Traffic Control and Accidents at Rural High-Speed Intersections

KENNETH R. AGENT

In many instances, when rural high-speed highways are constructed, there are a number of at-grade intersections along the roadway. These rural high-speed intersections create accident potential because of the conflicting traffic movements. The objectives of this study were to (a) determine the types of traffic control measures used at rural high-speed intersections, (b) establish the type of accidents that occur at rural highspeed intersections, (c) discover the factors that contribute to these accidents, and (d) recommend traffic control measures that could most effectively decrease accident potential at such locations. The site characteristics, traffic control used, and accidents that occurred at 65 rural high-speed intersections were summarized. The differences that resulted when the right of way was controlled by stop signs instead of a traffic signal are discussed. The factors that contributed to the accidents and the characteristics of the accidents were analyzed. The data obtained at each intersection were summarized, and recommendations that could be used as a guide for implementing changes at other, similar intersections were made for the study locations. The accident analysis shows that providing the driver adequate warning of the Intersection is of primary importance for this type of intersection. At signalized intersections, providing a proper change interval and maximizing the visibility of the signal heads are essential. The need to consider separate left-turn phasing also is shown.

In many instances, when rural high-speed highways, such as bypasses, are constructed, there are a number of at-grade intersections along the roadway. These rural high-speed intersections create accident potential because of the conflicting traffic movements. Various types of traffic control measures have been used. For example, one basic decision is whether the intersection should be controlled by stop signs (usually only the minor streets) or whether traffic signals should be used. Other traffic control measures, such as intersection control beacons, warning signs, channelization, and rumble strips, have been used.

There has been no systematic analysis of the results of using the various types of traffic control. There was a need for an analysis of the accidents that had occurred at several intersections of this type and a study to relate the accidents to the traffic control and other intersection characteristics to determine what types of traffic control may be used to reduce accident potential at such intersections.

The objectives of this study were to

• Determine the types of traffic control measures used at rural high-speed intersections,

• Establish the type of accidents that occur at rural highspeed intersections,

• Discover the factors that contribute to these accidents, and

• Recommend the traffic control measures that could most

effectively decrease accident potential at such locations.

PROCEDURE

A sample of rural high-speed at-grade intersections was selected from across Kentucky. The intersections were selected to provide a variety of traffic volume, roadway geometrics, and traffic control. In all, 65 study locations were selected. The list of locations was supplied by the Division of Traffic of the Kentucky Department of Highways. At a large number of the intersections, changes in traffic control had been implemented. In general, the intersections were high-volume locations. Several were on bypasses, and either a traffic signal or an intersection beacon was present at almost all the locations. The sample was not selected to represent the total sample of such intersections, which would include a high percentage of intersections that are unsignalized and without beacons.

A site visit was made to each intersection. The field data collected dealt with the intersection geometrics and the traffic control at the intersection and its approaches, including information such as intersection type, speed limit, right-of-way control, lighting, raised channelization, pavement markings, number of lanes, sight distance, signing, and traffic signal information. Data from the individual intersections were then coded into a computer file and summarized to show the typical characteristics of this type of intersection.

The dates of installation of traffic control, such as traffic signals and intersection control beacons, were determined. Accident data for several years were collected at each intersection, unless the intersection was new. Where appropriate, data were compared before and after the installation of a major traffic control device such as a traffic signal.

Accident rates were calculated for each intersection to determine the effect of any changes in traffic control as well as to determine an accident rate for each intersection. Intersections that had similar characteristics were combined to determine how factors such as the presence of a traffic signal influenced the accident rate.

Data from each accident report were coded into a computer file as well. This information was then summarized to obtain the characteristics of the accidents that occurred at each type of location. In addition to the information included on the police report, a "directional analysis" code was assigned to each

Kentucky Transportation Research Program, College of Engineering, Transportation Research Building, 533 South Limestone, University of Kentucky, Lexington, Ky. 40506-0043.

Agent

accident to further describe the type of accident, and a "comments" or "accident description" code was assigned to add information concerning the contributing factors to the accidents. The accident description code was generally obtained after reviewing the commentary included on the accident report.

RESULTS

Site Characteristics and Traffic Control at Study Intersections

The information obtained from the site visit and the accident history analysis for each study intersection was tabulated. Of the 65 locations, 15 had three approaches and 50 had four approaches. The speed limit on the major roadway was 55 mph at 49 locations and 45 mph at 16 locations. The speed limit on the road classified as the minor roadway was 55 mph at 31 locations, 45 mph at 14 locations, and less than 45 mph at 20 locations.

A traffic signal was the right-of-way control at 47 locations, with stop sign control at 18 locations. Three of the 18 stop sign locations had four-way stop intersection control. All but two of the 18 stop sign locations had an intersection control beacon. The beacon was yellow for the through roadway and red for stop approaches. Some form of lighting was present at 18 locations.

There were 245 approaches at the 65 study intersections. The total number of lanes on the approaches varied from one to four. Typically, additional lanes were added at the intersection for turning. Many of the approaches (64 percent) had a separate left-turn lane. Approximately half of the approaches had some form of right-turn lane.

The grade and curvature on the majority of approaches was classified as straight and level. Only 7 percent of the approaches had a steep grade and only 6 percent had curves classified as sharp.

Almost all approaches (96 percent) had either a painted centerline or a lane line. Most approaches (78 percent) also had a painted edge line. Several approaches (44 percent) had snowplowable markers (either Stimsonite 96 or recessed markers) installed. Slightly over half of the approaches (56 percent) had either a mountable or nonmountable median. More approaches had a mountable median than a nonmountable one.

A small number of approaches (7 percent) had rumble strips installed. The rumble strips were installed at nine intersections, of which four were controlled by stop sign and five by a traffic signal. Of the 16 approaches with rumble strips, 11 were approaches to a traffic signal and five were approaches to a stop sign. Most approaches had a painted stop bar. Excluding through approaches at which a stop bar was not appropriate, 86 percent of the approaches had stop bars.

The sight distances for vehicles stopped on an approach to observe vehicles approaching on the cross roadways was summarized. That distance was estimated for traffic signal- and stop-sign-controlled approaches. Results indicate that sight distances were generally very good, especially for the minor approach to observe the major approach (where sight distance was estimated to be over 1,000 ft in 67 percent of the cases). These findings reflect previous observations that most approaches were generally straight and level. Sight distances were less than 500 ft at only 5 percent of minor roadway approaches to observe the major street approach, compared to 42 percent of major roadway approaches to observe the minor roadway approach.

The characteristics of the 47 signalized intersections were summarized. Of the major roadways, 60 percent had a separate left-turn phase; only 6 percent of the minor roadways had a separate left-turn phase. Protected-only phasing was used for all left-turn phasing. A green extension system (GES) had been installed at nearly all locations. The length of yellow on the major roadway was 4 sec or greater at all but one location, and there was a yellow time of 5 or more sec at 34 percent of the locations. On the minor roadway, the yellow time was under 4 sec at 34 percent of the locations, compared to five or more sec at 17 percent of the locations. A red clearance time was provided at 60 percent of the major roadway approaches, compared to 36 percent of the minor roadway approaches. The length of the red clearance time was generally (71 percent) in the range 1.0 to 1.5 sec with a typical time of 1 sec. A 12-in. lens was used for all major roadways and all but two minor roadway signal heads. All of the signal heads were mounted overhead. Backplates were used on 32 percent of the major roadway approaches and 11 percent of the minor roadway installations. A pedestrian signal was present at only two locations.

A comparison of the length of yellow time with the speed limit was conducted. There was a general increase in the length of yellow time as speed increased, but a yellow time of 4.0 sec was the most common length of yellow for all speed limits. The average yellow time increased from 3.6 sec for locations with a speed limit of 35 mph to 4.1 sec where the speed limit was 45 mph to 4.3 sec for a speed limit of 55 mph. According to the standard method used to calculate yellow time, a yellow time of 5.0 sec would be appropriate for a speed limit of 55 mph.

As part of the site inspection, the types of warning signs present on the approaches were noted. The presence of various warning signs was summarized by type of approach and speed limit. For approaches to a traffic signal, a "signal ahead" sign was present at 71 percent of the approaches, with a crossroad sign present at very few approaches. Only 9 percent of the approaches that had a speed limit of 55 mph did not have a warning sign, compared to 59 percent of the approaches that had a speed limit of less than 45 mph. Also, 32 of the 40 approaches to a stop sign (80 percent) had a "stop ahead" sign, and 19 of the 30 nonstop approaches (63 percent) at a stop sign—controlled intersection had a crossroad warning sign.

Descriptions of the signal ahead signs used were summarized. The most common signing used a single standard size sign. However, the second most common signing consisted of two 48-in. signs. At five approaches, a continuous flasher was placed on the signal ahead sign. At two approaches to one intersection, overhead "prepare to stop when flashing" signs were placed, with flashers that work when the red indication is displayed. This was the only active advanced warning device used at any of the study locations.

A summary of the types of stop signing used was also compiled. Several sign combinations were used and the most prevalent was one 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 A summary of the crossroad warning signs used on nonstop approaches at stop sign-controlled intersections was made. Both one and two standard size or 48-in. signs were used, with the most common form being a single 48-in. sign with an advisory speed plate.

Accident Analysis by Type of Major Traffic Control

The current traffic control devices in place at each intersection were noted during the site visits. If an intersection beacon or traffic signal was present, the date of installation and the type of previous traffic control were determined. Dates of installation for other devices, such as signs or rumble strips, were not available. An accident analysis was conducted to compare the type of right-of-way control used. The three categories used were (a) stop sign with no intersection beacon, (b) stop sign with intersection beacon, and (c) traffic signal. Accident rates at the study locations were calculated as a function of right-ofway control.

The combined accident rates at intersections that had the designated type of right-of-way control are summarized in Table 1. The total number of locations exceeds the number of intersections included in the study because the right-of-way control had changed at some time during the study period at most of the intersections, resulting in data for more than one type of right-of-way control. The combined accident rate was similar for each type of right-of-way control.

A summary of the change in accidents when the right-of-way control was changed is given in Table 2. Of the 11 locations at which an intersection beacon was added to stop sign control, there were decreases in accidents at seven of the locations, compared to an increase at four locations. A statistical analysis revealed that two locations had a significant increase and two a significant decrease in accidents. The overall accident rate decreased from 1.1 to 1.0 ACC/MV when an intersection beacon was added. Of the 16 locations, an equal number of locations experienced decreases and increases in accidents when a stop sign (without intersection beacon) was replaced with a traffic signal. Four intersections experienced a statistically significant increase, compared to three with a statistically significant decrease. The overall accident rate actually increased from 1.3 to 1.8 ACC/MV (because of a large number of accidents at one intersection) when the traffic signal was added.

For 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. Also, there was a statistically significant decrease in accidents at six locations, compared to a significant increase at three locations. The overall accident rate decreased from 1.4 to 1.1 ACC/MV when the traffic signal was added. This was the result of a reduction in the number of right-angled accidents in which the side street vehicle pulled into the path of the through vehicle.

Data in the previous tables show a slight benefit with the installation of an intersection beacon. An overall benefit was observed when a traffic signal was installed, although results were not consistent. The intersections that had traffic signals and a high accident rate typically had a problem with opposing left-turn accidents.

Accident Characteristics

A summary of characteristics of accidents at the study intersections is presented in Table 3. The characteristics are compared to those for all intersection accidents statewide. A summary by directional analysis at the study locations revealed that angle accidents were the most common, followed by rear end and opposing left-turn accidents. When all intersection accidents were considered, angle accidents were still the most common, followed by rear end accidents. The largest difference in type of accident was the much higher percentage of opposing leftturn accidents at the study intersections with statewide intersection accidents indicated that accidents at the study locations were (a) more severe, (b) more likely to occur during darkness at an unlighted location, (c) less likely to occur during snow or ice conditions, and (d) more likely to involve failure to

TABLE 1 ACCIDENT SUMMARY BY TYPE OF RIGHT-OF-WAY CONTROL

Right-of-Way Control	Number of Locations	Accidents	Number of Vehicles (MV)	Accidents per MV	MV per Year
Stop sign	27	338	309	1.1	5.6
Stop sign with beacon	37	541	448	1.2	4.8
Traffic signal	46	1,290	1,058	1.2	6.1

TABLE 2	CHANGE IN	ACCIDENTS	WHEN RIGHT-	OF-WAY	CONTROL	CHANGED

Change in Right-of-Way Control		Number of	Change in Accidents/Year			Statistically Significan Change	
Original Control	New Control	Locations	Increase	Decrease	No Change	Increase	Decrease
Stop sign	Stop sign with beacon	11	4	7	0	2	2
Stop sign	Traffic signal	16	7	7	2	4	3
Stop sign with beacon	Traffic signal	20	7	12	1	3	6

		Percent in Given	Category
Variable	Category	Accidents at Study Intersections	Statewide Intersection Accidents ^a
Directional analysis	Angle	46.6	53.9
·	Rear end	21.1	23.1
	Sideswipe	7.5	9.8
	Single vehicle	4.0	6.5
	Opposing left-turn	20.5	3.7
	Bicycle	0.1	0.8
	Pedestrian	0.0	0.8
	Other	0.2	1.4
Accident severity	Fatal accident	1.3	0.2
	Injury accident	36.0	23.6
	Property damage only	62.7	76.2
Light condition	Daylight	76.8	78.7
-	Dawn-dusk	3.6	3.5
	Darkness, unlighted	10.2	5.0
	Darkness, lighted	9.4	12.8
Road surface condition	Dry	75.7	70.8
	Wet	20.7	20.4
	Snow-ice	3.6	8.8
Contributing factors	Unsafe speed	5.1	4.1
_	Failure to yield right-of-way	40.5	28.2
	Disregard of traffic control	11.9	8.1
	Alcohol	4.2	3.6
	Defective brakes	3.1	2.0
	Glare	1.3	0.9
	Limited view	3.0	4.3
	Improper or nonworking		
	traffic control	0.8	0.4
	Slippery surface	7.8	11.3

TABLE 3 CHARACTERISTICS OF ACCIDENTS AT RURAL HIGH-SPEED INTERSECTIONS AND COMPARISON TO ALL INTERSECTION ACCIDENTS

^aIn 1985, 39,980 accidents occurred at intersections.

yield right-of-way, disregard of a traffic control, or defective brakes as a contributing factor.

A comparison was made of the types of vehicles involved in accidents at the study locations versus all statewide accidents and statewide intersection accidents. The percentages were similar but did show a higher percentage of combination trucks involved in accidents at the study locations.

Characteristics of accidents involving passenger cars only or single-unit or combination trucks were tabulated. A higher percentage of accidents involved trucks at intersections controlled by a traffic signal than at intersections controlled by a stop sign. Compared to accidents involving only passenger cars, accidents involving a combination truck were more often associated with (a) increased accident severity, (b) wet, snowy, or icy pavement, (c) darkness with no lighting, and (d) sideswipe, single vehicle, and angle collisions. These accidents were less frequently associated with opposing left-turn and rear end collisions.

A summary of the characteristics of the accidents by type of major traffic control (stop sign, stop sign with beacon, and traffic signal) is presented in Table 4. The angle accident was the most common type for all types of traffic control, but its percentage decreased dramatically for intersections controlled by a traffic signal. Conversely, the percentage of rear end and opposing left-turn accidents increased substantially for traffic signal locations. The opposing left-turn accidents occurred almost exclusively on approaches that did not have protected left-turn phasing. Accidents were slightly less severe at intersections that had traffic signals. More accidents occurred during darkness and on wet pavements at traffic signal locations.

A summary of comments further describing the accident (accident description code) is given in Table 5. These comments would usually be obtained from a statement by a driver who had been involved in the accident or a comment from the investigating police officer. To help form a better understanding of the cause of the accident, the accident description narrative given on the police report was read and any relevant comments were coded and summarized. Although these comments by the police officer, driver, or both were not documented by a detailed accident reconstruction, it was felt that these remarks provided valuable insights into the causes of the accidents. The consistent types of comments found at certain locations added to their credibility. In a large number of accidents, no specific explanation was given for the action of the driver who was at fault. The summary in Table 5 places the descriptions of common accident types into various categories when possible. Some comments, such as defective brakes, would apply to more than one of the general description categories, so these types of comments were placed into the miscellaneous category. A common accident at locations not controlled by a traffic signal 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 very

Variable	Category	Stop Sign	Stop Sign with Beacon	Traffic Signal
Directional Analysis	Angle	70.7	68.2	31.3
•	Rear end	8.6	12.9	27.8
	Opposing left-turn	9.5	7.8	28.7
	Sideswipe	6.2	6.5	8.3
	Single vehicle	5.0	4.6	3.4
	Bicycle	0.0	0.0	0.2
	Other	0.0	0.0	0.3
Accident severity	Fatal accident	1.5	2.6	0.9
•	Injury accident	37.2	39.6	34.1
	Property damage only	61.3	57.8	65.0
Light condition	Daylight	76.6	81.6	74.9
0	Dawn-dusk	4.7	4.8	2.7
	Darkness, lighted	8.9	2.8	13.7
	Darkness, unlighted	9.8	10.8	8.7
Road surface condition	Dry	78.7	79.8	73.3
	Wet	18.3	16.5	23.0
	Snow-Ice	3.0	3.7	3.7

TABLE 4 CHARACTERISTICS OF ACCIDENTS BY TYPE OF MAJOR TRAFFIC CONTROL

good in the large 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 four-way stop, thought the through vehicle was turning, or saw the through vehicle but misjudged the time available.

The most frequent comment when a driver disregarded a traffic signal was that he did not have enough time to stop when the signal changed to red. Other common observations noted on the police report were that both drivers thought their signal indication was green, the signal was not working properly or had been set to the flash mode, or one vehicle entered the intersection on yellow. In a few instances, the driver failed to observe the signal. It also was noted in a few cases that the signal had just been installed and was not expected by the driver.

For opposing left-turn accidents, the most common driver comments were that the driver did not see the opposing vehicle or the driver's vision was obscured (in many instances, by a vehicle waiting to turn left in the opposite direction). Other comments were that the time available to make the turn was misjudged or that the driver thought the green ball was a leftturn arrow.

The most common rear end accidents involved a vehicle stopped or stopping at a traffic signal or a vehicle sliding on a wet or icy pavement. Other common circumstances in rear end accidents involved a vehicle stopped to turn or in the process of turning, or a vehicle stopping abruptly at the onset of a yellow indication.

The most common type of sideswipe accident involved changing lanes. Other accidents of this type resulted when a vehicle turned from the wrong lane, a turning vehicle hit a stopped vehicle on the intersecting roadway, or a vehicle passed a turning vehicle.

The comments or "accident description" codes are summarized by type of traffic control in Tables 6 through 8. The problems of opposing left-turn accidents and accidents involving a driver who disregarded the signal indications are shown at signalized intersections, as are the large number of rear end accidents. The larger number of comments stating that the driver did not have adequate time to stop, both drivers thought they had a green indication, and one driver entered the intersection on a yellow indication point out the need for an adequate change interval.

The comments presented in Tables 7 and 8 show that the major problem at stop sign—controlled intersections involves a side-street vehicle stopping and then pulling into the path of a through vehicle. The most common explanation, as stated before, was that the driver of the side-street vehicle did not observe the through vehicle, even though sight distance was very good in most instances. In approximately 10 percent of those accidents it was noted that the side-street vehicle did not stop at the stop sign. It should be noted that the percentage of vehicles disregarding the stop sign was slightly higher at locations that had an intersection beacon than at locations without a beacon.

Recommendations at Study Locations

After the site visit information and accident history had been used as input, recommendations were made for operational improvements at the study intersections. Because these locations were selected to give a sample of rural high-speed intersections, the recommendations for operational improvements at these locations could be used as a guide for other similar intersections. Some sort of recommendation was made for all but five of the intersections. The recommendations were made on the basis of the accident history or as operational improvements according to a standard method of application for a traffic control device. An example of a recommendation on the basis of accident history was the addition of left-turn phasing, which was recommended for cases in which there was a large number of opposing left-turn accidents. Guidelines for an excessive number of such accidents have been established. An example of an operational improvement was the modification of the change interval to conform to that given in the standard procedure.

TABLE 5 SUMMARY OF COMMENTS DESCRIBING ACCIDENT

Accident 182 92 37 18 18 18 18 18 5 273
92 37 18 18 18 5
18 18 18 18 5
18 18 18 5
18 18 5
18 5
5
273
415
66
40
17
15
ft-turn 12
10
243
d 71
44
44
41
19
17
12
8
7
125
81
66
41
38
24
22
19
10
125
47
28
21
19
8
5
54
46
16
16
9
7
7

Comment	Number of Accidents
Turned left into path of opposing vehicle, no explanation	196
One vehicle disregarded traffic signal, no explanation	147
Rear end, no explanation	91
Rear end, vehicle stopped or stopping at signal	81
Disregarded traffic signal; not enough time to stop when signal turned red	71
Opposing left turn; did not see opposing vehicle	56
Rear end; wet or icy pavement	57
Defective brakes	44
Signal on flash or not working properly	44
Disregarded traffic signal; driver said intersection was entered on yellow	41
Rear end; first vehicle stopped for yellow	38
Sideswipe; changed lanes	31
Opposing left turn; vision obscured	31
Rear end; vehicle stopped to turn left	25
Rear end; vehicle starting to accelerate	19
Disregarded traffic signal; driver did not see signal	19
Sideswipe; turned from wrong lane	17
Right turn on red	16
Opposing left turn; thought green light was left turn phase	15
Opposing left turn; driver thought there was time to turn	14
Rear end; backing	13

 TABLE 6
 SUMMARY OF COMMENTS CONCERNING ACCIDENTS AT TRAFFIC SIGNAL LOCATIONS

TABLE 7	SUM	MARY	OF C	OMMENTS C	ONCE	RNING
ACCIDEN	TS AT	' STOP	SIGN	LOCATIONS	WITH	BEACON

Comment	Number of Accidents
Side-street vehicle pulled into path of through vehicle	
No explanation	147
Did not observe through vehicle	118
Failed to stop	62
Opposing left turn; no explanation	26
Rear end; no explanation	22
Single vehicle lost control avoiding side-street vehicle	21
Rear end; first vehicle stopped when observed through vehicle	17
Side-street vehicle pulled into path of through vehicle; driver thought there was a four-way stop	15

 TABLE 8
 SUMMARY OF COMMENTS CONCERNING

 ACCIDENTS AT STOP SIGN LOCATIONS WITHOUT BEACON

Comment	Number of Accidents
Side-street vehicle pulled into path of through vehicle	
No explanation	122
Did not observe through vehicle	63
Failed to stop	30
Opposing left turn; no explanation	21
Rear end; no explanation	12
Single vehicle lost control avoiding side-street	
vehicle	9

A summary of the recommended operational improvements at the study locations is presented in Table 9. The recommendations are tabulated separately for intersections in which rightof-way is controlled by a traffic signal and for those controlled by a stop sign.

At intersections controlled by a traffic signal, the most common recommendation involved the change interval, with some modification recommended in either the yellow warning or red clearance interval at all such locations. The objective was to use a standard procedure to determine the change interval. Also, since disregard of the traffic signal was a problem, a recommendation was made that red clearance intervals should be used at all of this type of intersection. The recommendations generally involved increasing the length of the change interval. Another recommendation made at more than half of this type of intersection was the addition of backplates to the signal heads to increase their visibility. The addition of separate left-turn phasing was also recommended at several locations. As stated previously, the accident summary showed a large number of opposing left-turn accidents at this type of intersection, supplying the basis for this recommendation. Installing additional signs or modifying the warning signs also was recommended for several intersections as a means of providing additional warning to the drivers. Some type of recommendation was made for all of the traffic signal intersections. As noted previously, these were the result of either the accident history or the standard operational procedure.

At intersections controlled by stop signs, the major recommendations involved installing additional signs or modifying the warning signs to provide additional notice. Other recommendations included adding stop bars to inform motorists of the proper location to stop on the side street to have the maximum available sight distance and installing either rumble strips, transverse stripes, or post delineators on the stop approach to warn drivers that they would be required to stop. A recommendation was also made that a beacon be installed in one of the two stop sign–controlled intersections that lacked such a warning signal.

CONCLUSIONS

This study summarizes the intersection characteristics and types of traffic control at a number of rural high-speed intersections. The types of accidents that have occurred and the factors

Type of Right-of-Way Control	Recommendation	Number of Intersections
Traffic signal (total: 47 intersections)	Modify change interval	47
	Add backplates	28
	Install or consider left-turn phasing	12
	Install or modify warning sign	10
	Place stopbar	4
	Install GES	3
	Add left-turn lane	1
	Install rumble strips or transverse stripes	1
Stop sign (total: 18 intersections)	Install or modify warning sign	10
	Place stopbar	4
	Install rumble strips, transverse stripes, or	
	post delineators	4
	Consider intersection beacon	1
	None	5

TABLE 9 RECOMMENDED OPERATIONAL IMPROVEMENTS AT STUDY LOCATIONS

NOTE: More than one recommendation may have been made for any intersection.

contributing to those accidents were also analyzed. These findings were used in recommending operational improvements at the study intersections. These recommendations may be reviewed for possible implementation. Also, because these locations were selected to provide a sample of rural high-speed intersections, the analyses and resulting improvements recommended for the study intersections may be used as guides for implementing changes at other, similar intersections. The types of improvements recommended can be related to the conditions at a specific intersection to determine what type of traffic control would result in the safest intersection.

The accident analyses show that providing the driver adequate warning of the intersection is of primary importance for this type of location. On the through street, it is important to provide warning of the presence of a crossroad because even with adequate sight distance, many accidents occurred in which the driver of the side-street vehicle did not observe the through vehicle and consequently pulled into its path. Stop bars should be placed on the stop approaches to encourage the drivers to stop at a location that would maximize their sight distance of vehicles on the through roadway. The number of side-street vehicles that did not stop at the stop sign illustrates the need for adequate warning and stop signs on the stop approach. Rumble strips, transverse stripes, or post delineators could be used in addition to signing at locations for which there is a particular problem with vehicles disregarding the stop sign. It was found that installing an intersection beacon would not eliminate the problem of drivers who disregarded the stop sign. Providing adequate sight distance is critical.

Of equal importance at signalized intersections is provision of a proper change interval and maximization of the visibility of the signal heads. A red clearance interval should always be provided for both roadways. A vehicle detection and extension timing scheme also should be included for the major roadway. Backplates should always be used to increase the visibility of the overhead signal heads.

These conclusions were based on the reasons given for accidents involving a vehicle disregarding a traffic signal. The most common explanation was that there was not enough time to stop when the signal changed to red. Other common reasons were that both drivers thought they had a green indication or that one driver entered the intersection on a yellow indication. The need to consider separate left-turn phasing also is shown. The use of active advance warning signs should be considered at problem locations at which a large number of avoidable accidents have occurred.

DISCUSSION

Olga J. Pendleton

Texas A&M University, College Station, Tex. 77843-3135.

Statistical claims are made throughout this paper without support. For example, the claim is made that "A statistical analysis revealed that two locations had a significant increase . . . ". What statistical method was used? What was the level of significance? Given that several statistical methods exist for making this claim and the validity of these methods is based on assumptions, it is imperative that such a statement be followed by some description of the statistical method. The level of significance is obviously essential as well. Similar statements claiming "statistically significant" results appear throughout the text. As chair for the A3B11 Subcommittee on Statistical Methods in Accident Analysis, I felt compelled to comment on this all too common deficiency.

AUTHOR'S CLOSURE

The results of the only statistical analysis mentioned in the paper are summarized in Table 2 and the results described in the text. However, as correctly noted by the discussant, the statistical approach and level of significance were omitted. This information should have been included. The technique used was based on a Poisson distribution and a 95 percent confidence level.

Publication of this paper sponsored by Committee on Traffic Control Devices.