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Multiway Stop Sign Removal Procedures

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ABSTRACT

In recent years local jurisdictions have successfully converted unwarranted multiway stop-controlled intersections to less restrictive forms of control. However, there is wide variation in the approaches used and factors considered in the conversion decision. Therefore, FHWA initiated a national study of the processes, with two primary objectives: (a) to develop and test procedures to convert multiway stop-sign-controlled intersections to two-way stop-sign-controlled intersections, and (b) to document the safety effects of converting multiway stop controls to two-way controls. In this paper the study is summarized and the results are presented in the form of recommended conversion procedures. Thirty separate geographically distributed jurisdictions were visited and information and data regarding the various conversion experiences were collected. Data from more than 170 separate intersections were studied by the research team in arriving at the conclusions and recommended procedures in this paper. Laboratory driver preference studies were conducted to determine the most suitable warning and information signs. In addition to local government officials, several consultants as well as professionals in quasi-public agencies were interviewed and their experiences and knowledge of the conversion process were incorporated, where appropriate. The emphasis of the study has been on the safety aspects of the conversion process.

Within the past few decades there has been an increase in the use of multiway stop signs as the traffic control scheme at many intersections. Many elected officials believe that multiway stop signs are a panacea for intersection safety problems because they promote speed control, accident reduction, and pedestrian safety. Even though the Manual on Uniform Traffic Control Devices (MUTCD) (1) has warrants for the application of multiway stop control, in some cases the "political" warrant is the only one that is met. Multiway stop signs should ordinarily be used only where the intersecting road volumes are approximately equal. The MUTCD states that a stop sign should not be used for speed control.

Research has indicated that stop signs installed to control speed do not result in speed reduction (2-5). Also, studies have indicated that stop signs do not always result in increased safety (6).

Unwarranted stop signs increase stops, cause delays, and increase fuel consumption and pollutants. Further, installation of unwarranted traffic control devices breeds disrespect for such devices and can result in potentially dangerous behavior. For these reasons, it is desirable to remove unwarranted and unneeded stop signs that hinder traffic flow rather than aid it. Concern for the environment and for fuel conservation has led to a different attitude toward traffic control.

For several decades traffic engineering changes have, almost without exception, involved installing more positive or rigid control; for example, going from no control to two-way stop control or two-way to four-way stop control. Traffic engineers as well as the general public are conditioned to increasing degrees of control. Local jurisdictions are beginning to realize the mistakes of the past and understand that there are air pollution, delay, and energy impacts that result from excessive use of multiway stops.

A recent study (7) indicates that pedestrian and vehicle accidents may increase when certain traffic volumes, intersection configurations, and approach speeds are combined.

PROJECT OBJECTIVE AND SCOPE

This study was undertaken with two primary objectives in mind:

1. To develop and test procedures to convert multiway stop-sign-controlled intersections to two-way stop-sign-controlled intersections, and
2. To document the safety effects of converting multiway stop controls to two-way controls.

The general approach was to visit at least 30 political jurisdictions that had multiway stop sign conversion experience. From their collective past experiences, and from methods that appeared to be reasonable, a recommended procedure was developed to convert multiway stop intersections to lesser forms of control.

DATA COLLECTION

Each political jurisdiction selected for a site visit designated those intersections that had been converted from multiway stop sign control to lesser forms of control. Data on the sites and on the number of intersections so identified are given in Table 1.

Data on the average daily traffic (ADT) and the posted speeds of the converted intersections studied are given in Tables 2 and 3, respectively. The fact that more than one-half of the converted intersections had ADTs of less than 1,500 vehicles per day and posted speeds of 25 mph or less suggests that most conversions identified in this study had been accomplished at residential intersections. This is often where complaints of speeding are most common and the "political" warrant for multiway stop sign installation is exercised. This situation often creates a climate for wholesale stop sign removals when subdivisions are annexed by a larger urban area because subdivisions often use stop signs as speed control devices.

Special signing for conversions was found to run the gamut in sizes and wording. Figures 1-4 contain some examples of signs used by various jurisdictions to assist in the conversion process.

ACCIDENT ANALYSIS

Because of the concern for the safety effects of converting multiway stop controls to two-way stop controls, an analysis of changes in accidents before and after conversions was conducted by using data for 172 intersections representing 33 jurisdictions

TABLE 1 Political Entities Contributing to Multiway Stop Sign Study

Political Entity	County/Parish	Population (000s)	No. of Converted Intersections Studied
FHWA Region 1			
Manchester, Conn.	Hartford	50	27
Colonie, N.Y.	Albany	78	3
Niskayuna, N.Y.	Schenectady	18	3
Troy, N.Y.	Rensselaer	56	8
FHWA Region 4			
Palm Beach County, Fla.	–	–	3
West Palm Beach, Fla.	Palm Beach	63	4
FHWA Region 5			
Berkley, Mich.	Oakland	20	5
Beverly Hills, Mich.	Oakland	12	2
Madison Heights, Mich.	Oakland	35	5
Trenton, Mich.	Wayne	25	5
Dayton, Ohio	Montgomery	200	7
FHWA Region 6			
Baton Rouge, La.	East Baton Rouge	250	2
Bossier City, La.	Bossier	55	20
Lafayette, La.	Lafayette	82	2
Oklahoma City, Okla.	Oklahoma	450	2
Arlington, Tex.[a]	Tarrant	160	6
Bellaire, Tex.	Harris	15	3
Houston, Tex.	Harris	1,500	3
Pasadena, Tex.	Harris	120	3
Seabrook, Tex.	Harris	5	2
Sugarland, Tex.	Fort Bend	9	15
Taylor Lake Village, Tex.	Harris	4	4
West University Place, Tex.	Harris	12	2
FHWA Region 7			
Olathe, Kans.	Johnson	39	4
Overland Park, Kans.	Johnson	82	4
Kansas City, Mo.	Jackson	448	5
FHWA Region 8			
Butte-Silverbow, Mont.[a]	Silverbow	37	9
FHWA Region 9			
Inglewood, Calif.	Los Angeles	90	4
Pamona, Calif.	Los Angeles	100	2[b]
Riverside, Calif.	Riverside	171	2
Riverside County, Calif.	–	–	2
San Bernardino, Calif.	San Bernardino	130	6
San Bernardino County, Calif.	–	–	1[b]

[a]Not included in site visits.
[b]Accident data not available.

TABLE 2 ADT of Converted Intersections

Total Intersection ADT Range	No. of Converted Intersections Studied	Percentage of Total Intersections
< 1,500	98	57
1,500–3,000	32	19
> 3,000	42	24
Total	172	100

TABLE 3 Posted Speeds of Converted Intersections

Speed (mph)	No. of Intersections Posted	Percentage of Total Intersections
20	6	3
25	101	59
30	49	29
35	6	3
40	9	5
50	1	1
Total	172	100

FIGURE 1 Example of advance motorist warning (Lafayette, Louisiana).

FIGURE 2 Supplementary notice sign (Baton Rouge, Louisiana).

FIGURE 3 Supplementary sign after conversion (Kansas City, Missouri). Note supplementary sign on post on opposite corner.

FIGURE 4 Pavement markings and STOP AHEAD sign used to emphasize presence of remaining stop sign after conversions (San Bernardino County, California).

in 12 states. Because of data limitations, all accident types were grouped and the primary data element was the number of accidents before and after the conversions. Accident rates could not be used for this analysis because for many locations the volume data for both periods were not available. Based on information provided by the various agencies, it was reasonable to assume nearly equal volumes before and after conversion. Accident summary statistics are given in Table 4. Results of an analysis, using the Statistical Program for Social

TABLE 4 Accident Summary Statistics

		Supplementary Sign	
	Total	Yes	No
No. of accidents before	88	77	11
No. of accidents after	144	101	43
Total (all intersections)	232	178	54
No. of intersections with increased accidents	28	13	15
No. of intersections with decreased accidents	16	12	4
No. of intersections with no change	128	32	96
Total	172	57	115

Sciences (SPSS) computer package, indicated the following:

1. There was significant increase in the number of accidents (based on the Poisson distribution test) after the conversion. Although the aggregate effect was a significant increase in accidents, only 16 percent of the 172 sites experienced an increase and 9 percent experienced a decrease. This finding indicates that there might be certain geometric or operating characteristics that determine whether an increase in accidents will occur.
2. The percentage increase in accidents was significantly higher where there were no supplementary signs, based on a chi-square test.
3. Seventy-four percent of the intersections (128 of 172) had no change in the number of accidents.

At those sites where the accidents increased, another accident analysis was performed to determine how soon the accidents occurred after the conversion took place. It was expected that there might be an unusually high incidence of accidents immediately after the conversion with a return to a normal situation after the motorist had become fully aware that the intersection was a two-way stop control. This analysis considered the number of accidents that occurred for each of 12 months before and after the conversion for five sites combined. It appears that if accidents do increase, there is a concentration of accidents occurring within the first month. The remainder of the accidents occurred throughout the balance of the year, with the fluctuations expected of normal accident occurrence.

With regard to the issue of whether or not accident frequency changes as a result of the conversion, no generalized conclusions can be drawn. In aggregate, there was a significantly higher number of accidents, and more intersections increased in accidents rather than decreased. No positive relationships could be determined between any operational or geometric factors and accident change for the limited data available. However, it is noted that at none of the locations that experienced a high increase in accidents was there low traffic volume (less than 1,500 ADT for the total intersection).

There is evidence that the first month immediately after the conversion is the most critical period for accident increase. Motorists 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.

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 ascertained is what further increase in accidents might have occurred if the signs had not been used.

EVALUATION OF SUPPLEMENTARY SIGNS

To test warning and information signs and advance notice signs, several alternative warning signs were considered. Based on the data collected from the 172 intersections where multiway stop signs had been removed (on suggestions by state, county, and municipal agencies), on reviews of the literature, and on discussions with members of the research team, seven different sign messages were formulated. These were tested with about 30 participants at the University of Maryland. As a result of this preliminary preference test, four signs were fabricated by the Baltimore Department of Transit and Traffic. Once these were fabricated, slides of these signs, together with slides taken at actual field locations, formed the basis for a laboratory experiment to test both the meaning and the motorist's preferences from among 11 sign message alternatives (see Figure 5).

The actual laboratory experiment was developed in two parts. Part I tested sign meaning. It consisted of slides of a four-way stop intersection (before) and the same intersection as a two-way stop (after), followed by slides of each of the alternative sign messages for warning and information.

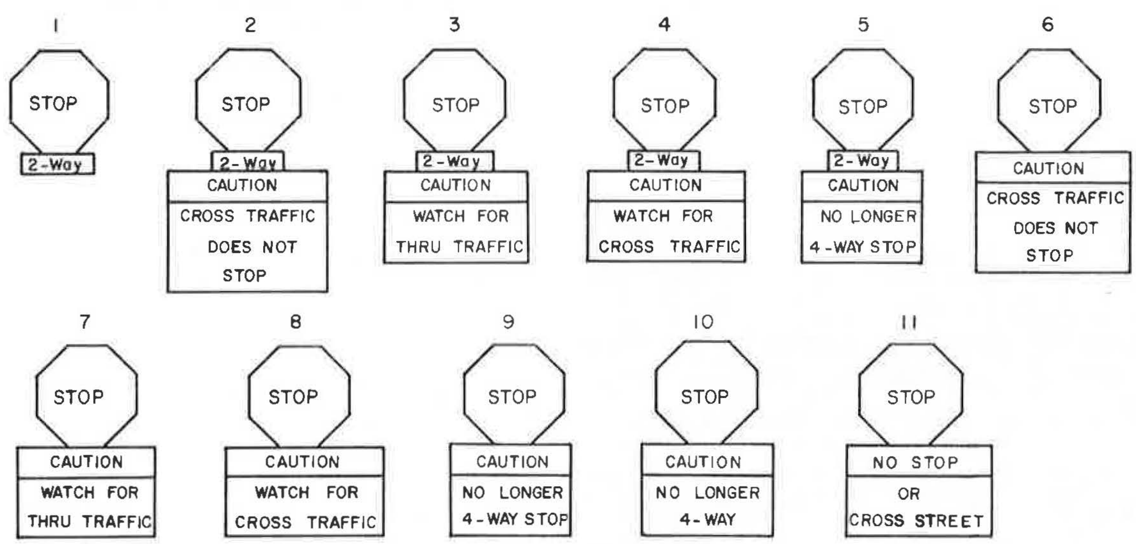


FIGURE 5 Sign messages selected for laboratory test evaluation.

A series of four answers were developed for testing the subject on sign message meaning for each sign. For example, the answers might be

a. I no longer have to stop.
b. I don't know which approaches have to stop, but I do have to stop.
c. Traffic approaching from the left and the right is not required to stop, but I am.
d. Not certain.

Part II tested the preference among the 11 signs for possible use in advance (i.e., as advance warning) of the intersection. This was followed by the comparative ranking of the top 3 of the 11 signs as first, second, or third choice. Finally, the subjects were given the opportunity to provide comments and suggestions.

Before beginning the laboratory sign evaluation test, each subject was requested to complete a five-question (checkoff) classification questionnaire of age, sex, driving experience, and frequency. The laboratory tests began with draft questionnaires and test questions at the FHWA Turner-Fairbank Highway Research Center. The questions, format, and testing procedure, including developing new and better slides of the candidate signs, were revised and the laboratory tests were administered to the groups indicated in Table 5.

TABLE 5 Summary of Laboratory Test of Candidate Signs

Site	Sign Sequence No.[a]	Question Sets[b]	No. of Subjects
FHWA	1	6	38
U.S. Army reserves	2	2	25
	3	2	20
	4	2	3
Maryland State Police Academy	5	2	37
University of Maryland senior class	6	2	30
University of Maryland health class	7	4	75
Total		20	228

[a]The 11 candidate signs were presented in seven randomized orders.
[b]A total of 53 multiple-choice questions (A through D answers, with one best and at least one correct answer) were developed. These were randomly assembled into 20 different sets of 11 questions each. The numbers in the column give the number of different sets used.

The laboratory testing was accomplished for each group by first briefly describing the general problem of excess stop sign control at intersections. Then the test began by showing a slide of a typical four-way stop-controlled intersection that indicated that the control has been changed, and then showing a slide of the first sign in the 11-sign sequence (at the same intersection) and asking the participants to answer a, b, c, or d. This continued until slides of all 11 signs had been shown.

Results of the sign meaning part of the test were almost identical with the preference (Table 6). Ranking of the signs by percentage of correct answers also revealed signs 2 and 6 (CROSS TRAFFIC DOES NOT STOP) to be the first and second choices, respectively, and sign 5 (NO LONGER 4-WAY STOP) to be the third choice (numbers are as indicated in Figure 5).

The classification questionnaire data were analyzed in two ways. First, the numbers of subjects by age and sex were reviewed to ascertain that there was a representative sample. A total of 102 female and 123 male subjects completed the questionnaire. The number of subjects older than 40 years of age was 30 male and 5 female. Thus the older female driver is not well represented. However, all other age groups are well represented, and this small sample of females older than 40 years is not believed to be a significant bias. The data in Tables 7 and 8 give the results of driving experience and frequency versus age and incorrect answers for female and male subjects, respectively. The average incorrect answer was 21.7 percent for female as compared with 19.1 percent incorrect for male subjects. Of the largest category of female subjects--age 20 to 24, with 5 to 9 years of driving experience, who drive every day--43 subjects had 18.6 percent incorrect answers. This is almost identical to male subjects in the same age and driving experience and frequency category, who had 19.2 percent incorrect answers. It was believed that the sample, when broken down into age, driving experience, and frequency, was too small for any statistical analysis to be undertaken.

TABLE 6 Sign Preference from the Laboratory Comparative Analysis

Sign No.	Choice: First	Choice: Second	Choice: Third	Weighted Preference[a]: Weight	Weighted Preference[a]: Rank
1	30	9	15	123	4
2	66	40	15	293	1
3	10	11	17	69	9
4	14	19	29	109	6
5	28	27	16	154	3
6	34	41	28	222	2
7	13	6	12	57	10
8	11	18	17	86	7
9	14	22	26	112	5
10	4	12	9	45	11
11	4	19	20	70	8
Total	228	224	204		

[a]1st choice 3, 2nd choice 2, 3rd choice 1.

TABLE 7 Driving Experience and Frequency Versus Incorrect Answers on Sign Evaluation–Female

Age	Experience (years)	Frequency of Driving	Sample No.	Incorrect Answers No.	Incorrect Answers Percent
16-19	3-4	Everyday	1	4	36.4
		3-4 times/week	2	1	4.5
		Total	3		
20-24	3-4	Everyday	8	19	21.6
		3-4 times/week	1	6	54.5
		1-2 times/week	1	2	18.2
		2-4 times/month	1	5	45.5
	5-9	Everyday	43	88	18.6
		3-4 times/week	9	17	17.2
		1-2 times/week	4	20	45.4
		Total	72		
25-29	5-9	Everyday	6	8	12.1
	10-14	Everyday	3	8	24.2
		3-4 times/week	2	9	40.9
		Total	11		
30-39	10-14	Everyday	3	8	24.2
	15-19	Everyday	8	31	35.2
		Total	11		
40-49	15-19	Everyday	1	2	18.2
	20+	Everyday	2	4	18.2
		3-4 times/week	1	2	18.2
		Total	4		
50-59	20+	Everyday	1	8	72.7
Total			102	243	21.7

TABLE 8 Driving Experience and Frequency Versus Incorrect Answers on Sign Evaluation—Male

Age	Experience (years)	Frequency of Driving	Sample No.	Incorrect Answers No.	Incorrect Answers Percent
16-19	3-4	Everyday	2	2	9.1
20-24	1	3-4 times/week	1	6	54.9
	1-2	Everyday	1	1	9.1
	3-4	Everyday	7	22	28.6
		3-4 times/week	2	9	40.9
	5-9	Everyday	18	38	19.2
		3-4 times/week	3	8	24.2
		1-2 times/week	2	10	45.5
		Total	34		
25-29	5-9	Everyday	4	10	22.7
		3-4 times/week	1	0	0
	10-14	Everyday	13	26	18.2
		3-4 times/week	2	4	18.2
		1-2 times/week	1	4	36.4
		Total	21		
30-39	10-14	Everyday	4	4	9.1
	15-19	Everyday	18	38	19.2
		3-4 times/week	3	6	18.2
	20+	Everyday	11	26	21.5
		Total	36		
40-49	15-19	Everyday	1	5	45.5
	20+	Everyday	19	22	10.5
		Total	20		
50-59	20+	Everyday	7	15	19.5
60-64	20+	Everyday	1	0	0
		3-4 times/week	2	2	9.1
		Total	3		
Total			123	258	19.1

In summary, the laboratory sign evaluation test results were consistent with the field experience and literature review, and were in agreement with philosophies of state, county, and municipal officials. The black CAUTION sign on yellow background separated from the black message on white background (CROSS TRAFFIC DOES NOT STOP) is the top candidate as a supplementary sign for safe removal of multiway stop signs. The same top portion CAUTION with the bottom message NO LONGER 4-WAY STOP is a close second preference.

RECOMMENDED PROCEDURE FOR REMOVAL OF MULTIWAY STOP SIGNS

The procedures recommended here were developed based largely on the experiences of traffic and law officials from more than 30 political jurisdictions, the laboratory experiments of supplementary signs, and the results of the field testing of these procedures.

The procedures recommended herein may be applied with slight modification to a situation where the right-of-way at an intersection is reassigned (i.e., stop sign reversals). This action might require the creation of a multiway stop condition and then the removal of the unwarranted stop sign(s).

Each local jurisdiction must determine to what degree the recommended procedures apply for a given intersection. Factors such as community concerns, intersection geometrics, speeds, volumes (vehicular and pedestrian), accident history, and sight distance must be considered.

A decision must likewise be made as to how many intersections are to be converted and when. This is where local politics and economics come into play. If mass removals of stop signs are likely to cause an outpouring of public opposition throughout the entire city or town, then perhaps a neighborhood-by-neighborhood or intersection-by-intersection strategy might be developed. In the second instance, if the nature of the intersections is such that supplementary signs are desirable, the timing of intersection conversions would depend on availability of funds to support materials and labor needed to accomplish the conversions.

There are three phases to the removal of multiway stop signs: the preconversion phase, the actual conversion phase, and the postconversion phase. Following all steps in the procedure will ensure that the conversion will minimize hazard to the driving public.

Preconversion Phase

Conduct Traffic Engineering Studies

Traffic studies should be conducted to determine whether a multiway stop intersection is justified (i.e., that all stop signs at that particular intersection are warranted). The warrants presented in the MUTCD (1) should be used as a basis for determining whether the multiway stop control is justified. If necessary, volume counts should be taken to determine whether the MUTCD warrants are satisfied. In addition, accident records should be checked to determine whether the multiway stop was originally warranted because of accident history at the intersection.

From the very beginning the importance of using appropriate supplementary plates (R1-3) in conjunction with stop signs at multiway stop intersections must be emphasized. The proper use of these supplementary plates (3-WAY, 4-WAY, ALL WAY, and so forth) fixes in the motorist's mind that the intersection is in fact a multiway stop intersection. The absence of these plates at a multiway stop intersection could cause confusion or uncertainty on the part of the motorists, thus resulting in an unsafe and inefficient intersection.

If supplementary plates are not in use at an intersection targeted for conversion, they should be added at least 30 days before the actual conversion. Thereafter, the removal of these plates on the day of conversion will further signal to the motorists that a change has occurred at that particular intersection.

Secure Approval for Stop Sign Removals

Permission should be sought to remove those stop signs determined to be unwarranted. In some instances the local council may have previously delegated the authority for traffic control device installation and removal to the individual responsible for traffic operations. These include the traffic engineer, police chief, director of public works, and so forth. If this is the case, removals are expedited.

Phasing of stop sign removals accomplishes several objectives:

1. Lessons learned at one location can be applied to succeeding locations.
2. Individual neighborhoods can be addressed regarding the stop sign removals as opposed to the entire municipality at once.
3. Supplementary signs can be used during future conversions, thereby reducing the inventory required.

4. Work can be accomplished by existing crews without excessive amounts of overtime.

5. Neighborhoods scheduled for future conversions can witness successful actions elsewhere in town, which will alleviate some of their fears.

6. Local approving officials may find this method more acceptable.

Publicize Planned Multiway Stop Intersection Conversions

The activities associated with obtaining legislative approval (as noted in a previous section) often will serve to publicize planned conversions. Notices to neighborhood residents might be dispatched by using any one or more of several media: newspapers, radio, television, utility bills, flyers, individual letters, and community newsletters.

In addition, notice signs should be posted at the affected intersection to alert the motorists who use the intersection of the impending change. The notice signs shown in Figures 6 and 7 were developed as a result of this study.

FIGURE 6 Notice sign for major approach.

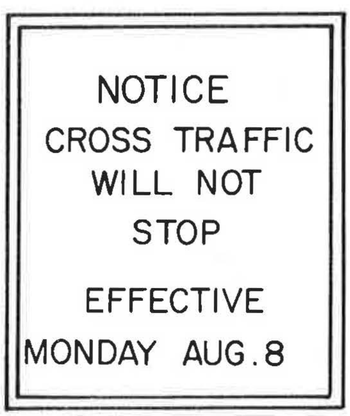


FIGURE 7 Notice sign for minor approach.

Install STOP AHEAD Messages

If not already in use, STOP AHEAD signs (W3-1 or W3-1A) should be installed in accordance with the MUTCD on those approaches that will remain under stop control. These should be considered for use to further emphasize the continued need to stop at a given intersection.

Install Necessary Pavement Markings

If not already present, stop lines and STOP pavement markings may be used in accordance with the MUTCD to highlight the requirement to stop at the intersection.

Conversion Phase

Remove Obsolete Pavement Markings

Before the day of conversion, any stop lines or other pavement markings rendered obsolete by the change should be removed or otherwise obliterated. If rental equipment is involved in the pavement marking removals, several sites should be considered for conversion during the same time period. This would make for more economical and efficient use of rental equipment.

Improve Sight Distance

Sight distance at the intersection should be improved, if necessary, by (a) imposing parking restrictions, (b) pruning vegetation, or (c) adjusting location of stop line. If the stop line is placed directly opposite the stop sign, and the stop sign is placed some distance from the intersecting street's curb line because of intersection geometrics, a motorist could have his sight distance severely reduced. In this instance the stop line should be placed forward of the stop sign but no closer than 4 ft to the intersecting street's curb line. This allows a driver to move to a point of improved visibility from which he can better make gap-acceptance decisions.

Change Signs

The following sequence of events should occur before the beginning of the morning peak period on the day of stop sign removals:

1. On the minor approach replace supplementary plate(s) and sign as shown in Figure 7 with the caution sign shown in Figure 8.

2. On the major approach, after completing the action in 1, remove the unwarranted stop sign(s), supplementary plate(s), and accompanying post(s) and notice sign(s) (Figure 6).

3. Remove unnecessary STOP AHEAD sign(s), including the post(s) on which they are mounted.

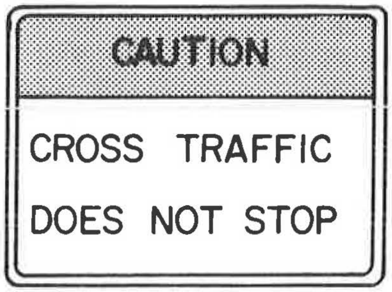
4. Replace 24-in. stop signs with 30-in. stop signs for added emphasis. (This could be a temporary or permanent change.)

It is extremely important to convert the intersection before the morning peak period so as not to cause doubt in the motorists' minds concerning the previously publicized action.

Postconversion Phase

Conduct Traffic Engineering Studies

As warranted by the nature of the intersection, any number of studies might be conducted to determine the effectiveness of the stop sign removal action as



Specifications

1. Overall sign dimensions = 24 x 18 in.
2. Caution band dimensions = 24 x 6 in.
3. Lettering height = 4 in.
4. Colors: black letters on yellow and white backgrounds
5. Surface: reflective sheeting

FIGURE 8 CAUTION sign for approach still required to stop after multiway stop intersection conversion.

well as to prepare the traffic engineer to address issues and concerns raised by interested citizens. Typical studies in varying degrees might include traffic volumes, traffic accidents, conflicts, speed, and observance of traffic control devices. These studies are all discussed at length in the Transportation and Traffic Engineering Handbook (8).

Request Police Enforcement

If it is observed or reported that speeding is a problem, increased police enforcement should be requested at the location in question. The length of this increased enforcement would depend on past experiences with similar problems in the local area.

Remove Caution Signs

Ninety days after the intersection has been converted, the caution signs should be removed from beneath the remaining stop signs. If 30-in. stop signs are to be replaced by 24-in. stop signs, that action should be accomplished at this time.

Continue Traffic Engineering Monitoring

After the intersection has been converted, it should be continuously monitored as a part of the regular traffic engineering program. Accident data should be evaluated for the 12-month period following conversion of the intersection to determine whether the modified traffic control condition is adequate. Comments from interested citizens should continue to be received and evaluated during this period.

CONCLUSIONS AND RECOMMENDATIONS

As a result of this study it has become obvious that no uniform procedures exist with which to convert multiway stop-sign-controlled intersections to lesser forms of control with minimum hazard. It is likewise concluded that little documentation is available concerning the actual conversion processes in the various jurisdictions nationally. Some jurisdictions do have complete studies available documenting their actions. The procedures developed in this paper and pilot tested in the field have been shown, through limited testing, to have great potential for minimizing the hazards associated with multiway stop sign removals.

It is recommended that the procedures developed herein be implemented and that the National Committee on Uniform Traffic Control Devices consider the two notice signs and the warning sign (CAUTION, CROSS TRAFFIC DOES NOT STOP) for inclusion in the MUTCD.

Discussion

Bhagwant N. Persaud*

Table 4 of the paper indicates that the total number of accidents at the converted intersections changed from 88 in the year before conversion to 144 in the year after. Ligon, Carter, and McGee, quite rightly, do not base any strong conclusions on these numbers. There is a danger, however, that these numbers could be interpreted as implying that the conversions resulted in a 64 percent increase in accidents. Such an interpretation might conceivably serve as a deterrent to the removal of unwarranted multiway stop control. The danger arises from the fact that, if the conversions were mainly done at intersections that recorded few or no accidents in the before period, as one might suspect, then the observed increase in accidents could be an illusion and an artifact of chance and may not be indicative of a real degradation in safety.

This phenomenon is illustrated by the data in Table 9, which gives changes in numbers of accidents at intersections in Philadelphia that retained multiway stop control during 1973 and 1974. For example, the data in the table indicate that the 85 such intersections that recorded 1 accident in 1973 recorded, on average, 1.4 accidents in 1974, an increase in accidents of 40 percent. As one might expect, those intersections that recorded no accidents in 1973 also experienced an increase in acci-

TABLE 9 Changes in Number of Accidents at Multiway Stops in Philadelphia

No. of Sites	No. of Accidents per Site 1973	No. of Accidents per Site 1974	Change (%)
81	0	1.23	Increase
85	1	1.40	+40
58	2	1.60	-20
30	3	1.47	-51
8	4	2.25	-44
7	5	1.71	-66
4	6	1.00	-83
1	7	6.00	-14
1	8	3.00	-63

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dents. Because the intersections remained unaltered, these increases are a result of chance, or, to use the technical term, regression-to-the-mean. [For further discussion of this phenomenon see the work by Hauer and Persaud (9).]

The 172 intersections examined by Ligon et al. recorded, on average, 0.51 accident in the before period and 0.84 accident in the after period. If some Philadelphia intersections that averaged 0.51 accident in 1973 were converted, then by interpolation from Table 9 these intersections would have recorded, on average, 1.32 accidents in 1974 if the conversions left safety unaffected. In other words, the average number of accidents recorded after conversion would have had to be higher than 1.32 to support a conclusion that removal of multiway stop control leads to a degradation in safety.

Although one might reasonably question whether the Philadelphia intersections are representative of the intersections studied by Ligon et al., this should not detract from the main point of the discussion--that it is misleading to draw conclusions about the safety effect of traffic control measures by simply comparing before-and-after accident records. By deemphasizing the apparent increase in accidents observed in this study, the authors have avoided this pitfall. It is hoped that, after this discussion, others will be persuaded to do likewise.

Authors' Closure

Persaud presents an interesting discussion concerning the safety aspects of the removal of unwarranted stop signs. It was thought that 3 years of accident data before and 3 years after conversion, as well as using control (nonconverted) sites (3 years before and 3 years after) would result in a meaningful experiment, statistically, because of the small number of accidents. Unfortunately, the agencies cooperating in the FHWA study could not provide the 3-year before data base and the study had to be completed in about 1 year. Persaud's Philadelphia example as well as his discussion of accounting for accident change due to chance agree with the authors' intuition and strengthens the recommendation for removal of unwarranted stop signs.

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Evaluation of Curve Delineation Signs

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ABSTRACT

The three post-mounted delineator systems currently used in Virginia were tested at five sites for their effectiveness in controlling run-off-the-road accidents. The changes in speed and lateral placement noted with the systems in place were taken as driver responses to the systems. The study indicated that drivers react most favorably to chevron signs on sharp curves greater than or equal to 7 degrees and to standard delineators on curves less than 7 degrees. It is suggested that statewide use of delineators based on these findings will improve the safety and uniformity in delineation on the rural highway system.