Effect of Flashing Beacons on Intersection Performance

R. B. Goldblatt, KLD Associates, Inc., Huntington Station, New York

This paper presents the results of a study on the operational effects of various types of continuously and vehicle-actuated flashing traffic control devices performed at the Federal Highway Administration's Maine facility. Both electronic and manual data collection techniques were used. Five intersection and three advance warning device configurations were tested at the intersection of US-2 and Me-152. The use of continuously flashing intersection beacons along stopped approaches encourages speeds consistently lower than those achieved by STOP signs or vehicle-actuated intersection beacons. Certain vehicle-actuated advisory warning devices helped to reduce speed variance on major (nonstopped) approaches. A vehicle-actuated STOP AHEAD beacon caused drivers to begin braking sooner than they would without a beacon. Reduced speed variance was also noted when the advance warning beacon was used. These effects disappeared if there was a beacon at the downstream intersection.

The use of flashing beacons at intersections is authorized by the Manual on Uniform Traffic Control Devices (1). These beacons supplement existing stop signs at intersections where traffic flow conditions do not justify the installation of a traffic signal but where a special hazard exists.

Although there is evidence (2, 3) of reduced accident rates accompanying the installation of intersection beacons, little work has been done to determine their effects on traffic flow. This paper presents the results of a study of the effects of both continuously and vehicle-actuated flashing beacons on a two-way stop controlled intersection. Both intersection beacons and STOP AHEAD beacons were tested. The work was performed as part of a larger study the Federal Highway Administration (FHWA) sponsored (4) to determine guidelines for the installation of various types of flashing beacons.

DESCRIPTION OF STUDY SITE

The performance studies were conducted at the FHWA Maine facility with the cooperation of FHWA, the Transportation Systems Center, and the Maine Department of Transportation. The Maine facility (5) is a computer controlled data acquisition system designed to track and record the passage of vehicles along an instrumented two-lane rural road. This system is installed along US-2 between Newport and Canaan, Maine, a distance of 24 km (15 miles).

Instrumentation consists of a configuration of four sensor loops that indicate vehicle location and direction. Each set of loops is defined as a node. Nodes are embedded at 61-m (200-ft) intervals along US-2 and on the important side-road approaches. Sensor nodes are connected to roadside electronic packages that process detector data and transmit it to the central computer. Although not all the nodes have a corresponding electronic package, the facility has a number of portable electronic packages that can be installed for individual experiments.

This experiment was performed at the intersection of US-2 and Me-152. The through traffic approaches studied were the eastbound and westbound approaches along US-2; the stopped approach was northbound along Me-152. Although the intersection has four legs, our equipment limitations allowed only one stopped approach to be studied. Figure 1 presents an intersection schematic.

EXPERIMENTAL DESIGN

Five intersection and three advance warning configurations were tested parallel to each other in order to study possible interaction. The configuration of the intersection devices is given below.

1. The existing conditions consisted of two-way stop without supplementary beacons. The major approaches along US-2 were uncontrolled.
2. A standard crosswire-mounted intersection beacon (1, 4E-3, p. 5) was added. The beacon flashed red to the approaches along Me-152 and yellow to the approaches along US-2.
3. The beacon was actuated by the approach of a vehicle along a minor (Me-152) approach. The detector used to actuate the intersection beacon was placed 114 m (373 ft) upstream of the intersection.
4. A set of vehicle-actuated WHEN FLASHING—VEHICLE CROSSING advisory warning signs and beacons were installed upstream of the intersection on US-2. The beacon flashed yellow to the nonstopped approaches along US-2 and was actuated by the same detector as the intersection beacon. Two advisory warning signs were tested (Figure 2); the dimensions corresponding to the letters in Figure 2 are A = 91 cm (36 in), B = 9 cm (3.5 in), C = 3.8 cm (1.5 in), D = 2.2 cm (0.9 in). The first, used in Charlotte, North Carolina (6), employed nonstandard colors; the second utilized standard colors (1, 2C-2).
5. In addition to configuration 4, a vehicle-actuated STOP sign beacon was mounted atop the STOP sign. The beacon flashed red to the approach along Me-152 and was actuated in the same manner as the other beacons tested.

The configuration of the advance warning devices is given below.

1. The existing condition was a STOP AHEAD pavement marking (1, 3B-18) and a standard STOP AHEAD warning sign (1, 2C-14).
2. A standard continuously flashing 30-cm (12-in) yellow beacon (1, 4E-1) was mounted above the standard STOP AHEAD sign.
3. The yellow beacon was actuated by the approach of a vehicle along the northbound lane of Me-152. The detector used to actuate the beacon was placed 91 m (300 ft) upstream of the STOP AHEAD sign.

Figure 3 is an intersection schematic showing the location of all control devices and sensor nodes.

DATA COLLECTION AND REDUCTION

Data Collection

Data were collected both electronically and manually. Data were collected electronically with the facility's computer, which polled each node 16 times/s as shown on Figure 3. Data include time of arrival at each node; vehicle length, direction, and speed; and the amount of time each vehicle spends at the stop line on the Me-152 northbound approach waiting for a gap.

For a sample of individual vehicles, three types of manual data were collected: the state in which the vehicle was licensed, whether the vehicle violated the stop line or made a rolling stop on Me-152, and the point on the approach where a vehicle's brake lights were observed for the first time.

License plates were noted in an attempt to discern whether drivers familiar with the study site reacted any differently to the devices tested than those unfamiliar with the location. Drivers of vehicles with out-of-state license plates were considered unfamiliar.

The collection of stop line violation data was designed to test whether changes in the type of intersection control affected compliance. Unfortunately, no usable data were obtained because the manual data collection crew assigned to this task were not well trained.

Brake light data were collected to see whether the point at which brakes were applied was affected either by intersection control or by type of advance warning. These data were put directly into the roadside electronics package by a manual input channel.

Data were collected in Maine between February 27, 1975, and September 30, 1975. The first three treatments were each run for a week. However, because of the light traffic on Me-152 and the need for additional time for acclimatization, the length of each treatment was extended to 2 weeks. A total of 24 h of manual data were collected for each treatment. Manual data were collected during the day under weather conditions no worse than cloudy skies and bare, wet pavement.

Data Reduction

A set of computer programs was written to decode and process the data, which, because of the large amount, were reduced and placed in a shorter format. The information from each run (there might be up to 40 runs per treatment) was processed into brakelight distance in meters and speed in meters per second for nodes 21-0, 19-2, and 19-1 northbound on Me-152, nodes 9 and 15 eastbound on US-2, and nodes 27 and 23 westbound on US-2.

If the analysis of data was to be meaningful, it was necessary to ascertain the expected measurement errors inherent at the Maine facility. Figure 4 presents the

Figure 1. Intersection schematic of US-2 and Me-152.

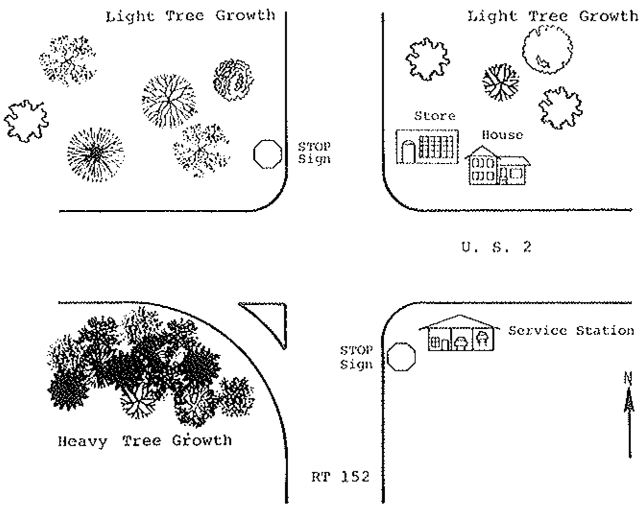


Figure 2. Advisory warning sign for major approaches.

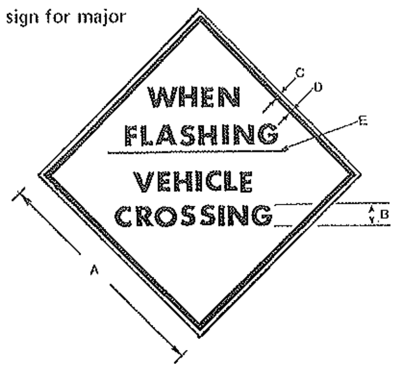
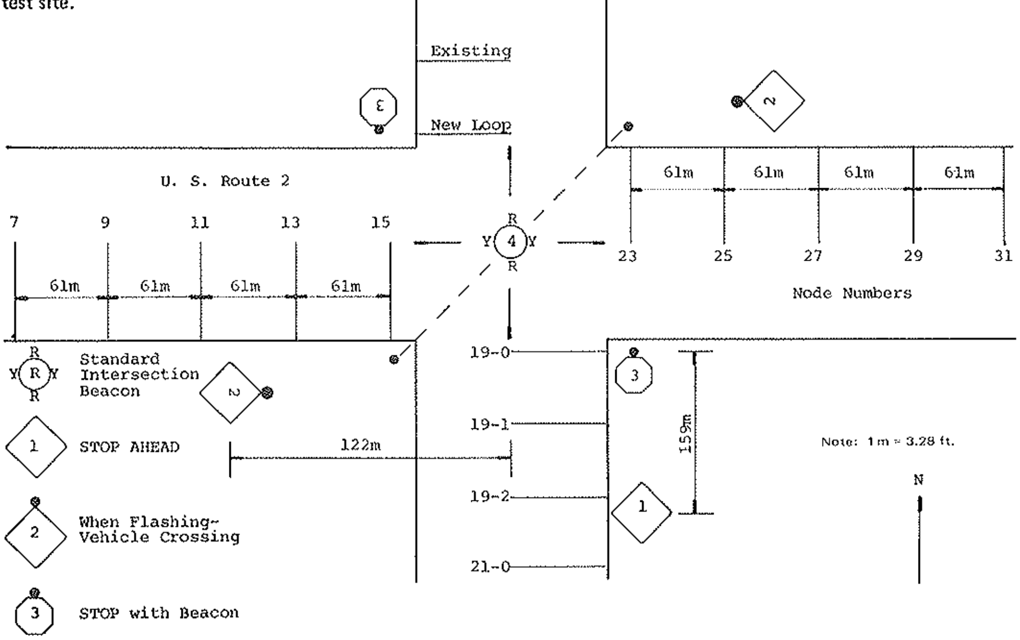


Figure 3. Schematic of Maine facility test site.



estimated error for both speed and brake light data.

A trap is defined as the distance between two successive sensor nodes. Our standard trap length was 61 m (200 ft). However, for the purposes of this experiment, trap lengths between 38 and 76 m (123 and 250 ft) were used.

The speed error was caused by the fact that the computer polled each node 16 times/s, which gave a time of arrival error on the order of $\pm\frac{1}{16}$ s. The error in the brake light measurements was caused by the computer time of arrival error and the observer reaction time error, estimated at $\frac{1}{2}$ s.

RESULTS

Intersection Control Devices

The effect of traffic control on speed along the main road (US-2) can be seen in Figure 5. Mean speeds and 85-percentile speeds are shown for the eastbound and westbound approaches to the intersection. Two positions are specified, the near position at the intersection and the far position approximately 122 m (400 ft) upstream of the intersection along US-2.

The five control types shown in Figure 5 are

1. Uncontrolled,
2. Standard with continuous intersection beacon,
3. Intersection beacon actuated by side street vehicles,
4. Intersection beacon with an advisory warning sign and beacon (Figure 2) placed along the major approaches and actuated by side street vehicles, and
5. Same as 4 except for a different advisory warning sign.

The t-test was used to determine whether the mean speeds associated with the control type differed significantly from the inherent measurement error. If the observed difference in mean speeds was less than the expected measurement error, the results could not be significant. Significance was determined by a two-tailed test at the 0.05 level.

The results showed that control type did little to explain changes in speed along the eastbound approach. However, along the westbound approach the use of the advisory warning signs and beacons seems to be of great importance in reducing speeds along the westbound approach, and significant differences are apparent for all devices except the uncontrolled case at the far location and for all devices at the near location.

The effects demonstrated for mean speeds are accentuated when 85-percentile speeds are used as a measure. Reductions in 85-percentile speeds are proportionally greater than the reduction in mean speeds. This fact indicates that the devices have greatest effects on faster vehicles.

The difference between the eastbound and westbound approaches can be explained by the following intersection geometry:

Direction	Grade (%)	Sight Distance (m)	Sight Time (s)
Eastbound	-3	305	14
Westbound	+3	152	8

The difference in grade explains the difference in approach speed, whereas the increased effectiveness of the westbound control devices might be related to restricted sight distance.

Figure 6 presents composite speed profiles along the approach to the stop sign on Me-152 for various intersection controls. The advance warning was a simple STOP AHEAD sign without beacons. The results in-

Figure 4. Maine facility measurement error.

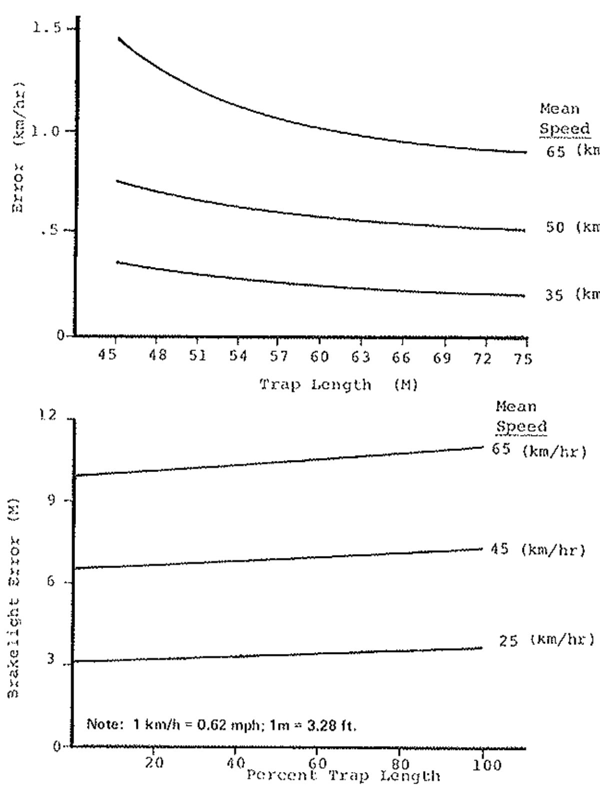


Figure 5. US-2 speed data.

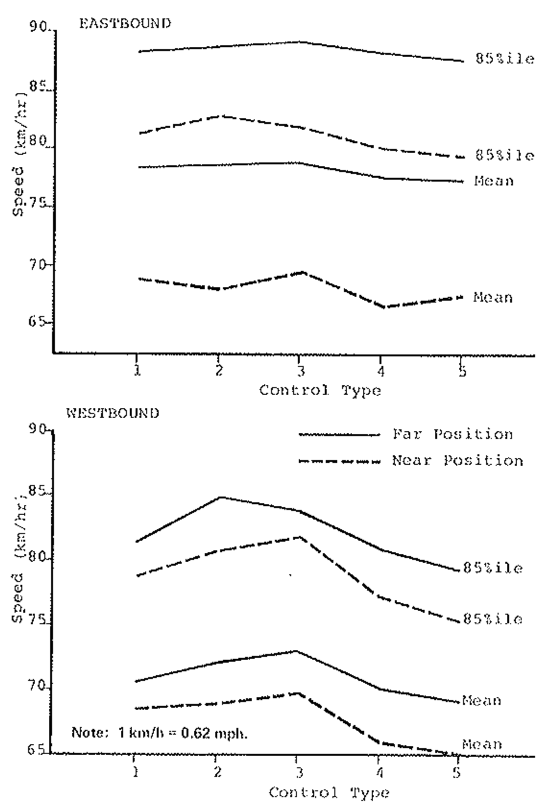


Figure 6. Me-152 speed profiles.

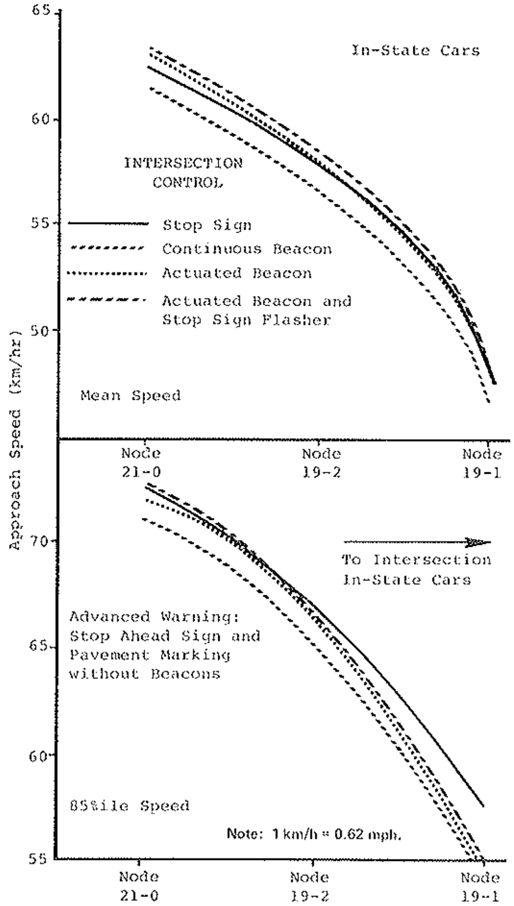
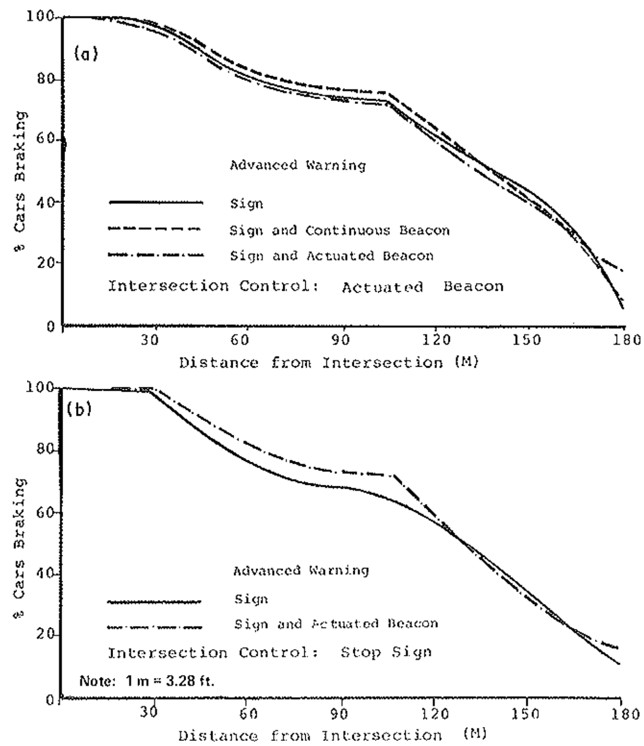


Figure 7. Effect of advance warning device on brakelight applications.



dicated that a simple flashing beacon encouraged significantly lower speeds at all locations. The use of actuated beacons and the addition of actuated stop sign beacons did not result in speed profiles significantly different from ones caused by the stop sign alone.

Day and Night Effects

The effects of a number of devices were tested both at night and during the day. The only difference noted was a slight decrease in mean speed at night that was found to be statistically insignificant.

Seasonal Differences

A number of identical control conditions were run during winter and summer. The results of these tests were not unexpected: summer conditions showed slightly higher mean speeds and lower variances than corresponding winter conditions. These results were tested statistically and were shown to be marginally significant.

Effect of Vehicle Population

Three types of vehicles were identified: in-state automobiles, out-of-state automobiles, and trucks. Analysis of traffic flow data indicates no significant changes that can be attributed to vehicle population.

Advance Warning Devices

Analysis of the speed data indicates that no significant changes in mean speed occur when a beacon is added to the STOP AHEAD sign. This result is independent of whether beacons are used at the intersection downstream or not.

Although mean speeds show no significant differences, there is a significant reduction in speed variance. It is interesting to note that the reduction in speed variance that occurs when a yellow beacon is added to the STOP AHEAD sign is significant only when the intersection control downstream is a simple stop sign. When any type of beacon control is present downstream, speed variance is unchanged or slightly increased when a continuously or actuated flashing beacon is used with an advance warning sign.

Figure 7 presents the cumulative brake light application distributions for vehicles approaching the stop sign, and the distributions for the three types of advance warning configurations tested (Figure 7a). The control at the intersection was an actuated intersection beacon. Note that there are no significant differences between the distributions. On the other hand, Figure 7b compares a STOP AHEAD sign alone and one with a vehicle-actuated beacon. The sign with beacon was 160 m (523 ft) from the stop line. In both cases, the downstream intersection was controlled by a stop sign without beacons. A Kolmogorov-Smirnov test was used to determine significance. The use of an actuated beacon significantly increased the percentage of vehicles braking at a point downstream of the STOP AHEAD sign.

CONCLUSIONS

A number of conclusions were drawn from our fieldwork in Maine regarding the use of beacons at stop sign controlled intersections. These conclusions were

1. The installation of continuously flashing intersection beacons without WHEN FLASHING—VEHICLES CROSSING advisory warning signs has little or no effect

on the main street speed distribution;

2. A continuously flashing beacon encourages lower vehicle speeds along the stopped approach, but not if the beacon is actuated; and

3. The use of the actuated WHEN FLASHING—VEHICLE CROSSING signs and beacons along the main street approaches causes a reduction in speed dispersion along the approach, which is more pronounced on the approach with poor sight distance.

The use of advance warning beacons in conjunction with a STOP AHEAD sign was found to reduce speed variance. In addition, vehicles begin the braking maneuver farther from the intersection. However, these results become less significant when any beacon is used at the downstream intersection, probably because the intersection beacon flashes red while the STOP AHEAD beacon flashes yellow. This presents the driver with conflicting indications and negates any positive benefits. There does not seem to be any operational advantage to actuating an advance warning beacon.

ACKNOWLEDGMENT

The work presented here was sponsored by the Federal Highway Administration, U.S. Department of Transportation. The contents of this paper reflect the views of KLD Associates, Inc., who are responsible for the facts and the accuracy of the data presented. The contents do not necessarily reflect the official views or policy of the Department of Transportation.

REFERENCES

1. Manual on Uniform Traffic Control Devices for Streets and Highway. U.S. Department of Transportation, 1970.
2. C. G. Hammer and T. N. Tamburri. Evaluation of Minor Improvements—Part 1, Flashing Beacons. California Division of Highways, May 1967.
3. J. W. Bennet, P. D. Cribbins, and C. M. Walton. Evaluation of Traffic Control Improvements on Low Volume Highways. Highway Research Program, North Carolina State Univ., June 1969.
4. R. B. Goldblatt. Guidelines for Flashing Traffic Control Devices. KLD Associates, Inc.; Federal Highway Administration, Rept. FHWA-DOT-FH-11-8532, July 1976.
5. S. R. Byington and M. J. Rosenbaum. The Maine Facility. Public Roads, Vol. 37, No. 7, Dec. 1973.
6. H. J. Hoose. Stop Signs Using Actuated Flashers, Speed Actuated Flashers, Speed Actuated Curve Flashers, and Green Extension Units. City of Charlotte, N.C., 1973.

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

Effects of Signal Phasing and Length of Left-Turn Bay on Capacity

Carroll J. Messer and Daniel B. Fambro, Texas Transportation Institute, Texas A&M University

A periodic scan computer simulation program was developed to investigate the effects of signal phasing and length of left-turn bay on capacity. After the simulation program was tested, inputs (phase sequence, volume, cycle length, and length of left-turn lane) were varied to evaluate their interrelationships under a range of conditions. Additional analysis was conducted by using a modified Poisson approach. The results show that, for a left-turn bay, traffic delay increases and signal capacity decreases when traffic interactions and flow blockages occur between left-turning and through vehicles. High left-turn volumes and short bay storage lengths experience the most severe reduction in capacity. We developed mathematical relationships between reductions in left-turn capacity and geometric and traffic conditions and provide design guidelines to minimize capacity reductions. Judicious selection of signal phasing reduces the loss in capacity to some extent, although all phasings can experience large losses under some geometric conditions.

Field observations of rush-hour traffic flow at signalized intersections having a protected left-turn bay suggest that the capacity of left-turn phases can be reduced by vehicles that block the entry of other vehicles into the left-turn bay. The left-turn bay may be blocked during the red phase of the signal so that the bay cannot fill, or vehicles may even be blocked from entering on a portion of the left-turn green phase. As traffic blockages begin to occur, the left turners may also begin to impede through vehicles, and capacity problems and intersection congestion are compounded.

Reductions in left-turn capacity generally occur as average traffic demands increase beyond the storage length of the left-turn bay and the cycle length of the signal. Shorter left-turn bays and longer cycles are more susceptible to such reductions. A shorter left-turn bay means that fewer vehicles can be stored before a blockage occurs; a longer cycle requires more vehicles to be stored for a given volume level before a green.

Some signal phasing sequences that improve traffic flow and left-turn capacity have been implemented, but primarily by trial and error methods. Little information that describes improvements made by increasing the left-turn bay length or by changing phasing sequence is readily available.

Basic design criteria for the length of the left-turn bay have been previously related to the Poisson approach (1, pp. 688-690), but design trade-off relationships are not provided. Operational corrective treatments for an existing situation are also limited and not emphasized.

The mathematical analysis of the movement of through and left-turning vehicles at an intersection under various traffic conditions, design configurations, and signal phasing sequences is extremely complicated, which is probably the reason for the lack of pertinent design and operations information.