign may be used at two-way stop or T intersections where accident records indicate a significant number of accidents involving drivers stopping at the *STOP* sign and pulling into the path of cross traffic. Use of this sign should be restricted to locations where an engineering study indicates a need for it. The sign shall be rectangular with a red legend and border on a white background, an should be mounted directly beneath the *STOP* sign.

(Note: the Illinois sign is 762 mm x 457 mm (30 in x 18 in), and includes left- and right-pointing arrows.)

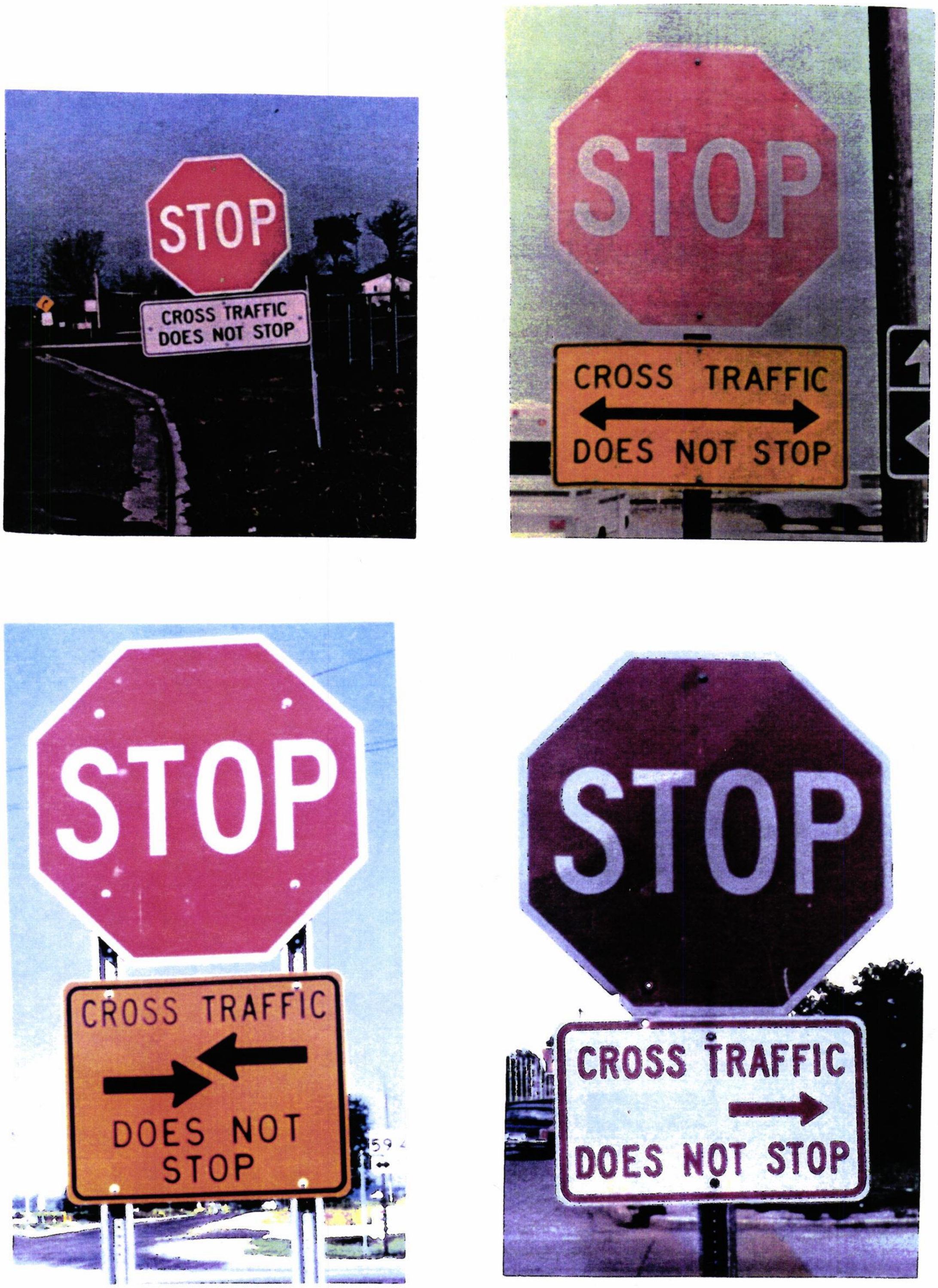
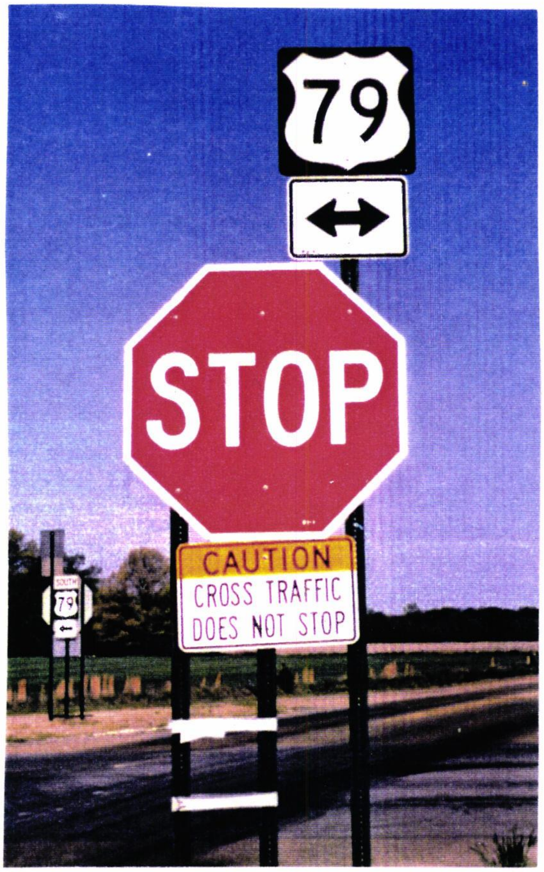


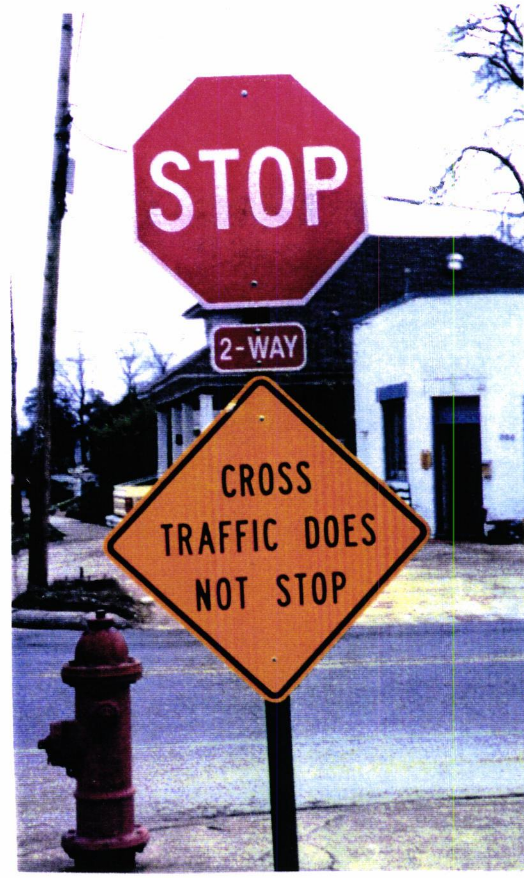
FIGURE 4.1 -- Examples of *CROSS TRAFFIC* Signs

FIGURE 4.1 (con't) -- Examples of *CROSS TRAFFIC* Signs

FIGURE 4.1 (con't) -- Examples of *CROSS TRAFFIC* Signs

FIGURE 4.2 -- Photographs of Arkansas Sites





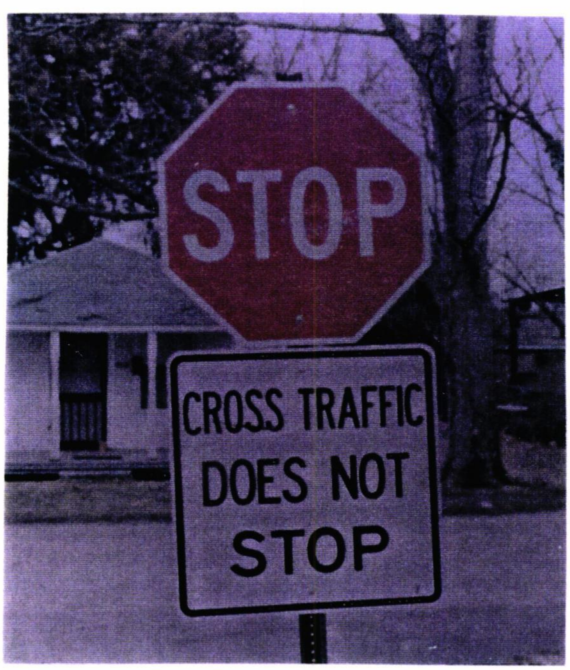


FIGURE 4.2 (con't) -- Photographs of Arkansas Sites

RESPONSES TO SUBSEQUENT DETAILED SURVEY

The responses to the initial survey helped identify a number of transportation agencies using *CROSS TRAFFIC* signs. The researchers selected agencies for the subsequent survey based on the number of signs reported and on geographical distribution. The researchers then conducted a telephone survey to obtain additional information about current practices and to identify sources of before-and-after accident data. A partial summary of responses to the follow-up telephone survey is presented in Figure 4.3.

Why *CROSS TRAFFIC* Signs Have Been Used

Respondents to the subsequent detailed survey described a number of scenarios that have led to the installation of *CROSS TRAFFIC DOES NOT STOP* signs. The identified situations or reasons given for use of these TCDs can be grouped into three general categories.

Category 1: Changing the assignment of right-of-way

1. converting an all-way to a 2-way stop
2. switching the direction that has to stop at an existing 2-way stop

Category 2: Unexpected or uncommon geometric/operational characteristics

3. one or more uphill intersection approaches where traffic is not required to stop because it is difficult to make an uphill start in snow and ice after stopping
4. due to the opening of a new roadway, an existing T-intersection was converted to a 4-leg intersection
5. the presence of a railroad grade crossing on one of the intersection approaches makes it undesirable to have that approach stop, while traffic conditions dictate that all other intersection approaches do stop

Category 3: Driver behavior

6. driver misperception at a 2-way stop that the through road also has a *STOP* when in fact it does not have a *STOP*
7. observed disregard of an existing *STOP* sign

Although common threads link all given reasons for installing the signs, each reason reflects a different set of circumstances.

CROSS TRAFFIC DOES NOT STOP Study: 46 separate responses -- some did not res[illegible]d to all questions; some questions elicited multiple responses

1. Estimate the number of signs or locations where the CROSS TRAFFIC DOES NOT STOP or similar sign is being used.

   "small number": 1 1-5: 17 6-10: 7 11-20: 9 >20: 5

2. What problem are you trying to address with the CROSS TRAFFIC DOES NOT STOP signs?

   12 converting a four-way to a two-way STOP
   12 an existing two-way STOP where switching the direction that has to stop
   31 driver misperception on a two-way that the through road also has a STOP when in fact it does not have a STOP
   2 one or more uphill intersection approaches where traffic not required to STOP because is difficult to drive in snow and ice
   5 something peculiar or unique with intersection, odd geometrics
   5 observed disregard of existing STOP sign(s)
   15 other

3. Had any other methods to address the problem been tried before the CROSS TRAFFIC DOES NOT STOP signs were installed? If "YES", what was tried?

   24 YES 17 NO 1 DON'T KNOW

   6 double STOP signs
   7 advance STOP AHEAD
   5 flags
   3 rumble strips
   9 larger STOP sign(s)
   2 stop lines on pavement
   7 flashers/beacons
   13 other

4. How did you find out about this sign?

   21 don't know; or before my time
   5 (only for City or County) from our State/Province DOT
   3 (only for State/Province DOT) from a City or County
   16 saw them used somewhere else/read about them/heard about them
   4 other

5. (a) Estimate when the signs were initially installed (for how long have the signs been used)?

   13 do not know 6 1970s 16 1980s 11 1990s

FIGURE 4.3 -- Responses to Subsequent Detailed Survey

Describe the device configuration:
(a) legend: ---> 10 if sign also has arrows, please check

- 33 CROSS TRAFFIC/...FROM LEFT/...FROM RIGHT DOES NOT STOP
- 6 CROSS STREET (or ROAD) DOES NOT STOP
- 0 CROSS STREET (or ROAD) TRAFFIC DOES NOT STOP
- 3 name of street (TRAFFIC) DOES NOT STOP
- 12 other

(b) colors:

- 24 black letters on white background
- 11 black letters on yellow background
- 3 black letters on white+yellow background
- 3 red letters on white background
- 2 white letters on red background
- 1 other

(c) placement:

- 42 on STOP sign pole
- 3 in advance of STOP sign
- 2 other

7. Have any additional passive or active devices been used in conjunction with the signs?

- 28 NO; usually use just sign alone
- 11 flashers/beacons
- 2 rumble strips
- 3 STOP AHEAD signs
- 1 stop lines on pavement
- 2 flags
- 2 other

8. Were there any sight distance or other problems at site(s) where sign(s) are installed?

11 YES   29 NO   4 DON'T KNOW

9. What has been the experience with/effectiveness of the CROSS TRAFFIC...sign?

- 19 improved situation
- 11 prevented/reduced accidents
- 6 no change/no improvement
- 14 don't know
- 3 other

(b) Has there been any opposition to or problem with the use of the sign?

6 YES   40 NO   0 DON'T KNOW

- 1 concern that it is not a standard sign
- 2 driver confusion

FIGURE 4.3 (con't) -- Responses to Subsequent Detailed Survey

Accident Experiences with the *CROSS TRAFFIC* Signs

A few respondents were able to furnish details about accident experiences with the sign. The degree of detail offered by the respondents varied. Some information furnished was thoroughly documented, while at the other end of the spectrum, some was anecdotal. Although it would have been desirable to get more detail from some of the respondents, the researchers were reluctant to ask for more than what was offered, since all but the Arkansas data was being furnished as a courtesy.

Arkansas

The survey found the following uses of *CROSS TRAFFIC DOES NOT STOP* or similar-purpose traffic control devices in Arkansas.

Arkansas Highway and Transportation Department

SH 25 @ SH 110 -- east of Heber Springs (has been changed to all-way stop)

US 64 @ SH 5 -- south of El Paso

SH 4 @ SH 15-- south of Warren

US 49 @ US 79 -- west of Monroe

Hot Springs -- one location, now converted to all-way stop

Jonesboro -- a number of intersections

Little Rock -- used on a temporary basis; none in use when inquiry made

Lonoke -- two intersections

North Little Rock -- a number of intersections

The Arkansas Highway and Transportation Department supplied individual accident reports for the four state-system intersections. The more recent reports included copies of statements written by the driver in violation of the *STOP* sign. Table 4.4 presents a comparison of accidents per month (acc/mo) at these four intersections before and after the *CROSS TRAFFIC* signs were installed. Table 4.5 summarizes the effects of the signs at each of the four intersections. One intersection was a T-intersection before the signs were installed, as the fourth leg was still under construction. At another location, the signs were installed on a newly-opened roadway, so there is no "before" period.

Beginning with 1991 accident reports, it became more common to encounter driver-comment forms attached to the police report, although prior to then the officer sometimes included victims' comments. Because the driver-comment sheets began to appear with the accident reports about the time the *CROSS TRAFFIC* signs were installed, there may be a greater decrease in driver misperception about the intersection being 4-way or the stop-driver not seeing the through vehicle than what appears in the data.

The experiences varied among the intersections. At some locations the installation of the signs was accompanied with reduced numbers of accidents, while at Ark 110--Ark 25, the number increased. It should be noted that at Ark 110--Ark 25, the bypass route stops for the radial route, and the "before" period involved a T-intersection while the "after" period involved a 4-leg intersection. At Ark 4--Ark 15, the lower volume bypass has the right-of-way over the higher volume radial route. In addition, the Ark 4--Ark 15 intersection is within the limits of urbanization, while Ark 110--Ark 25 is surrounded by undeveloped land.

At all but the Ark 110--Ark 25 intersection, accidents with a through vehicle coming from the right of the stopped vehicle are highly overrepresented. This, combined with driver statements about "not seeing the oncoming vehicle" suggest that a part of the problem is not driver misperception about right-of-way but rather the drivers are looking for but not seeing oncoming vehicles.

The presence of flashing beacons had a negative effect in one instance. A driver involved in an accident after the signs had been installed thought the intersection had all-way stop control because of the flashing lights.

Statewide average intersection accident rates were not available. The "after" accident rates at these intersections could be compared with rates at other intersections having similar volumes and environments to determine whether the "after" accident rates at the three locations with *CROSS TRAFFIC* signs were lower than those at intersections without the sign treatment.

Florida

A Florida city furnished before-and-after accident diagrams at an intersection where an unneeded traffic signal had been removed and converted to a 2-way stop. In a 19 month period before the sign was installed, there were 13 right angle intersection accidents, or 0.68 accidents per month. In the before period, 4 of the accidents occurred in the first 3 months; disregarding these accidents, there were 9 accidents in 16 months, or 0.56 accidents per month. In a 26 month "after" period, there were 7 right angle intersection accidents, or 0.27 accidents per month.

TABLE 4.4 -- Comparison of Arkansas Before and After Accident Data

	BEFORE				AFTER				COMMENTS
	# of Acc	# of Mos.	Acc/ Mo	% of all STOP Acc	# of Acc	# of Mos.	Acc/ Mo	% of all STOP Acc	
US 64 @ Ark 5									Aug. 1987 - Aug. 1993
STOP violation accident	31	36	0.86		20	36	0.56		month of conversion not included
"thought was 4-WAY"	7	36	0.19	23%	0	36	0.00	0%	comments lacking before mid-1991
STOP veh. "did not see"	9	36	0.25	29%	14	36	0.39	70%	
Acc. w/ Rt. of STOP veh	22	36	0.61	71%	18	36	0.50	90%	
US 79 @ US 49									Nov. 1989 - Dec. 1994
STOP violation accident	13	36	0.36		7	25	0.28		month of conversion not included
"thought was 4-WAY"	3	36	0.08	23%	2	25	0.08	29%	comments lacking before mid-1991
STOP veh. "did not see"	4	36	0.11	31%	5	25	0.20	71%	
Acc. w/ Rt. of STOP veh	6	36	0.17	46%	6	25	0.24	86%	
COMBINATION OF 2 ABOVE INTERSECTIONS									
STOP violation accident	44	72	0.61		27	61	0.44		
"thought was 4-WAY"	10	72	0.14	23%	2	61	0.03	7%	
STOP veh. "did not see"	13	72	0.18	30%	19	61	0.31	70%	
Acc. w/ Rt. of STOP veh	28	72	0.39	64%	24	61	0.39	89%	
Ark 110 @ Ark 25 (During "Before" period, was a T-intersection)									Jan. 1991 - Dec. 1993
STOP violation accident	6	7.5	0.80		22	16	1.38		month of conversion not included
"thought was 4-WAY"	0	7.5	0.00	0%	8	16	0.50	36%	comments lacking before mid-1991
STOP veh. "did not see"	1	7.5	0.13	17%	5	16	0.31	23%	NOTE: one "After" driver said
Acc. w/ Rt. of STOP veh	2	7.5	0.27	33%	5	16	0.31	23%	"thought was 4-way because of flashing light"
COMBINATION OF 3 ABOVE INTERSECTIONS									
STOP violation accident	50	79.5	0.63		49	77	0.64		
"thought was 4-WAY"	10	79.5	0.13	20%	10	77	0.13	20%	
STOP veh. "did not see"	14	79.5	0.18	28%	24	77	0.31	49%	
Acc. w/ Rt. of STOP veh	30	79.5	0.38	60%	29	77	0.38	59%	
Ark 4 @ Ark 15									Nov. 1990 - Oct. 1993
STOP violation accidents		0			10	36	0.28		Ark 4 Bypass opened Nov. 1990
"thought was 4-WAY"		0			0	36	0.00	0%	comments lacking before mid-1991
STOP veh. "did not see"		0			4	36	0.11	40%	
Acc. w/ Rt. of STOP veh.		0			10	36	0.28	100%	

CODES: "thought was 4-WAY": driver violating STOP made comment indicating misperception
STOP veh. "did not see": driver of STOP vehicle either did not see or thought Thru was turning right
Acc. w/ Rt. of STOP veh.: vehicle violating STOP collided with vehicle coming from right

TABLE 4.5 -- Discussion of Four Arkansas Sites

ROADWAYS	DESCRIPTION OF AREA	VOLUME (ADT) n-s	e-w	EXPERIENCE WITH SIGNS (with before;after Accident Rate per MV)
US 64 @ Ark 5	in a rural area with light commercial development near the intersection; is on a slight skew	4000	4900	It appears the *CROSS TRAFFIC* signs helped; accident frequency and reported driver misperception declined. The accident rate declined more at this location than at the others, and the "after" period experienced the lowest accident rate of the four locations studied. (3.18;2.05)
US 79 @ US 49	rural area	2000	2000	The number of accidents declined after the signs were installed. The fewer number of accidents and smaller changes in rates make any comparison less certain. (2.97;2.30)
Ark 110 @ Ark 25	intersection created by new Ark 25 bypass; SB Ark 25, approaching the intersection around a curve and downhill, was opened Oct. 1991, before the NB approach (Aug. 1992)	3100	4900	It appears the signs did not improve the overall accident situation, as the highest accident rate of all occurred during the "after" period; was converted to all-way stop control after less than two years. (3.29; 5.65)
Ark 4 @ Ark 15	intersection created by new Ark 4 bypass; area surrounded by scattered commercial and industrial land uses; NB Ark 15 traffic encounters a reverse curve before approaching the *STOP* sign, but advance sight distance is more than ample	2500	1600	The available data suggests this intersection was not experiencing a problem with driver misperception of who has a *STOP* sign. The accident rate falls in the mid-range of the four locations. (na; 2.23)

Another Florida city had "informal" data. Where a 4-way stop had been converted to 2-way, they experienced 2 accidents. After installing *CROSS TRAFFIC* signs, no accidents occurred.

A former Florida engineer recalled that a city "had a lot of right angle accidents where motorists were confusing 2-way for a 4-way." After installing *CROSS TRAFFIC* signs, accidents dropped from 14 per year to 2 per year.

Idaho

An Idaho county reported the use of *TRAFFIC FROM RIGHT DOES NOT STOP* at a 4-leg intersection. Most of the intersection traffic follows a WB-to-SB or a NB-to-EB route. There had been *STOP* signs for only EB and SB vehicles, as shown in Figure 4.4. An increase in NB traffic proceeding straight through (or north) led to the addition of a *STOP* sign for NB traffic along with the *TRAFFIC FROM RIGHT DOES NOT STOP* sign.

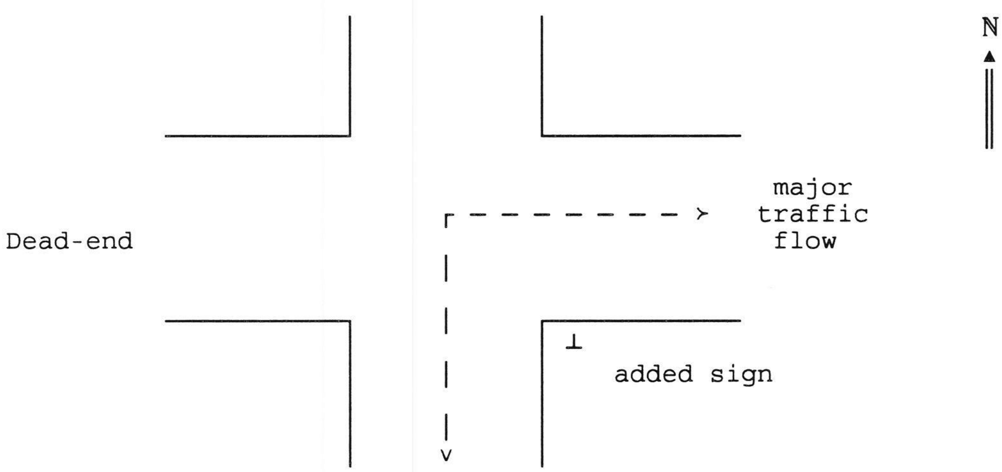


FIGURE 4.4 -- Idaho Intersection

According to the county engineer, there were no recorded accidents at the intersection either prior to or after installation of the sign. After the sign was installed, NB drivers initially resisted stopping, but that tendency has ceased. Local drivers have reported they initially resented the sign but have witnessed situations where the sign prevented collisions.

Indiana

The accident summaries at a number of intersections in a county with signs to warn drivers on a stop-controlled approach that the crossing approach does not stop are in Table 4.6. This data seems to suggest that conversion to 4-way stop or signal installation is more effective in reducing intersection accidents that the use of *CROSS TRAFFIC DOES NOT STOP* or similar signs. However, the notes accompanying the original data stating some intersections had been signalized or had been annexed into the city suggest that traffic volume growth could be playing a part in the rising accident frequencies exhibited at a number of these intersections. Given the extended duration of this data, it is likely that volumes rose over the time period presented.

TABLE 4.6 -- Comparison of Indiana Before and After Accident Data

	"BEFORE" Period				"AFTER" Period Install *CROSS* signs				SUBSEQUENT CHANGE *CROSS* signs removed			
	Begin Date	# Acc.	# Mos.	Acc/ Mo	Begin Date	# Acc.	# Mos.	Acc/ Mo	Begin Date	# Acc.	# Mos.	Acc/ Mo
GROUP "A"									changed to 4-way			
# 1	01/01/77	125	168.5	0.74	01/17/91	22	42.5	0.52	08/02/94	1	5.0	0.20
# 2	01/01/77	124	132.4	0.94	01/15/88	57	69.6	0.82	11/01/93	3	14.0	0.21
# 3	01/01/77	35	118.3	0.30	11/12/86	34	54.3	0.63	05/24/91	4	43.3	0.09
# 4	01/01/77	7	124.8	0.06	05/29/87	9	86.1	0.10	08/02/94	1	5.0	0.20
# 5	01/01/77	24	123.6	0.19	04/21/87	24	78.4	0.31	11/01/93	1	14.0	0.07
# 6	01/01/77	53	121.2	0.44	02/06/87	31	43.0	0.72	09/06/90	9	51.8	0.17
GROUP "B"									Installed Traffic Signal			
# 7	01/01/77	26	118.3	0.22	11/12/86	38	43.6	0.87	07/01/90	8	54.0	0.15
GROUP "C"									no change			
# 8	01/01/77	8	131.9	0.06	12/30/87	14	84.07	0.17				
# 9	01/01/77	29	112.6	0.26	05/22/86	27	103.4	0.26				
# 10	01/01/77	8	131.9	0.06	12/30/87	10	84.07	0.12				
# 11	01/01/77	18	194.7	0.09	03/25/93	1	21.26	0.05				
# 12	01/01/77	11	133.0	0.08	02/01/88	7	82.99	0.08				
# 13	01/01/77	5	164.1	0.03	09/04/90	1	51.91	0.02				
# 14	01/01/77	0	123.4	0.00	04/14/87	0	92.62	0.00				
SUMMARY												
GROUPS A & B		394	907.2	0.43		215	417.5	0.51		27	187.2	0.14
GROUP C		79	991.6	0.08		60	520.3	0.12				
ALL 3 GROUPS		473	1899	0.25		275	937.8	0.29				

Michigan

One Michigan county conducts an accident analysis at all intersections appearing on the annual listing as having five or more accidents per year. At one intersection, an E-W road with 3000 ADT (1995) stops for a major N-S road with 5200 ADT (1995). The *CAUTION CROSS ROAD TRAFFIC DOES NOT STOP* signs were installed on the E-W road in December 1993. Table 4.7 reports the accident totals.

TABLE 4.7 -- Michigan Accident Data

	Year											
	1	2	3	4	5	6	7	8	8.9	9	10	10.3
	1985	1986	1987	1988	1989	1990	1991	1992	1993	1993	1994	1995
									part	part		part
	<-----		before sign installed						----->	<---	after	--->
all accidents	3	5	3	11	9	7	3	6	5	0	9	2
right angle	2	5	3	10	5	6	2	4	4	0	4	1
# of months	<-----				107				----->	<---	17	--->
rt. ang. acc/yr					4.6						3.5	
# of months						<-----		47	----->	<---	17	--->
rt. ang. acc/yr								4.1			3.5	
# of months							<---	35	--->	<---	17	--->
rt. ang. acc/yr								3.4			3.5	

NOTE: 1995 accident data through April 1995

One's opinion of the signs' effectiveness depends upon which "before" period is compared with the "after" (December 1993 through April 1995) period. Accident occurrence peaked in the late 1980s; a "before" period including the late 1980s yields a higher accident frequency than using a shorter period excluding any 1980s years. If one uses only the most recent three or four year period before the *CROSS TRAFFIC* signs were installed to compare to the 17 month "after" period, then little improvement is apparent.

The average number of right-angle accidents per year in the before period was 4.6, with σ_n=2.3. The short "after" period is showing a rate of 3.5. For a better comparison, more months of "after" data will be required. If the "after" period right-angle accident mean were to be 3.1 for 8 years, with σ_n= 0.5 x mean, the "after" mean would be significantly less than the "before" mean with high confidence level (α=0.95).

Oregon

An Oregon city used *SIDE STREET TRAFFIC DOES NOT STOP* signs at a 4-leg intersection of a 44 ft. wide N-S collector with a 40 ft. wide E-W collector in a residential area. Volumes on both streets are around 3000 vpd. They made use of a sign already developed by their state highway department. The N-S collector has the *STOP* and a red-flashing beacon; the E-W collector has a yellow beacon. Two blocks to the north, the collector has a *4-WAY STOP*.

In a 68 month period before the signs were installed, there were 21 right angle intersection accidents, or 0.31 accidents per month. In a 20 month "after" period, there was 1 right angle intersection accident, or 0.05 accidents per month. The "after" period may need to be longer to obtain a true idea of "after" performance.

Saskatchewan

The intersection of two low-volume rural roadways south of a small town experienced 12 accidents in a 24 month period after 4-way stop control was changed to 2-way stop control. Compounding the change, what had earlier been a T-intersection had become a 4-way stop, and the completion of the fourth leg caused the primary travel directions to be shifted from one road to the other. Weekday volumes on one roadway are about 1200 vpd, on the other about 600 vpd. Weekend volumes are assumed to be higher. The two highways intersect at a 75° angle.

Only 3 of the accidents were on wet pavement. Of the 12 accidents, 9 were right-angle accidents, and 8 of the 9 involved SB vehicles. A consultant reported that 3 or 4 of the accidents involved drivers who incorrectly thought that all-way stop was in effect: drivers failed to respond to the presence of *CAUTION-CROSS TRAFFIC DOES NOT STOP* signs installed on the stop sign pole. In 6 of the 9, the "through" vehicle was to the right of the "stop" vehicle. In 3 of the accidents, erring drivers reported they did not see the oncoming "through" vehicle. Other reported accident causes included obscured vision due to sun glare or other vehicles, driver inattention, or driver incapacitation. Some of the erring drivers mentioned visual clutter in the area as contributing to driver confusion. The consultant considered two of the accidents to be unusual occurrences and recommended they not be considered as related to intersection control. The consultant also commented that the accident frequency was declining toward the end of the two year study period to a point where the intersection "can no longer be considered a problem area."

Wisconsin

A Wisconsin county uses the *TRAFFIC ON X DOES NOT STOP* signs at two intersections.

At one location, there are about 1200 vehicles per day (vpd) on the through road, and about 700 vpd on the stop-controlled road. The date of sign installation has been lost, but a review of intersection accidents between 1987 and 1993 shows some increase in the intersection accident rate.

At the second location, there are about 2800 vpd on the through road, and about 950 vpd on the stop-controlled road. There were 13 intersection accidents in a 55 month period before the signs were installed (0.24 accidents/month, or 2.8 acc/yr), and 6 intersection accidents in a 29 month period after the signs were installed (0.21 accidents/month, or 2.5 acc/yr). Data from both locations are in Table 4.8.

TABLE 4.8 -- Wisconsin Accident Data

	Year								
	1	2	3	4	5	5.6	5.4	6	7
	1987	1988	1989	1990	1991	1991	1991	1992	1993
Intersection 1		... year	of	change	unknown	...			
total # accidents	1	2	2	0	2	na	na	0	3
acc/mv	1.44	2.88	2.88	0	2.88			0	4.33
Intersection 2				before		---><---		after	
total # accidents	3	2	4	3	na	1	1	3	2
acc/mv	2.19	1.46	2.92	2.19		1.26	1.86	2.19	1.46

Issues Raised by Accident Data

A review of the accident data supplied by various transportation agencies, along with comments found in the literature and made by respondents to the surveys, raised the following issues.

1. The proportion of *STOP* sign violators who strike a through vehicle coming from the violator's right should be factored in any evaluation; a disproportionately high percentage could indicate the problem is driver oversight, not misperception about right-of-way.
2. Is the placement of sign posts at the intersection interfering with the stopped driver's view of oncoming traffic from the right?
3. Is the right-side front car roof pillar interfering with the stopped driver's view of oncoming traffic from the right?
4. Are skewed intersections overrepresented in the problem intersections?

There was not enough data to evaluate whether one version of the *CROSS TRAFFIC* sign was superior to others. Uniformity would be desirable; even if many of the numerous *CROSS TRAFFIC* sign variations were effective enough to warrant continued use, could a better job of informing the driver be performed if such signs were uniform? Ongoing research at other places may in part answer these questions. It does seem that practice of referring to a direction, such as *TRAFFIC FROM WEST*, makes an unrealistic assumption about the awareness of the driving population.

The issue of regression-to-the-mean must also be considered. The tendency for a high accident period to be followed by a low accident period can create the illusion of effectiveness of a particular accident countermeasure, when in fact the decline in accidents after the countermeasure has been implemented is the result of chance. A common traffic engineering practice has been to obtain three years of before and three years of after period data, for among other reasons, to overcome the effects of small sample size. Certainly there is more stability in three years of data than in one year's data. The Wisconsin data set showed an amount of stability over successive three year periods. In contrast, the Michigan data exhibited running three year totals of all accidents in the "before" period ranging from 11 to 27 (3.7 acc/yr to 9 acc/yr). Even the four year running totals yielded rates ranging from 5.2 acc/yr to 7.5 acc/yr. In this case, even a three year period does not seem to give a true average accident rate.

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CHAPTER 5
SUMMARY AND CONCLUSION

Attempts to inform a driver facing a *STOP* sign that the crossing roadway or some other conflicting traffic stream does not stop have been made in response to what seems to be driver misperception and the inability of some drivers to properly respond to standard traffic control devices. The objectives of this research were to investigate and report

1. the present usage of *CROSS TRAFFIC DOES NOT STOP* and other similar supplemental traffic control devices;
2. the circumstances under which these traffic control devices (TCDs) have been installed, and the situational needs warranting such TCDs, as perceived by traffic officials;
3. any studies or reports of experiences with such TCDs, and the effectiveness of such TCDs;
4. the broader issue of "where do we go from here?" Does the current state of affairs suggest alternative solutions, new warning methods, a change in the *MUTCD*, or new research directions?

To accomplish this, the researchers conducted a review of related literature, an extensive survey to determine the extent of *CROSS TRAFFIC* sign use, and a subsequent detailed survey targeted at sign users identified through the initial survey.

AN OVERALL PERSPECTIVE

An investigation of the *CROSS TRAFFIC DOES NOT STOP* or other similarly-worded signs cannot be separated from related traffic control issues. The circle of issues surrounding non-signalized intersection control can be drawn as large as one wishes. The following issues are related to *CROSS TRAFFIC* signing.

1. traffic engineers' desire to use minimal amounts of traffic control, and the relative merits of different levels of intersection traffic control -- the relative safety and delay with no control, yield control, 2-way stop control, and all-way stop control, and which option offers the least delay while preserving safety
2. traffic engineers' concerns that unnecessary proliferation of all-way stop increases delay to motorists, and breeds driver disrespect and disregard for justified all-way stop controls
3. traffic control for intersections with unusual geometric or right-of-way assignment patterns
4. the effectiveness of flashers or beacons at stop-controlled intersections

5. the relative safety of three-leg or T-intersections compared with 4-leg intersections
6. proper traffic control for residential areas -- should all-way stops be installed to calm traffic?

While the scope of any research project is of necessity limited, these issues must be considered when focusing on the specific issue of *CROSS TRAFFIC* signs.

RELATED LITERATURE

The literature does contain a few references to the use of *CROSS TRAFFIC* signs. Perhaps the most information is provided in a FHWA-sponsored study that recommended use of such signs when converting a 4-way to a 2-way stop.

When faced with perplexing intersection control problems, the traffic engineer may face difficult choices. Various research studies have reported that

1. installation of all-way stop controls in an urban area may reduce accidents at that intersection while increasing accidents at nearby intersections;
2. motorists may violate stop-controls, especially when cross street traffic volumes are low;
3. intersection beacons may not reduce intersection accident rates;
4. when traffic signals were installed at low volume, uncomplicated intersections, accident rates increased.

Thus many of the options one might employ to address a 2-way stop intersection accident problem may be ineffective or even harmful in a specific situation.

Even if a traffic engineer thinks safety concerns justify them, higher levels of intersection traffic control may not be justified under existing *MUTCD* warrants. The cited alternative warrant study based on delay is decades old, and work on stop-controlled intersection capacity and delay has continued since then.

As a commentary on this literature, it can be noted that many of the intersections reported herein had volumes under those needed to justify *ALL-WAY STOP* signs as a remedy for the accident problem. Warrants for all-way stop control based on delay alone may not give the practicing traffic engineer the range of options needed to deal with real-world problems. At an intersection with an accident problem, demands for an all-way stop may be rejected because the volume warrants are not met. However, it seems inconsistent to argue that all-way stop control should not be installed at low volume intersections because of the resulting unnecessary delay, then employ unusual right-of-way patterns (e.g., three of the four legs having *STOP*, or a 90° movement with priority) that cause drivers to be unsure who has right-of-way and unnecessarily wait for an approaching vehicle that comes to a stop upon reaching the intersection.

SURVEY RESULTS

Most of the over 300 respondents from the initial extent-of-use survey did use supplemental *ALL-WAY* or *4-WAY* plaques. About half used intersection beacons, while about 1/3 used *STOP* sign beacons. Over 1/4 responded they did have intersections at which one approach had a *YIELD* sign while another approach had the right-of-way to make a 90° movement.

About 40% indicated they did use supplemental *STOP* sign control devices at or in advance of the intersection to warn motorists they were at a 2-way stop, not an all-way stop. (It should not be inferred that this represents the proportion of all transportation agencies that use the sign.) A wide variety of legends, color combinations, shapes, and placement locations were found among various agencies using the *CROSS TRAFFIC* signs. A warrant for use of the sign in the Illinois manual was submitted.

Among reasons given for objecting to use of the sign were the adequacy of existing standard signs, the *CROSS TRAFFIC* sign is not a *MUTCD*-standard sign, and the potential for driver confusion and liability. Some who had used the signs did not think they were particularly effective.

Respondents to the subsequent detailed survey described a number of scenarios that have led to the installation of *CROSS TRAFFIC DOES NOT STOP* signs. The identified situations or reasons given for use of these TCDs can be grouped into three general categories.

Category 1: Changing the assignment of right-of-way

1. converting a 4-way to a 2-way stop
2. switching the direction that has to stop at an existing 2-way stop

Category 2: Unexpected or uncommon geometric/operational characteristics

3. one or more uphill intersection approaches where traffic is not required to stop because is difficult to make an uphill start in snow and ice after stopping
4. due to the opening of a new roadway, an existing T-intersection was converted to a 4-leg intersection
5. the presence of a railroad grade crossing on one of the intersection approaches makes it undesirable to have that approach stop, while traffic conditions dictate that all other intersection approaches do stop

Category 3: Driver behavior

6. driver misperception on at a 2-way stop that the through road also has a *STOP* when in fact it does not have a *STOP*
7. observed disregard of an existing *STOP* sign

Although common threads link all given reasons for installing the signs, each reason reflects a unique set of circumstances.

EFFECTS OF THE *CROSS TRAFFIC* SIGNS ON ACCIDENTS

A comparison of "before" and "after the sign was installed" accident frequencies was made in an effort to assess the effectiveness of the *CROSS TRAFFIC* signs. This analysis was not of just one specific sign (i.e., not of one specific wording, color, etc.), since a number of sign variations are in use.

Accident analysis is a less than perfect process, since accidents may be incorrectly reported or even be absent from the data base. While some insight may be obtained through analysis of statements made by the accident victims, there are some inherent weaknesses with such an analysis. At-fault drivers in right angle intersection accidents may not recall or even have ever been aware of "what made them do it." Drivers may make statements about "not seeing oncoming vehicles" or thinking the "other direction was also supposed to stop" when in fact they did not think this, or the drivers may neglect to make such statements when in fact that is what transpired.

Specific Effects on Accidents

The effectiveness of *CROSS TRAFFIC* signs, as measured by before-and-after traffic accident statistics, was not consistent across the range of studied intersections. By virtue of requesting before-and-after accident data, the data submitted was primarily from intersections at which the signs had been employed to address a supposed right-of-way misperception or driver violation situation, not from locations at which the right-of-way pattern was being changed.

Information submitted from Florida, Idaho, and Oregon indicated the signs had been effective in reducing accident rates at intersections or reducing numbers of "close calls." Data from Michigan and Wisconsin intersections offered no clear-cut conclusion.

Accident summaries from Indiana and Saskatchewan indicated ineffectiveness of the signs. The Indiana data suggested conversion to 4-way stop or signal installation is more effective in reducing intersection accidents than the use of *CROSS TRAFFIC DOES NOT STOP* or similar signs; perhaps rising traffic volumes were a factor in these statistics.

With both the Indiana and the Wisconsin county road accident data, it was not possible to evaluate only right angle or stop violation accident rates. Perhaps more detailed data would lead to different conclusions.

The Arkansas Highway and Transportation Department supplied individual accident reports for four state-system intersections. One of the intersections had been converted from a T- to a 4-leg intersection about the time the signs were installed, and the signs were installed on another when the intersection was opened, so there was no "before" period. The installation of the signs was accompanied by a decline in accident rates at two intersections. At the intersection changed from a "T" to a 4-leg (Ark 110--Ark 25), there was a jump in accidents after the sign appeared; this location consisted of a bypass route stopping for a radial route. Incomplete data sources suggest the *CROSS TRAFFIC* signs were connected with lower frequencies of driver misperception about the intersection being 4-way at all but the Ark 110--Ark 25 location. The Arkansas data confirmed what other researchers had noted: violating drivers reporting they did not see the oncoming through vehicles. There was also a high occurrence of accident involvement with a through vehicle approaching from the stopped driver's right, with the Ark 110--Ark 25 intersection being the lone exception. Overall, this suggests that a part of the problem is not driver misperception about right-of-way but rather drivers looking for but not seeing oncoming vehicles.

Statewide average intersection accident rates were not available. The "after" accident rates at these intersections could be compared with rates at other intersections having similar volumes and environments to determine whether the "after" accident rates at the three locations with *CROSS TRAFFIC* signs were lower than those at intersections without the sign treatment.

Inferences from Accident Data

A review of accident data suggests that the stop-controlled intersection "right-angle accident problem" is in actuality a number of different problems.

1. the line-of-sight of some drivers at *STOP* signs is blocked; contributing factors may include drivers not adequately "looking around" the vehicle door posts, intersection skew, or the presence of other vehicles
2. some drivers overlook plainly visible oncoming through roadway vehicles, and background "visual clutter" compounds this oversight problem
3. at "normal" intersections, some drivers incorrectly assume that cross traffic is supposed to stop; unusual right-of-way arrangements at some intersections violate driver expectancy, leading some drivers to incorrectly assume that one or more movements is supposed to stop, when in fact that movement is not required to stop

If the intersections at which it is suspected that drivers are making incorrect right-of-way assumptions are in fact experiencing right angle accidents due to a number of different factors, then countermeasures aimed at the right-of-way misperception problem may affect only a portion of the total number of accidents. Even if the countermeasure were 100% effective on that portion of accidents caused by right-of-way misperception, only a fraction of the total number of right angle intersection accidents would be eliminated. Elimination of only a fraction of all right angle intersection accidents could make it difficult to ascertain any statistically significant improvement in intersection safety attributable to installing *CROSS TRAFFIC* control devices.

Those agencies volunteering accident data submitted information in varying degrees of detail. After reviewing the variations, it was concluded that future *CROSS TRAFFIC* sign effectiveness studies should be based on individual accident reports, in order to obtain the degree of detail needed and to differentiate among various types of right-angle intersection accidents.

SUGGESTED IMPLEMENTATION

This project began with one of two stated outcomes expected. Either

a. based on the documented experiences of others, the project would define situations warranting the use of the sign, and define the preferred sign color, shape, and legend. Such definition would allow formulation of a request to include the sign in the *MUTCD*;

or

b. based on a lack of documented experience, the study would define the needs for a second phase, such as studies of the effectiveness of such signs, or tests to determine which alternative motorists best understand and respond to.

The second alternative was stated as the more likely outcome. The actual outcome fell somewhere between these two alternatives.

Reviews of *CROSS TRAFFIC* sign performance yield seemingly inconsistent results; perhaps more experience and studies will reveal a more pronounced trend. In the mean time, traffic engineers are in a perplexing situation: what to do about continued use of these signs. The following recommendations are offered.

1. Every transportation agency should develop typical intersection accident rates, classified for ranges of volume, type of traffic control present, and environment (e.g., large urban, rural, tourist, etc.). These rates can be used to determine the relative safety of intersections. It may be more feasible for state agencies to do this and distribute the information to cities and counties than for each agency to independently develop such information.
2. If accident rates for intersections of similar volume, character, and type of traffic control are available, these should be used as a baseline to determine whether a particular intersection is

experiencing an elevated accident rate. Engineers can use such "baseline comparison rates" both to evaluate the need for *CROSS TRAFFIC* signing or other TCDs at intersections, and for removal of existing signs. Removal can be justified in part by the concern that overuse of the signs may contribute to drivers assuming the absence of the sign means an all-way stop.

3. Do not install the *CROSS TRAFFIC* signs at additional intersections unless there is a documented problem with driver misperception or other situation correctable with the signs. (This restriction does not apply to temporary use of the signs at right-of-way change locations, such as changing a 4-way to 2-way stop.) When considering the use of the signs, there should be an analysis of at least two years, and preferably three years, of individual accident reports from the intersection.
4. Closely monitor the accident patterns at 2-way stop-controlled bypasses; compare rates where the radial route stops for the bypass against rates where the bypass stops for the radial route, factoring in the surrounding environment. If the contrast of the Ark 110--Ark 25 experience with the Ark 4--Ark 15 experience does hold true for other intersections, then there may be justification in certain circumstances for stopping the radial route for the bypass, even if the radial route has higher volumes.
5. Additional study is needed to document the effectiveness of these signs. Both a larger study pool and a long time period are needed.
6. Interested states should raise the issue of these signs at a national level, debating both the merit of the sign and particular alternative versions of the sign. The discussion should include the issues raised in "Possible Future Direction."

POSSIBLE FUTURE DIRECTION

A number of traffic engineers have felt a need to use non-standard *CROSS TRAFFIC* signs to alert motorists at intersections where there seems to be a right-of-way misperception problem. The use of these signs has spread, even without the sanction of the *MUTCD*. It would seem desirable for national groups to consider a future course of action, to achieve uniformity. The following is a listing of possible future directions.

1. Continue existing signing practices (do not use *CROSS TRAFFIC* signs). Some traffic engineers are of the opinion that there is nothing inherently wrong with current stop-controlled intersection signing practices: drivers should assume all *STOP* signs are 2-way

unless notified otherwise, not the other way around. Any operational problems that may exist result from uncorrectable driver error.

2. Mandate installation of *ALL-WAY* supplemental plates at all stop-controlled intersections where applicable. This approach assumes the hypothesis that if *ALL-WAY* were always posted where applicable, then there would be no driver confusion, because the absence of *ALL-WAY* would automatically imply that one or more conflicting movements was not required to stop.
3. Mandate universal use of an *ALL WAY* supplemental plate, considerably larger and more conspicuous than the current small supplemental plates.
4. Install *CROSS TRAFFIC DOES NOT STOP* or similar signs at problem intersection locations, and otherwise let stop-controlled intersection signing remain as-is. A possible flaw with this approach is that once an unknown threshold-number of intersections were signed with *CROSS TRAFFIC DOES NOT STOP*, then driver expectancy would cause a portion of drivers to either consciously or subconsciously assume that the absence of such sign implied that cross traffic **did** stop, leading to more right angle accidents. This in turn could create the need for universal signing of 2-way stop-controlled intersections with *CROSS TRAFFIC DOES NOT STOP*.
5. Install the *CROSS TRAFFIC DOES NOT STOP* sign at all applicable intersection locations. If there is actually a problem with some drivers thinking the signs mean they do not have to stop since they are crossing traffic, then the use of left-right arrows along with the words may clear up this misconception. This approach would be expensive to implement.
6. Assume that the current "one size fits all" practice of using the same *STOP* sign at intersections with different right-of-way assignment patterns is inherently flawed. As an alternative, *STOP* signs at all-way stop intersections could have a different appearance than those where one or more approaches were not required to stop. For instance, traffic approaching the common 2-way stop at a 4-leg intersection would see the standard octagon with the word "Stop," but with through arrows from the left and right added. This approach would be expensive to implement.

CLOSING

The findings of this research on the effectiveness of *CROSS TRAFFIC DOES NOT STOP* and similar signs can be summarized with the following points.

1. The accident data submitted for this research yielded mixed results about the sign's

effectiveness. At some locations, the signs did seem to reduce accident frequencies. At other locations, accidents continued in spite of the presence of the signs.

2. Expanded use of the sign could cause drivers to come to expect them at all 2-way stop control situations. If this concern were realized, the degree of use that would bring about this alteration in driver behavior is not known.
3. It is suggested that the sign be used only on a very limited basis, at locations where statements from those violating the *STOP* signs suggest repeated incidents of misperception, or temporarily for right-of-way changes. This policy is recommended until more information on the long term impact of the signs and a study of alternative approaches have been completed.

The proliferation of *CROSS TRAFFIC DOES NOT STOP* and similar signs has already occurred. A coordinated effort to direct this activity would be of service to traffic engineers and the motoring public, in accidents and injuries prevented.

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professors

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APPENDIX A
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APPENDIX B
SURVEY FORMS

SURVEY OF PRACTICES AT STOP-CONTROLLED INTERSECTIONS

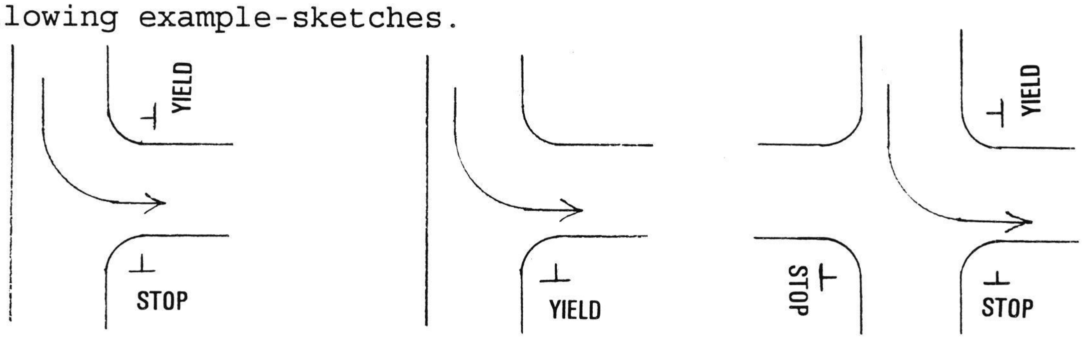
respond with checkmarks or short answers

1. In your jurisdiction, **do you have any of the following** traffic control devices at STOP-controlled intersections?
   ( ) have supplemental ALL WAY or 4-WAY plaques (per *MUTCD* 2B-4)
   ( ) have Intersection Control Beacons (per *MUTCD* 4E-3)
   ( ) have Stop Sign Beacons (per *MUTCD* 4E-4)

2. Do you **have any experiences or studies** that indicate either driver understanding or misunderstanding of flashing Intersection Control Beacons at intersections (some of which flash red toward traffic from all approaches, while other flash red in some directions and yellow in others).
   ( ) yes, we do have ( ) no, we do not have

3. In your jurisdiction, are you aware of any intersection control schemes in which
   a. one approach has **YIELD**
   b. while an opposing (either 90° or 180°) approach has **STOP**, or a 180° opposing approach has no control?

   Also, include any other "unusual" mixes of YIELD with STOP control, but do **NOT** include separate right turn lanes with YIELD control.
   One possible location for combined STOP-YIELD control may be at intersections with "perpendicular" right-of-way -- i.e., the major movement makes a 90° turn, as shown in the following example-sketches.



   ( ) yes, we do have them ( ) no, do not have any
   IF you DO have STOP-YIELD at any location, please estimate the number of locations.

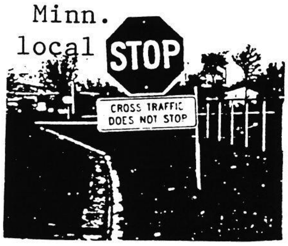
   ____

--OVER--

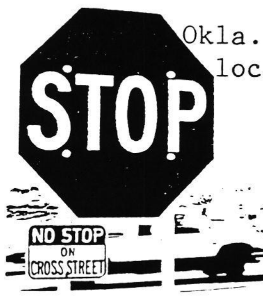
SURVEY OF PRACTICES AT STOP-CONTROLLED INTERSECTIONS page 2/2

4. In your jurisdiction, do you have any **supplemental stop sign control devices** or devices **in advance of stop signs** used specifically to warn motorists that they are **at a two-way stop, NOT an all-way stop**? (Examples include signs with messages similar to "CROSS STREET DOES NOT STOP" either in advance of the STOP sign or on the stop sign pole; overhead or post-mounted flashing lights; etc. This includes devices both in and not in the current *MUTCD*.)

Minn. local

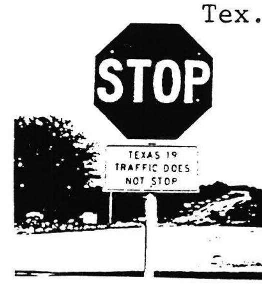


Okla. local



Ill.

Tex.



( ) yes, we do have them ( ) no, do not have any

IF you DO have any such devices, please briefly describe them, give their wording; estimate the number of locations.

____

____

____

____

____

If you know of another jurisdiction using supplemental traffic control devices to warn that the cross street does not stop, please forward a copy of the survey to them or tell us who they are

____

____

____

===

Your name ______________________ Title ______________

Your address ______________________________________

____

____

Phone number ______________ Fax number ______________

thank you for your help THE END

Rev. 2/27/95

CROSS TRAFFIC DOES NOT STOP Study

Date: . . . .

Name & Agency (City, County, State, etc.) of person you called:

____

1. Estimate the number of signs or locations where the CROSS TRAFFIC DOES NOT STOP or similar sign is being used.

2. What problem are you trying to address with the CROSS TRAFFIC DOES NOT STOP signs?
- ☐ converting a four-way to a two-way STOP
- ☐ an existing two-way STOP where switching the direction that has to stop
- ☐ driver misperception on a two-way that the through road also has a STOP when in fact it does not have a STOP?
- ☐ one or more uphill intersection approaches where traffic not required to STOP because is difficult to drive in snow and ice
- ☐ something peculiar or unique with intersection, odd geometrics
- ☐ observed disregard of existing STOP sign(s)
- ☐ other; please describe

3. Had any other methods to address the problem been tried before the CROSS TRAFFIC DOES NOT STOP signs were installed? If "YES", what was tried?
  ☐ YES ☐ NO ☐ DON'T KNOW
- ☐ double STOP signs
- ☐ advance STOP AHEAD
- ☐ flags
- ☐ larger STOP sign(s)
- ☐ stop lines on pavement
- ☐ flashers/beacons

4. How did you find out about this sign?
- ☐ don't know; or before my time.
- ☐ (only for City or County) from our State/Province DOT
- ☐ (only for State/Province DOT) from a City or County
- ☐ saw them used somewhere else/read about them/heard about them
- ☐ other; please describe.

5. (a) Estimate when the signs were initially installed (for how long have the signs been used)?
  ☐ do not know

   (b) Why or Under what conditions were the signs installed? Were there any identifiable factors influencing the decision to install the signs?

CROSS TRAFFIC DOES NOT STOP Study - continued

. Describe the device configuration:

(a) legend: ---> ☐ if sign also has arrows, please check

- ☐ CROSS TRAFFIC/...FROM LEFT/...FROM RIGHT DOES NOT STOP
- ☐ CROSS STREET (or ROAD) DOES NOT STOP
- ☐ CROSS STREET (or ROAD) TRAFFIC DOES NOT STOP
- ☐ name of street (TRAFFIC) DOES NOT STOP
- ☐ Other; please describe

(b) colors:

- ☐ black letters on white background
- ☐ black letters on yellow background
- ☐ black letters on white+yellow background
- ☐ red letters on white background
- ☐ white letters on red background
- ☐ other; please describe

(c) placement:

- ☐ on STOP sign pole ☐ in advance of STOP sign
- ☐ other; please describe

7. Have any additional passive or active devices been used in conjunction with the signs? ☐ NO; usually use just sign alone

- ☐ flashers/beacons ☐ rumble strips
- ☐ STOP AHEAD signs ☐ stop lines on pavement
- ☐ flags ☐ other; please describe

8. Were there any sight distance or other problems at site(s) where sign(s) are installed? ☐ YES ☐ NO ☐ DON'T KNOW

9. What has been the experience with/effectiveness of the CROSS TRAFFIC...sign?

- ☐ improved situation ☐ prevented/reduced accidents
- ☐ no change/no improvement ☐ don't know
- ☐ other; please describe

(b) Has there been any opposition to or problem with the use of the sign?

☐ YES ☐ NO ☐ DON'T KNOW

☐ concern that it is not a standard sign ☐ driver confusion

(c) Have any "before and after" studies been conducted and "written-up"?

☐ YES ☐ NO ☐ DON'T KNOW

IF "YES" TO HAVE STUDY, THEN REQUEST COPY OF STUDY

Were there significant changes in area that would affect a before-and-after comparison, such as changes in the roadway, traffic, or surrounding land uses?

☐ YES ☐ NO ☐ DON'T KNOW

(d) Have any local warrants for use of the sign been proposed or used?

☐ YES ☐ NO; just based on engineering judgement

IF "YES" TO HAVE WARRANT, THEN REQUEST COPY OF WARRANT(S)