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SEVEN EXPERIMENT DESIGNS ADDRESSING PROBLEMS OF SAFETY AND CAPACITY ON TWO-LANE RURAL HIGHWAYS
Volume VIII: Experimental Design and Evaluate Remedial Aids for Intersections with Inadequate Sight Distance

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16. Abstract This experiment is planned for low-volume rural intersections on or near the Maine Facility. A number of remedial aids, both active and dynamic, will be tested. The devices are designed either to focus the motorist's attention on existing conditions or to display information about a possible conflict at the intersection. This Technical Report consists of seven other volumes. They are:

Vol.	pp.	Title
I	38	Introduction, Description of Experiments and Common Elements
II	70	Develop and Evaluate Dynamic Aids for Narrow Bridges
III	72	Evaluation of MUTCD and Other Traffic Controls for Highway Construction and Maintenance Operations on Two-Lane Highways
IV	58	Develop and Evaluate Remedial Aids to Warn Drivers of Slow Moving
V	62	Vehicles on a Grade
	54	Comparative Evaluation of Warning-Advisory and Regulatory Traffic Control Devices
VII	50	Develop and Evaluate Measures for Reducing Effects of Roadside Friction

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1. INTRODUCTION

This report contains the Experimental Design to "Develop and Evaluate Remedial Aids for Intersections with Inadequate Sight Distance."* This is Volume VIII of an eight-volume report. Volume I contains background information and summaries of seven experiments, as well as a discussion of the elements common to each of the seven experimental designs.

This volume includes:

- Background and Objectives,
- A State-of-the-Art Review,
- Design and Results of a Pilot Study,
- The Experimental Design,
- A Bibliography.

1.1 Background

In numerous locations on rural roads, nationwide, inadequate sight distance exists at approaches to intersections. Although highway engineers have recognized these locations as dangerous and have attempted to alleviate the problem by regulating the approach speeds of through traffic, serious accidents continue to occur at those locations.

This may be due primarily to increased traffic volumes on the main highway and at the intersection. In many of these locations, the sight distance deficiencies could be corrected by reconstruction. Most states' budgets for highways, however, do not allow for sufficient upgrading of these intersections so remedial aids must be used.

The present experiment is focused on low volume rural intersections with restricted sight distance. Sight distance is defined as the length of roadway ahead of the driver, which is visible to him. Obviously, this distance should be adequate so that a vehicle traveling near or at the prevailing speed will be able to come to a stop before reaching an object in its path. A hazardous situation occurs whenever sight distance is smaller than the distance needed to stop a vehicle safely.

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*This experiment is referred to as Experiment G in Volume I.

2. STATE-OF-THE-ART

A summary of the State-of-the-Art is presented below. In addition to the specific area of the research problem, the following topics are addressed:

- Intersection Traffic Control Devices,
- Driver Response to Dynamic Traffic Control Devices,
- Intersection Accidents,
- General Bibliographic Items.

2.1 Intersection Traffic Control Devices

Due to the rural nature of the Maine Facility (see Volume I), the literature search concentrated on traffic control devices for low volume intersections. For this type of intersection, the standard flashing beacon has been used almost exclusively. Generally, the beacon is installed on a single span wire and can be supplemented with a beacon attached to the intersection stop sign.

Foody and Taylor (34), in an extensive before-and-after accident study, evaluated a total of five flashing beacon configurations:

1) Standard stop sign on the side of the road with one or two flashing beacons attached to the support post. The installation was on the right side, or on both sides of the minor approaches.

2) An overhead rectangular stop sign with two or four flashing beacons. The installation was made straddling all approach lanes on the minor approaches.

3) A single unit, placed overhead in the center of the minor approach, with two beacons flashing in a bouncing ball manner. The two beacons were mounted vertically or horizontally with a separation of one foot.

4) An installation similar to #3, centered over each lane on the approach.

5) An installation, similar to #4, except that all beacons flashed simultaneously.

On the basis of the field data collected in Maine, Goldblatt states the following result.

> "The use of the actuated "WHEN FLASHING - VEHICLE CROSSING" signs and beacons along the main street approaches causes a reduction in speed variance along the approach. The effect was more pronounced on the approach with poor sight distance."

In a study conducted by Foody and Taylor (34) on flashing systems, sight distance was used as a geometric variable. Their conclusions state that there was a significant reduction in accidents with the use of flashing beacons at all sight distances.

Another recent development is directly related to the problem of low volume restricted sight distance intersections. This installation, currently in use in DeKalb County, Georgia (86) involves the use of loop detectors to sense the presence of vehicles along the main street. The detectors are located 400 feet upstream of the intersection. When actuated, a red beacon facing the side street flashes over a warning sign indicating the approach of the vehicle. The time delay provides a continuous red flashing indication for a minimum of ten seconds for the side street traffic. Additional main street actuations extend the time of actuation by ten seconds per vehicle. Normal traffic control at such intersections consists of standard stop sign installations.

2.2 Driver Response to Dynamic Traffic Control Devices

Holmes (42) has defined four stages in the recognition of a flashing signal:

"1. To see it, to realize that it exists. This requires what I may call the 'appearance' time.

2. To see where it is, to relate it to our frame of reference in our visual field. This requires what I may call the 'search' time.

3. To see what it is, to recognize and identify it. This requires what I may call the 'appraisal' time.

tion of standard flashing beacons, there was a reduction in the number of left turn and multiple vehicle accidents.

A Nebraska accident study (61) on the effects of bouncing ball flashing beacons resulted in several noteworthy results:

1. Recent installations (completed in 1972) have experienced a greater accident rate reduction than earlier installations.

2. There is strong indication that accident rate reduction diminishes after a period of time following beacon installation.

3. Installations at lower traffic volume locations have been most effective.

4. A significant reduction in "angle" collisions occurred following beacon installation.

5. A significant reduction in nighttime accidents has occurred following beacon installation.

6. A significant reduction in accidents involving vehicles which failed to stop has occurred following beacon installation.

The first two of these conclusions indicate that the effectiveness of these devices is reduced as drivers become familiar with their operation. This "familiarity breeds contempt" effect can be related to the non-dynamic nature of the device itself. That is, the continuous flashing operation of the signal soon loses its relationship to the intermittent hazardous situation at the intersection.

Conclusion 5 of the Nebraska study can be related to the highly conspicuous nature of flashing beacons against a dark background. Conclusion 6 can also be explained by the fact that an active signal is more recognizable against the visual noise of the background.

According to a study done for the Committee on Traffic Control Devices (28), low volume rural intersections have disproportionally high accident rates. The same study found that the installation of a simple continuous flashing beacon directly related to a reduction in accident severity. Furthermore, a reduction in the variance of the speed distribution is related to a reduction in accident frequency.

2.4 General Bibliographic Items

A number of general bibliographic items have been included in the literature search. These include references dealing with driver reactions to standard signals and warning or advisory signs (11,12,9,10,18,30,39,44,49,52,70,72) and papers dealing with physiological responses to differing signal indications (15,16,19,20,23,24,29,33,37,38,42,46,58, 50,55,67).

- Testing of data collection techniques and procedures using the TDC equipment.

The TDC recorder was used by the staff of the Maine Facility to gather the data needed to accomplish these objectives. These data were reduced and analyzed. This section presents the results of these analyses and their impact on the final experiment design.

3.1 Procedure

The intersection of U.S. Route 2 (main street) and East Ridge Road (side street) was chosen as the study site for the pilot experiment. Figure 1 is a schematic of the site and the trap and loop positions. Speeds of vehicles in the westbound direction on Route 2 were detected by each trap and independently recorded as vehicles passed over them. Simultaneously, Loop 1 detected the presence of a stopped vehicle on the near side street, and Loop 2 detected the presence of a stopped vehicle on the far side street. The presence of a vehicle on the side street, as a vehicle passed over the traps on the main street, was noted as a conflict. Near-or far-side conflicts are terms determined by the direction of main street traffic. The reduced data supplied by the Maine Facility stratified the speeds of vehicles at each of the three traps on the main road by each of the three types of conflict conditions--near side conflict, far side conflict and no conflict.*

In addition, three separate stop times were studied. Stop time was defined as the minimum time a vehicle was stopped on the side street. If a vehicle was not over the loop the required seconds of stop time, it was ignored as a side street vehicle. Stop times of 2.0 seconds, 3.0 seconds and 4.0 seconds were used. This parameter was necessitated by the fact that vehicles turning from U.S. 2 onto East Ridge Road may pass over Loop 1 or Loop 2, indicating a conflict when none existed.

As vehicles crossed the three traps on the main street, their headways were recorded and automatically stratified into two groups:

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*Both sides classified as far side conflict.

- Less than 3.0 seconds,
- Greater than 3.0 seconds.

Since only the speeds of free-flowing vehicles are of interest, all data for main street vehicles with headways less than 3.0 seconds were eliminated from the analyses.

3.2 Results

The reduced main street speed data were subjected to three main types of analyses. These include:

- Reduced raw data results which define traffic flow characteristics;

- Three-way analyses of variance which delineate the effects of the independent variables on main road speed;

- The Kolmogorov-Smirnov Two-Sample Test which further describes, in a more refined manner, the effect of conflicts on main street speeds.

Three speed-based parameters were considered as dependent variables in representing main road speed. They are:

- Mean speed,
- Standard deviation of speed,
- 85th percentile of speed.

The independent variables and the levels of each considered are:

- Stop time: Three levels--2.0 seconds, 3.0 seconds, 4.0 seconds;

- Trap position: Three levels--Trap 1, Trap 2, Trap 3;

- Conflict: Three levels--none, near side, far side.

4. EXPERIMENTAL DESIGN

This section contains the Final Experimental Design to "Develop and Evaluate Remedial Aids for Intersections with Inadequate Sight Distance." Both dynamic and active remedial aids will be tested and evaluated.

4.1 Independent Variables

For each remedial aid system or device, several stratifications of the response data will be made. These stratifications constitute independent variables in the experiment design. These independent variables and their respective levels to be investigated are summarized in Table 1 below and detailed in the following subsections.

TABLE 1. - Levels of Independent Variables

Variable	Number of Levels
Devices	6
Site characteristics (geometry)	2
Vehicle type	2
Conflicts	2.5*
Ambient lighting conditions	2

4.1.1 Devices - Remedial Aids

The principal independent variable contains the devices to be tested in the experiment. These devices may be classified as active and dynamic within the context of this experiment. An active device is defined as a flashing beacon which does not require actuation and shows a continuous alternating display with or without the use of an advisory sign. A dynamic device is one which is similar to an active device but requires actuation by a vehicle.

*Far-side conflicts do not apply to the Tee intersection.

$$D = 10V_{.85}$$

where D is the distance in feet and $V_{.85}$ is the measured 85-percentile speed along the major approach in miles per hour. This equation is the standard used by the State of New York for determining the location of advance warning devices (78). In accordance with this convention, the sign should be placed approximately 550 feet from the intersection. This is a somewhat shorter distance than the 750-foot distance recommended in the MUTCD as a normal placement. As a compromise, all warning signs will be placed 600 feet from the center of the intersection in this experiment. Any convention that establishes guidelines for the actual warning distance which allows the driver enough time to perform the necessary action may be used in this experiment.

The MUTCD states that "the advance posting distance will be determined by two factors--the prevailing speed and the action required by the condition to be encountered." These factors govern the time available to the driver to see, comprehend and react to the message and the time needed to perform any necessary maneuver or action.

The New York State convention for the location of warning signs ($D = 10V_{.85}$) works for the purposes of this experiment. At an 85th percentile speed of 55 MPH, the placement of the sign, according to the formula, will be <u>550</u> feet from the intersection. The MUTCD requirement is met if, at the prevailing speed, the driver has enough time to perform the necessary action. At worst, the driver would want to stop before reaching the intersection. On wet pavement, a vehicle traveling at 55 MPH needs a minimum stopping distance of 538 feet. Thus, the minimum stopping distance requirement is met, and the 600-foot location of the signs is adequate.

The sign shall be diamond shaped with black legend and border on a yellow background. The dimensions shall be 36 inches by 36 inches, with the message, BLIND INTERSECTION AHEAD. In addition, two eight-inch yellow beacons will be mounted above the sign in accordance with specifications set forth in Section 4E-5 of the MUTCD. These beacons shall flash alternately. Figure 2 represents an illustration of this device.

Intersection Control Beacon in Conjunction with INTERSECTION AHEAD Sign (Device 3)

On the basis of field work performed in Maine (35), certain conclusions were drawn regarding the use of flashing beacons as intersection controls. Goldblatt's study found that "The installation of continuous intersection beacons without a main street advisory warning sign has little or no effect upon the main street speed distribution." It is from this conclusion that the independent use of a flashing beacon mounted on a wire span is eliminated from this experiment. However, this type of beacon will be tested in conjunction with the BLIND INTERSECTION AHEAD advisory warning sign previously presented. The type, as well as the installation of the warning sign, is identical to that discussed above.

Intersection control beacons and their mounting shall follow the criteria set forth in the MUTCD (Section 4E-3).

4.1.1.3 Dynamic Devices

Three dynamic devices are to be tested as part of this experiment. Each particular device has been designed to investigate its effects on the characteristics of either main street traffic or side street traffic. A primary consideration for the major approach is to give drivers information about a potential conflict ahead at an intersection. A primary consideration for the minor approach is to give drivers advance warning of an oncoming through vehicle.

These remedial aids are vehicle actuated and therefore require the use of detectors. As a safety precaution, all messages must be of the blank-out type when not active. This will serve as a fail-safe protection. That is, if failure of a dynamic device does occur, the intersection will be controlled by the base condition.

The three dynamic devices to be tested are listed below.

Device Advising Side Street Traffic (Device 4)

This remedial aid incorporates the use of a warning sign with vehicle actuated flashing beacons. The sign is actuated by through, non-stopped, vehicles. It advises drivers at the

Thus, solving for t,

$$d = 1/2\ at^2$$

where $d = 40$ feet,
$a = 5$ feet/sec^2,

$$t = \sqrt{\frac{40 \times 2}{5}} = 4 \text{ seconds.}$$

Add two seconds of decision-reaction time, and the result is a minimum of six seconds.

When a vehicle is sensed approaching the intersection, the flashers would be actuated and continue to flash alternately until the non-stopped vehicle has cleared the intersection. Additional through vehicles actuating the sensor would extend the flashing indication.

Figure 3 represents a schematic of an intersection, with restricted sight distance to the left, using this remedial aid.

This specific device was included in the Experimental Design as the result of comments received on the Preliminary Design report. It should be pointed out that use of this device as part of the experimental program may create a potential hazard. Repeat traffic using the stopped approach may, after the initial learning period, rely excessively on the warning message. Such reliance may lead to unsafe conditions if:

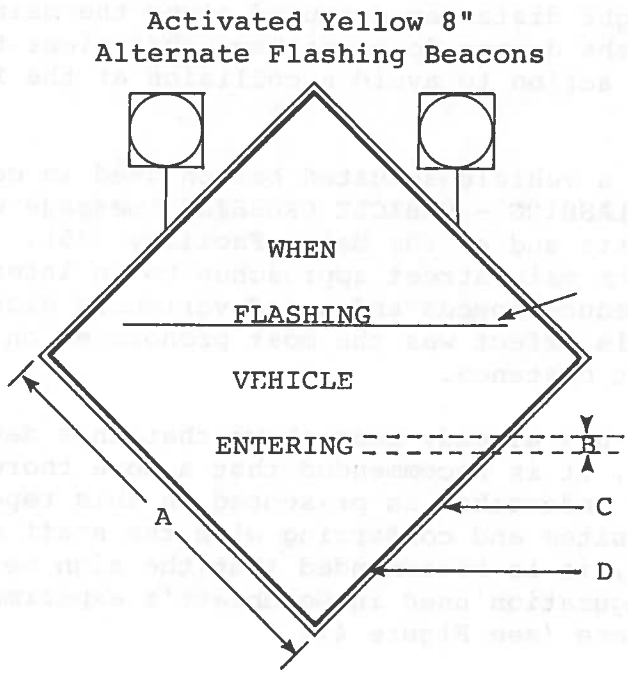
- Motorists fail to monitor the other, non-instrumented, main street approach;

- Motorists may rely on the absence of a warning message even if this absence is caused by system or equipment failure.

<u>Device Advising Main Street Traffic (Device 5)</u>

This remedial aid also incorporates the use of a warning sign with vehicle actuated flashing beacons. However, this device is actuated by a <u>side street</u> vehicle and advises drivers on the <u>non-stopped</u> approach of the presence of a vehicle at the STOP sign.

Figure 4 is a schematic of the sign to be tested.



Dimensions (inches)				
A	B	C	D	E
48	6 D Type	1 1/2	7/8	7/8

1. Colors: Legend - Black - (Backlighted)

Background - Yellow

FIGURE 4: Advisory Warning Sign, Advising Side Street Traffic

- The legend should read "WHEN FLASHING - VEHICLE ENTERING." The change of the word "CROSSING" to "ENTERING" is in accordance with the standard signs used in Maine, such as "TRUCK ENTERING."

- Two eight-inch yellow beacons will flash alternately and replace the one twelve-inch beacon used previously. The twelve-inch beacon proved too bright for comfortable viewing at night.

The sign beacons are actuated by a long loop detector operating in the presence mode, imbedded in the pavement of the STOP-sign controlled approach to the intersection.

The loop should be 50 feet (15 m) in length and extend upstream of the stop line. This distance was chosen because it would allow the actuated beacon to flash for approximately eight seconds before the vehicle approaching the STOP sign comes to a halt. This assumes an average normal deceleration rate for passenger cars of approximately six feet per second per second (8). The beacon will remain flashing until the vehicle departs the stop line.

The device is installed along the major (non-stopped) approaches to the intersection. The distance from the intersection at which the device is to be installed may again be computed using the New York standard formula,

$$D = 10V_{.85} ,$$

where D is the distance in feet and $V_{.85}$ is the measured 85th percentile speed along the major approach in miles per hour. If this distance criterion is used, it is expected that all vehicles on the major approach which are downstream of the advisory warning sign will either clear the intersection before the vehicle approaching along the minor (stopped) approach reaches the STOP sign or be close enough to the intersection that the vehicle can be seen by the stopped vehicle.

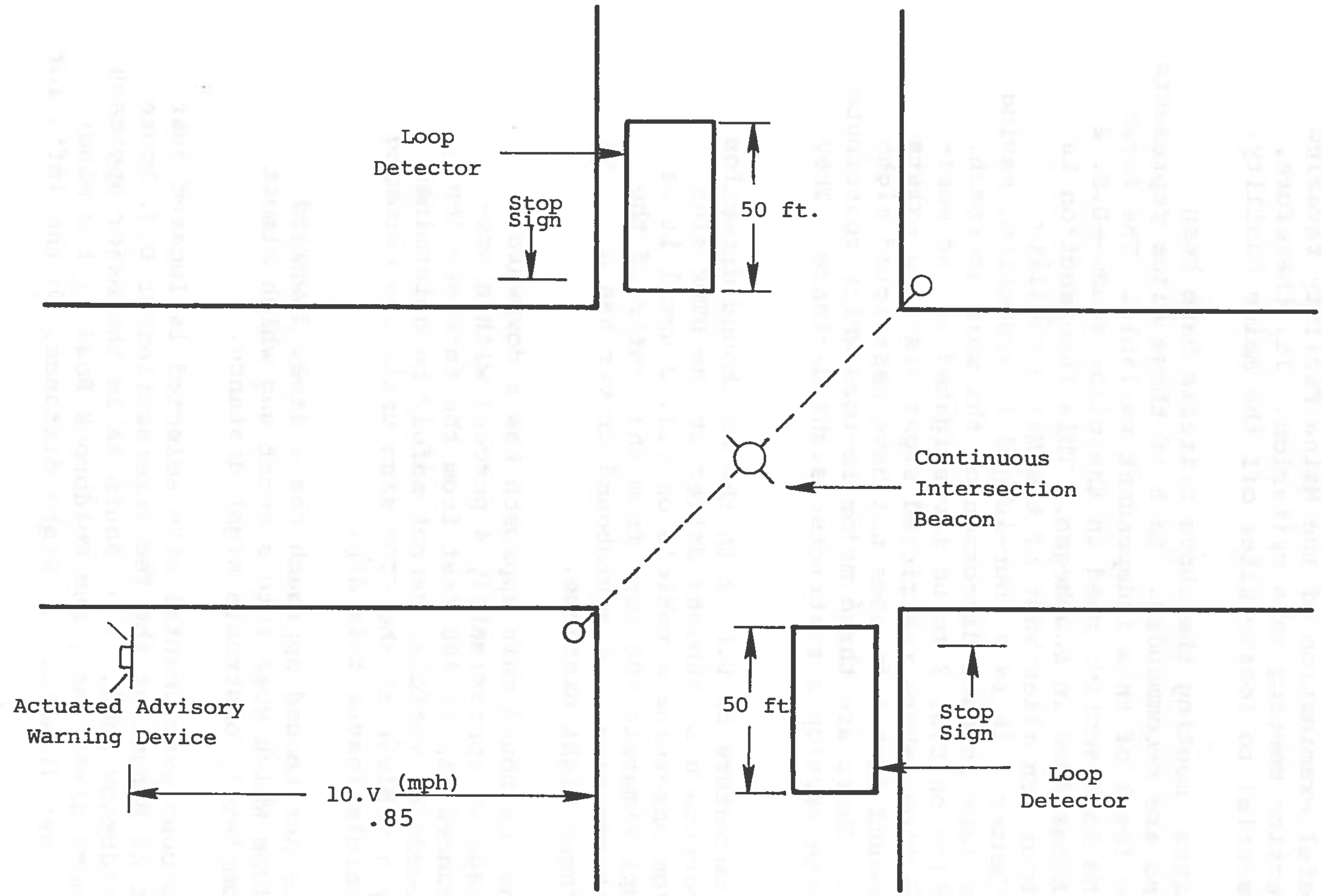


FIGURE 5: Actuated Advisory Warning Device Schematic (Advises Vehicles on the Major Approach)

a driver on Coldbrook Road is considerably restricted. Characteristics of the intersection contributing to this restricted sight distance include:

- Southbound U.S. Route 1A is on a curved alignment which prevents a driver at the stop line of Coldbrook Road from perceiving oncoming vehicles on U.S. Route 1A until they are approximately 350 feet from the center of the intersection.

- This distance is further restricted to approximately 245 feet by the foliage of trees during the summer months. Mail boxes on the side of the road are also in the direct line of sight.

The southbound approach on U.S. Route 1A has a downgrade of approximately 4 percent. The sight distance to the right (south) is over 1200 feet and is, therefore, not restricted. From spot speed checks, it is estimated that the mean speed is about 46 MPH which very closely approximates the speed on U.S. 2. It will be assumed that its 85th percentile speed is also 55 MPH.

4.1.3 Vehicle Types on the Main Approach

It is recommended that vehicles be stratified into two levels for this experiment:

- Passenger cars,
- Trucks.

For the purposes of this experiment, a truck is defined as any vehicle bigger than a van or pickup truck. This stratification is necessary due to the fact that the acceleration and braking characteristics of a truck differ from those of a passenger car. Furthermore, drivers waiting at a STOP sign may react differently to an oncoming truck than to a passenger car.

It may, however, be difficult to implement this recommendation fully due to the relatively low total number of trucks, especially at night on the minor approach.

- On low-volume roads, such as the test sites, it is a rare occurrence that an oncoming vehicle will be subjected to both types of conflicts simultaneously.
- The Pilot Study concluded that far side conflicts affected speeds of vehicles on the main approach, whereas near side conflicts did not have a significant effect. Therefore, so as not to throw out far side data points, when both conflicts occur, it will be classified as a far side conflict.
- In light of the above and to accomplish the experimental design within a reasonable time span, it is not recommended that this level of conflicts be investigated.

As will be discussed in Section 4.7, Data Collection, side street volumes are much too low on Eastridge Road to obtain adequate sample sizes within a reasonable time span, using only naturally occurring conflicts. It is, therefore, recommended that the side street vehicle be staged to create a conflict with a vehicle on a major approach. That is, a test vehicle will pull up to the stop line, as required, when a candidate sample vehicle is approaching on the major approach. It is also advisable that the staged vehicle be used at the second site as well.

4.1.5 Ambient Lighting Condition

The general approach to this experiment consists of testing devices which have the potential of enhancing the perception, by the driver, of a blind and thus hazardous intersection. Every device to be tested transmits information visually. Thus, ambient lighting becomes an essential independent variable.

Ideally, various levels of ambient lighting conditions would be desirable for inclusion in the experiment. However, only day and night conditions will be tested. Due to restrictions on sample size and length of the experiment, ambient lighting conditions during dusk will be excluded. The hours of dusk each day are inadequate to consider data collection during this time.

TABLE 2. - Independent Variables That Are Controlled by Remaining Fixed

Variable	Remains Fixed As
Day of Week	Weekday
Season of Year	Summer
Road Condition	Dry
Weather	Good
Stop time	Minimum
Vehicle Characteristic on Major Approach	Free-Flowing Non-Turner
Vehicle Type on Minor Approach	No Trucks*

*This restriction applies to the devices which affect traffic on the major approach. Data on trucks will be collected and analyzed for the minor approach for the one device that affects side street traffic.

To create conflicts in an adequate time span, a staged vehicle on the minor approach will be necessary. The staged vehicle should be a standard passenger car. It is not to have the appearance of an "official" vehicle. It is recommended that the staged vehicle be intermixed with other vehicles that normally travel the minor approach. It shall be used arbitrarily to fill in for lack of traffic on the minor approaches. This will especially be the case at the site on U.S. 2.

4.3 Concomitant Variable (Approach Speed of the Sample Vehicle)

It is expected that the majority of the remedial aids to be investigated will have a greater effect on faster moving vehicles than on slower moving ones. Therefore, it would be advisable to treat the approach speeds of the sample vehicles as a separate independent variable with a number of levels. However, this procedure would increase the size of the experimental design beyond that which realistically can be accomplished in a limited time frame. In order to reduce the size of the experimental design, approach speeds of sample vehicles will be treated, not as an independent variable, but as a concommitant variable or covariate. Approach speed will be collected with other dependent variable data for each sample vehicle.

4.4 Dependent Variables

The set of dependent variables consists of those parameters which change in value in response to changes in the independent variables discussed above. The dependent variables recommended are those that represent the best measures of effectiveness in the prevention of accidents (especially right-angle accidents which are predominant for two-way STOP sign control). The "best" remedial aid can be determined by analyzing and comparing the effect each device has on the measures.

The potential of accidents is related to a number of variables. Brifely, a collision at an intersection with restricted sight distance is caused because

- The side street vehicle could not clear the intersection (the driver could not see the approaching vehicle), and

- 85th Percentile Speed - This quantile is a much more sensitive indicator of changes in speed distribution. The Pilot Study concluded that "the 85th percentile of speed is more sensitive to changes in speed than is the mean of the distribution." Its only drawback is that considerably larger samples are needed to test for changes in this MOE as compared to change in the mean speed.

- Variance of Speeds - This is a standard MOE of speed distribution changes. Furthermore, it can be shown that this MOE is related to the frequency of accidents. A reduction in variance of speeds is an indication of the reduction in the accident potential of the intersection.

- Deceleration Requirement - Speed data collected as close as possible to the point at which the approaching vehicle can first see the intersection will be analyzed to determine the deceleration rates required to avoid an accident if a minor approach vehicle pulled out into the intersection. Further analysis will determine percentages of vehicles with unsafe, uncomfortable and safe deceleration rates for each device under investigation.

4.4.2 Traffic on Minor (Stopped) Approaches

To determine the effectiveness of the one device which affects side street traffic, different dependent variables must be investigated. Speeds on the major approach are not expected to be affected by a remedial aid which advises or warns traffic on the minor approach. One of the most logical MOEs that could be investigated is the gap acceptance distribution. However, as mentioned, due to extremely low traffic volumes, not enough short gaps occur to furnish adequate sample sizes for analysis. Therefore, other dependent variables must be considered. Four such variables are recommended.

- Location of Effective Stop Line - Due to sight distance restriction at the test sites, most vehicles on the stopped approaches must go past the STOP sign, and up to the edge of the major approach, in order to be able to see vehicles approaching on the main road. A reduction in the hazard potential of the intersection would be indicated by a shift in the

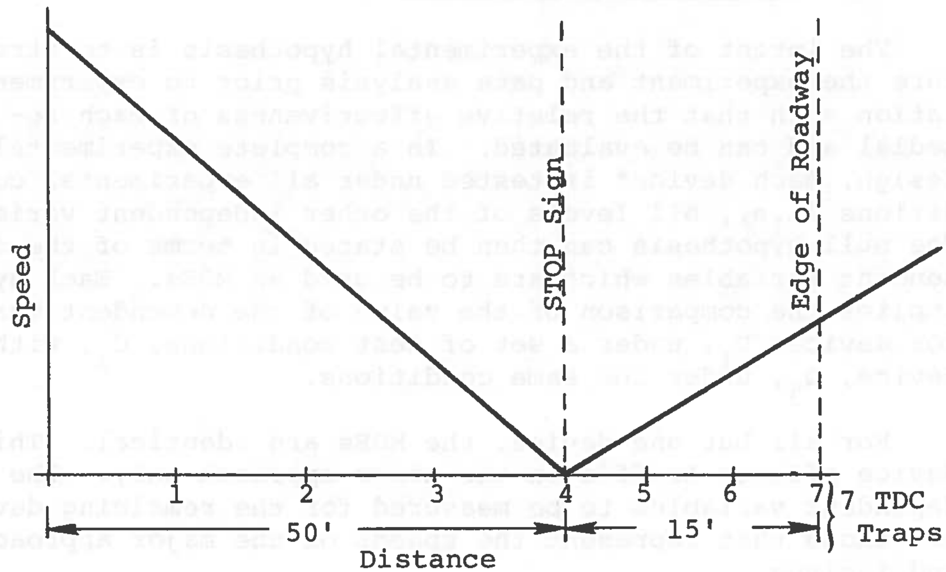


FIGURE 6: Schematic of Safe Speed Profile of a Vehicle Approach at a STOP Sign

A significant decrease in any of the MOEs mentioned in using device, D_i, and comparing it with D_j under condition, C_i, implies safer highway operations under device D_i. This, in turn, implies that D_i is a better device than D_j for condition, C_i.

However, the experimental hypothesis, as stated, cannot be tested directly by standard statistical methods. The superiority of any one device over any other, all other factors remaining constant, is evaluated against a set of pre-established criteria. The application of these individual criteria may lead to apparently contradictory results which must be resolved by trade-off analysis. The response to each individual criterion is ascertained by examining changes in a specific response measure.

It is recommended that all hypothesis testing be performed at the $\alpha = .05$ level.

To determine the effectiveness of the device which affects traffic on the minor approach, the following dependent variables are collected for the base condition and for the one remedial aid under investigation:

- Location of effective stop line
- Stop sign observance
- False starts
- Speed profile of minor approach vehicle.

Since this remedial aid is the only device which affects traffic on the minor approach, it can be compared to the base condition only.

The null hypothesis will, therefore, be:

H_0: There is no change in the dependent variable when the remedial aid is compared to the base condition under conditions, C_i.

The above hypothesis will be tested against the alternative.

H_1: During the use of the remedial aid, there was a change in the dependent variable under conditions, C_i.

Sample sizes for the MOE of effective stop line are calculated based on a rectangular (uniform) distribution. The variance of this distribution equals $b^2/12$, where b is the scale parameter. In this case, b equals 15 feet, the distance from the stop line to the edge of the intersecting road, and the variance is 18.75 ft^2. Since the distribution of sample mean for large samples from any distribution (central limit theorem) approaches normality, the standard sample size formula can be used:

$$n = \left(\frac{Z_{\alpha/2}\ \sigma}{\varepsilon} \right)^2$$

where ε, measurement precision, is equal to 0.5 foot.

A value of 288 vehicles/cell is needed. Rounding to 300 will yield adequate sample sizes for this MOE. This is probably also the upper limit on sample sizes that can realistically be obtained during the total time allotted to this experiment. The other MOEs for this device involve the estimation of proportion. A sample size of 300 will allow inferences at the $\alpha = .05$ level with the following percent of error estimate:

Proportion	Percent Error
.20	25
.26	20
.40	15
.58	10
.87	5

Due to low volumes at night, it may be necessary to reduce the sample size. A reduction in sample size means a decrease in the sensitivity of the experiment. Since mean speeds are the upper limit of the data collection, for devices which affect the main road, the data collection may be reduced by looking for a change in mean speed of ±2 MPH. This will reduce the sample size to 62 vehicles/cell.

The trap placement shown in Figure 7 is recommended. All distances are to be measured from the center of the intersection. Traps are formed by placing a pair of detectors six feet apart. The recommended trap placements are

- A trap at least 1200 feet upstream but not more than 1600 feet. Its primary function is to record the approach speed of the vehicle and determine free-flowing vehicles.

- A trap is to be placed at the location of the sign which will be about 600 feet upstream. Using six-inch lettering, it is expected that a driver with normal vision will be able to start reading the sign about 300 feet upstream. Thus, at 55 MPH, his initial response to the sign can be expected to be detected as he reaches the sign.

- A trap 400 feet upstream and a trap 200 feet upstream. These traps will add points for the construction of meaningful speed profiles. These two traps can also be used to determine required deceleration rates.

- A trap approximately 35 feet upstream (in line with the near edge of the intersecting street) will also add points to the speed profile. In addition, it may be used as a check to eliminate turning vehicles. Any vehicle traveling less than 25 MPH over this trap should be eliminated.

- A trap about 50 feet on the far side of the intersection. The primary purpose of this trap is to filter out turning vehicles. Only vehicles which pass this trap can be included in the sample.

These six traps utilize seven of the eight channels on the two TDC recorders. The remaining channel is to be used for two loops on either side of the minor approach to detect the presence of a vehicle* (only one loop is necessary at the Tee-intersection test site). Multi-level signals can be entered on a single channel by generating pseudo-speeds, a discrete speed for each of the minor approaches. The loops will effectively serve as a presence detector.

Inasmuch as both test sites have relatively small volumes, it will be necessary to stage a vehicle on the minor approach to create a conflict situation with a sample vehicle. As a candidate vehicle approaches the intersection on the main approach, a staged vehicle on the minor street will also approach the intersection. The staged vehicle is to trigger the detector as the vehicle on the major approach is approximately 900 feet upstream. The staged vehicle will start at least 100 feet upstream from the intersection, trigger the detector at 50 feet upstream and gradually come to a stop at the effective stop line of the intersection. The effective stop line is defined as that location at which 85 percent of the vehicles approaching the stop sign during the base condition have stopped.

The staged conflict will be intermixed with unstaged conflict occurrence and used whenever there is a lack of natural traffic conflicts. This is especially to be expected at Eastridge Road and U.S. 2, and in the collection of truck data at both sites. Since the experiment will be staged, it is anticipated that two crew members will be needed. One person, located upstream, will determine candidate sample vehicles and will advise the staged vehicle to proceed*. The second crew member will drive the staged vehicle.

<u>Device Affecting Side Street Traffic</u>

As discussed in Section 4.2.4, four dependent variables are to be measured and analyzed for this device and the base condition. They are:

- Location of effective stop line;
- Stop sign violations;
- False starts;
- Speed profile of minor approach vehicle (deceleration rates).

It is recommended that 16-mm time-lapse photography be used to collect data for the first three of these dependent variables. A TDC recorder will collect data for the speed profile measurements.

The 16-mm movie camera should have a film capacity of 400 feet. Film of this length has approximately 12,500 frames of useful film, after allowing for leader and title

*This function could be automated with the use of another TDC recorder.

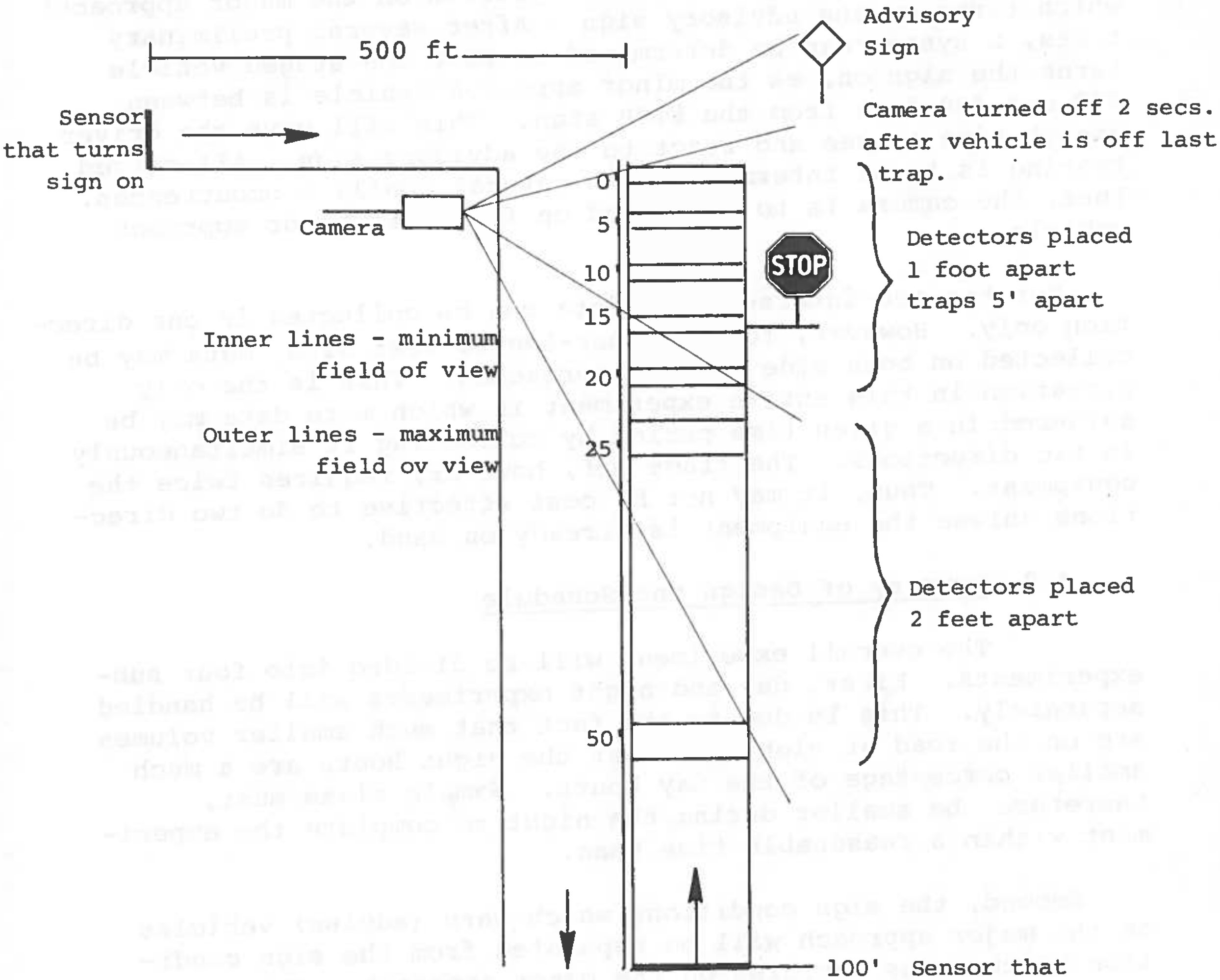


FIGURE 8 : Schematic of Data Collection Procedure for Device that Advises Street Traffic

4.8.1 Day Experiment for Devices Which Warn Traffic on Major Approach

This part of the experiment will be a full factorial randomized block design. There are five devices (includes the base condition), two site characteristics, two vehicle types, and two-and-a-half conflict conditions (three for the four-legged intersection and two for the tee-intersection). The number of cells for this subexperiment is

$$5 \times 2 \times 2 \times 2.5 = 50 \text{ cells.}$$

For each cell, data on 250 individual vehicles will be collected and measured. Thus, a total of 12,500 runs are to be made. It is roughly estimated that ten runs (with and without a staged vehicle) can be made in one hour. Thus, 1,250 daylight hours are needed to complete this part of the experiment. It is recommended that both sites be tested simultaneously. Thus, 625 hours are needed. During the summer months, approximately 14 hours of daylight hours are available (6 AM to 8 PM). Hence, this part of the experiment can be completed in approximately 45 days. Taking into account lost days for bad weather, maintenance of equipment, weekends and holidays, etc., a total elapsed time of 12 calendar weeks is estimated.

If the time involved to do this part is considered too long, two alternatives are recommended:

- Decrease the number of truck samples from 250 to 62. This will substantially reduce data collection time. The trade-off is that the standard error of mean speeds will double from ±1 mile per hour to ±2 miles per hour, and the standard error of the 85th percentile speed is increased from ±2 miles per hour to ±3 miles per hour.

- Investigate only far-side conflicts at the four-legged intersection. Near-side conflicts will be collected at the tee-intersection. The trade-off is that in the analysis, the site and conflicts variables must be confounded.

The number of cells is then

$$5 \text{ (devices)} \times 2 \text{ (sites)} \times 2.5 \text{ (conflicts)} = 25 \text{ cells.}$$

It is expected that each cell can be completed in two nights between the hours of 10 PM to midnight. Thus, approximately 25 nights are needed at each site. This time requirement is smaller than that for the corresponding day experiment, allowing for larger sample sizes than the minimum shown here.

4.8.4 Night Experiment for the Device Which Warns Traffic on the Minor Approach

Again, due to the low traffic volume on the side street at night, it is recommended that trucks be eliminated and a smaller sample of passenger cars be taken. As mentioned, a sample of 62 vehicle is the minimum required to detect a shift of the effective stop line within one foot. Assuming that data of between 15 to 20 vehicles can be collected on the side street each night (10 PM to midnight), each cell for this part of the experiment can be completed in about four nights.

The number of cells is then

$$2 \text{ (devices)} \times 2 \text{ (sites)} \times 2 \text{ (conflicts)} = 8 \text{ cells.}$$

Thus, 16 nights are needed at each site. During the six calendar weeks previously estimated for the day data collection, effective sample sizes exceeding the minimum will probably be achieved.

4.9 Data Analysis

As detailed in previous sections of this report, the experimental design produces two sets of MOEs. The first set is based on measurements of traffic characteristics on the major approach which are only collected for the remedial aids which affect this traffic. The TDC recorders are used to collect this data automatically. The second set of MOEs is based on measurements of traffic characteristics on the minor approach which are collected for the one remedial aid which affects this traffic. This data is collected automatically by the intersection. Any device which can more closely replicate this speed profile will reduce the hazard potential of the intersection. No standard statistical test exists to determine significant differences in speed profile. The closest approximation to the ideal profile will be equated with the test condition which produces the minimum mean sum of squares deviation. Significance of differences will be determined by pairwise t-tests on the velocities measured at each detector and by applying the Kolmogorov-Smirnov test to the distributions of the individual sample sums of square deviations.

All hypotheses will be tested at the $\alpha = .05$ level. Testing will be one-sided when comparisons are made with the base condition and two-sided when remedial aids are compared with each other.

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