STOP SIGN VERSUS YIELD SIGN

by

Harry S. Lum
Federal Highway Administration
Washington, D. C. 20590

William R. Stockton
Texas Transportation Institute
The Texas A&M University System
College Station, Texas 77843

Submitted for Publication by the

Transportation Research Board
Washington, D. C.

March 1982

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and

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ABSTRACT

This paper investigates the relative effectiveness of STOP and YIELD signs at low volume intersections (less 500 vpd on minor roadway) in rural and urban environments. Traditional rationales for installing STOP signs, such as inadequate sight distance and high major roadway volumes, are examined. It is shown that the current utilization of STOP signs is unrelated to sight distance availability and that STOP signs do not categorically reduce accidents at low volume intersections. Further, it is demonstrated that there is no relationship between accidents and major roadway volumes up to 6,000 vpd. STOP signs are shown to increase road user costs by more than 7 percent over YIELD signs.

STOP SIGN VERSUS YIELD SIGN

The STOP sign is by far the most prevalent type of traffic control at intersections. Its message is simple and clear, and the expected response of motorists is a "complete cessation of motion" (1). The distinct color and shape of the STOP sign result in quick recognition by motorists. Despite its clear meaning, Stockton, et al, (2) in a study sponsored by the Federal Highway Administration (FHWA) reported that less than 20 percent of the motorists "voluntarily" complied by completely stopping at STOP signs. (Those motorists who had to stop at a STOP sign because of traffic conditions were excluded from the computation). This compliance rate of 20 percent represents an overall average of three states: Florida, Texas, and New york. A total of 140 intersections in urban and rural environments were sampled. At least one roadway had an ADT of 500 vehicles or less; major road volume ranged up to 36,000 vehicles per day, and did not meet the Manual of Uniform Traffic Control Devices (MUTCD) (3) volume warrants for traffic signals.

Dyar (4), who also investigated driver's observance of STOP signs at rural and urban intersections in South Carolina, reported a voluntary compliance rate of 11 percent. Stockton, however, noted that there was a significant difference in compliance rates among the three states studied. Such low compliance rates indicate that STOP signs are being used indiscriminately; hence, defeating the sign's purpose of providing for orderly and predictable movement of traffic.

MUTCD Requirements

The MUTCD states that "to be effective, a traffic control device should meet five basic requirements." They are:

1. Fulfill a need
2. Command attention

3. Convey a clear, simple meaning
4. Command respect of road users
5. Give adequate time for proper response

In practice, the second, third, and fifth requirements are generally met without difficulty. The fourth is dependent on the first requirement which, of course, is the most critical one. In the eyes of the motoring public, the need must be visible and real, not merely perceived by the traffic engineer or unknowledgeable citizen groups or associations. Excessive and indiscriminate use of STOP signs eventually breeds disobedience and contempt for law enforcement.

The MUTCD warrants provide broad guidelines for the use of two-way STOP control. A STOP sign may be warranted at an intersection where one or more of the following conditions exist:

"1. Intersection of a less important road with a main road where application of the normal right-of-way rule is unduly hazardous.
2. Street entering a through highway or street.
3. Unsignalized intersection in a signalized area.
4. Other intersections where a combination of high speed, restricted view, and serious accident record indicates a need for control by the STOP sign." (3)

Conditions 1, 2, and 3 deal with the assignment of right-of-way at an intersection. STOP and YIELD signs both have that function, but the YIELD sign is less restrictive in that all traffic does not have to come to a complete stop. Condition 4 is vague and is open to the engineer's interpretation as to when a STOP sign should be used. Unlike signal warrants, guidelines for quantification of the variables, e.g., speed, restricted view, volume (not stated), accident record, are not discussed.

Warrants for YIELD control are somewhat vague:

"1. On a minor road at the entrance to an intersection where it is necessary to assign right-of-way to the major road, but where a stop is not necessary at all times, and where the safe approach speed on the minor road exceeds 10 miles per hour.

2. On the entrance ramp to an expressway where an acceleration lane is not provided.

3. Within an intersection with a divided highway, where a STOP sign is present at the entrance to the first roadway and further control is necessary at the entrance to the second roadway, and where the median width between the two roadways exceeds 30 feet.

4. Where there is a separate or channelized right-turn lane, without an adequate acceleration lane.

5. At any intersection where a special problem exists and where an engineering study indicates the problem to be susceptible to correction by use of the YIELD sign."

While the first four conditions are fairly straightforward for the application of the YIELD signs, it is not clear as to what is meant by "problem to be susceptible to correction by use of the YIELD sign."

Without specific guidelines to follow, the problem of when to use STOP or YIELD signs becomes one of interpretation of the word "need" by the individual traffic engineer. It would not be surprising then if the views of engineers differ on the need for STOP or YIELD signs. Tables 1 and 2 give criteria for the application of STOP and YIELD signs by six different traffic agencies. They all agree that sight distance is a critical criterion for STOP control; they disagree as to what the critical approach speed (distance) should be.

Table 1. STOP Control Application Criteria Other Than Or In Addition to MUTCD Criteria (2)

	VOLUME	ACCIDENTS	SIGHT DISTANCE CRITERIA	OTHER (School, Ped., etc.)
State of Delaware		Two accidents correctable by STOP within 12 months.	Safe approach speed less than 24 mph.	Minor approaches at school crossings. May on major if more than 2500ft from previous STOP or YIELD. May if minor approach serves 15 or more homes.
State of New York			Critical approach speed less than 8 mph.	
State of North Dakota	Major approach ADT greater than 150 or total ADT greater than 250.		Less than AASHTO Case II.	
City of Baltimore, MD	Major volume exceeds 100vph		Safe approach speed less than 5 mph.	
		2 in 5 years, AND	Safe approach speed 5-10 mph.	
		2 in 1 year, or 3 in 5 years, AND	Safe approach speed greater than 10 mph.	
City of Concord, CA	Major volume exceeds 1000 vpd (or 100vph) and minor volume exceeds 500vpd (or 50vph).	4 in 1 year	Critical approach speed of 10 mph or less.	
	Major volume exceeds 500vpd (or 50vph) and minor volume exceeds 250vpd (or 25vph), AND/OR	2 or more within 1 year, AND/OR	Critical approach speed less than 15 mph.	Two or more criteria must be met.
Montgomery County, Maryland			Sight distance along major from 35ft back on minor is less than 125ft	

Table 2. YIELD Control Application Criteria Other Than Or In Addition to MUTCD Criteria (2)

	VOLUME	ACCIDENTS	SIGHT DISTANCE CRITERIA	OTHER (School, Ped., etc.)
State of Delaware				Minor approach serves 5 or more homes.
State of New York			Critical approach speed greater than 8 mph.	
State of North Dakota	Less than 150vpd on major approach AND		Greater than AASHTO Case II modified for rural and urban separately, AND	Rural-gravel roads only. Urban-city streets only.
City of Baltimore, MD				At intersections where STOP is not-warranted.
City of Concord, CA	Major street 500vpd or (50 vph) peak and minor street 250vpd (or 25vph) peak.	Two or more of correctable type in 12 months (if only STOP warrant met).	Critical approach speed between 15 and 20 mph.	
Montgomery County, MD			Sight distance along major from 35ft back on minor is greater than 125ft.	Some control dictated by geometrics, accidents, or volumes.

Sight Distance

A recent study evaluated the effect of sight distance on choice of control type. The sight distance standard used was the AASHTO Case II (5) requirements. AASHTO Case II sight distance requires that drivers on all approaches have sight distance sufficient for the relative approach speeds to detect a vehicle on a conflicting approach and stop prior to entering the intersection. Since most of the approaches studied had approach speeds in excess of 25 mph (40 km/h), this test was considerable more conservative than the 10 mph (16 km/h) requirement of the Manual (3).

Table 3 gives the frequencies of control types used at 179 approaches (140 intersections) for varying degrees of available sight distance. Sight distance availability is defined as the ratio of available sight distance to the required AASHTO Case II sight distance. An index value of 1.0 indicates adequate sight distance.

The supposition that STOP signs are used at intersections where sight distance is poor is not supported by the data. Table 4 shows an analysis of the data presented in Table 3. Two null hypotheses are tested: 1) STOP and YIELD signs are used independently of sight distance, and 2) whether an intersection is controlled (STOP and YIELD) or uncontrolled is independent of sight distances.

The minimum discrimination information statistics (MDIS) are both less than the tabulated χ^2 value of 7.841 for three degrees of freedom at the five percent significance level. Hence, the hypotheses are not rejected. STOP control at low volume intersections is used in spite of adequate sight distance, and uncontrolled intersections are as likely to have poor sight distance, at least in practice.

With respect to driver behavior, it was hypothesized that voluntary stop rate would increase as sight distance decreases. Voluntary stop rate was

Table 3. Distribution of Control Type by Sight Distance at 179 Approaches

	Sight Distance Index				
Control Type	0-.5	.51-1.0	1.01-1.5	>1.5	TOTAL
STOP	18	26	16	9	69
YIELD	7	27	17	11	62
UNCONTROLLED	11	14	16	7	48
TOTAL	36	67	49	27	179

Source: Reference 2

Table 4. Analysis of Information Table for Data Presented in Table 3

COMPONENT	MDIS*($2\hat{I}$)	D.F.
Independence between STOP and YIELD control	4.885	3
Independence between Control (STOP and YIELD) and No Control	2.338	3
Total Independence	7.223	6

*In this paper Kullback's information-theoretic approach to the analysis of contingency tables was used instead of the conventional Pearson's chi-square test. The minimum discrimination information statistics (MDIS) whose symbolic representation is $2\hat{I}$, is asymtotically distributed as χ^2 for large sample and for a wide class of problems (6). The formula used to calculate $2\hat{I}$ is $2(\Sigma_i\Sigma_j n_{ij}\ln(n_{ij}) + n\ln(n) - \Sigma_i n_{i.}\ln(n_{i.}) - \Sigma_j n_{.j}\ln(n_{.j}))$, where $\Sigma_i n_i = \Sigma_j n_{.j} = n$.

based on the percentage of drivers stopping in the absence of a conflicting major road vehicle. A regression analysis of voluntary stop rate versus sight distance showed a very poor relationship (r = -0.126).

Voluntary stop rates were very low for all control types studied (STOP = 19%, YIELD = 8%, No Control = 9%). It was observed that drivers slowed down to whatever speed was required to evaluate the safety of entering the intersection before choosing a course of action. This behavior appeared to be consistent across all levels of sight distance and control type. Observations of more that 3,000 individual movements were made at 140 intersections. Of these 3,000+ movements, only a small portion exceeded a 5 mph (8 km/h) entry speed (STOP = 17%, YIELD = 13%, No Control = 11%). Though not tabulated, most of the entries above 5 mph (8 km/h) were made at less than 10 mph (16 km/h). Therefore the imposition of a 10 mph (16 km/h) sight distance criterion ignores the propensity of the vast majority of drivers to slow well below that speed. Further, it unnecessarily restricts the application of YIELD and No Control at locations where there is no evidence that STOP control is superior.

Accident Experience

Does the use of STOP signs help to reduce accidents at low volume intersections? Table 5 was compiled from Stockton's (2) data. The entries in the table represent the number of intersections experiencing a given number of accidents over a three year period (1975 to 1977 inclusive). It is readily seen that STOP-controlled intersections exhibit a higher proportion of intersections with one or more accidents. Had the one-accident intersections been reported for the uncontrolled classification instead of the STOP-controlled classification, it would lend support to the contention that STOP control helps in preventing accidents.

Table 5. Distribution of Accident Frequency by Intersection and Control Type

CONTROL TYPE	NUMBER OF ACCIDENTS				
	0	1	2	3 and over	TOTAL
STOP	33	13	0	2	48
YIELD	40	4	2	2	48
UNCONTROLLED	42	0	0	2	44
TOTAL	115	17	2	6	140

Source: Reference 2

One possible explanation for this deviation from the expected is that STOP signs were erected after an accident had occurred. However, a rechecking of the records did not indicate such was the case. A second possible explanation is that STOP signs were installed at hazardous intersections. Accident records and field visits to these intersections revealed no evidence of potential hazards. Another possible explanation is that the "unusual" number of accidents at these STOP-controlled intersections occurred at high volume intersections. Table 6 gives the distribution of one-accident intersections by volume and control type. The low cell frequencies preclude statistical analyses. It is certainly unconvincing that STOP signs were used at high volume intersections.

Our interpretation is that accidents at low volume intersections are rare events, but over a period of time, an accident will occur. Looking at Table 5, each control type shows two intersections with 3 or more accidents. Our conclusion is that STOP control at low volume intersections does not categorically help to reduce accidents.

Major Roadway Volume

Both the YIELD and STOP signs have the function of assigning the right-of-way, generally to the roadway with the higher volume. Data collected by Stockton (2) on major roadway traffic varied from 1,000 to 36,500 ADT. To determine if there is a relationship between volume and accident experience, Table 7 was constructed; volume was grouped by increments of 1,000 ADT except for the last group, which included all intersections with more than 6,000 ADT. The total MDIS of 12.0833 is slightly less than the tabulated χ^2 value of 12.6 for 6 degrees of freedom at the 5 percent significance level, indicating that there is no relationship between accident experience and traffic volume.

Our tentative conclusion is that up to 6,000 ADT, the YIELD or the STOP

Table 6. Distribution of Intersections with One Accident by Traffic Volume and Control Type

VOLUME	STOP	YIELD
0 - 1,000	7	1
1,000 - 2,000	2	0
2,000 - 3,000	1	1
3,000 - 4,000	3	1
over 4,000	0	1

Source: Reference 2

Table 7. Distribution of Intersections with Accidents by Major Road Volume

MAJOR ROAD VOLUME (ADT)	NUMBER OF INTERSECTIONS WITHOUT ACCIDENTS	NUMBER OF INTERSECTIONS WITH ACCIDENTS	TOTAL
0 - 1,000	68	10	78
1,001 - 2,000	12	1	13
2,001 - 3,000	9	4	13
3,001 - 4,000	7	1	8
4,001 - 5,000	2	3	5
5,001 - 6,000	4	0	4
Over 6,000	13	6	19
TOTAL	115	25	140

Source: Reference 2

sign may be used to assign the right-of-way. It is not clear, however, that the 6,000 ADT is the upper bound of no association between intersection accidents and traffic volume. It will have to be established in future studies how much higher than 6,000 ADT the upper bound might be.

Past Signing Practice

Signing for traffic control, unlike signalization, is passive; it cannot accommodate changing traffic conditions. Understandably, the traffic engineer with safety uppermost in his/her mind would choose the normally conservative, but more restrictive STOP sign in preference to the YIELD sign. This may have been acceptable engineering practice years ago, but with the proliferation of STOP signs, drivers are skeptical and disbelieving of a need for the STOP sign when they see one. Dyar (4) reported that there was no significant difference in driver's observance of STOP signs with or without special control measures at rural intersections with inadequate sight distance. It is not clear from the report whether these special control measures were used at selected hazardous intersections. The special control measures included:

1) STOP sign larger than the standard 30-inch sign.
2) STOP signs installed on both the left and right shoulders of the controlled approach.
3) Red flashing lights at STOP controlled approaches and amber flashing lights for through streets.
4) Larger rectangular overhead sign with the word STOP suspended above the intersection.
5) Combinations of the above.

It is fairly evident that the STOP sign has lost its meaning. Drivers treat it as a YIELD sign -- slow down, proceed with caution.

YIELD Sign

The YIELD sign (trapezoidal) was introduced in 1951 in Tulsa, Oklahoma and incorporated into the 1955 revision of the National MUTCD as an equilateral triangle with one corner pointed downward with black lettering on a yellow background (7), which was later changed to the now familiar red on white. It is less restrictive than the STOP sign and definitely assigns the right-of-way to the major road. The Supreme Court of South Dakota ruled that:

> "The only difference between a STOP sign and YIELD sign is the duty always exists to stop and look effectively (at) the STOP sign, and for a YIELD sign the duty is to slow down, effectively look to see if the highway is free from oncoming traffic, and stop if necessary to yield the right-of-way...." (emphasis added) (8).

Then, why isn't the YIELD sign in greater use? There are several notable reasons and they are listed below:

1) The application of YIELD signs would require engineering studies, whereas little or none is required for STOP signs, if conditions 1, 2, or 3 of the STOP warrant are used.
2) The belief by engineers that a single ultimate policy of stop control prepares them for all eventualities against tort liability.
3) Political pressure from citizen groups in the mistaken belief that STOP signs offer greater protection than YIELD signs.

Relative Efficiency

Total road user cost per cycle was estimated from more than 3,000 observations at both STOP and YIELD controlled intersections. This cost included both the vehicle operating cost and delay cost, and was based on entry speed and travel time through the intersection. Figure 1 shows the cost differentials for major roadway volumes above and below 2,000 vpd (the

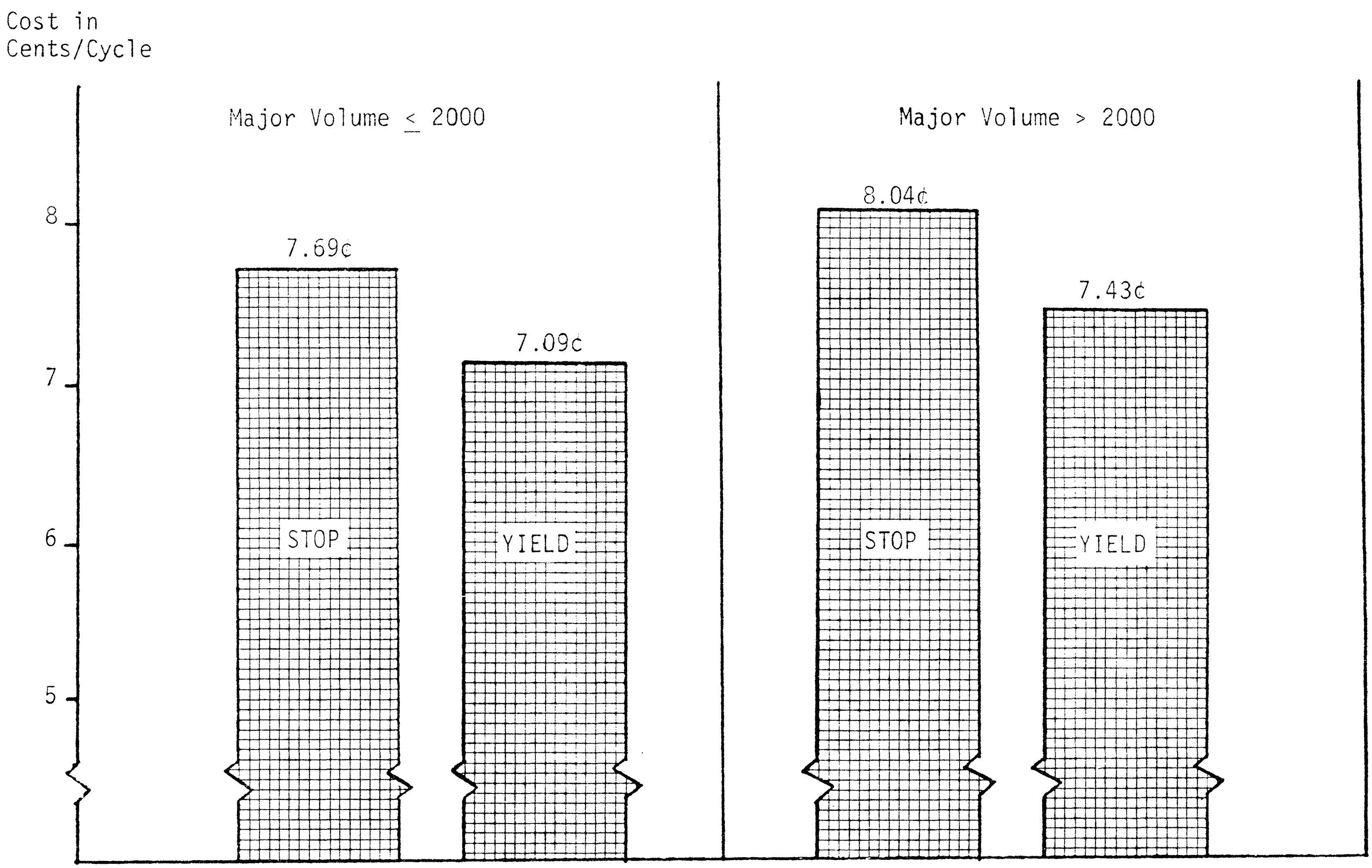

Figure 1. Costs per Cycle of STOP and YIELD Control

point of significant difference in driver behavior). YIELD control offers a 7.8% reduction in total cost below 2,000 vpd, and a 7.6% reduction at the higher volume level.

SUMMARY

Traffic control is highly visible and sensitive to public scrutiny. Understandably, the traffic engineer must consider and accommodate all drivers, from the novice to the experienced, the familiar and unfamiliar, the defensive and aggressive. The task is not an easy one. The ultimate measure of successful traffic control is a good safety record. This can only happen through public understanding and acceptance of the control devices. Many of the STOP signs at low volume intersections are unjustified (although warranted by the MUTCD) and could be replaced by YIELD signs without increasing accident experience. Furthermore, the use of YIELD signs would restore respect and effectiveness of the STOP sign, while improving operating efficiency. The path of least resistance of a single policy of STOP control is contraindicated by the low rate of obedience to the STOP signs. Our findings are summarized below:

1) The low rate of driver compliance to the STOP sign is a result of excessive usage at intersections where it is not reasonable and necessary that all motorists stop.
2) There is no relationship between major road traffic volume (up to 6,000 ADT) and accident experience at low volume intersections.
3) STOP signs do not reduce accident experience at low volume intersections.
4) The supposition that STOP signs are being used at locations with poor sight distance as defined by AASHTO is not supported by data.
5) STOP signs result in a higher road user cost than YIELD signs.

In keeping with the philosophy that the least restrictive device consistent with safety and smooth traffic flow should be used, the basic question is asked: When should the STOP sign be used? The question is easy; the answer may not be so.

ACKNOWLEDGEMENT

Much of the material in this paper has been taken from the study "STOP, YIELD and No Control at Intersections" Report No. FHWA/RD-81/084 sponsored by the Federal Highway Administration and is gratefully acknowledged. The findings and opinions are ours and do not reflect those of the Federal Highway Administration.

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TABLES

FIGURES

Figure 1. Costs per Cycle of STOP and YIELD Control